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Surgical instrument

Abstract

Provided are surgical instruments, and more particularly, surgical instruments that may be manually operated to perform laparoscopic operations or various surgical operations.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation application of U.S. application Ser. No. 18/215,955, filed on Jun. 29, 2023, which is a continuation application of U.S. application Ser. No. 16/999,520, filed on Aug. 21, 2020 (issued as U.S. Pat. No. 11,723,736 on Aug. 15, 2023), which is a divisional application of U.S. application Ser. No. 16/722,676 filed on Dec. 20, 2019 (issued as U.S. Pat. No. 11,628,027 on Apr. 18, 2023), which is a continuation application of U.S. application Ser. No. 14/360,586 filed on May 23, 2014 (issued as U.S. Pat. No. 10,695,141 on Jun. 30, 2020), which in turn is a national-stage application under 35 USC § 371 of international application No. PCT/KR2012/009364 filed on Nov. 8, 2012, and claims priority under 35 U.S.C. § 119 (a) to Korean Patent Application Nos. 10-2011-0123071, 10-2011-0123074, and 10-2011-0123075 filed on Nov. 23, 2011, the contents of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD
(1) The present invention relates to surgical instruments, and more particularly, to surgical instruments that may be manually operated to perform laparoscopic operations or various surgical operations.
BACKGROUND ART
(2) A surgical operation is an operation for curing a disease by cutting, incising, and processing skin, membranes, or other tissues by using medical instruments. However, open surgery, which cuts and opens the skin of a surgical region and cures, shapes, or removes an organ therein, may cause bleeding, side effects, pain, scars, or the like. Therefore, a surgical operation, which is performed by forming a hole through the skin and inserting a medical instrument, for example, a laparoscope, a surgical instrument, or a surgical microscope thereinto, or a robotic surgical operation have recently become popular alternatives.
(3) The surgical instrument is an instrument for performing, by a surgeon, an operation on a surgical region by operating an end tool, which is installed at one end of a shaft inserted into a hole formed through the skin, by using an operator or by using a robotic arm. The end tool provided in the surgical instrument performs a rotating operation, a gripping operation, a cutting operation, or the like through a predetermined structure.
(4) However, since a conventional surgical instrument uses an unbendable end tool, it is not suitable for accessing a surgical region and performing various surgical operations. In order to solve this problem, a surgical instrument having a bendable end tool has been developed.
(5) However, an operation of an operator for bending the end tool to perform a surgical operation is not intuitively identical to an actual bending operation of the end tool for performing the surgical operation. Therefore, for surgical operators, it is difficult to perform an intuitive operation and it takes a long time to learn how to use the surgical instrument.
(6) Information disclosed in this Background section was already known to the inventors of the present invention before achieving the present invention or is technical information acquired in the process of achieving the present invention. Therefore, it may contain information that does not form the prior art that is already known in this country to a person of ordinary skill in the art.
DETAILED DESCRIPTION OF THE INVENTION

Technical Problem

(7) The present invention provides a surgical instrument that is configured to intuitively match an actual operation of bending an end tool or performing a surgical operation with a corresponding operation of an operator. More particularly, to this end, the present invention provides an end tool having various degrees of freedom, an operator configured to intuitively control an operation of the end tool, and an operating force transmitter configured to transmit an operating force of the operator so that the end tool may operate in accordance with an operation of the operator.

Technical Solution

(8) According to an aspect of the present invention, there is provided a surgical instrument including: an end tool formed to rotate in two or more directions; an operator controlling an operation of the end tool; an operating force transmitter including one or more wires and one or more pulleys transmitting an operation of the operator to the end tool; and a connector having one end portion coupled to the end tool and the other end portion coupled to the operator to connect the operator and the end tool, wherein at least a portion of the operator is formed to extend toward the end tool, and when the operator is rotated in the two or more directions, the end tool rotates in substantially the same direction as an operation direction of the operator.

(9) According to another aspect of the present invention, there is provided an end tool of a surgical instrument, including: a first jaw and a second jaw operating independently of each other; and an end tool control member including: a J**11** pulley coupled with the first jaw and formed to rotate around a first axis; a J**12** pulley and a J**14** pulley formed to rotate around an axis making a predetermined angle with the first axis and formed to face each other; a J**13** pulley and a J**15** pulley formed to rotate around an axis making a predetermined angle with the first axis and formed to face each other; a J**21** pulley coupled with the second jaw and formed to face the J**11** pulley; a J**22** pulley and a J**24** pulley formed to rotate around an axis making a predetermined angle with the first axis and formed to face each other; and a J**23** pulley and a J**25** pulley formed to rotate around an axis making a predetermined angle with the first axis and formed to face each other, wherein at least a portion of a first jaw operating wire sequentially contacts the J**13** pulley, the J**12** pulley, the J**11** pulley, the J**14** pulley, and the J**15** pulley to rotate the J**11** pulley and the J**15** pulley, and at least a portion of a second jaw operating wire sequentially contacts the J**23** pulley, the J**22** pulley, the J**21** pulley, the J**24** pulley, and the J**25** pulley to rotate the J**21** pulley and the J**25** pulley.

(10) According to another aspect of the present invention, there is provided a surgical instrument including: an end tool including a first jaw and a second jaw operating independently of each other; an operator controlling operations of the first and second jaws of the end tool; an operating force transmitter including a first jaw operating wire connected with the operator to transmit a rotation of the operator to the first jaw and a second jaw operating wire connected with the operator to transmit a rotation of the operator to the second jaw; and a connector having one end portion coupled to the end tool and the other end portion coupled to the operator to connect the operator and the end tool, wherein at least a portion of the operator is formed to extend toward the end tool, and an operation direction of the operator and an operation direction of the end tool are intuitively identical to each other.

(11) According to another aspect of the present invention, there is provided a surgical instrument including: an end tool including a first jaw and a second jaw operating independently of each other; an operator controlling operations of the first and second jaws of the end tool; an operating force transmitter including a pitch wire connected with the operator to transmit a pitch motion of the operator to the end tool, a yaw wire connected with the operator to transmit a yaw motion of the operator to the end tool, and an actuation wire connected with the operator to transmit an actuation motion of the operator to the end tool; and a connector having one end portion coupled to the end tool and the other end portion coupled to the operator to connect the operator and the end tool, wherein at least a portion of the operator is formed to extend toward the end tool, and an operation direction of the operator and an operation direction of the end tool are intuitively identical to each

other.
(12) According to another aspect of the present invention, there is provided a surgical instrument including: an end tool including a first jaw and a second jaw operating independently of each other; an operator controlling operations of the first and second jaws of the end tool; an operating force transmitter including a pitch wire connected with the operator to transmit a pitch motion of the operator to the end tool, a first jaw operating wire connected with the operator to transmit a rotation of the operator to the first jaw, and a second jaw operating wire connected with the operator to transmit a rotation of the operator to the second jaw; and a connector having one end portion coupled to the end tool and the other end portion coupled to the operator to connect the operator and the end tool, wherein at least a portion of the operator is formed to extend toward the end tool, and an operation direction of the operator and an operation direction of the end tool are intuitively identical to each other.
Advantageous Effects
(13) According to the present invention, since an operation direction of the operator by a surgical operator and an operation direction of the end tool are intuitively identical to each other, the convenience of the surgical operator may be improved, and the accuracy, reliability, and the quickness of a surgical operation may be improved.

Description

DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a view illustrating a surgical instrument according to a first embodiment of the present invention;
(2) FIG. **2** is a detailed internal view of the surgical instrument of FIG. **1**;
(3) FIG. **3** is a schematic view of an operator of the surgical instrument of FIG. **2**;
(4) FIG. **3**A illustrates various modifications of the operator of the surgical instrument according to the first embodiment of the present invention;
(5) FIG. **4**A is a detailed view of a first differential pulley of the surgical instrument of FIG. **2**, and FIG. **4**B is a detailed view of a second differential pulley of the surgical instrument of FIG. **2**;
(6) FIG. **5** is a detailed view of an end tool of the surgical instrument of FIG. **2**;
(7) FIG. **5**A illustrates a modification of the end tool of FIG. **5**;
(8) FIG. **6** is a schematic view illustrating a pitch operation of the surgical instrument of FIG. **2**;
(9) FIG. **7** is a view illustrating a surgical instrument according to a modification of the end tool of the first embodiment illustrated in FIG. **1**;
(10) FIG. **8** is a detailed view of an end tool of the surgical instrument of FIG. **7**;
(11) FIG. **9** is a view illustrating a surgical instrument according to a modification of the operator of the first embodiment illustrated in FIG. **1**;
(12) FIG. **10** is a view illustrating a surgical instrument according to a modification of an operator control member of the first embodiment illustrated in FIG. **1**;
(13) FIG. **11** is a view illustrating a surgical instrument according to a modification of an end tool control member of the first embodiment illustrated in FIG. **1**;
(14) FIG. **12** is a view illustrating a surgical instrument according to a modification of the end tool control member and the operator control member of the first embodiment illustrated in FIG. **1**;
(15) FIG. **13** is a view illustrating a surgical instrument according to another modification of the end tool control member of the first embodiment illustrated in FIG. **1**;
(16) FIG. **14** is a bottom perspective view of the end tool control member of FIG. **13**;
(17) FIG. **15** is a view illustrating a first modification of a differential pulley of the surgical instrument illustrated in FIG. **2**;
(18) FIGS. **16** and **17** are views illustrating an operation of the first modification of the differential

pulley illustrated in FIG. **15**;
(19) FIG. **18** is a view illustrating a second modification of the differential pulley of the surgical instrument illustrated in FIG. **2**;
(20) FIGS. **19** and **20** are views illustrating an operation of the second modification of the differential pulley illustrated in FIG. **18**;
(21) FIGS. **21**A to **21**E are views illustrating other examples of the second modification of the differential pulley illustrated in FIG. **18**;
(22) FIGS. **22** and **23** are views illustrating a third modification of the differential pulley of the surgical instrument illustrated in FIG. **2**;
(23) FIG. **24** is a view illustrating a surgical instrument according to a modification of an operating force transmitter of the surgical instrument illustrated in FIG. **2**;
(24) FIG. **25** is a detailed view of a differential gear of FIG. **24**;
(25) FIG. **26** is a view illustrating a first modification of the differential gear of FIG. **24**;
(26) FIG. **27** is a view illustrating a second modification of the differential gear of FIG. **24**;
(27) FIG. **28** is a view illustrating a surgical instrument according to a second embodiment of the present invention;
(28) FIG. **29** is a view illustrating a surgical instrument according to a modification of a differential pulley of the second embodiment illustrated in FIG. **28**;
(29) FIG. **30** is a view illustrating a surgical instrument according to a third embodiment of the present invention;
(30) FIG. **31** is a view illustrating a surgical instrument according to a modification of the third embodiment illustrated in FIG. **30**;
(31) FIG. **32** is an exploded perspective view of an end tool included in a surgical instrument **400** according to a fourth embodiment of the present invention;
(32) FIG. **33** is an XZ-plane side view of the end tool;
(33) FIG. **34** is an XY-plane plan view of the end tool;
(34) FIG. **35** is a plan view illustrating a yaw motion of the end tool of FIG. **34**;
(35) FIG. **36** is a plan view illustrating an actuation motion of the end tool of FIG. **34**;
(36) FIG. **37** is a view illustrating a surgical instrument according to a fourth embodiment of the present invention;
(37) FIG. **38** is a view illustrating a surgical instrument according to a fifth embodiment of the present invention;
(38) FIG. **39** is a view illustrating a surgical instrument according to a sixth embodiment of the present invention;
(39) FIG. **40** is an XZ-plane side view of an end tool included in a surgical instrument **700** according to a seventh embodiment of the present invention;
(40) FIG. **41** is an XY-plane plan view of the end tool of FIG. **40**;
(41) FIG. **42** is a plan view illustrating a yaw motion of the end tool of FIG. **41**;
(42) FIG. **43** is a plan view illustrating an actuation motion of the end tool of FIG. **41**;
(43) FIG. **44** is a view illustrating a surgical instrument according to a seventh embodiment of the present invention;
(44) FIG. **45** is a view illustrating a surgical instrument according to an eighth embodiment of the present invention;
(45) FIG. **46** is a view illustrating a surgical instrument according to a modification of a differential pulley of the eighth embodiment illustrated in FIG. **45**; and
(46) FIG. **47** is a view illustrating a surgical instrument according to a ninth embodiment of the present invention.

BEST MODE

(47) The present invention may include various embodiments and modifications, and exemplary embodiments thereof are illustrated in the drawings and will be described herein in detail.

However, it will be understood that the present invention is not limited to the exemplary embodiments and includes all modifications, equivalents and substitutions falling within the spirit and scope of the present invention. In the following description, detailed descriptions of well-known functions or configurations will be omitted since they would unnecessarily obscure the subject matters of the present invention.

(48) Although terms such as “first” and “second” may be used herein to describe various elements or components, these elements or components should not be limited by these terms. These terms are only used to distinguish one element or component from another element or component.

(49) The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the inventive concept. As used herein, the singular forms “a”, “an”, and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be understood that terms such as “comprise”, “include”, and “have”, when used herein, specify the presence of stated features, integers, steps, operations, elements, components, or combinations thereof, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, or combinations thereof.

(50) Hereinafter, embodiments of the present invention will be described in detail with reference to the accompanying drawings. In the following description, like reference numerals denote like elements, and redundant descriptions thereof will be omitted.

(51) Also, it will be understood that various embodiments of the present invention may be interpreted or implemented in combination, and technical features of each embodiment may be interpreted or implemented in combination with technical features of other embodiments.

<First Embodiment of Surgical Instrument> (E3+H1+D3)

(52) FIG. **1** is a view illustrating a surgical instrument **100** according to a first embodiment of the present invention, and FIG. **2** is a detailed internal view of the surgical instrument **100** of FIG. **1**.

(53) Referring to FIGS. **1** and **2**, the surgical instrument **100** according to a first embodiment of the present invention includes an operator **110**, an end tool **120**, an operating force transmitter **130**, and a connector **140**. Herein, the connector **140** may be formed to have a shape of a hollow shaft, so that one or more wires (which will be described later) may be accommodated therein. The operator **110** may be coupled to one end portion of the connector **140**, and the end tool **120** may be coupled to the other end portion of the connector **140**, so that the connector **140** may connect the operator **110** and the end tool **120**.

(54) In detail, the operator **110** is formed at one end portion of the connector **140** and is provided as an interface having, for example, a tweezers shape, a stick shape, or a lever shape, which may be directly operated by a surgical operator. When a surgical operator operates the operator **110**, the end tool **120**, which is connected to the interface and is inserted into the body of a surgical patient, performs an operation, thereby performing a surgical operation. Although FIG. **1** illustrates that the operator **110** is formed to have a tweezers shape, the present invention is not limited thereto, and the operator **110** may have various shapes that may be connected with the end tool **120** to operate the end tool **120**.

(55) The end tool **120** is formed at the other end portion of the connector **140** and is inserted into a surgical region to perform a necessary surgical operation. As an example of the end tool **120**, a pair of jaws, namely, first and second jaws **121** and **122**, may be used to perform a grip operation, as illustrated in FIG. **1**. However, the present invention is not limited thereto, and various surgical devices may be used as the end tool **120**. For example, a one-armed cautery may be used as the end tool **120**. The end tool **120** is connected with the operator **110** by the operating force transmitter **130** to receive an operating force of the operator **110** through the operating force transmitter **130**, thereby performing a necessary surgical operation such as a grip, cutting, or suturing. Herein, the end tool **120** of the surgical instrument **100** according to the first embodiment of the present invention is formed to rotate in two or more directions. For example, the end tool **120** may be formed to perform a pitch motion around a Y axis of FIG. **1** and also perform a yaw motion and an

actuation motion around a Z axis of FIG. **1**. This will be described later in detail.
(56) The operating force transmitter **130** connects the operator **110** and the end tool **120** to transmit an operating force of the operator **110** to the end tool **120** and may include a plurality of wires and pulleys.
(57) Hereinafter, the operator **110**, the end tool **120**, and the operating force transmitter **130** of the surgical instrument **100** of FIG. **1** will be described in more detail.
(58) (Operator)
(59) FIG. **3** is a schematic view of the operator **110** of the surgical instrument **100** of FIG. **2**. Referring to FIGS. **1**, **2**, and **3**, the operator **110** of the surgical instrument **100** according to the first embodiment of the present invention includes a pitch operator **111** controlling a pitch motion of the end tool **120**, a yaw operator **112** controlling a yaw motion of the end tool **120**, and an actuation operator **113** controlling an actuation motion of the end tool **120**.
(60) A pitch operation, a yaw operation, and an actuation operation used in the present invention are summarized as follows:
(61) First, the pitch operation refers to a vertical motion with respect to an extension direction (an X-axis direction of FIG. **1**) of the connector **140**, that is, an operation of rotating around the Y axis of FIG. **1**. In other words, the pitch operation refers to a vertical rotation of the end tool **120**, which is formed to extend in the extension direction (the X-axis direction of FIG. **1**) of the connector **140**, around the Y axis. The yaw operation refers to a horizontal motion with respect to the extension direction (the X-axis direction of FIG. **1**) of the connector **140**, that is, an operation of rotating around the Z axis of FIG. **1**. In other words, the yaw operation refers to a horizontal rotation of the end tool **120**, which is formed to extend in the extension direction (the X-axis direction of FIG. **1**) of the connector **140**, around the Z axis. The actuation operation refers a folding or unfolding operation of the first and second jaws **121** and **122** when the first and second jaws **121** and **122** rotate in opposite directions while rotating around the same rotating axis as the yaw operation. That is, the actuation operation refers to rotations of the first and second jaws **121** and **122**, which is formed at the end tool **120**, in opposite directions around the Z axis.
(62) Herein, when the operator **110** of the surgical instrument **100** is rotated in one direction, the end tool **120** rotates in a direction that is intuitively identical to an operation direction of the operator **110**. In other words, when the pitch operator **111** of the operator **110** rotates in one direction, the end tool **120** rotates in a direction intuitively identical to the one direction to perform a pitch operation, and the end tool **120** rotates in the direction intuitively identical to the one direction to perform a yaw operation. Herein, it may be said that the intuitively identical direction refers to a case where a movement direction of an index finger of a user gripping the operator **110** is substantially identical to a movement direction of the end portion of the end tool **120**. In addition, the identical direction may not be an exactly identical direction on a three-dimensional coordinate system. For example, the identical direction may refer to a case where when the index finger of the user moves to the left, the end portion of the end tool **120** also moves to the left, and when the index finger of the user moves to the right, the end portion of the end tool **120** also moves to the right.
(63) To this end, in the surgical instrument **100**, the operator **110** and the end tool **120** are formed in the same direction with respect to a plane perpendicular to an extension axis (X axis) of the connector **140**. That is, in view of a YZ plane of FIG. **1**, the operator **110** is formed to extend in a +X-axis direction, and the end tool **120** is also formed to extend in the +X-axis direction. In other words, it may be said that a formation direction of the end tool **120** at one end portion of the connector **140** may be identical to a formation direction of the operator **110** at the other end portion of the connector **140** in view of the YZ plane. In other words, it may be said that the operator **110** is formed to extend away from a body of the user gripping the operator **110**, that is, the operator **110** is formed to extend toward the end tool **120**.
(64) In detail, in the case of a surgical instrument of the related art, an operation direction of an

operator by a user is different from and is not intuitively identical to an actual operation direction of an end tool. Therefore, a surgical operator has difficulty in performing an intuitive operation and it takes a long time to skillfully move the end tool in a desired direction. Also, in some cases, a faulty operation may occur, thus damaging a surgical patient.
(65) In order to solve such problems, the surgical instrument **100** according to the first embodiment of the present invention is configured such that an operation direction of the operator **110** is intuitively identical to an operation direction of the end tool **120**. To this end, the operator **110** and the end tool **120** are formed on the same side in view of the YZ plane including a pitch operating axis **1111**. This will be described below in more detail.
(66) Referring to FIGS. **1**, **2**, and **3**, the operator **110** of the surgical instrument **100** according to the first embodiment of the present invention includes the pitch operator **111** controlling a pitch motion of the end tool **120**, a yaw operator **112** controlling a yaw motion of the end tool **120**, and an actuation operator **113** controlling an actuation motion of the end tool **120**.
(67) The pitch operator **111** includes the pitch operating axis **1111** and a pitch operating bar **1112**. Herein, the pitch operating axis **1111** may be formed in a direction parallel to the Y axis, and the pitch operating bar **1112** may be connected with the pitch operating axis **1111** to rotate along with the pitch operating axis **1111**. For example, when the user grips and rotates the pitch operating bar **1112**, the pitch operating axis **1111** connected with the pitch operating bar **1112** rotates along with the pitch operating bar **1112**. Then, the resulting rotating force is transmitted to the end tool **120** through the operating force transmitter **130**, so that the end tool **120** rotates in the same direction as the rotation direction of the pitch operating axis **1111**. That is, when the pitch operator **111** rotates in the clockwise direction around the pitch operating axis **1111**, the end tool **120** also rotates in the clockwise direction around an axis parallel to the pitch operating axis **1111**, and when the pitch operator **111** rotates in the counterclockwise direction around the pitch operating axis **1111**, the end tool **120** also rotates in the counterclockwise direction around the axis parallel to the pitch operating axis **1111**.
(68) The yaw operator **112** and the actuation operator **113** are formed on one end portion of the pitch operating bar **1112** of the pitch operator **111**. Thus, when the pitch operator **111** rotates around the pitch operating axis **1111**, the yaw operator **112** and the actuation operator **113** also rotate along with the pitch operator **111**. FIGS. **1** and **3** illustrate a state in which the pitch operating bar **1112** of the pitch operator **111** is perpendicular to the connector **140**, while FIG. **2** illustrates a state in which the pitch operating bar **1112** of the pitch operator **111** is at an angle to the connector **140**.
(69) Therefore, a coordinate system of the yaw operator **112** and the actuation operator **113** is not fixed, but relatively changes according to the rotation of the pitch operator **111**. As illustrated in FIG. **1**, since a yaw operating axis **1121** of the yaw operator **112** and an actuation operating axis **1131** of the actuation operator **113** are parallel to the Z axis, the yaw operator **112** and the actuation operator **113** rotate around an axis parallel to the Z axis. However, as illustrated in FIG. **2**, when the pitch operator **111** rotates, the yaw operating axis **1121** of the yaw operator **112** and the actuation operating axis **1131** of the actuation operator **113** are not parallel to the Z axis. That is, the coordinate system of the yaw operator **112** and the actuation operator **113** change according to the rotation of the pitch operator **111**. However, for convenience of description, the coordinate system of the yaw operator **112** and the actuation operator **113** will be described on the assumption that the pitch operating bar **1112** is perpendicular to the connector **140** as illustrated in FIG. **1**.
(70) The yaw operator **112** includes the yaw operating axis **1121** and a yaw operating bar **1122**. Herein, the yaw operating axis **1121** may be formed to be at a predetermined angle to an XY plane where the connector **140** is formed. For example, the yaw operating axis **1121** may be formed in a direction parallel to the Z axis as illustrated in FIG. **1**, and when the pitch operator **111** rotates, the coordinate system of the yaw operator **112** may relatively change as described above. However, the present invention is not limited thereto, and the yaw operating axis **1121** may be formed in various directions by ergonomic design according to the structure of a hand of the user gripping the yaw

operator **112**. The yaw operating bar **1122** is connected with the yaw operating axis **1121** to rotate along with the yaw operating axis **1121**. For example, when the user holds and rotates the yaw operating bar **1122** with the index finger, the yaw operating axis **1121** connected with the yaw operating bar **1122** rotates along with the yaw operating bar **1122**. Then, the resulting rotating force is transmitted to the end tool **120** through the operating force transmitter **130**, so that the first and second jaws **121** and **122** of the end tool **120** horizontally rotate in the same direction as the rotation direction of the yaw operating axis **1121**.

(71) A first pulley **1121***a* and a second pulley **1121***b* may be formed respectively at both end portions of the yaw operating axis **1121**. A YC**1** wire **135**YC**1** may be connected to the first pulley **1121***a*, and a YC**2** wire **135**YC**2** may be connected to the second pulley **1121***b*.

(72) The actuation operator **113** includes the actuation operating axis **1131** and an actuation operating bar **1132**. Herein, the actuation operating axis **1131** may be formed to be at a predetermined angle to the XY plane where the connector **140** is formed. For example, the actuation operating axis **1131** may be formed in a direction parallel to the Z axis as illustrated in FIG. **1**, and when the pitch operator **111** rotates, the coordinate system of the actuation operator **113** may relatively change as described above. However, the present invention is not limited thereto, and the actuation operating axis **1131** may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the actuation operator **113**. The actuation operating bar **1132** is connected with the actuation operating axis **1131** to rotate along with the actuation operating axis **1131**. For example, when the user holds and rotates the actuation operating bar **1132** with the thumb finger, the actuation operating axis **1131** connected with the actuation operating bar **1132** rotates along with the actuation operating bar **1132**. Then, the resulting rotating force is transmitted to the end tool **120** through the operating force transmitter **130**, so that the first and second jaws **121** and **122** of the end tool **120** perform an actuation operation. Herein, as described above, the actuation operation refers to an operation of folding or unfolding the first and second jaws **121** and **122** by rotating the first and second jaws **121** and **122** in opposite directions. That is, when the actuation operator **113** is rotated in one direction, as the first jaw **121** rotates in the counterclockwise direction and the second jaw **122** rotates in the clockwise direction, the end tool **120** is folded; and when the actuation operator **113** is rotated in the opposite direction, as the first jaw **121** rotates in the clockwise direction and the second jaw **122** rotates in the counterclockwise direction, the end tool **120** is unfolded.

(73) A first pulley **1131***a* and a second pulley **1131***b* may be formed respectively at both end portions of the actuation operating axis **1131**. An AC**1** wire **135**AC**1** may be connected to the first pulley **1131***a*, and an AC**2** wire **135**AC**2** may be connected to the second pulley **1131***b*.

(74) Referring to FIG. **3**, the pitch operator **111** and the end tool **120** are formed on the same or parallel axis (X axis) in the surgical instrument **100** according to the first embodiment of the present invention. That is, the pitch operating axis **1111** of the pitch operator **111** is formed at one end portion of the connector **140**, and the end tool **120** is formed at the other end portion of the connector **140**. Although it is illustrated that the connector **140** is formed to have a shape of a straight line, the present invention is not limited thereto. For example, the connector **140** may be curved with a predetermined curvature, or may be bent one or more times. Also in this case, it may be said that the pitch operator **111** and the end tool **120** are formed on substantially the same or parallel axis. Although FIG. **3** illustrates that the pitch operator **111** and the end tool **120** are formed on the same axis (X axis), the present invention is not limited thereto. For example, the pitch operator **111** and the end tool **120** may be formed on different axes. This will be described later in detail.

(75) The operator **110** of the surgical instrument **100** according to the first embodiment of the present invention further includes an operator control member **115** engaged with the pitch operating axis **1111** of the pitch operator **111**. The operator control member **115** may include a relay pulley **115***a*. Since the configuration of the operator control member **115** is substantially identical to the

configuration of the end tool **120**, the relations between the operator control member **115** and other elements of the operator **110** and an end tool control member **123** will be described later.
(76) FIG. **3**A illustrates various modifications of the operator **110** of the surgical instrument **100** according to the first embodiment of the present invention.
(77) As for H**1** of FIG. **3**A, as described with reference to FIG. **3**, (1) since the yaw operator **112** and the actuation operator **113** of the operator **110** are formed independently of each other, the rotation of one of the yaw operator **112** and the actuation operator **113** does not affect the rotation of the other of the yaw operator **112** and the actuation operator **113**, (2) the pitch operator **111** is disposed under the plane formed by the yaw operator **112** and the actuation operator **113**, and (3) the yaw operator **112** and the actuation operator **113** are formed over an extension line of the end tool **120**. H**1** may be seen in the first, fourth, and seventh embodiments of the present invention.
(78) As for H**2** of FIG. **3**A, (1) since the actuation operator **113** of the operator **110** is formed on the yaw operator **112**, when the yaw operator **112** rotates, the actuation operator **113** also rotates, (2) the pitch operator **111** is disposed under the plane formed by the yaw operator **112** and the actuation operator **113**, and (3) the yaw operator **112** and the actuation operator **113** are formed over the extension line of the end tool **120**. H**2** may be seen in the second, fifth, and eighth embodiments of the present invention.
(79) As for H**3** of FIG. **3**A, (1) a first jaw operator **112** and a second jaw operator **113**, which rotate independently of each other, are formed in the operator **110**, (2) the pitch operator **111** is disposed under the plane formed by the yaw operator **112** and the actuation operator **113**, and (3) the yaw operator **112** and the actuation operator **113** are formed over the extension line of the end tool **120**. H**3** may be seen in the third, sixth, and ninth embodiments of the present invention.
(80) As for H**4** of FIG. **3**A, (1) since the yaw operator **112** and the actuation operator **113** of the operator **110** are formed independently of each other, the rotation of one of the yaw operator **112** and the actuation operator **113** does not affect the rotation of the other of the yaw operator **112** and the actuation operator **113**, (2) the pitch operator **111** is disposed on a plane identical to or adjacent to the plane formed by the yaw operator **112** and the actuation operator **113** such that the pitch operator **111** is more adjacent to the yaw operator **112** and the actuation operator **113** as compared to the H**1** case, and (3) the yaw operator **112** and the actuation operator **113** are formed over the extension line of the end tool **120**. H**4** may be seen in detail in FIG. **9**.
(81) As for H**5** of FIG. **3**A, (1) since the actuation operator **113** of the operator **110** is formed on the yaw operator **112**, when the yaw operator **112** rotates, the actuation operator **113** also rotates, (2) the pitch operator **111** is disposed on a plane identical to or adjacent to the plane formed by the yaw operator **112** and the actuation operator **113** such that the pitch operator **111** is more adjacent to the yaw operator **112** and the actuation operator **113** as compared to the H**2** case, and (3) the yaw operator **112** and the actuation operator **113** are formed over the extension line of the end tool **120**.
(82) As for H**6** of FIG. **3**A, (1) a first jaw operator **112** and a second jaw operator **113**, which rotate independently of each other, are formed in the operator **110**, (2) the pitch operator **111** is disposed on a plane identical to or adjacent to the plane formed by the yaw operator **112** and the actuation operator **113** such that the pitch operator **111** is more adjacent to the yaw operator **112** and the actuation operator **113** as compared to the H**3** case, and (3) the yaw operator **112** and the actuation operator **113** are formed over the extension line of the end tool **120**.
(83) As for H**7** of FIG. **3**A, (1) since the yaw operator **112** and the actuation operator **113** of the operator **110** are formed independently of each other, the rotation of one of the yaw operator **112** and the actuation operator **113** does not affect the rotation of the other of the yaw operator **112** and the actuation operator **113**, (2) the pitch operator **111** is disposed under the plane formed by the yaw operator **112** and the actuation operator **113**, and (3) the yaw operator **112** and the actuation operator **113** are formed on the extension line of the end tool **120**.
(84) As for H**8** of FIG. **3**A, (1) since the actuation operator **113** of the operator **110** is formed on the yaw operator **112**, when the yaw operator **112** rotates, the actuation operator **113** also rotates, (2)

the pitch operator **111** is disposed under the plane formed by the yaw operator **112** and the actuation operator **113**, and (3) the yaw operator **112** and the actuation operator **113** are formed on the extension line of the end tool **120**.
(85) As for H**9** of FIG. **3**A, (1) a first jaw operator **112** and a second jaw operator **113**, which rotate independently of each other, are formed in the operator **110**, (2) the pitch operator **111** is disposed under the plane formed by the yaw operator **112** and the actuation operator **113**, and (3) the yaw operator **112** and the actuation operator **113** are formed on the extension line of the end tool **120**.
(86) As for H**10** of FIG. **3**A, (1) since the yaw operator **112** and the actuation operator **113** of the operator **110** are formed independently of each other, the rotation of one of the yaw operator **112** and the actuation operator **113** does not affect the rotation of the other of the yaw operator **112** and the actuation operator **113**, (2) the pitch operator **111** is disposed on a plane identical to or adjacent to the plane formed by the yaw operator **112** and the actuation operator **113** such that the pitch operator **111** is more adjacent to the yaw operator **112** and the actuation operator **113** as compared to the H**7** case, and (3) the yaw operator **112** and the actuation operator **113** are formed on the extension line of the end tool **120**.
(87) As for H**11** of FIG. **3**A, (1) since the actuation operator **113** of the operator **110** is formed on the yaw operator **112**, when the yaw operator **112** rotates, the actuation operator **113** also rotates, (2) the pitch operator **111** is disposed on a plane identical to or adjacent to the plane formed by the yaw operator **112** and the actuation operator **113** such that the pitch operator **111** is more adjacent to the yaw operator **112** and the actuation operator **113** as compared to the H**8** case, and (3) the yaw operator **112** and the actuation operator **113** are formed on the extension line of the end tool **120**.
(88) As for H**12** of FIG. **3**A, (1) a first jaw operator **112** and a second jaw operator **113**, which rotate independently of each other, are formed in the operator **110**, (2) the pitch operator **111** is disposed on a plane identical to or adjacent to the plane formed by the yaw operator **112** and the actuation operator **113** such that the pitch operator **111** is more adjacent to the yaw operator **112** and the actuation operator **113** as compared to the H**9** case, and (3) the yaw operator **112** and the actuation operator **113** are formed on the extension line of the end tool **120**.
(89) In addition to the above modifications, various other modifications of the operator **110** may be applicable to the surgical instrument of the present invention.
(90) (Operating Force Transmitter)
(91) FIG. **4**A is a detailed view of a first differential pulley **131** of the surgical instrument **100** of FIG. **2**, and FIG. **4**B is a detailed view of a second differential pulley of the surgical instrument **100** of FIG. **2**.
(92) Referring to FIGS. **1**, **2**, **4**A, and **4**B, the operating force transmitter **130** of the surgical instrument **100** according to the first embodiment of the present invention includes first and second differential pulleys **131** and **132**, a plurality of pulleys, and a plurality of wires **135**YC**1**, **135**YC**2**, **135J11**, **135J12**, **135J13**, **135J21**, **135J22**, and **135J23**.
(93) First, the first differential pulley **131** of the operating force transmitter **130** will be described below.
(94) As described above, the yaw operator **112** and the actuation operator **113** are formed on one end portion of the pitch operating bar **1112** of the pitch operator **111**. Thus, when the pitch operator **111** rotates around the pitch operating axis **1111**, the yaw operator **112** and the actuation operator **113** also rotate along with the pitch operator **111**. Also, the yaw operator **112** is connected with the first jaw **121** and the second jaw **122** to operate the first jaw **121** and the second jaw **122**, and the actuation operator **113** is connected with the first jaw **121** and the second jaw **122** to operate the first jaw **121** and the second jaw **122**. However, when the yaw operator **112** is rotated, the first jaw **121** and the second jaw **122** have to rotate in the same direction; and when the actuation operator **113** is rotated, the first jaw **121** and the second jaw **122** have to rotate in opposite directions. In order to implement this operation, a separate structure is required.
(95) Thus, two rotation inputs of the yaw operator **112** and the actuation operator **113** have to be

applied to one jaw. Accordingly, a structure for receiving two or more inputs and outputting a rotation of one jaw is required. In this case, two rotation inputs have to be independent of each other.
(96) To this end, the surgical instrument **100** according to the first embodiment of the present invention includes a differential member including two or more input units and one output unit to receive an input of rotating forces from two or more input units from the two input units, extract a desired rotating force through the sum of or the difference between the two rotating forces, and output the desired rotating force through the output unit. The differential member may include a differential pulley using pulleys and wires, and a differential gear using gears, and a differential pulley is illustrated as an example of the differential member in FIGS. **1**, **2**, **4**A, and **4**B. Various embodiments of the differential member are illustrated in FIGS. **15** to **27**.
(97) In detail, the first differential pulley **131** includes a first input unit **1311**, a second input unit **1312**, and an output unit **1313**.
(98) The first input unit **1311** includes a first pulley **1311***a* and a second pulley **1311***b*. The first pulley **1311***a* and the second pulley **1311***b* rotate together around the same rotating axis. Herein, the first pulley **1311***a* of the first input unit **1311** is connected with the first pulley **1121***a* of the yaw operator **112** by the YC**1** wire **135**YC**1** to transmit a rotation of the yaw operator **112** to the first input unit **1311**. Also, the second pulley **1311***b* of the first input unit **1311** is connected with the output unit **1313** by the differential control wire **135J11** to transmit a rotation of the first input unit **1311** to the output unit **1313**.
(99) The second input unit **1312** includes a first pulley **1312***a* and a second pulley **1312***b*. The first pulley **1312***a* and the second pulley **1312***b* rotate together around the same rotating axis. Herein, the first pulley **1312***a* of the second input unit **1312** is connected with the first pulley **1131***a* of the actuation operator **113** by the AC**1** wire **135**AC**1** to transmit a rotation of the actuation operator **113** to the second input unit **1312**. Also, the second pulley **1312***b* of the second input unit **1312** is connected with the output unit **1313** by the differential control wire **135J11** to transmit a rotation of the second input unit **1312** to the output unit **1313**.
(100) The output unit **1313** includes an output pulley **1313***a*, an extension portion **1313***b*, a first differential control pulley **1313***c*, and a second differential control pulley **1313***d*. Herein, the output pulley **1313***a* of the output unit **1313** is connected with the operator control member **115** by the J**12** wire **135J12** to transmit a rotation of the output unit **1313** to the first jaw **121** of the end tool **120** through the operator control member **115**. The extension portion **1313***b* extends in one direction from a rotating axis of the output pulley **1313***a* to rotate along with the output pulley **1313***a*. The first differential control pulley **1313***c* and the second differential control pulley **1313***d* are formed at one end portion of the extension portion **1313***b* to face each other and rotate around both end portions of an axis **1313***e* that is formed at a predetermined angle to the rotating axis of the output pulley **1313***a*.
(101) Herein, the first input unit **1311**, the second input unit **1312**, and the output unit **1313** rotate independently around independent axes.
(102) The differential control wire **135J11** is wound along the second pulley **1311***b* of the first input unit **1311**, the first differential control pulley **1313***c* of the output unit **1313**, the second pulley **1312***b* of the second input unit **1312**, and the second differential control pulley **1313***d* of the output unit **1313** to transmit a rotation of the first input unit **1311** and the second input unit **1312** to the output unit **1313**.
(103) Herein, the first differential pulley **131** includes the first input unit **1311**, the second input unit **1312**, and the output unit **1313**, receives an input of rotation amounts from the first input unit **1311** and the second input unit **1312**, and outputs the sum of the rotation amounts through the output unit **1313**. That is, when only the first input unit **1311** rotates, the rotation of the first input unit **1311** is output through the output unit **1313**; when only the second input unit **1312** rotates, the rotation of the second input unit **1312** is output through the output unit **1313**; when the first input

unit **1311** and the second input unit **1312** rotate in the same direction, the sum of the rotations of the first input unit **1311** and the second input unit **1312** is output through the output unit **1313**; and when the first input unit **1311** and the second input unit **1312** rotate in opposite directions, the difference between the rotations of the first input unit **1311** and the second input unit **1312** is output through the output unit **1313**. This may be expressed as the following equation:
(104) $C = A + B$
(105) (where C denotes a rotation of an output unit, A denotes a rotation of a first input unit, and B denotes a rotation of a second input unit.)
(106) The operation of the first differential pulley **131** will be described later in detail.
(107) Like the first differential pulley **131**, the second differential pulley **132** includes a first input unit **1321**, a second input unit **1322**, and an output unit **1323**.
(108) Herein, a first pulley **1321***a* of the first input unit **1321** is connected with the second pulley **1121***b* of the yaw operator **112** by the YC**2** wire **135**YC**2** to transmit a rotation of the yaw operator **112** to the first input unit **1321**. Also, a second pulley **1321***b* of the first input unit **1321** is connected with the output unit **1323** by a differential control wire **135J21** to transmit a rotation of the first input unit **1321** to the output unit **1323**.
(109) A first pulley **1322***a* of the second input unit **1322** is connected with the second pulley **1131***b* of the actuation operator **113** by the AC**2** wire **135**AC**2** to transmit a rotation of the actuation operator **113** to the second input unit **1322**. Also, the second pulley **1322***b* of the second input unit **1322** is connected with the output unit **1323** by the differential control wire **135J21** to transmit a rotation of the second input unit **1322** to the output unit **1323**.
(110) The output unit **1323** includes an output pulley **1323***a*, an extension portion **1323***b*, a first differential control pulley **1323***c*, and a second differential control pulley **1323***d*. Herein, the output pulley **1323***a* of the output unit **1323** is connected with the operator control member **115** by the J**22** wire **135**J**22** to transmit a rotation of the output unit **1323** to the second jaw **122** of the end tool **120** through the operator control member **115**.
(111) Herein, the second differential pulley **132** includes the first input unit **1321**, the second input unit **1322**, and the output unit **1323**, receives an input of rotation amounts from the first input unit **1321** and the second input unit **1322**, and outputs the sum of the rotation amounts through the output unit **1323**. That is, when only the first input unit **1321** rotates, the rotation of the first input unit **1321** is output through the output unit **1323**; when only the second input unit **1322** rotates, the rotation of the second input unit **1322** is output through the output unit **1323**; when the first input unit **1321** and the second input unit **1322** rotate in the same direction, the sum of the rotations of the first input unit **1321** and the second input unit **1322** is output through the output unit **1323**; and when the first input unit **1321** and the second input unit **1322** rotate in opposite directions, the difference between the rotations of the first input unit **1321** and the second input unit **1322** is output through the output unit **1323**.
(112) The operations of the first differential pulley **131** and the second differential pulley **132** will be described below.
(113) First, a case where only the yaw operator **112** rotates and the actuation operator **113** does not rotate will be described below.
(114) When the yaw operator **112** rotates in the direction of an arrow Y of FIG. **2**, the first pulley **1121***a* of the yaw operator **112**, the YC**1** wire **135**YC**1** wound around the first pulley **1121***a*, the first pulley **1311***a* of the first input unit **1311** of the first differential pulley **131** around which the YC**1** wire **135**YC**1** is wound, and the second pulley **1311***b* connected with the first pulley **1311***a* rotate together. However, the second input unit **1312** of the first differential pulley **131** connected with the actuation operator **113** does not rotate. In this manner, when the first input unit **1311** of the first differential pulley **131** rotates in the direction of an arrow R**1** of FIG. **4**A and the second input unit **1312** does not rotate, a portion wound around the first input unit **1311** of the differential control wire **135J11** rotates but a portion wound around the second input unit **1312** of the

differential control wire **135J11** does not rotate. Accordingly, the wire wound around the second input unit **1312** is unwound as much as the rotation of the portion wound around the first input unit **1311** of the differential control wire **135J11**, and the differential control wire **135J11** moves as much. Concurrently, the second differential control pulley **1313***d* rotates in the clockwise direction, and the first differential control pulley **1313***c* rotates in the counterclockwise direction. At the same time, the output unit **1313**, which includes the output pulley **1313***a*, the extension portion **1313***b*, the first differential control pulley **1313***c*, and the second differential control pulley **1313***d*, rotates in the direction of the arrow R**1** of FIG. **4**A around the rotating axis of the output pulley **1313***a*. Then, the rotation of the output unit **1313** is transmitted to the first jaw **121** of the end tool **120** through the operator control member **115**, so that the first jaw **121** rotates in the direction of an arrow YJ of FIG. **2**.

(115) Also, when the yaw operator **112** rotates in the direction of the arrow Y of FIG. **2**, the second pulley **1121***b* of the yaw operator **112**, the YC**2** wire **135**YC**2** wound around the second pulley **1121***b*, the first pulley **1321***a* of the first input unit **1321** of the second differential pulley **132** around which the YC**2** wire **135**YC**2** is wound, and the second pulley **1321***b* connected with the first pulley **1321***a* rotate together. However, the second input unit **1322** of the second differential pulley **132** connected with the actuation operator **113** does not rotate. In this manner, when the first input unit **1321** of the second differential pulley **132** rotates in the direction of an arrow R**3** of FIG. **4**B and the second input unit **1322** does not rotate, a portion wound around the first input unit **1321** of the differential control wire **135J21** rotates but a portion wound around the second input unit **1322** of the differential control wire **135J21** does not rotate. Accordingly, the wire wound around the second input unit **1322** is unwound as much as the rotation of the portion wound around the first input unit **1321** of the differential control wire **135J21**, and the differential control wire **135J21** moves as much. Concurrently, the second differential control pulley **1323***d* rotates in the clockwise direction, and the first differential control pulley **1323***c* rotates in the counterclockwise direction. At the same time, the output unit **1323**, which includes the output pulley **1323***a*, the extension portion **1323***b*, the first differential control pulley **1323***c*, and the second differential control pulley **1323***d*, rotates around the rotating axis of the output pulley **1323***a* in the direction of the arrow R**3** of FIG. **4**B. Then, the rotation of the output unit **1323** is transmitted to the second jaw **122** of the end tool **122** through the operator control member **115**, so that the second jaw **122** rotates in the direction of the arrow YJ of FIG. **2**.

(116) A case where only the actuation operator **113** rotates and the yaw operator **112** does not rotate will be described below.

(117) When the actuation operator **113** rotates in the direction of an arrow A of FIG. **2**, the first pulley **1131***a* of the actuation operator **113**, the AC**1** wire **135**AC**1** wound around the first pulley **1131***a*, the first pulley **1312***a* of the second input unit **1312** of the first differential pulley **131** around which the AC**1** wire **135**AC**1** is wound, and the second pulley **1312***b* connected with the first pulley **1312***a* rotate together. Herein, since the AC**1** wire **135**AC**1** is twisted one time, the rotating force of the actuation operator **113** is reversed and transmitted to the first differential pulley **131**. However, the first input unit **1311** of the first differential pulley **131** that is connected with the yaw operator **112** does not rotate. In this manner, when the second input unit **1312** of the first differential pulley **131** rotates in a direction opposite to the direction of an arrow R**2** of FIG. **4**A and the first input unit **1311** does not rotate, a portion wound around the second input unit **1312** of the differential control wire **135J11** rotates but a portion wound around the first input unit **1311** of the differential control wire **135J11** does not rotate. Accordingly, the wire wound around the first input unit **1311** is unwound as much as the rotation of the portion wound around the second input unit **1312** of the differential control wire **135J11**, and the differential control wire **135J11** moves as much. Concurrently, the second differential control pulley **1313***d* rotates in the counterclockwise direction, and the first differential control pulley **1313***c* rotates in the clockwise direction. At the same time, the output unit **1313**, which includes the output pulley **1313***a*, the extension portion

1313*b*, the first differential control pulley **1313***c*, and the second differential control pulley **1313***d*, rotates around the rotating axis of the output pulley **1313***a* in a direction opposite to the direction of the arrow R**2** of FIG. **4**A. Then, the rotation of the output unit **1313** is transmitted to the first jaw **121** of the end tool **120** through the operator control member **115**, so that the first jaw **121** rotates in the direction of the arrow YJ of FIG. **2**.

(118) Also, when the actuation operator **113** rotates in the direction of the arrow A of FIG. **2**, the second pulley **1131***b* of the actuation operator **113**, the AC**2** wire **135**AC**2** wound around the second pulley **1131***b*, the first pulley **1322***a* of the second input unit **1322** of the second differential pulley **132** around which the AC**2** wire **135**AC**2** is wound, and the second pulley **1322***b* connected with the first pulley **1322***a* rotate together. However, the first input unit **1321** of the second differential pulley **132** that is connected with the yaw operator **112** does not rotate. In this manner, when the second input unit **1322** of the second differential pulley **132** rotates in the direction of an arrow R**4** of FIG. **4**B and the first input unit **1321** does not rotate, a portion wound around the second input unit **1322** of the differential control wire **135**J**21** rotates but a portion wound around the first input unit **1321** of the differential control wire **135**J**21** does not rotate. Accordingly, the wire wound around the first input unit **1321** is unwound as much as the rotation of the portion wound around the second input unit **1322** of the differential control wire **135**J**21**, and the differential control wire **135**J**21** moves as much. Concurrently, the second differential control pulley **1323***d* rotates in the clockwise direction, and the first differential control pulley **1323***c* rotates in the counterclockwise direction. At the same time, the output unit **1323**, which includes the output pulley **1323***a*, the extension portion **1323***b*, the first differential control pulley **1323***c*, and the second differential control pulley **1323***d*, rotates around the rotating axis of the output pulley **1323***a* in the direction of the arrow R**4** of FIG. **4**B. Then, the rotation of the output unit **1323** is transmitted to the second jaw **122** of the end tool **122** through the operator control member **115**, so that the second jaw **122** rotates in a direction opposite to the direction of the arrow YJ of FIG. **2**.

(119) That is, when the first jaw **121** rotates in the direction of the arrow YJ of FIG. **2** and the second jaw **122** rotates in a direction opposite to the direction of the arrow YJ of FIG. **2**, an actuation operation of the end tool **120** is performed.

(120) There is a case where, in a differential pulley including two input units and one output unit, the rotation of one input unit does not generate the rotation of the output unit and generates the rotation of another input unit. In order to prevent this case, according to the present invention, in a situation where two operators are connected respectively to two differential pulleys, when one operator is connected with two input units of each of two differential pulleys, one of the wires connecting the operator and the input unit is twisted, thereby preventing a situation where the input of one operator causes another operator to rotate.

(121) In order to describe this in more detail, a case where the second input unit **1312** of the first differential pulley **131** and the second input unit **1322** of the second differential pulley **132** also rotate in the same direction as a rotation input of the yaw operator **112** by the rotation input of the yaw operator **112** connected to the first input unit **1311** of the first differential pulley **131** and the first input unit **1321** of the second differential pulley **132** is assumed. In this case, the actuation operator **113** and the second input unit **1312** of the first differential pulley **131** are connected by the AC**1** wire **135**AC**1** that is twisted one time, and the actuation operator **113** and the second input unit **1322** of the second differential pulley **132** are connected by the AC**2** wire **135**AC**2** that is not twisted. Thus, rotations of the second input units **1312** and **1322** of the first and second differential pulleys **131** and **132** rotate the actuation operator **113** in opposite directions by the AC**1** wire **135**AC**1** and the AC**2** wire **135**AC**2**. Therefore, the rotations offset each other and do not rotate the actuation operator **113**, and the remaining rotation is transmitted to each of the output units **1313** and **1323** to rotate each of the output units **1313** and **1323**. This is also applied to the rotation input of the actuation operator **113**. Thus, the rotation input of the actuation operator **113** does not cause the yaw operator **112** to rotate and is transmitted to each of the output units **1313** and **1323** to rotate

each of the output units **1313** and **1323**.
(122) In summary, according to this configuration, the rotation input of one operator does not cause another operator to rotate and is transmitted to each output unit to rotate each output unit.
(123) By this operational principle, even when the yaw operator **112** and the actuation operator **113** rotate simultaneously, the sum of (or the difference between) the rotation inputs of the yaw operator **112** and the actuation operator **113** is transmitted to the output units **1313** and **1323** of the first and second differential pulleys **131** and **132** through the first and second differential pulleys **131** and **132** to rotate the output units **1313** and **1323**, and the rotations of the output units **1313** and **1323** are transmitted to the first and second jaws **121** and **122** of the end tool **120** through the operation control member **115**, thus causing the first and second jaws **121** and **122** to rotate according to the operations of the yaw operator **112** and the actuation operator **113**.
(124) (End Tool)
(125) FIG. **5** is a schematic view of the end tool **120** of the surgical instrument **100** of FIG. **2**. Referring to FIGS. **1**, **2**, and **5**, the end tool **120** of the surgical instrument **100** according to the first embodiment of the present invention includes the end tool control member **123**. The end tool control member **123** includes a J**11** pulley **123J11**, a J**12** pulley **123J12**, a J**13** pulley **123J13**, a J**14** pulley **123J14**, and a J**15** pulley **123J15** that are related to the rotation motion of the first jaw **121**, and a J**21** pulley **123J21**, a J**22** pulley **123J22**, a J**23** pulley **123J23**, a J**24** pulley **123J24**, and a J**25** pulley **123J25** that are related to the rotation motion of the second jaw **122**. Herein, the J**12** pulley **123J12**, the J**14** pulley **123J14**, the J**22** pulley **123J22**, and the J**24** pulley **123J24** may be formed to rotate around an end tool pitch operating axis **1231**. Although it is illustrated that pulleys facing each other are formed to be parallel to each other and to have the same size, the present invention is not limited thereto. For example, the pulleys may be formed to have various positions and sizes suitable for the configuration of the end tool **120**.
(126) Herein, the end tool **120** of the surgical instrument **100** according to the first embodiment of the present invention includes the end tool control member **123** and only two wires, namely, a first jaw operating wire **135J13** and a second jaw operating wire **135J23**, thereby making it possible to conveniently perform a pitch operation, a yaw operation, and an actuation operation of the end tool **120**. This will be described below in more detail.
(127) The J**11** pulley **123J11** and the J**21** pulley **123J21** are formed to face each other and rotate independently around the Z-axis direction. Although not illustrated in FIG. **5**, the first jaw **121** may be coupled to the J**11** pulley **123J11** to rotate along with the J**11** pulley **123J11**, and the second jaw **122** may be coupled to the J**21** pulley **123J21** to rotate along with the J**21** pulley **123J21**. A yaw operation and an actuation operation of the end tool **120** are performed according to the rotations of the J**11** pulley **123J11** and the J**21** pulley **123J21**. That is, the yaw operation is performed when the J**11** pulley **123J11** and the J**21** pulley **123J21** rotate in the same direction, and the actuation operation is performed when the J**11** pulley **123J11** and the J**21** pulley **123J21** rotate in opposite directions.
(128) The elements related to the rotation of the J**11** pulley **123J11** will be described below.
(129) On one side of the J**11** pulley **123J11**, the J**12** pulley **123J12** and the J**14** pulley **123J14** are disposed to be spaced apart from each other by a predetermined distance and face each other. Herein, the J**12** pulley **123J12** and the J**14** pulley **123J14** are formed to rotate independently around the Y-axis direction. Also, on one side of the J**12** pulley **123J12** and the J**14** pulley **123J14**, the J**13** pulley **123J13** and the J**15** pulley **123J15** are disposed to be spaced apart from each other by a predetermined distance and face each other. Herein, the J**13** pulley **123J13** and the J**15** pulley **123J15** are formed to rotate independently around the Y-axis direction. Although it is illustrated that all of the J**12** pulley **123J12**, the J**13** pulley **123J13**, the J**14** pulley **123J14**, and the J**15** pulley **123J15** are formed to rotate around the Y-axis direction, the present invention is not limited thereto, and the rotating axes of the respective pulleys may be formed in various directions according to their configurations.

(130) At least a portion of the first jaw operating wire **135J13** contacts the J**13** pulley **123J13**, the J**12** pulley **123J12**, the J**11** pulley **123J11**, the J**14** pulley **123J14**, and the J**15** pulley **123J15**, so that the first jaw operating wire **135J13** may move along the pulleys while rotating the pulleys.
(131) Thus, when the first jaw operating wire **135J13** is pulled in the direction of an arrow J**1**R of FIG. **5**, the first jaw operating wire **135J13** sequentially rotates the J**15** pulley **123J15**, the J**14** pulley **123J14**, the J**11** pulley **123J11**, the J**12** pulley **123J12**, and the J**13** pulley **123J13**. In this case, the J**11** pulley **123J11** rotates in the direction of an arrow R of FIG. **5** to rotate the first jaw **121** together.
(132) On the other hand, when the first jaw operating wire **135J13** is pulled in the direction of an arrow J**1**L of FIG. **5**, the first jaw operating wire **135J13** sequentially rotates the J**13** pulley **123J13**, the J**12** pulley **123J12**, the J**11** pulley **123J11**, the J**14** pulley **123J14**, and the J**15** pulley **123J15**. In this case, the J**11** pulley **123J11** rotates in the direction of an arrow L of FIG. **5** to rotate the first jaw **121** together therewith.
(133) The elements related to the rotation of the J**21** pulley **123J21** will be described below.
(134) On one side of the J**21** pulley **123J21**, the J**22** pulley **123J22** and the J**24** pulley **123J24** are disposed to be spaced apart from each other by a predetermined distance and face each other. Herein, the J**22** pulley **123J22** and the J**24** pulley **123J24** are formed to rotate independently around the Y-axis direction. Also, on one side of the J**22** pulley **123J22** and the J**24** pulley **123J24**, the J**23** pulley **123J23** and the J**25** pulley **123J25** are disposed to be spaced apart from each other by a predetermined distance and face each other. Herein, the J**23** pulley **123J23** and the J**25** pulley **123J25** are formed to rotate independently around the Y-axis direction. Although it is illustrated that all of the J**22** pulley **123J22**, the J**23** pulley **123J23**, the J**24** pulley **123J24**, and the J**25** pulley **123J25** are formed to rotate around the Y-axis direction, the present invention is not limited thereto, and the rotating axes of the respective pulleys may be formed in various directions according to their configurations.
(135) At least a portion of the second jaw operating wire **135J23** contacts the J**23** pulley **123J23**, the J**22** pulley **123J22**, the J**21** pulley **123J21**, the J**24** pulley **123J24**, and the J**25** pulley **123J25**, so that the second jaw operating wire **135J23** may move along the pulleys while rotating the pulleys.
(136) Thus, when the second jaw operating wire **135J23** is pulled in the direction of an arrow J**2**R of FIG. **5**, the second jaw operating wire **135J23** sequentially rotates the J**25** pulley **123J25**, the J**24** pulley **123J24**, the J**21** pulley **123J21**, the J**22** pulley **123J22**, and the J**23** pulley **123J23**. In this case, the J**21** pulley **123J21** rotates in the direction of the arrow R of FIG. **5** to rotate the second jaw **122** together therewith.
(137) On the other hand, when the second jaw operating wire **135J23** is pulled in the direction of an arrow J**2**L of FIG. **5**, the second jaw operating wire **135J23** sequentially rotates the J**23** pulley **123J23**, the J**22** pulley **123J22**, the J**21** pulley **123J21**, the J**24** pulley **123J24**, and the J**25** pulley **123J25**. In this case, the J**21** pulley **123J21** rotates in the direction of the arrow L of FIG. **5** to rotate the second jaw **122** together therewith.
(138) When one end portion of the first jaw operating wire **135J13** is pulled in the direction of the arrow J**1**R of FIG. **5** and the other end portion of the first jaw operating wire **135J13** is pulled in the direction of the arrow J**1**L of FIG. **5**, the end tool control member **123** rotates around the end tool pitch operating axis **1231** in the counterclockwise direction, so that the end tool **120** rotates downward to perform a pitch motion.
(139) On the other hand, when one end portion of the second jaw operating wire **135J23** is pulled in the direction of the arrow J**2**R of FIG. **5** and the other end portion of the second jaw operating wire **135J23** is pulled in the direction of the arrow J**2**L of FIG. **5**, the end tool control member **123** rotates around the end tool pitch operating axis **1231** in the clockwise direction, so that the end tool **120** rotates upward to perform a pitch motion.
(140) That is, since the end tool **120** includes the end tool control member **123** and only two wires, namely, the first jaw operating wire **135J13** and the second jaw operating wire **135J23**, a pitch

operation, a yaw operation, and an actuation operation of the end tool **120** may be conveniently performed. This will be described later in detail.
(141) In the end tool control member **123** of the end tool **120** according to an embodiment of the present invention, the end tool pitch operating axis **1231** is disposed adjacent to the first and second jaws **121** and **122** (that is, the end tool pitch operating axis **1231** is disposed adjacent to the J**12** pulley **123J12** and the J**14** pulley **123J14**, not to the J**13** pulley **123J13** and the J**15** pulley **123J15**), thereby reducing a pitch rotation radius of the first and second jaws **121** and **122**. Accordingly, a space necessary for a pitch operation of the first and second jaws **121** and **122** may be reduced.
(142) FIG. **5**A illustrates a modification of the end tool **120** of FIG. **5**.
(143) Referring to FIG. **5**A, an end tool **120′** includes an end tool control member **123′**, and the end tool control member **123′** includes a J**11** pulley **123J11**, a J**12** pulley **123J12**, a J**14** pulley **123J14** related to the rotation motion of a first jaw, and a J**21** pulley **123J21**, a J**22** pulley **123J22**, a J**24** pulley **123J24** related to the rotation motion of a second jaw. Herein, the J**12** pulley **123J12**, the J**14** pulley **123J14**, the J**22** pulley **123J22**, and the J**24** pulley **123J24** may be formed to rotate around an end tool pitch operating axis **1231**. Although it is illustrated that pulleys facing each other are formed to be parallel to each other and have the same size, the present invention is not limited thereto, and the pulleys may be formed to have various positions and sizes suitable for the configuration of the end tool **120**.
(144) In this modification, not two pairs of pulleys facing each other, but only a pair of pulleys (i.e., the J**12** pulley **123J12** and the J**14** pulley **123J14**) are disposed on one side of the J**11** pulley **123J11** coupled with the first jaw, wherein the first jaw operating wire **135J13** is wound one or more times around the pair of pulleys while contacting the pair of pulleys.
(145) In detail, the J**11** pulley **123J11** and the J**21** pulley **123J21** are formed to face each other and rotate independently around the Z-axis direction.
(146) On one side of the J**11** pulley **123J11**, the J**12** pulley **123J12** and the J**14** pulley **123J14** are disposed to be spaced apart from each other by a predetermined distance and face each other. Herein, the J**12** pulley **123J12** and the J**14** pulley **123J14** are formed to rotate independently around the Y-axis direction. At least a portion of the first jaw operating wire **135J13** contacts the J**12** pulley **123J12**, the J**11** pulley **123J11**, and the J**14** pulley **123J14**, so that the first jaw operating wire **135J13** may move along the pulleys while rotating the pulleys. Herein, the first jaw operating wire **135J13** may be wound one or more times around the J**12** pulley **123J12** and then wound one or more times around the J**14** pulley **123J14** through the J**11** pulley **123J11**.
(147) Likewise, on one side of the J**21** pulley **123J21**, the J**22** pulley **123J22** and the J**24** pulley **123J24** are disposed to be spaced apart from each other by a predetermined distance and face each other. Herein, the J**22** pulley **123J22** and the J**24** pulley **123J24** are formed to rotate independently around the Y-axis direction. At least a portion of the second jaw operating wire **135J23** contacts the J**22** pulley **123J22**, the J**21** pulley **123J21**, and the J**24** pulley **123J24**, so that the second jaw operating wire **135J23** may move along the pulleys while rotating the pulleys. Herein, the second jaw operating wire **135J23** may be wound one or more times around the J**22** pulley **123J22** and then wound one or more times around the J**24** pulley **123J24** through the J**21** pulley **123J21**.
(148) By the above configuration, the number of pulleys may be reduced, and thus the size of a surgical instrument may be further reduced.
(149) (Pitch Operation Control and Wire Mirroring)
(150) FIG. **6** is a schematic view illustrating a pitch operation of the surgical instrument **100** of FIG. **2**.
(151) As described above, the operator **110** of the surgical instrument **100** according to the first embodiment of the present invention further includes the operator control member **115** engaged with the pitch operating axis **1111** of the pitch operator **111**. The operator control member **115** has substantially the same configuration of the end tool control member **123**, and the end tool control member **123** and the operator control member **115** are disposed symmetrical to each other about the

YZ plane of FIG. **1**. In other words, it may be said that the end tool control member **123** and the operator control member **115** are mirrored with respect to the YZ plane of FIG. **1**.
(152) In detail, the operator control member **115** includes a J**11** pulley **115J11**, a J**12** pulley **115J12**, a J**13** pulley **115J13**, a J**14** pulley **115J14**, and a J**15** pulley **115J15** that are related to the rotation motion of the first jaw **121**, and a J**21** pulley **115J21**, a J**22** pulley **115J22**, a J**23** pulley **115J23**, a J**24** pulley **115J24**, and a J**25** pulley **115J25** that are related to the rotation motion of the second jaw **122**.
(153) At least a portion of the first jaw operating wire **135J13** contacts the J**13** pulley **115J13**, the J**12** pulley **115J12**, the J**11** pulley **115J11**, the J**14** pulley **115J14**, and the J**15** pulley **115J15**, so that the first jaw operating wire **135J13** may move along the pulleys while rotating the pulleys.
(154) At least a portion of the second jaw operating wire **135J23** contacts the J**23** pulley **115J23**, the J**22** pulley **115J22**, the J**21** pulley **115J21**, the J**24** pulley **115J24**, and the J**25** pulley **115J25**, so that the second jaw operating wire **135J23** may move along the pulleys while rotating the pulleys.
(155) Herein, the rotating axis of the J**12** pulley **115J12**, the J**14** pulley **115J14**, the J**22** pulley **115J22**, and the J**24** pulley **115J24** may be identical to the pitch operating axis **1111** of the pitch operator **111**. Also, a bar extending from the rotating axis of the J**11** pulley **115J11** and the J**21** pulley **115J21** may be identical to the pitch operating bar **1112** of the pitch operator **111**.
(156) The pitch operation in the first embodiment of the present invention is performed as follows:
(157) When the user grips the pitch operating bar **1112** of the pitch operator **111** of the operator **110** and rotates the pitch operating bar **1112** around the pitch operating axis **1111** in the direction of an arrow OP (Operator Pitch) of FIG. **6**, the first jaw operating wire **135J13** is pulled toward the operator **110** and moves in the direction of an arrow PJ**1** of FIG. **6**. At the same time, the second jaw operating wire **135J23** is unwound from the operator **110**, moves toward the end tool **120**, and moves in the direction of an arrow PJ**2** of FIG. **6**. Then, as the first jaw operating wire **135J13** is pulled toward the operator **110**, the J**12** pulley **123J12** and the J**14** pulley **123J14** rotate around the rotating axis (see FIG. **5**) in the counterclockwise direction. At the same time, as the second jaw operating wire **135J23** is pulled toward the end tool **120**, the J**22** pulley **123J22** and the J**24** pulley **123J24** rotate around the rotating axis (see FIG. **5**) in the counterclockwise direction. Consequently, the end tool **120** rotates downward to perform a pitch motion.
(158) In this manner, since the end tool control member **123** and the operator control member **115** are disposed symmetrical to each other (i.e., mirrored) about the YZ plane of FIG. **1**, the pitch operation may be conveniently performed. That is, the pitch operation may be performed regardless of the yaw operation and the actuation operation. Herein, the yaw operation refers to a rotating operation of the first and second jaws **121** and **122** according to the rotations of the J**11** pulley **123J11** and the J**21** pulley **123J21** of the end tool control member **123** and the J**11** pulley **115J11** and the J**21** pulley **115J21** of the operator control member **115**.
Overall Operation of First Embodiment
(159) Hereinafter, an overall configuration for the pitch operation, the yaw operation, and the actuation operation of the surgical instrument **100** according to the first embodiment of the present invention will be summarized with reference to the above descriptions.
(160) For the configuration of the end tool **120** of the present embodiment, the operating force transmitter **130** capable of dividing the operation input of the operator **110** into a pitch operation, a yaw operation, and an actuation operation is necessary to perform the pitch, yaw, and actuation operations of the end tool **120**. As described above, through the structure in which the end tool control member **123** and the operator control member **115** are disposed symmetrical to each other, the rotation operation of the pitch operator **111** enables the pitch operation of the end tool **120** regardless of the operations of the yaw operator **112** and the actuation operator **113**. However, in order for the operations of the yaw operator **112** and the actuation operator **113** to lead to the yaw operation and the actuation operation of the end tool **120**, the operations of the yaw operator **112** and the actuation operator **113** have to be converted into the operations of two jaws of the end tool

120. The rotation of the yaw operator **112** causes the two jaws to rotate in the same direction, and the rotation of the actuation operator **113** causes the two jaws to rotate in different directions. That is, the first jaw **121** rotates as much as the sum of the operation inputs of the yaw operator **112** and the actuation operator **113**, and the second jaw **122** rotates as much as the difference between the operation inputs of the yaw operator **112** and the actuation operator **113**. This may be expressed as the following equation:
$J1=Y+A$ (the first jaw rotates in the same direction in both the yaw operation and the actuation operation.)
$J2=Y-A$ (the second jaw rotates in the same direction in the yaw operation and rotates in an opposite direction in the actuation operation.)
(161) (where Y denotes the rotation of the yaw operating pulley, and A denotes the rotation of the actuation operating pulley.)
(162) To this end, the operating force transmitter includes a differential pulley that receives Y and A and outputs the sum (J**1**) of Y and A, and a differential pulley that receives Y and A and outputs the difference (J**2**) between Y and A, and the rotation of the output unit of each differential pulley is transmitted to each jaw of the end tool.
(163) This will be described below in more detail.
(164) First, the pitch operation will be described below.
(165) As described above, when the user grips the pitch operating bar **1112** of the pitch operator **111** of the operator **110** and rotates the pitch operating bar **1112** around the pitch operating axis **1111** in the direction of the arrow OP of FIG. **6**, the operator control member **115** also rotates around the pitch operating axis **1111**. Then, the first jaw operating wire **135J13** wound around the operation control member **115** is pulled toward the operator **110** and moves in the direction of the arrow PJ**1** of FIG. **6**. At the same time, the second jaw operating wire **135J23** wound around the operation control member **115** is unwound from the operator control member **115** and moves in the direction of the arrow PJ**2** of FIG. **6**. Then, the end tool control member **123** connected with the first jaw operating wire **135J13** and the second jaw operating wire **135J23** rotates around the end tool pitch operating axis **1231** in the direction of an arrow EP of FIG. **6** to perform a pitch motion.
(166) The yaw operation will be described below.
(167) When the yaw operator **112** rotates in the direction of the arrow Y of FIG. **2**, the first pulley **1121***a* of the yaw operator **112**, the YC**1** wire **135**YC**1** wound around the first pulley **1121***a*, and the first input unit **1311** of the first differential pulley **131**, around which the YC**1** wire **135**YC**1** is wound, rotate together. In this manner, when the first input unit **1311** of the first differential pulley **131** rotates, the rotating force of the differential control wire **135J11** connecting the first input unit **1311** and the output unit **1313** rotates the output unit **1313** in the direction of the arrow R**1** of FIG. **4**A. Then, the rotation of the output unit **1313** is transmitted to the operator control member **115** through the J**12** wire **135J12** wound around the output unit **1313**, to rotate the J**11** pulley **115J11** (see FIG. **6**) of the operator control member **115**. Then, when the J**11** pulley **115J11** of the operator control member **115** rotates, the first jaw operating wire **135J13** connected therewith is moved, and the first jaw **121** of the end tool **120** connected with the first jaw operating wire **135J13** rotates in the direction of the arrow YJ of FIG. **2**.
(168) Also, when the yaw operator **112** rotates in the direction of the arrow Y of FIG. **2**, the second pulley **1121***b* of the yaw operator **112**, the YC**2** wire **135**YC**2** wound around the second pulley **1121***b*, and the first input unit **1321** of the second differential pulley **132**, around which the YC**2** wire **135**YC**2** is wound, rotate together therewith. In this manner, when the first input unit **1321** of the second differential pulley **132** rotates, the rotating force of the differential control wire **135J21** connecting the first input unit **1321** and the output unit **1323** rotates the output unit **1323** in the direction of the arrow R**3** of FIG. **4**B. Then, the rotation of the output unit **1323** is transmitted to the operator control member **115** through the J**22** wire **135J22** wound around the output unit **1323**, to rotate the J**21** pulley **115J21** (see FIG. **6**) of the operator control member **115**. Then, when the J**21**

pulley **115J21** of the operator control member **115** rotates, the second jaw operating wire **135J23** connected therewith is moved, and the second jaw **122** of the end tool **120** connected with the second jaw operating wire **135J23** rotates in the direction of the arrow YJ of FIG. **2**.

(169) In this manner, when the yaw operator **112** is rotated in one direction, the first and second jaws **121** and **122** rotate in the same direction to perform a yaw operation. Herein, the surgical instrument **100** according to an embodiment of the present invention includes one or more differential pulleys, so that the operation of the yaw operator **112** is not accompanied by the operation of the actuation operator **113**.

(170) The actuation operation will be described below.

(171) When the actuation operator **113** rotates in the direction of the arrow A of FIG. **2**, the first pulley **1131***a* of the actuation operator **113**, the AC**1** wire **135**AC**1** wound around the first pulley **1131***a*, and the second input unit **1312** of the first differential pulley **131**, around which the AC**1** wire **135**AC**1** is wound, rotate together. Herein, since the AC**1** wire **135**AC**1** is twisted one time, the rotating force of the actuation operator **113** is reversed and transmitted to the first differential pulley **131**. In this manner, when the second input unit **1312** of the first differential pulley **131** rotates, the rotating force of the differential control wire **135J11** connecting the second input unit **1312** and the output unit **1313** rotates the output unit **1313** in a direction opposite to the direction of the arrow R**2** of FIG. **4**A. Then, the rotation of the output unit **1313** is transmitted to the operator control member **115** through the J**12** wire **135J12** wound around the output unit **1313**, to rotate the J**11** pulley **115J11** (see FIG. **6**) of the operator control member **115**. Then, when the J**11** pulley **115J11** of the operator control member **115** rotates, the first jaw operating wire **135J13** connected therewith is rotated, and the first jaw **121** of the end tool **120** that is connected with the first jaw operating wire **135J13** rotates in the direction of the arrow YJ of FIG. **2**.

(172) Also, when the actuation operator **113** rotates in the direction of the arrow A of FIG. **2**, the second pulley **1131***b* of the actuation operator **113**, the AC**2** wire **135**AC**2** wound around the second pulley **1131***b*, and the second input unit **1322** of the second differential pulley **132**, around which the AC**2** wire **135**AC**2** is wound, rotate together. In this manner, when the second input unit **1322** of the second differential pulley **132** rotates, the rotating force of the differential control wire **135J21** connecting the second input unit **1322** and the output unit **1323** rotates the output unit **1323** in the direction of the arrow R**4** of FIG. **4**A. Then, the rotation of the output unit **1323** is transmitted to the operator control member **115** through the J**22** wire **135J22** wound around the output unit **1323**, to rotate the J**21** pulley **115J21** (see FIG. **6**) of the operator control member **115**. Then, when the J**21** pulley **115J21** of the operator control member **115** rotates, the second jaw operating wire **135J23** connected therewith is rotated, and the second jaw **122** of the end tool **120** that is connected with the second jaw operating wire **135J23** rotates in a direction opposite to the direction of the arrow YJ of FIG. **2**.

(173) In this manner, when the actuation operator **113** is rotated in one direction, the first and second jaws **121** and **122** rotate in opposite directions to perform an actuation operation. Herein, the surgical instrument **100** according to an embodiment of the present invention includes one or more differential pulleys, so that the operation of the actuation operator **113** is not accompanied by the operation of the yaw operator **112**.

(174) Thus, according to the present invention, a surgical instrument performing an output operation of an end tool by the independent inputs of a pitch operator, a yaw operator, and an actuation operator may be implemented solely by a mechanical configuration without using motors, electronic control, or software. That is, since the pitch operation, the yaw operation, and the actuation operation, which affect each other, are separated from each other solely by a mechanism, the configuration of the surgical instrument may be significantly simplified.

(175) Also, the rotating force of the operator **110** may be transmitted to the end tool **120** solely by a minimum wire and pulley structure. In particular, according to the present invention, since the operation direction of the operator **110** is intuitively identical to the operation direction of the end

tool **120**, the convenience of a surgical operator may be improved and the accuracy of a surgical operation may be improved. In addition, since the end tool **120** includes only two wires, namely, the first jaw operating wire **135**J**13** and the second jaw operating wire **135**J**23**, the pitch operation, the yaw operation, and the actuation operation of the end tool **120** may be conveniently performed. Furthermore, since the end tool control member **123** and the operator control member **115** are disposed symmetrical to each other (i.e., mirrored) about the YZ plane of FIG. **1**, the pitch operation may be conveniently performed. That is, the pitch operation may be performed regardless of the yaw operation and the actuation operation.

Modification of End Tool and Operator Control Member of First Embodiment

(176) FIG. **7** is a view illustrating a surgical instrument **100***b* according to a modification of the end tool **120** and the operator control member **115** of the first embodiment illustrated in FIG. **1**, and FIG. **8** is a detailed view of the end tool **120** of the surgical instrument **100***b* of FIG. **7**. Since the surgical instrument **100***b* according to a modification of the end tool **120** of the first embodiment of the present invention is similar to the surgical instrument **100** according to the first embodiment of the present invention and is different from the surgical instrument **100** in terms of the configuration of the end tool **120**, the configuration of the end tool **120** will be mainly described below.

(177) Referring to FIGS. **7** and **8**, the surgical instrument **100***b* according to a modification of the end tool **120** of the first embodiment of the present invention includes an operator **110**, an end tool **120**, an operating force transmitter **130**, and a connector (not illustrated).

(178) The end tool **120** includes an end tool control member **123**, and the end tool control member **123** includes a J**11** pulley **123**J**11**, a J**12** pulley **123**J**12**, a J**13** pulley **123**J**13**, a J**14** pulley **123**J**14**, and a J**15** pulley **123**J**15** that are related to the rotation motion of the first jaw **121**, and a J**21** pulley **123**J**21**, a J**22** pulley **123**J**22**, a J**23** pulley **123**J**23**, a J**24** pulley **123**J**24**, and a J**25** pulley **123**J**25** that are related to the rotation motion of the second jaw **122**. Herein, the first jaw **121**, the J**11** pulley **123**J**11**, the J**12** pulley **123**J**12**, the J**14** pulley **123**J**14**, the second jaw **122**, the J**21** pulley **123**J**21**, the J**22** pulley **123**J**22**, and the J**24** pulley **123**J**24** may be formed to rotate around the end tool pitch operating axis **1231**.

(179) The surgical instrument **100***b* is different from the surgical instrument **100** of the first embodiment in that the end tool **120** further includes a pitch pulley **123**P, the operator **110** further includes a pitch pulley **115**P, and the operating force transmitter **130** further includes a pitch wire **135**P. In detail, the pitch pulley **123**P of the end tool **120** may be integrated with the end tool pitch operating axis **1231** to rotate along with the end tool pitch operating axis **1231**. The pitch pulley **115**P of the operator **110** may be integrated with the pitch operating axis **1111** to rotate along with the pitch operating axis **1111**. Also, the pitch wire **135**P may connect the pitch pulley **123**P of the end tool **120** and the pitch pulley **115**P of the operator **110**.

(180) Thus, when the user grips the pitch operating bar **1112** of the pitch operator **111** and rotates the pitch operating bar **1112** around the pitch operating axis **1111**, the pitch operating axis **1111** connected with the pitch operating bar **1112** and the pitch pulley **115**P connected therewith rotate, the rotation of the pitch pulley **115**P is transmitted to the pitch pulley **123**P of the end tool **120** through the pitch wire **135**P, and the pitch pulley **123**P also rotates together therewith. Consequently, the end tool **120** rotates to perform a pitch motion.

(181) In the surgical instrument **100** of the first embodiment, since the pitch operation of the surgical instrument **100** is performed solely by the first jaw operating wire **135**J**13** and the second jaw operating wire **135**J**23**, when the first jaw operating wire **135**J**13** and the second jaw operating wire **135**J**23** are extended due to long-term use, the pitch operation may not be performed properly. In addition, the operating force of the pitch operator **111** may not be properly transmitted to the end tool **120**. In order to solve such problems, the surgical instrument **100***b* according to a modification of the end tool **120** of the first embodiment of the present invention further includes the pitch pulley **123**P of the end tool **120**, the pitch pulley **115**P of the operator **110**, and the pitch wire **135**P of the operating force transmitter **130** to more perfectly transmit the operating force of the pitch

operation of the pitch operator **111** to the end tool **120**, thereby improving operational reliability.
(182) The end tool **120** of the surgical instrument **100***b* may further include a wire guide **123**WG. In detail, the wire guide **123**WG may be formed to protrude in the Z-axis direction in the end tool control member **123**. The wire guide **123**WG may be formed to contact the first jaw operating wire **135J13** and guide a rotating path of the first jaw operating wire **135J13**, thereby making it possible to prevent the first jaw operating wire **135J13** from being removed from the J**12** pulley **115J12** and the J**14** pulley **115J14**.
(183) In this manner, in order to increase the reliability of the pitch operation, the first embodiment may be modified such that pulleys are added in the end tool and operator and wires are added, and may be modified such that a wire guide is also added in the end tool.
(184) Also, the above modification of the end tool of the first embodiment of the present invention may also be applied to various other modifications and embodiments that will be described later.
(185) Although FIG. **7** illustrates that the pitch operation is performed by the wires and pulleys, the present invention is not limited thereto. That is, various structures, in which the end tool control member **123** and the operator control member **115** may be connected symmetrically, may be applied to the present invention. For example, a four-bar link may be used to connect the end tool control member **123** and the operator control member **115**. That is, when a long side of the four-bar link functions as the jaw operating wires **135J13** and **135J23** and the end tool control member **123** and the operator control member **115** are connected to a central portion of a short side of the four-bar link, the end tool control member **123** and the operator control member **115** may be disposed symmetrical to each other (i.e., mirrored) about the YZ plane of FIG. **1**.
Modification of Operator of First Embodiment
(186) FIG. **9** is a view illustrating a surgical instrument **100***a* according to a modification of the operator **110** of the first embodiment illustrated in FIG. **1**. Since the surgical instrument **100***a* according to a modification of the operator **110** of the first embodiment of the present invention is similar to the surgical instrument **100** according to the first embodiment of the present invention and is different from the surgical instrument **100** in terms of the position of the operator **110**, the configuration of the operator **110** will be mainly described below.
(187) Referring to FIG. **9**, the surgical instrument **100***a* according to a modification of the operator **110** of the first embodiment of the present invention includes an operator **110**, an end tool **120**, an operating force transmitter **130**, and a connector (not illustrated).
(188) In the surgical instrument **100***a*, the pitch operator **111** and the end tool **120** are not formed on the same axis (X axis), but are formed on different axes. That is, additional direction-changing pulleys P are further provided between the first jaw operating wire **135J13** and the second jaw operating wire **135J23**, and the first jaw operating wire **135J13** and the second jaw operating wire **135J23** are bent one time. Accordingly, the pitch operator **111** and the end tool **120** are not formed on the same axis (X axis), and the pitch operator **111** may be formed adjacent to the yaw operator **112** and the actuation operator **113**.
(189) In the surgical instrument **100***a*, the pitch operator **111** may be formed adjacent to the yaw operator **112** and the actuation operator **113**. In this manner, the relative positions of the pitch operator **111**, the yaw operator **112**, and the actuation operator **113** may be modified within the scope of improving user convenience.
(190) Also, by forming the connector to be nonlinear, the relative positions of the end tool, the pitch operator, the yaw operator, and the actuation operator may be modified variously.
(191) Also, the above modification of the operator of the first embodiment of the present invention may also be applied to various other modifications and embodiments.
Modification of Operator Control Member of First Embodiment
(192) FIG. **10** is a view illustrating a surgical instrument **100***c* according to a modification of the operator control member **115** of the first embodiment illustrated in FIG. **1**. Since the surgical instrument **100***c* according to a modification of the operator control member **115** of the first

embodiment of the present invention is similar to the surgical instrument **100** according to the first embodiment of the present invention and is different from the surgical instrument **100** in terms of the configuration of the operator control member, the configuration of the operator control member will be mainly described below.
(193) Referring to FIG. **10**, the surgical instrument **100***c* according to a modification of the operator control member **115** of the first embodiment of the present invention includes an operator **110**, an end tool **120**, an operating force transmitter **130**, and a connector (not illustrated). Also, the operator **110** includes an operator control member **115***c*, and the operator control member **115***c* does not include the relay pulley **115***a* (see FIG. **2**), unlike in the surgical instrument **100** of the first embodiment of the present invention illustrated in FIG. **2**. Since a relay pulley is removed from the operator control member **115***c*, the configuration of the operator control member **115***c* may be simplified.
(194) In this manner, a relay pulley may be removed from the operator **110**.
(195) Also, the above modification of the operator control member **115** of the first embodiment of the present invention may also be applied to various other modifications and embodiments.
<Modification of End Tool Control Member and Operator Control Member of First Embodiment
(196) FIG. **11** is a view illustrating a surgical instrument **100***d* according to a modification of the end tool control member **123** and the operator control member **115** of the first embodiment illustrated in FIG. **1**. Since the surgical instrument **100***d* according to a modification of the end tool control member **123** and the operator control member **115** of the first embodiment of the present invention is similar to the surgical instrument **100** according to the first embodiment of the present invention and is different from the surgical instrument **100** in terms of the configuration of the end tool control member and the operator control member, the configurations of the end tool control member and the operator control member will be mainly described below.
(197) Referring to FIG. **11**, the surgical instrument **100***d* according to a modification of the end tool control member **123** and the operator control member **115** of the first embodiment of the present invention includes an operator **110**, an end tool **120**, an operating force transmitter **130**, and a connector (not illustrated). Herein, the operator **110** includes an operator control member **115***d*, and the end tool **120** includes an end tool control member **123***d*.
(198) This will be described below in more detail.
(199) In the surgical instrument **100** according to the first embodiment of the present invention illustrated in FIGS. **2** and **5**, the end tool pitch operating axis **1231** is formed adjacent to the first jaw **121** and the second jaw **122**. That is, the end tool pitch operating axis **1231** functions as the rotating axis of the J**12** pulley **123J12**, the J**14** pulley **123J14**, the J**22** pulley **123J22**, and the J**24** pulley **123J24**, and the first jaw **121** and the second jaw **122** rotate around the end tool pitch operating axis **1231**.
(200) However, as illustrated in FIG. **11**, in the surgical instrument **100***d* according to a modification of the end tool control member **123** of the first embodiment of the present invention, an end tool pitch operating axis **1231***d* is formed distant from the first jaw **121** and the second jaw **122**. That is, the end tool pitch operating axis **1231***d* functions as the rotating axis of the J**13** pulley **123J13**, the J**15** pulley **123J15**, the J**23** pulley **123J23**, and the J**25** pulley **123J25**, so that the J**11** pulley **123J11**, the J**12** pulley **123J12**, the J**13** pulley **123J13**, the J**14** pulley **123J14**, and the J**15** pulley **123J15** related to the rotation motion of the first jaw **121** and the J**21** pulley **123J21**, the J**22** pulley **123J22**, the J**23** pulley **123J23**, the J**24** pulley **123J24**, and the J**25** pulley **123J25** related to the rotation motion of the second jaw **122** rotate around the end tool pitch operating axis **1231***d*. In this manner, by moving the position of the end tool pitch operating axis **1231***d*, the rotation radius of the end tool **120** and rotating elements may be modified. Likewise, the operating axis of the operator control member **115***d* may also be formed distant from the relay pulley **115***a* (see FIG. **2**).
(201) Also, the above modification of the end tool control member **123** and the operator control member **115** of the first embodiment of the present invention may also be applied to various other

modifications and embodiments.

Modification of End Tool Control Member and Operator Control Member of First Embodiment

(202) FIG. **12** is a view illustrating a surgical instrument **100***e* according to a modification of the end tool control member **123** and the operator control member **115** of the first embodiment illustrated in FIG. **1**. Since the surgical instrument **100***e* according to a modification of the end tool control member **123** and the operator control member **115** of the first embodiment of the present invention is similar to the surgical instrument **100** according to the first embodiment of the present invention and is different from the surgical instrument **100** in terms of the configuration of the end tool control member **123** and the operator control member **115**, the configurations of the end tool control member and the operator control member will be mainly described below.

(203) Referring to FIG. **12**, the surgical instrument **100***e* according to a modification of the end tool control member **123** and the operator control member **115** of the first embodiment of the present invention includes an operator **110**, an end tool **120**, an operating force transmitter **130**, and a connector (not illustrated). Herein, the operator **110** includes an operator control member **115***e*, and the end tool **120** includes an end tool control member **123***c*.

(204) As illustrated in FIG. **12**, the surgical instrument **100***e* according to a modification of the end tool control member **123** of the first embodiment of the present invention is an example of the combination of the structure of FIG. **10** in which a relay pulley is not provided and the structure of FIG. **11** in which an axis is disposed therebehind, and corresponds to the structure in which the relay pulley **115***a* (see FIG. **2**) is removed from the surgical instrument **100***d* illustrated in FIG. **11**. Since a relay pulley is removed from the operator control member **115***e*, the configuration of the operator control member **115***e* may be simplified.

(205) Also, the above modification of the end tool control member **123** and the operator control member **115** of the first embodiment of the present invention may also be applied to various other modifications and embodiments.

Another Modification of End Tool Control Member and Operator Control Member of First Embodiment

(206) FIG. **13** is a view illustrating a surgical instrument **100***f* according to another modification of the end tool control member **123** and the operator control member **115** of the first embodiment illustrated in FIG. **1**, and FIG. **14** is a bottom perspective view of an end tool control member **123***f* of FIG. **13**. Since the surgical instrument **100***f* according to a modification of the end tool control member **123** and the operator control member **115** of the first embodiment of the present invention is similar to the surgical instrument **100** according to the first embodiment of the present invention and is different from the surgical instrument **100** in terms of the configuration of the end tool control member and the operator control member, the configurations of the end tool control member and the operator control member will be mainly described below. That is, an end tool control member that is different in form from the end tool control member **123** illustrated in FIGS. **5** and **8** is used in this modification.

(207) Referring to FIGS. **13** and **14**, the surgical instrument **100***f* according to a modification of the end tool control member **123** and the operator control member **115** of the first embodiment of the present invention includes an operator **110**, an end tool **120**, an operating force transmitter **130**, and a connector (not illustrated). Herein, the end tool **120** includes the end tool control member **123***f*. The end tool control member **123***f* includes a J**11** pulley **123J11**, a J**12** pulley **123J12**, a J**13** pulley **123J13**, a J**14** pulley **123J14**, and a J**15** pulley **123J15** that are related to the rotation motion of the first jaw **121**, and a J**21** pulley **123J21**, a J**22** pulley **123J22**, a J**23** pulley **123J23**, a J**24** pulley **123J24**, and a J**25** pulley **123J25** that are related to the rotation motion of the second jaw **122**. Herein, the J**13** pulley **123J13**, the J**15** pulley **123J15**, the J**23** pulley **123J23**, and the J**25** pulley **123J25** may be formed to rotate around an end tool pitch operating axis **1231***f*.

(208) Herein, the surgical instrument **100***f* of this modification is different from the surgical instrument **100** illustrated in FIG. **5** or **8** in terms of the winding mode of arranged pulleys. That is,

at least a portion of the first jaw operating wire **135J13** contacts the J**13** pulley **123J13**, the J**12** pulley **123J12**, the J**11** pulley **123J11**, the J**14** pulley **123J14**, and the J**15** pulley **123J15**, so that the first jaw operating wire **135J13** may move along the pulleys while rotating the pulleys. In this case, in the surgical instrument **100** illustrated in FIG. **5**, the first jaw operating wire **135J13** entering at the upper portion of the J**13** pulley **123J13** exits through the upper portion of the J**15** pulley **123J15**. However, in the surgical instrument **100***f* of this modification, the first jaw operating wire **135J13** entering at the upper portion of the J**13** pulley **123J13** exits through the lower portion of the J**15** pulley **123J15**.
(209) Likewise, at least a portion of the second jaw operating wire **135J23** contacts the J**23** pulley **123J23**, the J**22** pulley **123J22**, the J**21** pulley **123J21**, the J**24** pulley **123J24**, and the J**25** pulley **123J25**, so that the second jaw operating wire **135J23** may move along the pulleys while rotating the pulleys. In the surgical instrument **100***f* of this modification, the second jaw operating wire **135J23** entering at the upper portion of the J**23** pulley **123J23** exits through the lower portion of the J**25** pulley **123J25**.
(210) To this end, the arrangement of pulleys may also be modified. That is, the rotating axis (X**1**) of the J**12** pulley **123J12** and the J**22** pulley **123J22** and the rotating axis (X**2**) of the J**14** pulley **123J14** and the J**24** pulley **123J24** may not be located on the same line so that the first jaw operating wire **135J13** entering at the upper portion of the J**13** pulley **123J13** exits through the lower portion of the J**15** pulley **123J15**, as illustrated in FIGS. **13** and **14**. That is, the rotating axis (X**1**) of the J**12** pulley **123J12** and the J**22** pulley **123J22** may be formed over the end tool pitch operating axis **1231***f*, while the rotating axis (X**2**) of the J**14** pulley **123J14** and the J**24** pulley **123J24** may be formed under the end tool pitch operating axis **1231***f*.
(211) In addition, due to a difference in the wire winding mode, there may be a difference in the pitch operating mode. In the surgical instrument **100** illustrated in FIG. **5**, all of the pitch operation, the yaw operation, and the actuation operation may be performed by two wires, namely, the first jaw operating wire **134J13** and the second jaw operating wire **134J23**. However, in the surgical instrument **100***f* of this modification, a wire for performing the pitch operation is additionally provided, in addition to the first jaw operating wire **134J13** and the second jaw operating wire **134J23** for performing the yaw operation and the actuation operation.
(212) Also, the above modification of the end tool control member **123** and the operator control member **115** of the first embodiment of the present invention may also be applied to various other modifications and embodiments.
<First Modification of Differential Pulley> (D1)
(213) FIG. **15** is a view illustrating a first modification of the differential pulley of the surgical instrument **100** illustrated in FIG. **2**, and FIGS. **16** and **17** are views illustrating an operation of the first modification of a differential pulley illustrated in FIG. **15**.
(214) As described above, the differential pulley according to the present invention includes two or more input units and one output unit, receives an input of rotating forces from the two or more input units, extracts a desired rotating force from the sum of (or the difference between) the input rotating forces, and outputs the desired rotating force through the output unit.
(215) Referring to FIG. **15**, the first modification of the differential pulley of the surgical instrument includes a first input unit **1361**, a second input unit **1362**, an output unit **1363**, and a differential control member **1364**.
(216) The first input unit **1361** includes a first pulley **1361**P**1**, a second pulley **1361**P**2**, and a first input wire **1361**W. The first pulley **1361**P**1** and the second pulley **1361**P**2** are connected by the first input wire **1361**W to rotate together.
(217) The second input unit **1362** includes a first pulley **1362**P**1**, a second pulley **1362**P**2**, and a second input wire **1362**W. The first pulley **1362**P**1** and the second pulley **1362**P**2** are connected by the second input wire **1362**W to rotate together.
(218) The output unit **1363** includes an output pulley **1363**P and an output wire **1363**W. The output

pulley **1363**P and the differential control member **1364** are connected by the output wire **1363**W. When the differential control member **1364** translates, the output pulley **1363**P connected with the differential control member **1364** by the output wire **1363**W rotates.
(219) The differential control member **1364** includes a first pulley **1364**P**1**, a second pulley **1364**P**2**, and a differential control wire **1364**W. In addition, the differential control member **1364** includes a first differential joint **1364**J**1** and a second differential joint **1364**J**2**. The first pulley **1364**P**1** and the second pulley **1364**P**2** are connected by the differential control wire **1364**W to rotate together. The differential control member **1364** may translate in the direction of an arrow T of FIG. **15**. For example, the differential control member **1364** may be installed on a guide rail (not illustrated), and may translate along the guide rail in the direction of the arrow T of FIG. **15**.
(220) The first differential joint **1364**J**1** may be coupled to the first input wire **1361**W and the differential control wire **1364**W to transmit a rotation of the first input wire **1361**W to the differential control wire **1364**W. The second differential joint **1364**J**2** may be coupled to the second input wire **1362**W and the differential control wire **1364**W to transmit a rotation of the second input wire **1362**W to the differential control wire **1364**W.
(221) An operation of the first modification of the differential pulley will be described below.
(222) First, a case where the first input unit **1361** rotates will be described below.
(223) Referring to FIGS. **15** and **16**, when the first pulley **1361**P**1** of the first input unit **1361** rotates in the direction of an arrow A**1** of FIG. **16**, the first input wire **1361**W connected therewith moves along the first pulley **1361**P**1** in the direction of an arrow A**2** of FIG. **16**. Also, since the first input wire **1361**W and the differential control wire **1364**W are coupled to the first differential joint **1364**J**1**, when the first input wire **1361**W moves in the direction of the arrow A**2** of FIG. **16**, the first differential joint **1364**J**1** connected therewith also moves in the direction of the arrow A**2**. In this case, when the second input unit **1362** is fixed due to no rotation input, the second differential joint **1364**J**2** is also fixed. Thus, the differential control member **1364** translates in the direction of an arrow A**3** as much as the movement of the first differential joint **1364**J**1**, the first pulley **1364**P**1**, the second pulley **1364**P**2**, and the differential control wire **1364**W also move together as much, and the first pulley **1364**P**1** and the second pulley **1364**P**2** rotate in the counterclockwise direction. When the differential control member **1364** moves in the direction of the arrow A**3**, the output wire **1363**W connected therewith moves in the direction of an arrow A**4** and thus the output pulley **1363**P connected with the output wire **1363**W rotates in the direction of an arrow C.
(224) According to this configuration of the present invention, the rotation of the first input unit **1361** does not affect the second input unit **1362** and may be transmitted only to the output unit **1363** to rotate the output pulley **1363**P.
(225) A case where the second input unit **1362** rotates will be described below.
(226) Referring to FIGS. **15** and **17**, when the first pulley **1362**P**1** of the second input unit **1362** rotates in the direction of an arrow B**1** of FIG. **17**, the second input wire **1362**W connected therewith moves along the first pulley **1362**P**1** in the direction of an arrow B**2** of FIG. **17**. Also, since the second input wire **1362**W and the differential control wire **1364**W are coupled to the second differential joint **1364**J**2**, when the second input wire **1362**W moves in the direction of the arrow B**2** of FIG. **17**, the second differential joint **1364**J**2** connected therewith also moves in the direction of the arrow B**2**. In this case, when the first input unit **1361** is fixed due to no rotation input, the first differential joint **1364**J**1** is also fixed. Thus, the differential control member **1364** translates in the direction of an arrow B**3** as much as the movement of the second differential joint **1364**J**2**, the first pulley **1364**P**1**, the second pulley **1364**P**2**, and the differential control wire **1364**W also move together as much, and the first pulley **1364**P**1** and the second pulley **1364**P**2** rotate in the clockwise direction. When the differential control member **1364** moves in the direction of the arrow B**3**, the output wire **1363**W connected therewith moves in the direction of an arrow B**4** and thus the output pulley **1363**P connected with the output wire **1363**W rotates in the direction of the arrow C.

(227) According to this configuration of the present invention, the rotation of the second input unit **1362** does not affect the first input unit **1361** and may be transmitted only to the output unit **1363** to rotate the output pulley **1363**P.
(228) A case where the first input unit **1361** and the second input unit **1362** rotate together will be described below.
(229) When the first pulley **1361**P**1** of the first input unit **1361** rotates in the clockwise direction, the output pulley **1363**P of the output unit **1363** rotates in the counterclockwise direction; and when the first pulley **1362**P**1** of the second input unit **1362** rotates in the counterclockwise direction, the output pulley **1363**P of the output unit **1363** rotates in the counterclockwise direction. Thus, when the first pulley **1361**P**1** of the first input unit **1361** and the second pulley **1362**P**1** of the second input unit **1362** rotate in opposite directions, the output pulley **1363**P of the output unit **1363** rotates as much as the sum of the two rotating forces. On the other hand, when the first pulley **1361**P**1** of the first input unit **1361** and the second pulley **1362**P**1** of the second input unit **1362** rotate in the same direction, the output pulley **1363**P of the output unit **1363** rotates as much as the difference between the two rotating forces.
(230) Thus, according to the present invention, when only one of the two or more input units rotates, only the output unit may be rotated without other input units rotating. Also, when the two or more input units rotate together, a single rotating force equal to the sum of (or the difference between) the rotating forces of the two input units may be output through the output unit.
(231) The differential pulley of the first modification is a modification of the differential pulley illustrated in FIGS. **4**A and **4**B, and an example of applying the differential pulley of the first modification to the surgical instrument will not be described herein.
<Second Modification of Differential Pulley> (D2)
(232) FIG. **18** is a view illustrating a second modification of the differential pulley of the surgical instrument **100** illustrated in FIG. **2**, and FIGS. **19** and **20** are views illustrating an operation of the second modification of the differential pulley illustrated in FIG. **18**.
(233) As described above, the differential pulley according to the present invention includes two or more input units and one input unit, and outputs rotating forces, which are input from the two or more input units, as a desired rotating force, while each of the two or more input units does not affect other input units.
(234) Referring to FIG. **18**, the second modification of the differential pulley of the surgical instrument includes a first input unit **1371**, a second input unit **1372**, an output unit **1373**, a first differential control member **1374**, a second differential control member **1375**, and a differential control wire **1376**.
(235) The first input unit **1371** includes a first input pulley **1371**P and a first input wire **1371**W. The first input pulley **1371**P is connected with the first input wire **1371**W to rotate along with the first input wire **1371**W.
(236) The second input unit **1372** includes a second input pulley **1372**P and a second input wire **1372**W. The second input pulley **1372**P is connected with the second input wire **1372**W to rotate along with the second input wire **1372**W.
(237) The output unit **1373** includes an output pulley **1373**P. The output pulley **1373**P is connected with the differential control wire **1376** to rotate along with the differential control wire **1376**.
(238) The first differential control member **1374** includes a first pulley **1374**P**1**, a second pulley **1374**P**2**, and a first differential control bar **1374***a*. The first pulley **1374**P**1** and the second pulley **1374**P**2** are respectively formed at both end portions of the first differential control bar **1374***a*, and may rotate independently. Also, both end portions of the first input wire **1371**W are coupled to both end portions of the first differential control member **1374**. The first differential control member **1374** may translate in the direction of an arrow T**1** of FIG. **18**. For example, the first differential control member **1374** may be installed on a guide rail (not illustrated), and may translate along the guide rail in the direction of the arrow T**1** of FIG. **18**. Thus, when the first input pulley **1371**P

rotates, the first input wire **1371**W connected therewith rotates, and when the first input wire **1371**W rotates, the first differential control member **1374** coupled to both end portions thereof translates in the direction of the arrow T**1** of FIG. **18**.
(239) The second differential control member **1375** includes a first pulley **1375**P**1**, a second pulley **1375**P**2**, and a second differential control bar **1375***a*. The first pulley **1375**P**1** and the second pulley **1375**P**2** are respectively formed at both end portions of the second differential control bar **1375***a*, and may rotate independently. Also, both end portions of the second input wire **1372**W are coupled to both end portions of the second differential control member **1375**, respectively. The second differential control member **1375** may translate in the direction of an arrow T**2** of FIG. **18**. For example, the second differential control member **1375** may be installed on a guide rail (not illustrated), and may translate along the guide rail in the direction of the arrow T**2** of FIG. **18**. Thus, when the second input pulley **1372**P rotates, the second input wire **1372**W connected therewith rotates, and when the second input wire **1372**W rotates, the second differential control member **1375** coupled to both end portions thereof translates in the direction of the arrow T**2** of FIG. **18**.
(240) The differential control wire **1376** is connected along the first pulley **1374**P**1** of the first differential control member **1374**, the first pulley **1375**P**1** of the second differential control member **1375**, the second pulley **1374**P**2** of the first differential control member **1374**, and the second pulley **1375**P**2** of the second differential control member **1375**. The differential control wire **1376** is wound along the four pulleys, and is formed to move according to the translation motions of the first differential control member **1374** and the second differential control member **1375**. Herein, a fixed point F**1** may be formed at the differential control wire **1376**, as a reference point for the movement of the differential control wire **1376**.
(241) An operation of the second modification of the differential pulley will be described below.
(242) First, a case where the first input unit **1371** rotates will be described below.
(243) Referring to FIGS. **18** and **19**, when the first input pulley **1371**P**1** of the first input unit **1371** rotates in the direction of an arrow A**1** of FIG. **19**, the first input wire **1371**W connected therewith moves along the first input pulley **1371**P**1** in the direction of an arrow A**2** of FIG. **19**. Since the first input wire **1371**W is connected with the first differential control member **1374**, when the first input wire **1371**W moves in the direction of the arrow A**2** of FIG. **19**, the first differential control member **1374** translates in the direction of an arrow A**3**. When the first differential control member **1374** translates in the direction of the arrow A**3**, a point P**1** of the differential control wire **1376** of FIG. **18** moves to a point P**1**′ of the differential control wire **1376** of FIG. **19**, and thus the differential control wire **1376** moves in the direction of an arrow A**4** of FIG. **19**. Thus, the output pulley **1373**P connected with the differential control wire **1376** rotates in the direction of an arrow C. In this case, the first pulley **1374**P**1** and the second pulley **1374**P**2** of the first differential control member **1374** and the second pulley **1375**P**2** of the second differential control member **1375** rotate in the clockwise direction.
(244) According to this configuration of the present invention, the rotation of the first input unit **1371** does not affect the second input unit **1372** and may be transmitted only to the output unit **1373** to rotate the output pulley **1373**P.
(245) A case where the second input unit **1372** rotates will be described below.
(246) Referring to FIGS. **18** and **20**, when the second input pulley **1372**P of the second input unit **1372** rotates in the direction of an arrow B**1** of FIG. **20**, the second input wire **1372**W connected therewith moves along the second input pulley **1372**P in the direction of an arrow B**2** of FIG. **20**. Since the second input wire **1372**W is connected with the second differential control member **1375**, when the second input wire **1372**W moves in the direction of the arrow B**2** of FIG. **20**, the second differential control member **1375** translates in the direction of an arrow B**3**. When the second differential control member **1375** translates in the direction of the arrow B**3**, a point P**2** of the differential control wire **1376** of FIG. **18** moves to a point P**2**′ of the differential control wire **1376** of FIG. **20**, and thus the differential control wire **1376** moves in the direction of an arrow B**4** of

FIG. **20**. Thus, the output pulley **1373**P connected with the differential control wire **1376** rotates in the direction of an arrow C. In this case, the first pulley **1375**P**1** and the second pulley **1375**P**2** of the second differential control member **1375** and the first pulley **1374**P**1** of the first differential control member **1374** rotate in the clockwise direction.
(247) According to this configuration of the present invention, the rotation of the second input unit **1372** does not affect the first input unit **1371** and may be transmitted only to the output unit **1373** to rotate the output pulley **1373**P.
(248) A case where the first input unit **1371** and the second input unit **1372** rotates together will be described below.
(249) When the first input pulley **1371**P of the first input unit **1371** rotates in the counterclockwise direction, the output pulley **1373**P of the output unit **1373** rotates in the counterclockwise direction; and when the second input pulley **1372**P of the second input unit **1372** rotates in the clockwise direction, the output pulley **1373**P of the output unit **1373** rotates in the counterclockwise direction. Thus, when the first input pulley **1371**P of the first input unit **1371** and the second input pulley **1372**P of the second input unit **1372** rotate in opposite directions, the output pulley **1373**P of the output unit **1373** rotates as much as the sum of the two rotating forces. On the other hand, when the first input pulley **1371**P of the first input unit **1371** and the second input pulley **1372**P of the second input unit **1372** rotate in the same direction, the output pulley **1373**P of the output unit **1373** rotates as much as the difference between the two rotating forces.
(250) Thus, according to the present invention, when only one of the two or more input units rotates, only the output unit may be rotated without other input units rotating. Also, when the two or more input units rotate together, a single rotating force equal to the sum of (or the difference between) the rotating forces of the two input units may be output through the output unit.
(251) Other examples of the second modification of the differential pulley of the surgical instrument will be described below. FIGS. **21**A to **21**E are views illustrating other examples of the second modification of the differential pulley illustrated in FIG. **18**. In FIGS. **21**A to **21**E, the first input and the second input are omitted, and first differential control members **1374***a* to **1374***c*, second differential control members **1375***a* to **1375***e*, output units **1373***a* to **1373***e*, and differential control wires **1376***a* to **1376***e* connecting them are illustrated. Although their external shapes are slightly different from each other, the respective examples are substantially identical to the second modification of the differential pulley of FIGS. **18** to **20** in that when the first input unit (not illustrated) rotates, the first differential control members **1374***a* to **1374***c* translate vertically to rotate the differential control wires **1376***a* to **1376***e* to rotate the output units **1373***a* to **1373***e*, and when the second input unit (not illustrated) rotates, the second differential control members **1375***a* to **1375***e* translate vertically to rotate the differential control wires **1376***a* to **1376***e* to rotate the output units **1373***a* to **1373***c*.
(252) The differential pulley of the second modification is a modification of the differential pulley illustrated in FIGS. **4**A and **4**B, and an example of applying the differential pulley of the second modification to the surgical instrument will not be described herein.
<Third Modification of Differential Pulley> (D4)
(253) FIGS. **22** and **23** are views illustrating a third modification of the differential pulley of the surgical instrument **100** illustrated in FIG. **2**.
(254) As described above, the differential pulley according to the present invention includes two or more input units and one input unit, and outputs rotating forces, which are input from the two or more input units, as a desired rotating force, while each of the two or more input units does not affect other input units.
(255) Referring to FIGS. **22** and **23**, the third modification of the differential pulley of the surgical instrument includes a first input unit **1381**, a second input unit **1382**, an output unit **1383**, and a connector **1384**.
(256) The first input unit **1381** includes a first rotating axis **1381***a* and a first input pulley **1381***b*,

and the first input pulley **1381***b* is coupled with the first rotating axis **1381***a* to rotate around the first rotating axis **1381***a*.
(257) The second input unit **1382** includes a second rotating axis **1382***a* and two second input pulleys **1382***b* facing each other, and the two second input pulleys **1382***b* are not coupled with the second rotating axis **1382***a* and rotate around the second rotating axis **1382***a*. The first input unit **1381** is formed to extend from the second input pulley **1382***b*. That is, since the first input pulley **1381***b* is connected to the second input pulley **1382***b* by a connecting member (not illustrated), when the second input pulley **1382***b* rotates, the first input unit **1381**, including the first input pulley **1381***b* connected therewith, rotates.
(258) The output unit **1383** includes a third rotating axis **1383***a* and an output pulley **1383***b*, and the output pulley **1383***b* is coupled with the third rotating axis **1383***a* to rotate around the third rotating axis **1383***a*.
(259) The connector **1384** includes a fourth rotating axis **1384***a* and two connecting pulleys **1384***b* facing each other, and the two connecting pulleys **1384***b* are not coupled with the fourth rotating axis **1384***a* and rotate around the fourth rotating axis **1384***a*.
(260) A differential control wire **1385** is formed to sequentially contact the output unit **1383**, one of the two connecting pulleys **1384***b*, one of the two input pulleys **1382***b*, the first input pulley **1381***b*, the other of the two second input pulleys **1382***b*, the other of the two connecting pulleys **1384***b*, and the output unit **1383** and rotate along the output unit **1383**, the connector **1384**, the second input unit **1382**, and the first input unit **1381**.
(261) Although not illustrated, a coupling member (not illustrated) connecting the first input unit **1381** and the second input unit **1382** may be further provided. The first rotating axis **1381***a* of the first input unit **1381** and the second rotating axis **1382***a* of the second input unit **1382** may be connected to the coupling member. Since the coupling member and the second rotating axis **1382***a* are fixedly coupled, when the second rotating axis **1382***a* rotates, the coupling member and the first input unit **1381** connected therewith rotate together therewith. On the other hand, since the coupling member and the first rotating axis **1381***a* are not fixedly coupled, even when the first rotating axis **1381***a* rotates, the coupling member may not rotate.
(262) An operation of the third modification of the differential pulley will be described below.
(263) First, a case where the first input unit **1381** rotates will be described below. When the first input pulley **1381***b* of the first input unit **1381** rotates around the first rotating axis **1381***a*, the differential control wire **1385** and the first input pulley **1381***b* rotate together by a frictional force or a fixed point and thus the differential control wire **1385** wound around the two second input pulleys **1382***b* and the connecting pulley **1384***b* also move. Consequently, the output pulley **1383***b* of the output unit **1383** connected to the opposite side of the differential control wire **1385** also rotate around the third rotating axis **1383***a*. In this case, the two second input pulleys **1382***a* and the two connecting pulleys **1384***b*, around which the moving differential control wire **1385** is wound, also rotate together.
(264) A case where the second input unit **1382** rotates will be described below. When the second input pulley **1382***b* of the second input unit **1382** rotates around the second rotating axis **1382***a* in the counterclockwise direction in the state of FIG. **22**, the first input unit **1381** rotates around the second rotating axis **1382***a* in the counterclockwise direction as illustrated in FIG. **23**. In this case, when there is no rotation input to the first input unit **1381** and thus the rotation of the differential control wire **1385** wound around the first input pulley **1381***b* is relatively small on the first rotating axis **1381***a*, the differential control wire **1385** wound around the first rotating axis **1381***a* rotates around the second rotating axis **1382***a*. Accordingly, the differential control wire **1385** wound around the two second input pulleys **1382***b* is pulled and extended to rotate the two second input pulleys **1382***b*. The movement of the differential control wire **1385** on the two second input pulleys **1382***b* causes the two connecting pulleys **1384***b* and the output pulley **1383***b* to rotate.
(265) Thus, according to the present invention, the rotation of one of the two or more input units

may lead to the rotation of the output unit without other input units rotating. Also, when the two or more input units rotate together, a single rotating force equal to the sum of (or the difference between) the rotating forces of the two input units may be output through the output unit.
(266) The third modification of the differential pulley is different from the first and second modifications of the differential pulley in that one input unit is provided on the rotating axis of another input unit and the position of the input unit rotates according to another rotation input. That is, while the input units are disposed independently of each other in the first and second modifications of the differential pulley, one input unit is disposed on a coordinate system of another input unit in the third modification of the differential pulley. As an example of this, in a second embodiment (which will be described later with reference to FIG. **28**), one operation input unit is provided on another operation input unit, and the operation input unit also rotates or moves together when the other operation input unit rotates or moves.
(267) Although it is illustrated that the output unit **1383**, the connector **1384**, the second input unit **1382**, and the first input unit **1381** are sequentially arranged in the order stated, the present invention is not limited thereto. For example, the positions of the connector **1384** and the second input unit **1382** may be interchanged with each other. Also in this case, the first input pulley may be connected to the second input pulley by a connecting member (not illustrated), and when the second input pulley rotates, the first input pulley of the first input unit and the connecting pulley of the connector connected thereto may rotate together therewith.
(268) The differential pulley of the third modification is a modification of the differential pulley illustrated in FIGS. **4**A and **4**B, and an example of applying the differential pulley of the third modification to the surgical instrument will not be described herein.
(269) <Differential Gear>
(270) FIG. **24** is a view illustrating a surgical instrument **100***g* according to a modification of the operating force transmitter of the surgical instrument **100** illustrated in FIG. **2**, and FIG. **25** is a detailed view of a differential gear of FIG. **24**. Since the surgical instrument **100***g* according to a modification of the operating force transmitter **130** of the first embodiment of the present invention is similar to the surgical instrument **100** according to the first embodiment of the present invention and is different from the surgical instrument **100** in terms of the configuration of the operating force transmitter, the configuration of the operating force transmitter will be mainly described below.
(271) In this modification, a differential gear is used instead of the differential pulleys of FIGS. **2** and **4**A. That is, the differential gear of the surgical instrument **100***g* illustrated in FIGS. **24** and **25** may be considered as a structure in which the pulley and wire of the differential pulley of the surgical instrument **100** illustrated in FIG. **4**A are replaced with a gear.
(272) Referring to FIGS. **24** and **25**, the surgical instrument **100***g* according to a modification of the operating force transmitter **130** of the first embodiment of the present invention includes an operator **110**, an end tool **120**, an operating force transmitter **130**, and a connector (not illustrated). The operating force transmitter **130** includes a first differential gear **151** and a second differential gear **152**.
(273) In detail, the first differential gear **151** includes a first input unit **1511**, a second input unit **1512**, and an output unit **1513**.
(274) The first input unit **1511** includes a first pulley **1511***a* and a first gear **1511***b*. The first pulley **1511***a* and the first gear **1511***b* rotate together around the same rotating axis. Herein, the first pulley **1511***a* of the first input unit **1511** is connected with the first pulley **1121***a* of the yaw operator **112** by the YC**1** wire **135**YC**1** to transmit a rotation of the yaw operator **112** to the first input unit **1511**. Also, the first gear **1511***b* of the first input unit **1511** is connected with the output unit **1513** to transmit a rotation of the first input unit **1511** to the output unit **1513**.
(275) The second input unit **1512** includes a second pulley **1512***a* and a second gear **1512***b*. The second pulley **1512***a* and the second gear **1512***b* rotate together around the same rotating axis.

Herein, the second pulley **1512***a* of the second input unit **1512** is connected with the first pulley **1131***a* of the actuation operator **113** by the AC**1** wire **135**AC**1** to transmit a rotation of the actuation operator **113** to the second input unit **1512**. Also, the second gear **1512***b* of the second input unit **1512** is connected with the output unit **1513** to transmit a rotation of the second input unit **1512** to the output unit **1513**.

(276) The output unit **1513** includes an output pulley **1513***a*, an extension portion **1513***b*, and a differential control gear **1513***c*. Herein, the output pulley **1513***a* of the output unit **1513** is connected with the operator control member **115** by the J**12** wire **135**J**12** to transmit a rotation of the output unit **1513** to the first jaw **121** of the end tool **120** through the operator control member **115**. The extension portion **1513***b* extends in one direction from a rotating axis of the output pulley **1513***a* to rotate around the rotating axis of the output pulley **1513***a* along with the output pulley **1513***a*. The extension portion **1513***b* is inserted through the differential control gear **1513***c* such that the differential control gear **1513***c* rotates around the extension portion **1513***b*.

(277) Herein, the first input unit **1511**, the second input unit **1512**, and the output unit **1513** rotate independently around independent axes.

(278) Herein, the first differential gear **151** includes the first input unit **1511**, the second input unit **1512**, and the output unit **1513**, receives an input of rotating forces from the first input unit **1511** and the second input unit **1512**, and outputs the sum of (or the difference between) the rotating forces through the output unit **1513**. That is, when only the first input unit **1511** rotates, the rotation of the first input unit **1511** is output through the output unit **1513**; when only the second input unit **1512** rotates, the rotation of the second input unit **1512** is output through the output unit **1513**; when the first input unit **1511** and the second input unit **1512** rotate in the same direction, the sum of the rotations of the first input unit **1511** and the second input unit **1512** is output through the output unit **1513**; and when the first input unit **1511** and the second input unit **1512** rotate in opposite directions, the difference between the rotations of the first input unit **1511** and the second input unit **1512** is output through the output unit **1513**. This may be expressed as the following equation:

(279) $C=A+B$ (where C denotes a rotation of the output unit, A denotes a rotation of the first input unit, and B denotes a rotation of the second input unit.)

(280) By the first differential gear **151** and the second differential gear **152**, even when the yaw operator **112** and the actuation operator **113** rotate freely, the output unit of each differential gear rotates independently of the rotations of the yaw operator **112** and the actuation operator **113**. Consequently, the output unit of each differential gear moves as much as the sum of (or the difference between) the rotations of the yaw operator **112** and the actuation operator **113** to extract a desired rotating force.

First Modification of Differential Gear

(281) FIG. **26** is a view illustrating a first modification of the differential gear of FIG. **24**.

(282) As described above, the differential gear according to the present invention includes two or more input units and one input unit, receives an input of rotating forces from the two or more input units, extracts a desired rotating force from the sum of (or the difference between) the input rotating forces, and outputs the desired rotating force through the output unit.

(283) Referring to FIG. **26**, the first modification of the differential gear of the surgical instrument includes a first input unit **1561**, a second input unit **1562**, an output unit **1563**, and a differential control member **1564**. The first modification of the differential gear of the surgical instrument illustrated in FIG. **26** may be considered as a structure in which the pulley and wire in the first modification of the differential pulley of the surgical instrument illustrated in FIG. **15** are replaced with a gear.

(284) The first input unit **1561** includes a first pulley **1561**P, a first gear **1561**G, and a first input wire **1561**W. The first pulley **1561**P and the first gear **1561**G are connected by the first input wire **1561**W, so that the first gear **1561**G moves vertically when the first pulley **1561**P rotates.

(285) The second input unit **1562** includes a second pulley **1562**P, a second gear **1562**G, and a second input wire **1562**W. The second pulley **1562**P and the second gear **1562**G are connected by the second input wire **1562**W, so that the second gear **1562**G moves vertically when the second pulley **1562**P rotates.
(286) The output unit **1563** includes an output pulley **1563**P and an output wire **1563**W. The output pulley **1563**P and the differential control member **1564** are connected by the output wire **1563**W. Thus, when the differential control member **1564** translates, the output pulley **1563**P connected with the differential control member **1564** by the output wire **1563**W rotates.
(287) The differential control member **1564** includes a differential control gear **1564**G and a differential control base **1564**B. The differential control gear **1564**G is formed to engage with the first gear **1561**G and the second gear **1562**G. Thus, when the first gear **1561**G and the second gear **1562**G move vertically, the differential control gear **1564**G rotates and translates vertically. That is, the first gear **1561**G and the second gear **1562**G function as a rack, and the differential control gear **1564**G functions as a pinion. Thus, the differential control member **1564** may translate in the direction of an arrow T of FIG. **26**. For example, the differential control base **1564**B of the differential control member **1564** may be installed on a guide rail (not illustrated), so that the differential control member **1564** may translate along the guide rail in the direction of the arrow T of FIG. **26**.
(288) Thus, according to the present invention, when only one of the two or more input units rotates, only the output unit may be rotated without other input units rotating. Also, when the two or more input units rotate together, a single rotating force equal to the sum of (or the difference between) the rotating forces of the two input units may be output through the output unit.
Second Modification of Differential Gear
(289) FIG. **27** is a view illustrating a second modification of the differential gear of FIG. **24**.
(290) As described above, the differential gear according to the present invention includes two or more input units and one input unit, receives an input of rotating forces from the two or more input units, extracts a desired rotating force from the sum of (or the difference between) the input rotating forces, and outputs the desired rotating force through the output unit.
(291) Referring to FIG. **27**, the second modification of the differential gear of the surgical instrument includes a first input unit **1571**, a second input unit **1572**, an output unit **1574**, and a differential control member **1573**.
(292) In detail, the first input unit **1571** and the second input unit **1572** may be provided in the form of a gear that may rotate around a central rotating axis **1575**. In particular, the second input unit **1572** is provided in the form of a gear that has sawteeth inside a pitch cylinder, and the differential control member **1573** is provided to engage with the gears of the first input unit **1571** and the second input unit **1572**. The differential control member **1573** may rotate around a differential control member gear axis **1573***a* that is connected to the output unit **1574**. The output unit **1574** may rotate around the central rotating axis **1575**.
(293) When only the first input unit **1571** rotates, the differential control member **1573** engaged with the gear teeth rotates around the differential control member gear axis **1573***a* and simultaneously rotates around the central rotating axis **1575** of the output unit **1574** connected to the differential control member gear axis **1573***a*. Also, when only the second input unit **1572** rotates, the differential control member **1573** engaged with the gear teeth rotates around the differential control member gear axis **1573***a* and simultaneously rotates around the central rotating axis **1575** of the output unit **1574** connected to the differential control member gear axis **1573***a*. When the first input unit **1571** and the second input unit **1572** rotate in the same direction, the differential control member **1573** and the output unit **1574** rotate around the central rotating axis **1575** in the same direction. In this case, the differential control member **1573** may not rotate around the differential control member gear axis **1573***a*.
(294) On the other hand, when the first input unit **1571** and the second input unit **1572** rotate in

opposite directions, the differential control member **1573** and the output unit **1574** may not rotate around the central rotating axis **1575**. In this case, the differential control member **1573** may rotate around the differential control member gear axis **1573***a*.

(295) Thus, according to the present invention, a single rotating force equal to the sum of (or the difference between) the rotation inputs of two or more input units may be output through the output unit.

MODE OF THE INVENTION

<Second Embodiment of Surgical Instrument> (E3+H**2**+D3)

(296) Hereinafter, a surgical instrument **200** according to a second embodiment of the present invention will be described. The surgical instrument **200** according to the second embodiment of the present invention is different from the surgical instrument **100** according to the first embodiment of the present invention in terms of the configuration of an operator. That is, in the surgical instrument **100** according to the first embodiment of the present invention, the yaw operator and the actuation operator are formed independently of each other and the rotation of the yaw operating axis and the rotation of the actuation operating axis are performed independently of each other, while in the surgical instrument **200** according to the second embodiment of the present invention, the actuation operator is formed on the yaw operator and the actuation operator rotates along with the yaw operator when the yaw operator rotates. This difference in the configuration of the operator from the first embodiment will be described later in detail.

(297) FIG. **28** is a view illustrating a surgical instrument **200** according to a second embodiment of the present invention. Referring to FIG. **28**, the surgical instrument **200** according to the second embodiment of the present invention includes an operator **210**, an end tool **220**, an operating force transmitter **230**, and a connector (not illustrated).

(298) The end tool **220** includes a first jaw **221**, a second jaw **222**, and an end tool control member **223**, and the operating force transmitter **230** includes a first jaw operating wire **235J1** and a second jaw operating wire **235J2**, so that a pitch operation, a yaw operation, and an actuation operation of the end tool **220** may be conveniently performed. Since the end tool **220** is substantially identical to the end tool **120** of the first embodiment, a detailed description thereof will be omitted herein.

(299) The operating force transmitter **230** includes a plurality of pulleys and a plurality of wires **235**AY**1**, **235**AY**2**, **235J1**, and **235J2**. Since the operating force transmitter **230** is substantially identical to the operating force transmitter **130** of the first embodiment, a detailed description thereof will be omitted herein.

(300) Hereinafter, the operator **210** of the surgical instrument **200** according to the second embodiment of the present invention will be described in more detail.

(301) Referring to FIG. **28**, the operator **210** of the surgical instrument **200** according to the second embodiment of the present invention includes a pitch operator **211** controlling a pitch motion of the end tool **220**, a yaw operator **212** controlling a yaw motion of the end tool **220**, and an actuation operator **213** controlling an actuation motion of the end tool **220**.

(302) The pitch operator **211** includes a pitch operating axis **2111** and a pitch operating bar **2112**. Herein, the pitch operating axis **2111** may be formed in a direction parallel to the Y axis, and the pitch operating bar **2112** may be connected with the pitch operating axis **2111** to rotate along with the pitch operating axis **2111**. For example, when the user grips and rotates the pitch operating bar **2112**, the pitch operating axis **2111** connected with the pitch operating bar **2112** and a pitch operating pulley **2113** connected therewith rotate together therewith. Then, the resulting rotating force is transmitted to the end tool **220** through the operating force transmitter **230**, so that the end tool **220** rotates in the same direction as the rotation direction of the pitch operating axis **2111**. That is, when the pitch operator **211** rotates in the clockwise direction around the pitch operating axis **2111**, the end tool **230** also rotates in the clockwise direction around an end tool pitch operating axis **2231**, and when the pitch operator **211** rotates in the counterclockwise direction around the end tool pitch operating axis **2231**, the end tool **230** also rotates in the counterclockwise direction

around the end tool pitch operating axis **2231**. The pitch operating pulley **2113** is integrated with the pitch operating axis **2111** to rotate along with the pitch operating axis **2111**.
(303) The yaw operator **212** includes a yaw operating axis **2121** and a yaw operating bar **2122**. Although it is illustrated that the yaw operating axis **2121** is formed to extend from the pitch operating bar **2112**, the present invention is not limited thereto. For example, the pitch operating bar **2112** and the yaw operating axis **2121** may be formed as separate members on different axes. In this case, the yaw operating axis **2121** may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **210**.
(304) When the pitch operator **211** rotates as described above, a coordinate system of the yaw operator **212** may change accordingly. In this case, the yaw operating bar **2122** is formed to rotate around the yaw operating axis **2121**. For example, when the user holds and rotates the yaw operating bar **2122** with the index finger, the yaw operating bar **2122** rotates around the yaw operating axis **2121**. Then, the resulting rotating force is transmitted to the end tool **220** through a first yaw-actuation operating wire **235**AY**1** and a second yaw-actuation operating wire **235**AY**2**, so that the first and second jaws **221** and **222** of the end tool **220** horizontally rotate in the same direction as the rotation direction of the yaw operator **212**.
(305) The actuation operator **213** includes an actuation operating axis **2131**, an actuation operating bar **2132**, a first actuation operating pulley **2133***a*, and a second actuation operating pulley **2133***b*. Herein, the actuation operating bar **2132**, the first actuation operating pulley **2133***a*, and the second actuation operating pulley **2133***b* are formed to rotate around the actuation operating axis **2131**. For example, when the user holds and rotates the actuation operating bar **2132** with the thumb finger, the first actuation operating pulley **2133***a* and the second actuation operating pulley **2133***b* connected with the actuation operating bar **2132** rotate around the actuation operating axis **2131**. Then, the resulting rotating force is transmitted to the end tool **220** through the operating force transmitter **230**, so that the first and second jaws **221** and **222** of the end tool **220** perform an actuation operation. Although it is illustrated that the operating axis of the actuation operator is parallel to the operating axis of the yaw operator, the present invention is not limited thereto, and they may be formed in various shapes by ergonomic design.
(306) The actuation operator **213** is formed on a yaw-actuation connector **2124** extending from the yaw operator **212**. Thus, when the yaw operator **212** rotates, the actuation operator **213** also rotates along with the yaw operator **212**. A first yaw-actuation operating pulley **214**P**1** and a second yaw-actuation operating pulley **214**P**2** are formed to rotate around the yaw operating axis **2121**. The first actuation operating pulley **2133***a* and the first yaw-actuation operating pulley **214**P**1** are connected by a first yaw-actuation connecting wire **214**W**1**, and the first yaw-actuation operating wire **235**AY**1** is connected to the first yaw-actuation operating pulley **214**P**1**. Likewise, the second actuation operating pulley **2133***b* and the second yaw-actuation operating pulley **214**P**2** are connected by a second yaw-actuation connecting wire **214**W**2**, and the second yaw-actuation operating wire **235**AY**2** is connected to the second yaw-actuation operating pulley **214**P**2**.
(307) Consequently, the first yaw-actuation operating pulley **214**P**1** and the second yaw-actuation operating pulley **214**P**2** are formed to rotate when the yaw operator **212** rotates and also rotate when the actuation operator **213** rotates.
(308) However, the first yaw-actuation connecting wire **214**W**1** is twisted one time and connected to the first yaw-actuation operating pulley **214**P**1** to reversely transmit an operation input of the actuation operator **213**, while the second yaw-actuation connecting wire **214**W**2** is straightly connected to the second yaw-actuation operating pulley **214**P**2** to straightly transmit an operation input of the actuation operator **213**.
(309) The operator **210** of the surgical instrument **200** according to the second embodiment of the present invention further includes an operator control member **215** engaged with the pitch operating axis **2111** of the pitch operator **211**. Since the operator control member **215** is substantially identical to the operator control member **115** described with reference to FIG. **5**, a

detailed description thereof will be omitted herein.

Overall Operation of Second Embodiment

(310) Hereinafter, an overall configuration for the pitch operation, the yaw operation, and the actuation operation of the surgical instrument **200** according to the second embodiment of the present invention will be summarized with reference to the above descriptions.

(311) For the configuration of the end tool **220** of the present embodiment, the operating force transmitter **230** capable of dividing the operation input of the operator **210** into a pitch operation, a yaw operation, and an actuation operation is necessary to perform the pitch, yaw, and actuation operations of the end tool **220**. As described above, through the structure in which the end tool control member **223** and the operator control member **215** are disposed symmetrical to each other, the rotation operation of the pitch operator **211** enables the pitch operation of the end tool **220** regardless of the operations of the yaw operator **212** and the actuation operator **213**. However, in order for the operations of the yaw operator **212** and the actuation operator **213** to lead to the yaw operation and the actuation operation of the end tool **220**, the operations of the yaw operator **212** and the actuation operator **213** have to be converted into the operations of two jaws of the end tool **220**. The rotation of the yaw operator **212** causes the two jaws to rotate in the same direction, and the rotation of the actuation operator **213** causes the two jaws to rotate in different directions. That is, the first jaw **221** rotates as much as the sum of the operation inputs of the yaw operator **212** and the actuation operator **213**, and the second jaw **222** rotates as much as the difference between the operation inputs of the yaw operator **212** and the actuation operator **213**. This may be expressed as the following equation:

$J1=Y+A$ (the first jaw rotates in the same direction in both the yaw operation and the actuation operation.)

$J2=Y-A$ (the second jaw rotates in the same direction in the yaw operation and rotates in an opposite direction in the actuation operation.)

(312) However, since the actuation operator **213** is disposed on the yaw operator **212**, the sum of the operation input of the actuation operator **213** and the operation input of the yaw operator **212** is transmitted to the operating force transmitter **230**. This may be expressed as the following equation:

(313) $Y_A = Y + A$

(314) This is equal to the above J**1** component and may be transmitted to the first jaw **221**.

(315) However, in order to extract the J**2** component of the second jaw **222**, the difference between the operation input of the yaw operator **212** and the operation input of the actuation operator **213** has to be obtained as described above. To this end, as described above, the first yaw-actuation connecting wire **214**W**1** is twisted one time and connected to the first yaw-actuation operating pulley **214**P**1** to reversely transmit the operation input of the actuation operator **213**. This may be expressed as the following equation:

(316) $Y_{A2} = Y - A$

(317) This is equal to the above J**2** component and may be transmitted to the second jaw **222**. (where Y denotes the rotation of the yaw operating pulley, and A denotes the rotation of the actuation operating pulley.)

(318) By this configuration, in the operator **210** having the actuation operator **213** disposed on the yaw operator **212**, the operation inputs of the yaw operator **212** and the actuation operator **213** may be converted into the operation components of the two jaws. This will be described below in more detail.

(319) First, the pitch operation will be described below.

(320) As described above, when the user grips the pitch operating bar **2112** of the pitch operator **211** of the operator **210** and rotates the pitch operating bar **2112** around the pitch operating axis **2111** in the direction of an arrow OP of FIG. **28**, the operator control member **215** also rotates around the pitch operating axis **2111**. Then, the first jaw operating wire **235J1** wound around the

operation control member **215** is pulled toward the operator **210**. At the same time, the second jaw operating wire **235J2** wound around the operation control member **215** is unwound from the operation control member **215**. Then, the end tool control member **223** connected with the first jaw operating wire **235J1** and the second jaw operating wire **235J2** rotates around the end tool pitch operating axis **2231** to perform a pitch motion.

(321) The yaw operation will be described below.

(322) When the user holds and rotates the yaw operating bar **2122** with the index finger in the direction of an arrow Y of FIG. **28**, the yaw operator **212** and the actuation operator **213** connected therewith rotate around the yaw operating axis **2121**. Then, the resulting rotating force is transmitted to the operation control member **215** through the first yaw-actuation connecting wire **214**W**1**, the first yaw-actuation operating pulley **214**P**1**, and the first yaw-actuation operating wire **235**AY**1** to rotate a J**11** pulley **215J11** of the operator control member **215** in the direction of an arrow YA of FIG. **8**. When the J**11** pulley **215J11** of the operator control member **215** rotates, the first jaw operating wire **235J1** connected therewith is rotated, and the first jaw **221** of the end tool **220** that is connected with the first jaw operating wire **235J1** rotates in the direction of an arrow YJ of FIG. **28**.

(323) At the same time, when the user rotates the yaw operating bar **2122** in the direction of the arrow Y of FIG. **28**, the yaw operator **212** and the actuation operator **213** connected therewith rotate around the yaw operating axis **2121**. Then, the resulting rotating force is transmitted to the operation control member **215** through the second yaw-actuation connecting wire **214**W**2**, the second yaw-actuation operating pulley **214**P**2**, and the second yaw-actuation operating wire **235**AY**2** to rotate a J**21** pulley **215J21** of the operator control member **215** in the direction of the arrow YA of FIG. **28** When the J**21** pulley **215J21** of the operator control member **215** rotates, the second jaw operating wire **235J2** connected therewith is rotated, and the second jaw **222** of the end tool **220** that is connected with the second jaw operating wire **235J2** rotates in the direction of the arrow YJ of FIG. **28**.

(324) In this manner, when the yaw operator **212** is rotated in one direction, the first and second jaws **221** and **222** rotate in the same direction to perform a yaw operation.

(325) The actuation operation will be described below.

(326) When the user holds and rotates the actuation operating bar **2132** with the thumb finger in the direction of an arrow A of FIG. **28**, the actuation operator **213** rotates around the actuation operating axis **2131**. Then, the resulting rotating force is transmitted to the operation control member **215** through the first yaw-actuation connecting wire **214**W**1**, the first yaw-actuation operating pulley **214**P**1**, and the first yaw-actuation operating wire **235**AY**1** to rotate the J**11** pulley **215J11** of the operator control member **215** in the direction of the arrow YA of FIG. **28** When the J**11** pulley **215J11** of the operator control member **215** rotates, the first jaw operating wire **235J1** connected therewith is rotated, and the first jaw **221** of the end tool **220** that is connected with the first jaw operating wire **235J1** rotates in the direction of the arrow YJ of FIG. **28**.

(327) At the same time, when the user rotates the actuation operating bar **2132** in the direction of the arrow A of FIG. **28**, the actuation operator **213** rotates around the actuation operating axis **2131**. Then, the resulting rotating force is transmitted to the operation control member **215** through the second yaw-actuation connecting wire **214**W**2**, the second yaw-actuation operating pulley **214**P**2**, and the second yaw-actuation operating wire **235**AY**2** to rotate the J**21** pulley **215J21** of the operator control member **215** in a direction opposite to the direction of the arrow YA of FIG. **28**. When the J**21** pulley **215J21** of the operator control member **215** rotates, the second jaw operating wire **235J2** connected therewith is rotated, and the second jaw **222** of the end tool **220** that is connected with the second jaw operating wire **235J2** rotates in a direction opposite to the direction of the arrow YJ of FIG. **28**.

(328) In this manner, when the actuation operator **213** is rotated in one direction, the first and second jaws **221** and **222** rotate in opposite directions to perform an actuation operation.

(329) Any combination of various configurations of the operator described with reference to FIG. **3**A, various configurations of the operating force transmitter described with reference to FIGS. **4**A and **15** to **27**, and various modifications described with reference to FIGS. **7** to **14** may be applied to the surgical instrument **200** according to the second embodiment of the present invention.

<Modification of Operating Force Transmitter of Second Embodiment of Surgical Instrument>

(E3+H**2**+D4)

(330) FIG. **29** is a view illustrating a surgical instrument **200***a* according to a modification of the operating force transmitter **230** of the second embodiment illustrated in FIG. **28**. Since the surgical instrument **200***a* according to a modification of the operating force transmitter **230** of the second embodiment of the present invention is similar to the surgical instrument **200** (see FIG. **28**) according to the second embodiment of the present invention and is different from the surgical instrument **200** in terms of the configuration of the operating force transmitter, the configuration of the operating force transmitter will be mainly described below.

(331) Referring to FIG. **29**, the surgical instrument **200***a* according to a modification of the operating force transmitter **230** of the second embodiment of the present invention includes an operator **210**, an end tool **220**, an operating force transmitter **230**, and a connector (not illustrated).

(332) The end tool **220** includes a first jaw **221**, a second jaw **222**, and an end tool control member **223**, and the operating force transmitter **230** includes a first jaw operating wire **235**J**1** and a second jaw operating wire **235**J**2**, so that a pitch operation, a yaw operation, and an actuation operation of the end tool **220** may be conveniently performed. Since the end tool **220** is substantially identical to the end tool **220** of the second embodiment described with reference to FIG. **28**, a detailed description thereof will be omitted herein.

(333) The operating force transmitter **230** includes a plurality of pulleys and a plurality of wires **235**AY**1**, **235**AY**2**, **235**J**1**, and **235**J**2**. The operating force transmitter **230** of the surgical instrument **200***a* according to this modification uses the third modification of the differential pulley illustrated in FIGS. **22** and **23**.

(334) In detail, the yaw and actuation operations of the end tool **220** of this modification are performed by the rotation of two jaws, and the operation of the operator **210** is converted into a rotation component of each jaw of the end tool **220**. Thus, the rotation component of each jaw may correspond to the sum of or difference between a yaw operation input and an actuation operation input as follows:

(335)
$$J1 = Y + A$$
$$J2 = Y - A$$

(336) According to the configuration of the operator of this embodiment, since the actuation operator **213** is formed to extend from the yaw operator **212**, the actuation operator **213** moves along with the rotation of the yaw operator **212**. In this case, since the rotation input of actuation is a relative rotation of an actuation pulley with respect to an actuation axis, it is not affected by the rotation of the yaw operator. This configuration may be implemented by using the third modification of the differential pulley (see FIGS. **22** and **23**) in which one input unit is formed on another input unit. Thus, a differential pulley is configured to include a first input unit corresponding to a reference numeral **2132** of FIG. **29** and a second input unit corresponding to a reference numeral **2122** of FIG. **29**, each of two differential pulleys is connected to one jaw of the end tool **220**. One differential pulley according to the above equation may be configured to transmit the sum of the two inputs, namely, the yaw input and the actuation input to a relevant jaw, and another differential pulley may be configured to transmit the difference between the two inputs, namely, the yaw input and the actuation input to a relevant jaw.

(337) That is, the operating force transmitter **230** of the surgical instrument **200***a* according to this modification includes a first differential pulley **238** and a second differential pulley **239**, and each of the differential pulleys **238** and **239** includes a first input unit **1381** (see FIG. **22**), a second input unit **1382** (see FIG. **22**), an output unit **1383** (see FIG. **22**), and a connector **1384** (see FIG. **22**). In

this case, when only one of two or more input units rotates, only the output unit is rotated without other input units rotating, and when two or more input units rotate simultaneously, a single rotating force equal to the sum of (or the difference between) the rotating forces of two input units is output through the output unit.
(338) Any combination of various configurations of the operator described with reference to FIG. **3**A, various configurations of the operating force transmitter described with reference to FIGS. **4**A and **15** to **27**, and various modifications described with reference to FIGS. **7** to **14** may be applied to the surgical instrument **200** according to the second embodiment of the present invention.
<Third Embodiment of Surgical Instrument> (E3+H**3**+D3)
(339) Hereinafter, a surgical instrument **300** according to a third embodiment of the present invention will be described. The surgical instrument **300** according to the third embodiment of the present invention is different from the surgical instrument **100** according to the first embodiment of the present invention in terms of the configuration of an operator. That is, the surgical instrument **100** according to the first embodiment of the present invention includes the yaw operator and the actuation operator are formed independently of each other such that the rotation of the yaw operating axis and the rotation of the actuation operating axis are performed independently of each other, while the surgical instrument **300** according to the third embodiment of the present invention includes a first jaw operator and a second jaw operator that operate a first jaw and a second jaw independently instead of the yaw operator and the actuation operator. This difference in the configuration of the operator from the first embodiment will be described later in detail.
(340) FIG. **30** is a view illustrating the surgical instrument **300** according to the third embodiment of the present invention. Referring to FIG. **30**, the surgical instrument **300** according to the third embodiment of the present invention includes an operator **310**, an end tool **320**, an operating force transmitter **330**, and a connector (not illustrated).
(341) The end tool **320** includes a first jaw **321**, a second jaw **322**, and an end tool control member **323**, and the operating force transmitter **330** includes a first jaw operating wire **335J12** and a second jaw operating wire **335J22**, so that a pitch operation, a yaw operation, and an actuation operation of the end tool **320** may be conveniently performed. Since the end tool **320** is substantially identical to the end tool **120** described with reference to FIG. **5**, a detailed description thereof will be omitted herein.
(342) The operating force transmitter **330** includes a plurality of pulleys and a plurality of wires **335J11**, **335J12**, **335J21**, and **335J22**. Since the operating force transmitter **330** is substantially identical to the operating force transmitter **130** of the first embodiment, a detailed description thereof will be omitted herein.
(343) Hereinafter, the operator **310** of the surgical instrument **300** according to the third embodiment of the present invention will be described in more detail.
(344) Referring to FIG. **30**, the operator **310** of the surgical instrument **300** according to the third embodiment of the present invention includes a pitch operator **311** controlling a pitch motion of the end tool **320**, a first jaw operator **312** controlling a motion of the first jaw **321** of the end tool **320**, and a second jaw operator **313** controlling a motion of the second jaw **322** of the end tool **320**.
(345) The pitch operator **311** includes a pitch operating axis **3111** and a pitch operating bar **3112**. Herein, the pitch operating axis **3111** may be formed in a direction parallel to the Y axis, and the pitch operating bar **3112** may be connected with the pitch operating axis **3111** to rotate along with the pitch operating axis **3111**. For example, when the user grips and rotates the pitch operating bar **3112**, the pitch operating axis **3111** connected with the pitch operating bar **3112** and a pitch operating pulley **3113** connected therewith rotate together. Then, the resulting rotating force is transmitted to the end tool **320** through the operating force transmitter **330**, so that the end tool **320** rotates in the same direction as the rotation direction of the pitch operating axis **3111**. That is, when the pitch operator **311** rotates in the clockwise direction around the pitch operating axis **3111**, the end tool **320** also rotates in the clockwise direction around the pitch operating axis **3111**, and when

the pitch operator **311** rotates in the counterclockwise direction around the pitch operating axis **3111**, the end tool **320** also rotates in the counterclockwise direction around the pitch operating axis **3111**. The pitch operating pulley **3113** is integrated with the pitch operating axis **3111** to rotate along with the pitch operating axis **3111**.

(346) The first jaw operator **312** includes a first jaw operating axis, a first jaw operating bar **3122**, and a first jaw operating pulley **3123**. Although it is illustrated that the first jaw operating axis is formed to extend from the pitch operating bar **3112** and the pitch operating bar **3112** is inserted into the first jaw operating pulley **3123**, the present invention is not limited thereto. For example, the pitch operating bar **3112** and the first jaw operating axis may be formed as separate members on different axes. In this case, the first jaw operating axis may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **310**. The first jaw operating wire **335J12** may be connected to the first jaw operating pulley **3123**. The first jaw operating bar **3122** and the first jaw operating pulley **3123** are formed to rotate around the first jaw operating axis. For example, when the user holds and rotates the first jaw operating bar **3122** with the index finger, the first jaw operating pulley **3123** connected with the first jaw operating bar **3122** rotates around the first jaw operating axis. Then, the resulting rotating force is transmitted to the end tool **320** through the operating force transmitter **330**, so that the first jaw **321** of the end tool **120** horizontally rotates in the same direction as the rotation direction of the first jaw operating pulley **3123**.

(347) The second jaw operator **313** includes a second jaw operating axis, a second jaw operating bar **3132**, and a second jaw operating pulley **3133**. Although it is illustrated that the second jaw operating axis is formed to extend from the pitch operating bar **3112** and the pitch operating bar **3112** is inserted into the second jaw operating pulley **3133**, the present invention is not limited thereto. For example, the pitch operating bar **3112** and the second jaw operating axis may be formed as separate members on different axes. In this case, the second jaw operating axis may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **310**. The second jaw operating wire **335J22** may be connected to the second jaw operating pulley **3133**. The second jaw operating bar **3132** and the second jaw operating pulley **3133** are formed to rotate around the second jaw operating axis. For example, when the user holds and rotates the second jaw operating bar **3132** with the thumb finger, the second jaw operating pulley **3133** connected with the second jaw operating bar **3132** rotates around the second jaw operating axis. Then, the resulting rotating force is transmitted to the end tool **320** through the operating force transmitter **330**, so that the second jaw **322** of the end tool **320** horizontally rotates in the same direction as the rotation direction of the second jaw operating pulley **3133**.

(348) The operator **310** of the surgical instrument **300** according to the third embodiment of the present invention further includes an operator control member **315** engaged with the pitch operating axis **3111** of the pitch operator **311**. Since the operator control member **315** is substantially identical to the operator control member with reference to FIG. **5**, a detailed description thereof will be omitted herein.

Overall Operation of Third Embodiment

(349) Hereinafter, an overall configuration for the pitch operation, the yaw operation, and the actuation operation of the surgical instrument **300** according to the third embodiment of the present invention will be summarized with reference to the above descriptions.

(350) For the configuration of the end tool **320** of the present embodiment, the operating force transmitter **330** capable of dividing the operation input of the operator **310** into a pitch operation, a yaw operation, and an actuation operation is necessary to perform the pitch, yaw, and actuation operations of the end tool **320**. As described above, through the structure in which the end tool control member **323** and the operator control member **315** are disposed symmetrical to each other, the rotation operation of the pitch operator **311** enables the pitch operation of the end tool **320** regardless of the operations of the first jaw operator **312** and the second jaw operator **313**.

(351) The operator **310** includes the first jaw operator **312** and the second jaw operator **313**. Thus, without the need to provide an additional configuration for conversion into the operations of two jaws of the end tool **320**, the operation input of the first jaw operator **312** is directly transmitted to the first jaw **321**, and the operation input of the second jaw operator **313** is directly transmitted to the second jaw **322**.
(352) Through this configuration, a pitch operation, a yaw operation (two jaws moves in the same direction), an actuation operation (two jaws moves in opposite directions) may be implemented. This will be described below in more detail.
(353) First, the pitch operation will be described below.
(354) As described above, when the user grips the pitch operating bar **3112** of the pitch operator **311** of the operator **310** and rotates the pitch operating bar **3112** around the pitch operating axis **3111** in the direction of an arrow OP of FIG. **30**, the operator control member **315** also rotates around the pitch operating axis **3111**. Then, the first jaw operating wire **335J12** wound around the operation control member **315** is pulled toward the operator **310**. At the same time, the second jaw operating wire **335J22** wound around the operation control member **315** is unwound from the operation control member **315**. Then, the end tool control member **323** connected with the first jaw operating wire **335J12** and the second jaw operating wire **335J22** rotates around the end tool pitch operating axis **3231** to perform a pitch motion.
(355) The yaw operation will be described below.
(356) For a yaw operation, the user holds and rotates the first jaw operating bar **3122** with the index finger in the direction of an arrow J**1** of FIG. **30**, and holds and rotates the second jaw operating bar **3132** with the thumb finger in the direction of an arrow J**2** of FIG. **30** (that is, rotates the first jaw operating bar **3122** and the second jaw operating bar **3132** in the same direction).
(357) Then, the first jaw operating pulley **3123** connected with the first jaw operating bar **3122** rotates around the first jaw operating axis, and the resulting rotating force is transmitted to the operator control member **315** through the first jaw operating wire **335J11** to rotate a J**11** pulley **315J11** of the operator control member **315** in the direction of an arrow YA of FIG. **30**. When the J**11** pulley **315J11** of the operator control member **315** rotates, the first jaw operating wire **335J12** connected therewith is rotated, and the first jaw **321** of the end tool **320** that is connected with the first jaw operating wire **335J12** rotates in the direction of an arrow YJ of FIG. **30**.
(358) At the same time, the second jaw operating pulley **3133** connected with the second jaw operating bar **3132** rotates around the second jaw operating axis, and the resulting rotating force is transmitted to the operator control member **315** through the second jaw operating wire **335J21** to rotate a J**21** pulley **315J21** of the operator control member **315** in the direction of the arrow YA of FIG. **30**. When the J**21** pulley **315J21** of the operator control member **315** rotates, the second jaw operating wire **335J2** connected therewith is rotated, and the second jaw **322** of the end tool **320** that is connected with the second jaw operating wire **335J22** rotates in the direction of the arrow YJ of FIG. **30**.
(359) In this manner, when the first jaw operator **312** and the second jaw operator **313** are rotated in the same direction, the first and second jaws **321** and **322** rotate in the same direction to perform a yaw operation.
(360) The actuation operation will be described below.
(361) For an actuation operation, the user holds and rotates the first jaw operating bar **3122** with the index finger in the direction of the arrow J**1** of FIG. **30**, and holds and rotates the second jaw operating bar **3132** with the thumb finger in a direction opposite to the direction of the arrow J**2** of FIG. **30** (that is, rotates the first jaw operating bar **3122** and the second jaw operating bar **3132** in opposite directions).
(362) Then, the first jaw operating pulley **3123** connected with the first jaw operating bar **3122** rotates around the first jaw operating axis, and the resulting rotating force is transmitted to the operator control member **315** through the first jaw operating wire **335J11** to rotate the J**11** pulley

315J**11** of the operator control member **315** in the direction of the arrow YA of FIG. **30**. When the J**11** pulley **315**J**11** of the operator control member **315** rotates, the first jaw operating wire **335**J**1** connected therewith is rotated, and the first jaw **321** of the end tool **320** that is connected with the first jaw operating wire **335**J**12** rotates in the direction of the arrow YJ of FIG. **30**.
(363) At the same time, the second jaw operating pulley **3133** connected with the second jaw operating bar **3132** rotates around the second jaw operating axis, and the resulting rotating force is transmitted to the operator control member **315** through the second jaw operating wire **335**J**22** to rotate the J**21** pulley **315**J**21** of the operator control member **315** in a direction opposite to the direction of the arrow YA of FIG. **30**. When the J**21** pulley **315**J**21** of the operator control member **315** rotates, the second jaw operating wire **335**J**22** connected therewith is rotated, and the second jaw **322** of the end tool **320** that is connected with the second jaw operating wire **335**J**22** rotates in a direction opposite to the direction of the arrow YJ of FIG. **30**.
(364) In this manner, when the first jaw operator **312** and the second jaw operator **313** are rotated in opposite directions, the first and second jaws **321** and **322** rotate in opposite directions to perform an actuation operation.
(365) Any combination of various configurations of the operator described with reference to FIG. **3**A, various configurations of the operating force transmitter described with reference to FIGS. **4**A and **15** to **27**, and various modifications described with reference to FIGS. **7** to **14** may be applied to the surgical instrument **300** according to the third embodiment of the present invention.
<Modification of Third Embodiment of Surgical Instrument> (One-Armed Cautery)
(366) FIG. **31** is a view illustrating a surgical instrument **300***a* according to a modification of the third embodiment illustrated in FIG. **30**. Since the surgical instrument **300***a* according to a modification of the third embodiment of the present invention is similar to the surgical instrument **300** (see FIG. **30**) according to the third embodiment of the present invention and is different from the surgical instrument **300** in that only one jaw is provided, the configuration of one jaw will be mainly described below.
(367) Referring to FIG. **31**, the surgical instrument **300***a* according to a modification of the third embodiment of the present invention includes an operator **310***a*, an end tool **320***a*, an operating force transmitter **330***a*, and a connector (not illustrated).
(368) The end tool **320***a* includes a jaw **321***a* and an end tool control member **323***a*, and the operating force transmitter **330***a* includes only a jaw operating wire **335**J**1**, so that a pitch operation and a yaw operation of the end tool **320***a* may be conveniently performed. Since the end tool **320***a* is substantially identical to the end tool **120** described with reference to FIG. **5**, a detailed description thereof will be omitted herein.
(369) The operating force transmitter **330***a* includes one or more pulleys and wires **335**J**1**. Since the operating force transmitter **330***a* is substantially identical to the operating force transmitter **130** of the first embodiment, a detailed description thereof will be omitted herein.
(370) The operator **310***a* includes a pitch operator **311***a* controlling a pitch motion of the end tool **320***a* and a jaw operator **312***a* controlling a jaw motion of the end tool **320***a*.
(371) The pitch operator **311***a* includes a pitch operating axis **3111***a* and a pitch operating bar **3112***a*.
(372) The jaw operator **312***a* includes a jaw operating axis, a jaw operating bar **3122***a*, and a jaw operating pulley **3123***a*. Although it is illustrated that the jaw operating axis is formed to extend from the pitch operating bar **3112***a* and the pitch operating bar **3112***a* is inserted into the jaw operating pulley **3123***a*, the present invention is not limited thereto. For example, the pitch operating bar **3112***a* and the jaw operating axis may be formed as separate members on different axes. In this case, the jaw operating axis may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **310***a*. The jaw operating wire **335**J**1** may be connected to the jaw operating pulley **3123***a*. The jaw operating bar **3122***a* and the jaw operating pulley **3123***a* are formed to rotate around the jaw operating axis. For example,

when the user holds and rotates the jaw operating bar **3122***a* with the index finger, the jaw operating pulley **3123***a* connected with the jaw operating bar **3122***a* rotates around the jaw operating axis. Then, the resulting rotating force is transmitted to the end tool **320***a* through the operating force transmitter **330***a*, so that the first jaw **321***a* of the end tool **320***a* horizontally rotate in the same direction as the rotation direction of the jaw operating pulley **3123***a*.

<End Tools of Fourth to Sixth Embodiments of Surgical Instrument> (E1)

(373) Hereinafter, surgical instruments **400**, **500**, and **600** according to fourth, fifth, and sixth embodiment of the present invention will be described. The surgical instruments **400**, **500**, and **600** according to the fourth, fifth, and sixth embodiment of the present invention are substantially identical to the surgical instruments **100**, **200**, and **300** according to the first, second, and third embodiments of the present invention and are different in terms of the configuration of the end tool from the surgical instruments **100**, **200**, and **300** according to the first, second, and third embodiments of the present invention. Thus, the configuration of the end tool applied in common to the fourth, fifth, and sixth embodiment will be described first.

(374) FIGS. **32** to **36** are schematic views illustrating an end tool **420** included in a surgical instrument **400** according to a fourth embodiment of the present invention. FIG. **32** is an exploded perspective view of the end tool **420**, FIG. **33** is an XZ-plane side view of the end tool **420**, FIG. **34** is an XY-plane plan view of the end tool **420**, FIG. **35** is a plan view illustrating a yaw motion of the end tool **420** of FIG. **34**, and FIG. **36** is a plan view illustrating an actuation motion of the end tool **420** of FIG. **34**.

(375) Referring to FIGS. **32** to **36**, the end tool **420** included in the surgical instrument **400** according to the fourth embodiment of the present invention includes a first jaw **421**, a second jaw **422**, one or more pitch pulleys **423**, and one or more yaw pulleys **424**. An operating force transmitter included in the surgical instrument **400** according to the fourth embodiment of the present invention includes one or more pitch wires **435**P, one or more yaw wires **435**Y, and an actuation wire **435**A.

(376) In the present embodiments, a pitch operation is performed by the rotation of the pitch wire wound around the pitch pulley, the yaw wire is formed to intersect the pitch pulley and extend toward the end tool, and the yaw wire is wound around the yaw pulley to perform a yaw operation. When a yaw operation is performed by the rotation of the yaw wire, since the yaw wire is formed to intersect the pitch pulley, the yaw wire is minimally affected by the rotation of the pitch pulley during a pitch operation. Likewise, the actuation wire is formed to intersect the pitch pulley and the yaw pulley and extend toward the end tool, and is connected to an opening (**421***a* and **422***a*) formed in each of the two jaws. The actuation wire is pulled and pushed to perform an actuation operation for opening and closing the two jaws. Since the actuation wire is formed to intersect the pitch pulley and the yaw pulley, the actuation wire is minimally affected by the rotations of the pitch pulley and the yaw pulley during a pitch operation and a yaw operation.

(377) In detail, a pitch pulley coupler **440***a* is formed to protrude from one end portion of a connector **440**, and the pitch pulley **423** is coupled with the pitch pulley coupler **440***a* to rotate around a pitch rotating axis **420**PX with respect to the pitch pulley coupler **440***a*. Also, the pitch pulley **423** is integrated with a pitch pulley base **423***a*, and a yaw pulley coupler **423***b* is formed on one side of the pitch pulley base **423***a*. Thus, the pitch pulley **423** is formed to rotate around the pitch rotating axis **420**PX, and the yaw pulley coupler **423***b* and the pitch pulley base **423***a* coupled therewith rotate along with the pitch pulley **423**. Herein, a pitch wire pass hole **440**HP is formed at the one end portion of the connector **440**, and the pitch wire **435**P extends through the pitch wire pass hole **440**HP toward the end tool **420**.

(378) The yaw pulley **424** is coupled with the yaw pulley coupler **423***b* to rotate around a yaw rotating axis **420**YX with respect to the yaw pulley coupler **423***b*. Also, the yaw pulley **424** is integrated with a yaw pulley base **424***a*. A guide hole **424***b* is formed in the yaw pulley base **424***a*. The yaw pulley **424** is formed to rotate around the yaw rotating axis **420**YX, and the yaw pulley

base **424***a* coupled therewith rotates along with the yaw pulley **424**. Herein, a yaw wire pass hole **440**HY is formed at one end portion of the connector **440**, and the yaw wire **435**Y passes through the yaw wire pass hole **440**HY toward the end tool **420**.
(379) An actuation wire pass hole **440**HA is formed at one end portion of the connector **440**, and the actuation wire **435**A passes through the actuation wire pass hole **440**HA toward the end tool **420**. The actuation wire **435**A passing through the actuation wire pass hole **440**HA is connected to an actuation axis **420**AX along an actuation wire guide **423**G formed at the yaw pulley coupler **423***b*.
(380) Guide holes **421***a* and **422***a* are formed respectively at the first jaw **421** and the second jaw **422**, and the actuation axis **420**AX is inserted through the guide hole **421***a* of the first jaw **421**, the guide hole **422***a* of the second jaw **422**, and the guide hole **424***b* of the yaw pulley base **424***a*. The actuation wire **435**A is coupled to the actuation axis **420**AX. When the actuation wire **435**A translates, the actuation axis **420**AX connected therewith translates along the guide hole **424***b* to perform an actuation operation of the first jaw **421** and the second jaw **422**.
(381) In the end tool **420** of the surgical instrument **400** according to the fourth embodiment of the present invention, the pulley/wire for a pitch operation, the pulley/wire for a yaw operation, and the pulley/wire for an actuation operation are separately formed such that one operation does not affect other operations. This will be described below in more detail.
(382) First, the pitch operation of the present embodiment will be described below.
(383) The pitch wire **435**P of the operating force transmitter **430** for a pitch operation of the end tool **420** connects a pitch operator (not illustrated) of an operator (not illustrated) and the pitch pulley **423** of the end tool **420**. Thus, when the pitch operator rotates around a pitch operating axis (not illustrated) in the counterclockwise direction in FIG. **33**, the pitch wire **435**P connected therewith moves in the direction of an arrow P**2** of FIG. **33**. Accordingly, the pitch pulley **423** connected with the pitch wire **435**P, the yaw pulley **424** connected therewith, the first jaw **421**, and the second jaw **422** rotate around the pitch rotating axis **420**PX in the direction of an arrow P of FIG. **33** to perform a pitch operation. On the other hand, when the pitch operator rotates around the pitch operating axis in the clockwise direction in FIG. **33**, the pitch wire **435**P connected therewith moves in the direction of an arrow P**1** of FIG. **33**. Accordingly, the pitch pulley **423** connected with the pitch wire **435**P, the yaw pulley **424** connected therewith, the first jaw **421**, and the second jaw **422** rotate around the pitch rotating axis **420**PX in the direction of the arrow P of FIG. **33** to perform a pitch operation.
(384) The yaw operation of the present embodiment will be described below.
(385) The yaw wire **435**Y of the operating force transmitter **430** for a yaw operation of the end tool **420** connects a yaw operator (not illustrated) of an operator (not illustrated) and the yaw pulley **424** of the end tool **420**. Thus, when the yaw operator rotates around a yaw operating axis (not illustrated) in the clockwise direction, the yaw wire **435**Y connected therewith moves in the direction of an arrow Y**1** of FIG. **35**. Accordingly, the yaw pulley **424** connected with the yaw wire **435**Y, and the first jaw **421** and the second jaw **422** connected therewith rotate around the yaw rotating axis **420**YX in the direction of an arrow Y of FIG. **35** to perform a yaw operation.
(386) The actuation operation of the present embodiment will be described below.
(387) The actuation wire **435**A of the operating force transmitter **430** for an actuation operation of the end tool **420** connects an actuation operator (not illustrated) of an operator (not illustrated) and the actuation axis **420**AX of the end tool **420**. Thus, when the actuation operator rotates around an actuation operating axis (not illustrated), the actuation wire **435**A moves linearly in the direction of an arrow A of FIG. **35**. Accordingly, the actuation axis **420**AX connected with the actuation wire **435**A translates along the guide hole **424***b* to perform an actuation operation of the first jaw **421** and the second jaw **422**.
<Fourth Embodiment of Surgical Instrument> (E1+H**1**+D)
(388) Hereinafter, the surgical instrument **400** according to the fourth embodiment of the present

invention will be described. In the surgical instrument **400** according to the fourth embodiment of the present invention, the end tool **420** has the configuration described with reference to FIGS. **32** to **36**, and an operator **410** has a yaw operator and an actuation operator formed independently of each other as in the surgical instrument **100** according to the first embodiment of the present invention (illustrated in FIG. **2**), so that a rotation of a yaw operating axis and a rotation of an actuation operating axis are performed independently of each other.
(389) FIG. **37** is a view illustrating the surgical instrument **400** according to the fourth embodiment of the present invention. Referring to FIG. **37**, the surgical instrument **400** according to the fourth embodiment of the present invention includes an operator **410**, the end tool **420**, the operating force transmitter **430**, and a connector (not illustrated).
(390) The end tool **420** includes the first jaw **421**, the second jaw **422**, one or more pitch pulleys **423**, and one or more yaw pulleys **424**, and the operating force transmitter **430** includes one or more pitch wires **435**P, one or more yaw wires **435**Y, and one or more actuation wires **435**A. In the end tool **420**, the pulley/wire for a pitch operation, the pulley/wire for a yaw operation, and the pulley/wire for an actuation operation are separately formed such that one operation does not affect other operations. Since the end tool **420** is substantially identical to the end tool described with reference to FIGS. **32** to **36**, a detailed description thereof will be omitted herein.
(391) The operating force transmitter **430** includes a first differential member **431** and a second differential member **432**. The first differential member **431** and the second differential member **432** each include two or more input units and one input unit, receives an input of rotating forces from the two or more input units, extract a desired rotating force from the sum of (or the difference between) the input rotating forces, and output the desired rotating force through the output unit. The first and second differential members **431** and **432** may include various differential pulleys and differential gears, such as, the differential pulley of the surgical instrument **100** according to the first embodiment illustrated in FIGS. **4**A and **4**B, the first modification of the differential pulley illustrated in FIG. **15**, the second modification of the differential pulley illustrated in FIG. **18**, and the third modification of the differential pulley illustrated in FIG. **22**. That is, although the differential pulley of FIG. **21**E is illustrated as the first and second differential members **431** and **432** of the surgical instrument **400** according to the fourth embodiment in FIG. **37**, the present invention is not limited thereto, and various differential pulleys and differential gears may be used in the present embodiment.
(392) Hereinafter, the operator **410** of the surgical instrument **400** according to the fourth embodiment of the present invention will be described in more detail.
(393) Referring to FIG. **37**, the operator **410** of the surgical instrument **400** according to the fourth embodiment of the present invention includes a pitch operator **411** controlling a pitch motion of the end tool **420**, a yaw operator **412** controlling a yaw motion of the end tool **420**, and an actuation operator **413** controlling an actuation motion of the end tool **420**.
(394) The pitch operator **411** includes a pitch operating axis **4111**, a pitch operating bar **4112**, and a pitch operating pulley **4113**. Herein, the pitch operating axis **4111** may be formed in a direction parallel to the Y axis, and the pitch operating bar **4112** may be connected with the pitch operating axis **4111** to rotate along with the pitch operating axis **4111**. For example, when the user grips and rotates the pitch operating bar **4112**, the pitch operating axis **4111** connected with the pitch operating bar **4112** and the pitch operating pulley **4113** connected therewith rotate together therewith. Then, the resulting rotating force is transmitted to the end tool **420** through the operating force transmitter **430**, so that the end tool **420** rotates in the same direction as the rotation direction of the pitch operating axis **4111**. That is, when the pitch operator **411** rotates in the clockwise direction around the pitch operating axis **4111**, the end tool **420** also rotates in the clockwise direction around a pitch pulley operating axis (not illustrated), and when the pitch operator **411** rotates in the counterclockwise direction around the pitch operating axis **4111**, the end tool **420** also rotates in the counterclockwise direction around the pitch pulley operating axis. The pitch operating

pulley **4113** is integrated with the pitch operating axis **4111** to rotate along with the pitch operating axis **4111**.
(395) The yaw operator **412** includes a yaw operating axis **4121**, a yaw operating bar **4122**, and a yaw operating pulley **4123**. A yaw operating wire **435**Y**2** may be connected to the yaw operating pulley **4123**. Although it is illustrated that the yaw operating axis **4121** is formed to extend from the pitch operating bar **4112**, the present invention is not limited thereto. For example, the pitch operating bar **4112** and the yaw operating axis **4121** may be formed as separate members on different axes. In this case, the yaw operating axis **4121** may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **410**.
(396) As described above, when the pitch operator **411** rotates, a coordinate system of the yaw operator **412** may change relatively. The yaw operating bar **4122** and the yaw operating pulley **4123** are formed to rotate around the yaw operating axis **4121**. For example, when the user holds and rotates the yaw operating bar **4122** with the index finger, the yaw operating pulley **4123** connected with the yaw operating bar **4122** rotates around the yaw operating axis **4121**. Then, the resulting rotating force is transmitted to the end tool **420** through the operating force transmitter **430**, so that the first and second jaws **420** and **421** of the end tool **420** horizontally rotate in the same direction as the rotation direction of the yaw operating pulley **4123**.
(397) The actuation operator **413** includes an actuation operating axis **4131**, an actuation operating bar **4132**, and an actuation operating pulley **4133**. An actuation operating wire **435**A**2** may be connected to the actuation operating pulley **4133**. The actuation operating axis **4131** is formed to extend from the pitch operating bar **4112** and may be formed in the direction parallel to the Z axis or in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **410**. As described above, when the pitch operator **411** rotates, a coordinate system of the actuation operator **413** may change relatively. The actuation operating bar **4132** and the actuation operating pulley **4133** are formed to rotate around the actuation operating axis **4131**. For example, when the user holds and rotates the actuation operating bar **4132** with the thumb finger, the actuation operating pulley **4133** connected with the actuation operating bar **4132** rotates around the actuation operating axis **4131**. Then, the resulting rotating force is transmitted to the end tool **420** through the operating force transmitter **430**, so that the first and second jaws **420** and **421** of the end tool **120** perform an actuation operation.
(398) The pitch operating axis **4111** is inserted into a first yaw-pitch (YP) pulley **414***a* and a first actuation-pitch (AP) pulley **415***a* such that the first YP pulley **414***a* and the first AP pulley **415***a* rotate around the pitch operating axis **4111**.
(399) When the yaw operating bar **4122** rotates, the first YP pulley **414***a* and a second YP pulley **414***b* connected therewith rotate along with the yaw operating pulley **4123**; and when the pitch operating bar **4112** and the yaw operator **412** and the actuation operator **413** connected therewith rotate together around the pitch operating axis **4111**, the first YP pulley **414***a* and the second YP pulley **414***b* connected therewith rotate along with the pitch operating pulley **4113**. That is, the first YP pulley **414***a* and the second YP pulley **414***b* may be considered as pulleys that reflect the rotations of the yaw operating bar **4122** and the rotation of the pitch operating bar **4112** together.
(400) In detail, when the yaw operating bar **4122** rotates, the yaw operating pulley **4123** connected with the yaw operating bar **4122** rotates along with the yaw operating bar **4122**, and thus the yaw operating wire **435**Y**2** moves to rotate the first YP pulley **414***a* and the second YP pulley **414***b* connected therewith. When the pitch operating axis **4111** and the pitch operating bar **4112** rotate in the direction of an arrow P of FIG. **37**, the yaw operating axis **4121** and the yaw operating pulley **4123** also rotate around the pitch operating axis **4111**. Then, the yaw operating wire **435**Y**2** rotates around the pitch operating axis **4111** in the direction of the arrow P of FIG. **37** according to the rotation of the operator **410**, and the first YP pulley **414***a* connected therewith also rotates accordingly. Consequently, the first YP pulley **414***a* and the second YP pulley **414***b* rotate when the yaw operating pulley **4123** rotates, and also rotate when the pitch operating pulley **4113** rotates.

This means that a yaw operation input and a pitch operation input are added together by the first YP pulley **414**a and the second YP pulley **414**b of the operator **410** to output the sum of the yaw operation input and the pitch operation input.

(401) When the actuation operating bar **4132** rotates, the first AP pulley **415**a and a second AP pulley **415**b connected therewith rotate along with the actuation operating pulley **4133**; and when the actuation operating bar **4112** and the yaw operator **412** and the actuation operator **413** connected therewith rotate together around the pitch operating axis **4111**, the first AP pulley **415**a and the second AP pulley **415**b connected therewith rotate along with the pitch operating pulley **4113**. That is, the first AP pulley **415**a and the second AP pulley **415**b may be considered as pulleys that reflect the rotations of the actuation operating bar **4132** and the rotation of the pitch operating bar **4112** together.

(402) In detail, when the actuation operating bar **4132** rotates, the actuation operating pulley **4133** connected with the actuation operating bar **4132** rotates along with the actuation operating bar **4132**, and thus the actuation operating wire **435**A**2** connected therewith moves to rotate the first AP pulley **415**a and the second AP pulley **415**b connected therewith. When the pitch operating axis **4111** and the pitch operating bar **4112** rotate in the direction of the arrow P of FIG. **37**, the actuation operating axis **4131** and the actuation operating pulley **4133** also rotate around the pitch operating axis **4111**. Then, the actuation operating wire **435**A**2** rotates around the pitch operating axis **4111** in the direction of the arrow P of FIG. **37** according to the rotation of the operator **410**, and the first AP pulley **415**a connected therewith also rotates accordingly. Consequently, the first AP pulley **415**a and the second AP pulley **415**b rotate when the actuation operating pulley **4133** rotates, and also rotate when the pitch operating pulley **4113** rotates. This means that an actuation operation input and a pitch operation input are added together by the first AP pulley **415**a and the second AP pulley **415**b of the operator **410** to output the sum of the actuation operation input and the pitch operation input.

(403) Although it is illustrated that the first YP pulley **414**a is connected to the second YP pulley **414**b, and the second YP pulley **414**b is connected to a first input unit **4311** of the first differential member **431**, this is merely for convenience of description, and the first YP pulley **414**a may be directly connected to the first input unit **4311** of the first differential member **431**, without using the second YP pulley **414**b.

(404) Likewise, although it is illustrated that the first AP pulley **415**a is connected to the second AP pulley **415**b, and the second AP pulley **415**b is connected to a first input unit **4321** of the second differential member **432**, this is merely for convenience of description, and the first AP pulley **415**a may be directly connected to the first input unit **4321** of the second differential member **432**, without using the second AP pulley **415**b.

(405) Likewise, although it is illustrated that the pitch operating pulley **4113** is connected to a second pitch operating pulley **4113**b, and the second pitch operating pulley **4113**b is connected to a second input unit **4312** of the first differential member **431** and a second input unit **4322** of the second differential member **432**, this is merely for convenience of description, and the pitch operating pulley **4113** may be directly connected to the second input unit **4312** of the first differential member **431** and the second input unit **4322** of the second differential member **432**, without using the second pitch operating pulley **4113**b.

Overall Operation of Fourth Embodiment

(406) Hereinafter, an overall configuration for the pitch operation, the yaw operation, and the actuation operation of the surgical instrument **400** according to the fourth embodiment of the present invention will be summarized with reference to the above descriptions.

(407) In the surgical instrument **400** according to the fourth embodiment of the present invention, the first differential member **431** includes the first input unit **4311**, the second input unit **4312**, an output unit **4313**, a first differential control member **4314**, a second differential control member **4315**, and a differential control wire **4316**, and the second differential member **432** includes the

first input unit **4321**, the second input unit **4322**, an output unit **4323**, a first differential control member **4324**, a second differential control member **4325**, and a differential control wire **4326**.
(408) In detail, for the configuration of the end tool **420** of the present embodiment, the operating force transmitter **430** capable of dividing the operation input of the operator **410** into a pitch operation, a yaw operation, and an actuation operation is necessary to perform the pitch, yaw, and actuation operations of the end tool **420**. The rotation operation of the pitch operating bar may be directly connected to the pitch operation of the end tool. However, since the yaw operator and the actuation operator are disposed on the pitch operator, the operation input of the yaw operator and the operation input of the actuation operator may be added to the pitch operation input prior to transmission thereof to the operating force transmitter, as described above. This may be expressed as the following equation:
(409) $$\begin{aligned} Y_P &= Y + P \\ A_P &= A + P \end{aligned}$$ (where Y.sub.P denotes a rotation of the Y.sub.P pulley, A.sub.P denotes a rotation of the A.sub.P pulley, Y denotes a rotation of the yaw operating pulley, and P denotes a rotation of the pitch operating pulley.)
(410) Thus, in order to transmit the output of the operator **410** as only the Y and A components to the end tool **420**, the operating force transmitter **430** extracts the following components:
(411) $$\begin{aligned} Y &= Y_P - P \\ A &= A_P - P \end{aligned}$$
(412) To this end, the operating force transmitter **430** includes a differential pulley that receives an input of Y.sub.P and P and outputs only the difference (Y component) between Y.sub.P and P, and a differential pulley that receives an input of A.sub.P and P and outputs only the difference (A component) between A.sub.P and P.
(413) Herein, the first input unit **4311** of the first differential member **431** is connected with the first YP pulley **414***a* (or the second YP pulley **414***b* connected therewith) to rotate when the yaw operating pulley **4123** rotates and also rotate when the pitch operating pulley **4113** rotates. Also, the second input unit **4312** of the first differential member **431** is connected with the pitch operating pulley **4113** to rotate when the pitch operating pulley **4113** rotates. Also, the output unit **4313** of the first differential member **431** is connected with the yaw wire **435**Y to control the yaw operation of the end tool **420**.
(414) The first input unit **4321** of the second differential member **432** is connected with the first AP pulley **415***a* (or the second AP pulley **415***b* connected therewith) to rotate when the actuation operating pulley **4133** rotates and also rotate when the pitch operating pulley **4113** rotates. Also, the second input unit **4322** of the second differential member **432** is connected with the pitch operating pulley **4113** to rotate when the pitch operating pulley **4113** rotates. Also, the output unit **4323** of the second differential member **432** is connected with the actuation wire **435**A to control the actuation operation of the end tool **420**.
(415) The pitch operating pulley **4113** is connected with the pitch wire **435**P to control the pitch operation of the end tool **420**.
(416) First, the pitch operation will be described below.
(417) As described above, when the user grips the pitch operating bar **4112** of the pitch operator **411** of the operator **410** and rotates the pitch operating bar **4112** around the pitch operating axis **4111** in the direction of an arrow P (pitch) of FIG. **37**, the pitch operating pulley **4113** rotates along with the pitch operating axis **4111**. Then, the pitch pulley **423** connected with the pitch operating pulley **4113** by the pitch wire **435**P, the yaw pulley **424** connected therewith, the first jaw **421**, and the second jaw **422** rotate around the pitch rotating axis **420**PX (see FIG. **32**) to perform a pitch operation.
(418) In this case, the pitch operation does not affect the output units of the differential pulleys **431** and **432** of the operating force transmitter **430** which determine the yaw and actuation operations of

the end tool **420**. In more detail, when the first YP pulley **414***a* and the first AP pulley **415***a* rotate around the pitch operating axis **4111** according to the pitch operation, the first input unit **4311** of the first differential member **431** that is connected with the second YP pulley **414***b* and the second input unit **4312** of the first differential member **431** that is connected with the pitch operating pulley **4113** rotate; however, since the rotations are offset in the first differential member **431**, the output unit **4313** of the first differential member **431** does not rotate. Likewise, the first input unit **4321** of the second differential member **432** that is connected with the second AP pulley **415***b* and the second input unit **4322** of the second differential member **432** that is connected with the pitch operating pulley **4113** rotate; however, since the rotations are offset in the second differential member **432**, the output unit **4323** of the second differential member **432** does not rotate. Thus, the pitch operation may be performed independently of the yaw operation and the actuation operation.
(419) The yaw operation of the present embodiment will be described below.
(420) When the user holds and rotates the yaw operating bar **4122** with the index finger in the direction of an arrow Y of FIG. **37**, the yaw operating pulley **4123** connected with the yaw operating bar **4122** rotates around the yaw operating axis **4121**. Then, the resulting rotating force is transmitted through the yaw operating wire **435**Y**2** to the first YP pulley **414***a* and the second YP pulley **414***b* connected therewith, to rotate the second YP pulley **414***b*. When the second YP pulley **414***b* rotates, the first input unit **4311** of the first differential member **431** connected therewith and the output unit **4313** of the first differential member **431** connected therewith rotate. Consequently, when the output unit **4313** of the first differential member **431** rotates, the yaw wire **435**Y connected with the output unit **4313**, the yaw pulley **424** connected with the yaw wire **435**Y, and the first and second jaws **421** and **422** connected with the yaw pulley **424** rotate around the yaw rotating axis **420**YX (see FIG. **32**) to perform a yaw operation.
(421) The actuation operation of the present embodiment will be described below.
(422) When the user holds and rotates the actuation operating bar **4132** with the thumb finger in the direction of an arrow A of FIG. **37**, the actuation operating pulley **4133** connected with the actuation operating bar **4132** rotates around the actuation operating axis **4131**. Then, the resulting rotating force is transmitted through the actuation operating wire **435**A**2** to the first AP pulley **415***a* and the second AP pulley **415***b* connected therewith, to rotate the second AP pulley **415***b*. When the second AP pulley **415***b* rotates, the first input unit **4321** of the second differential member **432** connected therewith and the output unit **4323** of the second differential member **432** connected therewith rotate. Consequently, when the output unit **4323** of the second differential member **432** rotates, the actuation wire **435**A connected with the output unit **4323** moves linearly in the direction of the arrow A of FIG. **37**. Accordingly, the actuation axis **420**AX (see FIG. **32**) connected with the actuation wire **435**A translates to perform an actuation operation of the first jaw **421** and the second jaw **422**.
(423) A case where the yaw operating pulley **4123** and the pitch operating pulley **4113** rotate together will be described below.
(424) As described above, the first YP pulley **414***a* and the second YP pulley **414***b* connected therewith rotate along with the yaw operating pulley **4123** when the yaw operating pulley **4123** rotates, and rotate along with the pitch operating pulley **4113** when the pitch operating pulley **4113** rotates. The yaw wire **435**Y for performing the yaw operation of the end tool **420** is only affected by the operation of the yaw operator **412** but not by the operation of the pitch operator **411**. Thus, the first input unit **4311** of the first differential member **431** is connected with the second YP pulley **414***b*, and the second input unit **4312** of the first differential member **431** is connected with the pitch operating pulley **4113**, to extract only a pure yaw operation control component from the rotation of the pitch operating pulley **4113** and the rotation of the yaw operating pulley **4123**.
(425) According to the present invention, even when the yaw operator **412** rotates along with the pitch operating axis **4111**, the yaw operation of the end tool **420** may depend only on the operation of the yaw operator **412** and not be affected by the pitch operating axis **4111**.

(426) A case where the actuation operating pulley **4133** and the pitch operating pulley **4113** rotate together will be described below.
(427) As described above, the first AP pulley **415***a* and the second AP pulley **415***b* connected therewith rotate along with the actuation operating pulley **4133** when the actuation operating pulley **4133** rotates, and rotate along with the pitch operating pulley **4113** when the pitch operating axis **4111** rotates. The actuation wire **435**A for performing the actuation operation of the end tool **420** is only affected by the operation of the actuation operator **413** but not by the operation of the pitch operator **411**. Thus, the first input unit **4321** of the second differential member **432** is connected with the second AP pulley **415***b*, and the second input unit **4322** of the second differential member **432** is connected with the pitch operating pulley **4113**, to extract only a pure actuation operation control component from the rotation of the pitch operating pulley **4113** and the rotation of the actuation operating pulley **4133**.
(428) According to the present invention, even when the actuation operator **413** rotates along with the pitch operating pulley **4113**, the actuation operation of the end tool **420** may depend only on the operation of the actuation operator **413** and not be affected by the pitch operating pulley **4113**.
(429) Thus, as described above, the pitch, yaw, and actuation operations of the operator are independently divided into the pitch, yaw, and actuation operations of the end tool. Also, even when the pitch, yaw, and actuation operations of the operator occur simultaneously or not, the pitch, yaw, and actuation operations of the operator may be independently divided into the pitch, yaw, and actuation operations of the end tool.
(430) Any combination of various configurations of the operator described with reference to FIG. **3**A, various configurations of the operating force transmitter described with reference to FIGS. **4**A and **15** to **27**, and various modifications described with reference to FIGS. **7** to **14** may be applied to the surgical instrument **400** according to the fourth embodiment of the present invention.
<Fifth Embodiment of Surgical Instrument> (E1+H**2**+D)
(431) Hereinafter, the surgical instrument **500** according to the fifth embodiment of the present invention will be described. In the surgical instrument **500** according to the fifth embodiment of the present invention, an end tool **520** has the configuration described with reference to FIGS. **32** to **36**, and an operator **510** has an actuation operator formed on a yaw operator as in the surgical instrument **200** according to the second embodiment of the present invention (illustrated in FIG. **8**), so that the actuation operator rotates along with the yaw operator when the yaw operator rotates.
(432) FIG. **38** is a view illustrating a surgical instrument **500** according to a fifth embodiment of the present invention. Referring to FIG. **38**, the surgical instrument **500** according to the fifth embodiment of the present invention includes an operator **510**, an end tool **520**, an operating force transmitter **530**, and a connector (not illustrated).
(433) The end tool **520** includes a first jaw **521**, a second jaw **522**, one or more pitch pulleys **523**, and one or more yaw pulleys **524**, and the operating force transmitter **530** includes one or more pitch wires **535**P, one or more yaw wires **535**Y, and one or more actuation wires **535**A. In the end tool **520**, the pulley/wire for a pitch operation, the pulley/wire for a yaw operation, and the pulley/wire for an actuation operation are separately formed such that one operation does not affect other operations. Since the end tool **520** is substantially identical to the end tool **420** described with reference to FIGS. **32** to **36**, a detailed description thereof will be omitted herein.
(434) The operating force transmitter **530** includes a first differential member **531** and a second differential member **532**. The first differential member **531** and the second differential member **532** includes two or more input units and one input unit, receives an input of rotating forces from the two or more input units, extracts a desired rotating force from the sum of (or the difference between) the input rotating forces, and outputs the desired rotating force through the output unit. The first and second differential members **531** and **532** may include various differential pulleys and differential gears, such as, the differential pulley of the surgical instrument **100** according to the first embodiment illustrated in FIGS. **4**A and **4**B, the first modification of the differential pulley

illustrated in FIG. **15**, the second modification of the differential pulley illustrated in FIG. **18**, and the third modification of the differential pulley illustrated in FIG. **22**. That is, although the differential pulley of FIG. **21**E is illustrated as the first and second differential members **531** and **532** of the surgical instrument **500** according to the fifth embodiment in FIG. **38**, the present invention is not limited thereto, and various differential pulleys and differential gears may be used in the present embodiment.
(435) Hereinafter, the operator **510** of the surgical instrument **500** according to the fifth embodiment of the present invention will be described in more detail.
(436) Referring to FIG. **38**, the operator **510** of the surgical instrument **500** according to the fifth embodiment of the present invention includes a pitch operator **511** controlling a pitch motion of the end tool **520**, a yaw operator **512** controlling a yaw motion of the end tool **520**, and an actuation operator **513** controlling an actuation motion of the end tool **520**.
(437) The pitch operator **511** includes a pitch operating axis **5111**, a pitch operating bar **5112**, and a pitch operating pulley **5113**. Herein, the pitch operating axis **5111** may be formed in a direction parallel to the Y axis, and the pitch operating bar **5112** may be connected with the pitch operating axis **5111** to rotate along with the pitch operating axis **5111**. For example, when the user grips and rotates the pitch operating bar **5112**, the pitch operating axis **5111** connected with the pitch operating bar **5112** and the pitch operating pulley **5113** connected therewith rotate together therewith. Then, the resulting rotating force is transmitted to the end tool **520** through the operating force transmitter **530**, so that the end tool **520** rotates in the same direction as the rotation direction of the pitch operating axis **5111**. That is, when the pitch operator **511** rotates in the clockwise direction around the pitch operating axis **5111**, the end tool **520** also rotates in the clockwise direction around a pitch pulley operating axis (not illustrated), and when the pitch operator **511** rotates in the counterclockwise direction around the pitch operating axis **5111**, the end tool **520** also rotates in the counterclockwise direction around the pitch pulley operating axis. The pitch operating pulley **5113** is integrated with the pitch operating axis **5111** to rotate along with the pitch operating axis **5111**.
(438) The yaw operator **512** includes a yaw operating axis **5121**, a yaw operating bar **5122**, and a yaw operating pulley **5123**. Although it is illustrated that the yaw operating axis **5121** is formed to extend from the pitch operating bar **5112**, the present invention is not limited thereto. For example, the pitch operating bar **5112** and the yaw operating axis **5121** may be formed as separate members on different axes. In this case, the yaw operating axis **5121** may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **510**. A yaw operating wire **535**Y**2** may be connected to the yaw operating pulley **5123**.
(439) As described above, when the pitch operator **511** rotates, a coordinate system of the yaw operator **512** may change relatively. The yaw operating bar **5122** and the yaw operating pulley **5123** are formed to rotate around the yaw operating axis **5121**. For example, when the user holds and rotates the yaw operating bar **5122** with the index finger, the yaw operating pulley **5123** connected with the yaw operating bar **5122** rotates around the yaw operating axis **5121**. Then, the resulting rotating force is transmitted to the end tool **520** through the yaw operating wire **535**Y**2**, so that the first and second jaws **521** and **522** of the end tool **520** horizontally rotate in the same direction as the rotation direction of the yaw operating pulley **5123**.
(440) The actuation operator **513** includes an actuation operating axis **5131**, an actuation operating bar **5132**, and an actuation operating pulley **5133**. The actuation operating bar **5132** and the actuation operating pulley **5133** are formed to rotate around the actuation operating axis **5131**. For example, when the user holds and rotates the actuation operating bar **5132** with the thumb finger, the actuation operating pulley **5133** connected with the actuation operating bar **5132** rotates around the actuation operating axis **5131**. Then, the resulting rotating force is transmitted to the end tool **520** through the operating force transmitter **530**, so that the first and second jaws **521** and **522** of the end tool **520** perform an actuation operation. In this case, the actuation operator **513** may be

formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **510**.

(441) The actuation operator **513** is formed on a yaw-actuation connector **5124** extending from the yaw operator **512**. Thus, when the yaw operating bar **5122** of the yaw operator **512** rotates, the actuation operator **513** rotates around the yaw operating axis **5121** along with the yaw operating bar **5122** and the yaw operating pulley **5123**. A yaw-actuation operating pulley **514**P may be formed to rotate around the yaw operating axis **5121**. The actuation operating pulley **5133** and the yaw-actuation operating pulley **514**P are connected by a yaw-actuation connecting wire **514**W. A yaw-actuation operating wire **535**AY is connected to the yaw-actuation operating pulley **514**P.

(442) Thus, when the yaw operating bar **5122** rotates, the yaw-actuation connector **5124** extending therefrom and the actuation operator **513** rotate around the yaw operating axis **5121**, the yaw-actuation connecting wire **514**W connected to the actuation operating pulley **5133** also rotates around the yaw operating axis **5121**, and consequently, the yaw-actuation operating pulley **514**P rotates around the yaw operating axis **5121**.

(443) Consequently, the yaw-actuation operating pulley **514**P rotates when the yaw operating pulley **5123** rotates, and also rotates when the actuation operating pulley **5133** rotates.

(444) The pitch operating axis **5111** is inserted into a first yaw-pitch (YP) pulley **514***a* and a first actuation-yaw-pitch (AYP) pulley **515***a* such that the first YP pulley **514***a* and the first AYP pulley **515***a* rotate around the pitch operating axis **5111**.

(445) When the yaw operating bar **5122** rotates, the first YP pulley **514***a* and a second YP pulley **514***b* connected therewith rotate along with the yaw operating pulley **5123**; and when the pitch operating bar **5112** and the yaw operator **512** and the actuation operator **513** connected therewith rotate together around the pitch operating axis **5111**, the first YP pulley **514***a* and the second YP pulley **514***b* connected therewith rotate along with the pitch operating pulley **5113**. That is, the first YP pulley **514***a* and the second YP pulley **514***b* may be considered as pulleys that reflect the rotations of the yaw operating bar **5122** and the rotation of the pitch operating bar **5112** together.

(446) In detail, when the yaw operating bar **5122** rotates, the yaw operating pulley **5123** connected with the yaw operating bar **5122** rotates along with the yaw operating bar **5122**, and thus the yaw operating wire **535**Y**2** moves to rotate the first YP pulley **514***a* and the second YP pulley **514***b* connected therewith. When the pitch operating axis **5111** and the pitch operating bar **5112** rotate in the direction of an arrow P of FIG. **38**, the yaw operating axis **5121** and the yaw operating pulley **5123** also rotate around the pitch operating axis **5111**. Then, the yaw operating wire **535**Y**2** rotates around the pitch operating axis **5111** in the direction of the arrow P of FIG. **38** according to the rotation of the operator **510**, and the first YP pulley **514***a* connected therewith also rotates accordingly. Consequently, the first YP pulley **514***a* and the second YP pulley **514***b* rotate when the yaw operating pulley **5123** rotates, and also rotate when the pitch operating pulley **5113** rotates. This means that a yaw operation input and a pitch operation input are added together by the first YP pulley **514***a* and the second YP pulley **514***b* of the operator **510** to output the sum of the yaw operation input and the pitch operation input.

(447) The first AYP pulley **515***a* and a second AYP pulley **515***b* connected therewith rotate along with the actuation operating pulley **5133** when the actuation operating bar **5132** rotates, rotate along with the yaw operating pulley **5123** when the yaw operating bar **5122** rotates, and rotate along with the pitch operating pulley **5113** when the pitch operating bar **5112** rotates. That is, the first AYP pulley **515***a* and the second AYP pulley **515***b* may be considered as pulleys that reflect the rotations of the actuation operating bar **5132** and the rotation of the yaw operating bar **5122** together.

(448) In detail, when the actuation operating bar **5132** rotates, the actuation operating pulley **5133** connected with the actuation operating bar **5132** rotates along with the actuation operating bar **5132**, and thus the yaw-actuation connecting wire **514**W moves to rotate the yaw-actuation operating pulley **514**P. When the yaw-actuation operating pulley **514**P rotates, the yaw-actuation

operating wire **535**AY connected therewith moves to rotate the first AYP pulley **515***a* and the second AYP pulley **515***b* connected therewith. When the yaw operating bar **5122** rotates, the actuation operator **513** connected with the yaw operating bar **5122** rotates along with the yaw operating bar **5122**, and thus the yaw-actuation connecting wire **514**W connected with the actuation operating pulley **5133** of the actuation operator **513** rotates around the yaw operating axis **5121** to rotate the yaw-actuation operating pulley **514**P. When the yaw-actuation operating pulley **514**P rotates, the yaw-actuation operating wire **535**AY connected therewith moves to rotate the first AYP pulley **515***a* and the second AYP pulley **515***b* connected therewith. When the pitch operating axis **5111** and the pitch operating bar **5112** rotate in the direction of the arrow P of FIG. **38**, the actuation operating axis **5131** and the actuation operating pulley **5133** also rotate around the pitch operating axis **5111**. Then, the yaw-actuation operating wire **535**AY rotates around the pitch operating axis **5111** in the direction of the arrow P of FIG. **38** according to the rotation of the operator **510**, and the first AYP pulley **515***a* connected therewith also rotates accordingly. Consequently, the first AYP pulley **515***a* and the second AYP pulley **515***b* rotate when the actuation operating bar **5132** rotates, rotate when the yaw operating bar **5122** rotates, and rotate when the pitch operating bar **5112** rotates. This means that an actuation operation input, a yaw operation input, and a pitch operation input are added together by the first AYP pulley **515***a* and the second AYP pulley **515***b* of the operator **510** to output the sum of the actuation operation input, the yaw operation input, and the pitch operation input.

(449) Although it is illustrated that the first YP pulley **514***a* is connected to the second YP pulley **514***b*, and the second YP pulley **514***b* is connected to a first input unit **5311** of the first differential member **531**, this is merely for convenience of description, and the first YP pulley **514***a* may be directly connected to the first input unit **5311** of the first differential member **531**, without using the second YP pulley **514***b*.

(450) Likewise, although it is illustrated that the first AYP pulley **515***a* is connected to the second AYP pulley **515***b*, and the second AYP pulley **515***b* is connected to a first input unit **5321** of the second differential member **532**, this is merely for convenience of description, and the first AYP pulley **515***a* may be directly connected to the first input unit **5321** of the second differential member **532**, without using the second AYP pulley **515***b*.

(451) Likewise, although it is illustrated that the pitch operating pulley **5113** is connected to a second pitch operating pulley **5113***b*, and the second pitch operating pulley **5113***b* is connected to a second input unit **5312** of the first differential member **531**, this is merely for convenience of description, and the pitch operating pulley **5113** may be directly connected to the second input unit **5312** of the first differential member **531**, without using the second pitch operating pulley **5113***b*.

Overall Operation of Fifth Embodiment

(452) Hereinafter, an overall configuration for the pitch operation, the yaw operation, and the actuation operation of the surgical instrument **500** according to the fifth embodiment of the present invention will be summarized with reference to the above descriptions.

(453) In the surgical instrument **500** according to the fifth embodiment of the present invention, the first differential member **531** includes the first input unit **5311**, the second input unit **5312**, an output unit **5313**, a first differential control member **5314**, a second differential control member **5315**, and a differential control wire **5316**, and the second differential member **532** includes a first input unit **5321**, a second input unit **5322**, an output unit **5323**, a first differential control member **5324**, a second differential control member **5325**, and a differential control wire **5326**.

(454) For the configuration of the end tool **520** of the present embodiment, the operating force transmitter **530** capable of dividing the operation input of the operator **510** into a pitch operation, a yaw operation, and an actuation operation is necessary to perform the pitch, yaw, and actuation operations of the end tool **520**. The rotation operation of the pitch operating bar may be directly connected to the pitch operation of the end tool. However, since the yaw operator and the actuation operator are disposed on the pitch operator and the actuation operator is disposed on the yaw

operator, the yaw operation input is added to the pitch operation input and the actuation operation input is added to the yaw operation input and the pitch operation input, prior to transmission thereof to the operating force transmitter, as described above. This may be expressed as the following equation:

(455) $$\begin{aligned} Y_P &= Y + P \\ A_{YP} &= A + Y + P (A_Y = A + Y) \end{aligned}$$ (where Y.sub.P denotes a rotation of the Y.sub.P pulley, A.sub.YP denotes a rotation of the A.sub.YP pulley, A denotes a rotation of the actuation operating pulley, Y denotes a rotation of the yaw operating pulley, and P denotes a rotation of the pitch operating pulley.)

(456) Thus, in order to transmit the output of the operator **510** as only the Y and A components to the end tool **520**, the operating force transmitter **530** extracts the following components:

(457) $$\begin{aligned} Y &= Y_P - P \\ A &= A_{YP} - Y_P \end{aligned}$$

(458) To this end, the operating force transmitter **530** includes a differential pulley that receives an input of Y.sub.P and P and outputs only the difference (Y component) between Y.sub.P and P, and a differential pulley that receives an input of A.sub.YP and Y.sub.P and outputs only the difference (A component) between A.sub.YP and Y.sub.P.

(459) Herein, the first input unit **5311** of the first differential member **531** is connected with the first Y.sub.P pulley **514***a* (or the second Y.sub.P pulley **514***b* connected therewith) to rotate when the yaw operating pulley **5123** rotates and also rotate when the pitch operating pulley **5113** rotates. Also, the second input unit **5312** of the first differential member **531** is connected with the pitch operating pulley **5113** to rotate when the pitch operating pulley **5113** rotates. Also, the output unit **5313** of the first differential member **531** is connected with the yaw wire **535**Y to control the yaw operation of the end tool **520**.

(460) The first input unit **5321** of the second differential member **532** is connected with the first A.sub.YP pulley **515***a* (or the second A.sub.YP pulley **515***b* connected therewith) to rotate when the actuation operating pulley **5133** rotates, rotate when the yaw operating pulley **5123** rotates, and rotate when the pitch operating pulley **5113** rotates. Also, the second input unit **5322** of the second differential member **532** is connected with the second Y.sub.P pulley **514***b* to rotate when the second Y.sub.P pulley **514***b* rotates. Also, the output unit **5323** of the second differential member **532** is connected with the actuation wire **535**A to control the actuation operation of the end tool **520**.

(461) The pitch operating pulley **5113** is connected with the pitch wire **535**P to control the pitch operation of the end tool **520**.

(462) First, the pitch operation will be described below.

(463) As described above, when the user grips the pitch operating bar **5112** of the pitch operator **511** of the operator **510** and rotates the pitch operating bar **5112** around the pitch operating axis **5111** in the direction of an arrow P of FIG. **38**, the pitch operating pulley **5113** rotates along with the pitch operating axis **5111**. Then, the pitch pulley **523** connected with the pitch operating pulley **5113** by the pitch wire **535**P, the yaw pulley **524** connected therewith, the first jaw **521**, and the second jaw **522** rotate around the pitch rotating axis **420**PX (see FIG. **32**) to perform a pitch operation.

(464) In this case, the pitch operation does not affect the first and second differential pulleys **531** and **532** of the operating force transmitter **530** which determine the yaw and actuation operations of the end tool **520**. In more detail, when the first YP pulley **514***a* and the first AYP pulley **515***a* rotate around the pitch operating axis **5111** according to the pitch operation, the first input unit **5311** of the first differential member **531** that is connected with the second YP pulley **514***b* and the second input unit **5312** of the first differential member **531** that is connected with the pitch operating pulley **5113** rotate; however, since the rotations are offset in the first differential member **531**, the

output unit **5313** of the first differential member **531** does not rotate. Likewise, the first input unit **5321** of the second differential member **532** that is connected with the second AYP pulley **515***b* and the second input unit **5322** of the second differential member **532** that is connected with the second YP pulley **514***b* rotate; however, since the rotations are offset in the second differential member **532**, the output unit **5323** of the second differential member **532** does not rotate. Thus, the pitch operation may be performed independently of the yaw operation and the actuation operation.
(465) The yaw operation of the present embodiment will be described below.
(466) When the user holds and rotates the yaw operating bar **5122** with the index finger in the direction of an arrow Y of FIG. **38**, the yaw operating pulley **5123** connected with the yaw operating bar **5122** rotates around the yaw operating axis **5121**. Then, the resulting rotating force is transmitted through the yaw operating wire **535**Y**2** to the first YP pulley **514***a* and the second YP pulley **514***b* connected therewith, to rotate the second YP pulley **514***b*. When the second YP pulley **514***b* rotates, the first input unit **5311** of the first differential member **531** connected therewith and the output unit **5313** of the first differential member **531** connected therewith rotate. Consequently, when the output unit **5313** of the first differential member **531** rotates, the yaw wire **535**Y connected with the output unit **5313**, the yaw pulley **524** connected with the yaw wire **535**Y, and the first and second jaws **521** and **522** connected with the yaw pulley **524** rotate around the yaw rotating axis **420**YX (see FIG. **32**) to perform a yaw operation.
(467) The actuation operation of the present embodiment will be described below.
(468) When the user holds and rotates the actuation operating bar **5132** with the thumb finger in the direction of an arrow A of FIG. **38**, the actuation operating pulley **5133** connected with the actuation operating bar **5132** rotates around the actuation operating axis **5131**. Then, the resulting rotating force is transmitted through the yaw-actuation connecting wire **514**W to the yaw-actuation operating pulley **514**P. When the yaw-actuation operating pulley **514**P rotates, the resulting rotating force is transmitted through the yaw-actuation operating wire **535**AY connected therewith to the first AYP pulley **515***a* and the second AYP pulley **515***b* connected therewith to rotate the second AYP pulley **515***b*. When the second AYP pulley **515***b* rotates, the first input unit **5321** of the second differential member **532** connected therewith and the output unit **5323** of the second differential member **532** connected therewith rotate. Consequently, when the output unit **5323** of the second differential member **532** rotates, the actuation wire **535**A connected with the output unit **5323** moves linearly in the direction of the arrow A of FIG. **38**. Accordingly, the actuation axis **420**AX (see FIG. **32**) connected with the actuation wire **535**A translates to perform an actuation operation of the first jaw **521** and the second jaw **522**.
(469) A case where the yaw operating pulley **5123** and the pitch operating pulley **5113** rotate together will be described below.
(470) As described above, the first YP pulley **514***a* and the second YP pulley **514***b* connected therewith rotate along with the yaw operating pulley **5123** when the yaw operating pulley **5123** rotates, and rotate along with the pitch operating pulley **5113** when the pitch operating axis **5111** rotates. The yaw wire **535**Y for performing the yaw operation of the end tool **520** is only affected by the operation of the yaw operator **512** but not by the operation of the pitch operator **511**. Thus, the first input unit **5311** of the first differential member **531** is connected with the second YP pulley **514***b*, and the second input unit **5312** of the first differential member **531** is connected with the pitch operating pulley **5113**, to extract only a pure yaw operation control component from the rotation of the pitch operating pulley **5113** and the rotation of the yaw operating pulley **5123**.
(471) According to the present invention, even when the yaw operator **512** rotates along with the pitch operating axis **5111**, the yaw operation of the end tool **520** may depend only on the operation of the yaw operator **512** and not be affected by the pitch operating axis **5111**.
(472) A case where the actuation operating pulley **5133**, the yaw operating pulley **5123**, and the pitch operating pulley **5113** rotate together will be described below.
(473) As described above, the first AYP pulley **515***a* and the second AYP pulley **515***b* connected

therewith rotate along with the actuation operating pulley **5133** when the actuation operating pulley **5133** rotates, rotate along with the yaw operating pulley **5123** when the yaw operating pulley **5123** rotates, and rotate along with the pitch operating pulley **5113** when the pitch operating axis **5111** rotates. The actuation wire **535**A for performing the actuation operation of the end tool **520** is only affected by the operation of the actuation operator **513** but not by the operation of the pitch operator **511** and the operation of the yaw operator **512**. Thus, the first input unit **5321** of the second differential member **532** is connected with the second AYP pulley **515***b*, and the second input unit **5322** of the second differential member **532** is connected with the second YP pulley **514***b*, to extract only a pure actuation operation control component from the rotation of the pitch operating pulley **5113**, the rotation of the yaw operating pulley **5123**, and the rotation of the actuation operating pulley **5133**.
(474) According to the present invention, even when the actuation operator **513** rotates along with the yaw operating pulley **5123** or the pitch operating pulley **5113**, the actuation operation of the end tool **420** may depend only on the operation of the actuation operator **513** and not be affected by the yaw operating pulley **5123** or the pitch operating pulley **5113**.
(475) Thus, as described above, the pitch, yaw, and actuation operations of the operator are independently divided into the pitch, yaw, and actuation operations of the end tool. Also, even when the pitch, yaw, and actuation operations of the operator occur simultaneously or not, the pitch, yaw, and actuation operations of the operator may be independently divided into the pitch, yaw, and actuation operations of the end tool.
(476) Any combination of various configurations of the operator described with reference to FIG. **3**A, various configurations of the operating force transmitter described with reference to FIGS. **4**A and **15** to **27**, and various modifications described with reference to FIGS. **7** to **14** may be applied to the surgical instrument **500** according to the fifth embodiment of the present invention.
<Sixth Embodiment of Surgical Instrument> (E1+H**3**+D)
(477) Hereinafter, the surgical instrument **600** according to the sixth embodiment of the present invention will be described. In the surgical instrument **600** according to the sixth embodiment of the present invention, an end tool **620** has the configuration described with reference to FIGS. **32** to **36**, and an operator **610** includes a first jaw operator and a second jaw operator that operate a first jaw and second jaw independently instead of the yaw operator and the actuation operator as in the surgical instrument **300** according to third second embodiment illustrated in FIG. **30**.
(478) FIG. **39** is a view illustrating the surgical instrument **600** according to the sixth embodiment of the present invention. Referring to FIG. **39**, the surgical instrument **600** according to the sixth embodiment of the present invention includes the operator **610**, the end tool **620**, an operating force transmitter **630**, and a connector (not illustrated).
(479) The end tool **620** includes a first jaw **621**, a second jaw **622**, one or more pitch pulleys **623**, and one or more yaw pulleys **624**, and the operating force transmitter **630** includes one or more pitch wires **635**P, one or more yaw wires **635**Y, and one or more actuation wires **635**A. In the end tool **620**, the pulley/wire for a pitch operation, the pulley/wire for a yaw operation, and the pulley/wire for an actuation operation are separately formed such that one operation does not affect other operations. Since the end tool **620** is substantially identical to the end tool **420** described with reference to FIGS. **32** to **36**, a detailed description thereof will be omitted herein.
(480) The operating force transmitter **630** includes a first differential member **631** and a second differential member **632**. The first differential member **631** and the second differential member **632** each include two or more input units and one input unit, receive an input of rotating forces from the two or more input units, extract a desired rotating force from the sum of (or the difference between) the input rotating forces, and output the desired rotating force through the output unit. The first and second differential members **631** and **632** may include various differential pulleys and differential gears, such as, the differential pulley of the surgical instrument **100** according to the first embodiment illustrated in FIGS. **4**A and **4**B, the first modification of the differential pulley

illustrated in FIG. **15**, the second modification of the differential pulley illustrated in FIG. **18**, and the third modification of the differential pulley illustrated in FIG. **22**. That is, although the differential pulley of FIG. **21**E is illustrated as the first and second differential members **631** and **632** of the surgical instrument **600** according to the sixth embodiment in FIG. **39**, the present invention is not limited thereto, and various differential pulleys and differential gears may be used in the present embodiment.

(481) Hereinafter, the operator **610** of the surgical instrument **600** according to the sixth embodiment of the present invention will be described in more detail.

(482) Referring to FIG. **39**, the operator **610** of the surgical instrument **600** according to the sixth embodiment of the present invention includes a pitch operator **611** controlling a pitch motion of the end tool **620**, a first jaw operator **612** controlling a motion of the first jaw **621** of the end tool **620**, and a second jaw operator **613** controlling a motion of the second jaw **622** of the end tool **620**.

(483) The pitch operator **611** includes a pitch operating axis **6111**, a pitch operating bar **6112**, and a pitch operating pulley **6113**. Herein, the pitch operating axis **6111** may be formed in the direction parallel to the Y axis, and the pitch operating bar **6112** may be connected with the pitch operating axis **6111** to rotate along with the pitch operating axis **6111**. For example, when the user grips and rotates the pitch operating bar **6112**, the pitch operating axis **6111** connected with the pitch operating bar **6112** and the pitch operating pulley **6113** connected therewith rotate together therewith. Then, the resulting rotating force is transmitted to the end tool **620** through the operating force transmitter **630**, so that the end tool **620** rotates in the same direction as the rotation direction of the pitch operating axis **6111**. That is, when the pitch operator **611** rotates in the clockwise direction around the pitch operating axis **6111**, the end tool **620** also rotates in the clockwise direction around a pitch pulley operating axis (not illustrated), and when the pitch operator **611** rotates in the counterclockwise direction around the pitch operating axis **6111**, the end tool **620** also rotates in the counterclockwise direction around the pitch pulley operating axis. The pitch operating pulley **6113** is integrated with the pitch operating axis **6111** to rotate along with the pitch operating axis **6111**.

(484) The first jaw operator **612** includes a first jaw operating axis, a first jaw operating bar **6122**, and a first jaw operating pulley **6123**. Although it is illustrated that the first jaw operating axis is formed to extend from the pitch operating bar **6112** and the pitch operating bar **6112** is inserted into the first jaw operating pulley **6123**, the present invention is not limited thereto. For example, the pitch operating bar **6112** and the first jaw operating axis may be formed as separate members on different axes. In this case, the first jaw operating axis may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **610**.

(485) A first jaw operating wire **635J1** and a first additional jaw operating wire **635J1′** may be connected to the first jaw operating pulley **6123**. In this case, any one of the first jaw operating wire **635J1** and the first additional jaw operating wire **635J1′** may be twisted one time such that the rotating force transmission directions of the first jaw operating wire **635J1** and the first additional jaw operating wire **635J1′** are opposite to each other. The first jaw operating bar **6122** and the first jaw operating pulley **6123** are formed to rotate around the first jaw operating axis. For example, when the user holds and rotates the first jaw operating bar **6122** with the thumb finger, the first jaw operating pulley **6123** connected with the first jaw operating bar **6122** rotates around the first jaw operating axis. Then, the resulting rotating force is transmitted to the end tool **620** through the operating force transmitter **630**, so that the first jaw **621** of the end tool **620** horizontally rotate in the same direction as the rotation direction of the first jaw operating pulley **6123**.

(486) The second jaw operator **613** includes a second jaw operating axis, a second jaw operating bar **6132**, and a second jaw operating pulley **6133**. Although it is illustrated that the second jaw operating axis is formed to extend from the pitch operating bar **6112** and the pitch operating bar **6112** is inserted into the second jaw operating pulley **6133**, the present invention is not limited thereto. For example, the pitch operating bar **6112** and the second jaw operating axis may be

formed as separate members on different axes. In this case, the second jaw operating axis may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **610**.

(487) A second jaw operating wire **635**J**2** may be connected to the second jaw operating pulley **6133**. The second jaw operating bar **6132** and the second jaw operating pulley **6133** are formed to rotate around the second jaw operating axis. For example, when the user holds and rotates the second jaw operating bar **6132** with the index finger, the second jaw operating pulley **6133** connected with the second jaw operating bar **6132** rotates around the second jaw operating axis. Then, the resulting rotating force is transmitted to the end tool **620** through the operating force transmitter **630**, so that the second jaw **622** of the end tool **620** horizontally rotates in the same direction as the rotation direction of the second jaw operating pulley **6133**.

(488) The pitch operating axis **6111** is inserted into a first second jaw-pitch (J**2**P) pulley **614***a*, a first first jaw-pitch (J**1**P) pulley **615***a*, and a first J**1**P additional pulley **616***a* such that the first J**2**P pulley **614***a*, the first J**1**P pulley **615***a*, and the first J**1**P additional pulley **616***a* may rotate around the pitch operating axis **6111**.

(489) The first J**2**P pulley **614***a* and a second J**2**P pulley **614***b* connected therewith rotate along with the second jaw operating pulley **6133** when the second jaw operating pulley **6133** rotates, and rotate along with the pitch operating pulley **6113** when the pitch operating bar **6112**, and the first operator **612** and the second operator **613** connected therewith rotate around the pitch operating axis **6111**. That is, the first J**2**P pulley **614***a* and the second J**2**P pulley **614***b* may be considered as pulleys that reflect the rotations of the second jaw operating bar **6132** and the rotation of the pitch operating bar **6112** together.

(490) In detail, when the second jaw operating bar **6132** rotates, the second jaw operating pulley **6133** connected with the second jaw operating bar **6132** rotates along with the second jaw operating bar **6132**, and thus the second jaw operating wire **635**J**2** connected therewith moves to rotate the first J**2**P pulley **614***a* and the second J**2**P pulley **614***b* connected therewith. When the pitch operating axis **6111** and the pitch operating bar **6112** rotate in the direction of an arrow P of FIG. **39**, the second jaw operating axis and the second jaw operating pulley **6133** also rotate around the pitch operating axis **6111**. Then, the second jaw operating wire **635**J**2** rotates around the pitch operating axis **6111** in the direction of the arrow P of FIG. **39** according to the rotation of the operator **610**, and the first J**2**P pulley **614***a* connected therewith also rotates accordingly. Consequently, the first J**2**P pulley **614***a* and the second J**2**P pulley **614***b* rotate when the second jaw operating pulley **6132** rotates, and rotate when the pitch operating bar **6112** rotates. This means that a second jaw operation input and a pitch operation input are added together by the first J**2**P pulley **614***a* and the second J**2**P pulley **614***b* of the operator **610** to output the sum of the second jaw operation input and the pitch operation input.

(491) The first J**1**P pulley **615***a* and a second J**1**P pulley **615***b* connected therewith rotate along with the first jaw operating pulley **6123** when the first jaw operating bar **6122** rotates, and rotate along with the pitch operating pulley **6113** when the pitch operating bar **6112**, and the first operator **612** and the second operator **613** connected therewith rotate around the pitch operating axis **6111**. That is, the first J**1**P pulley **615***a* and the second J**1**P pulley **615***b* may be considered as pulleys that reflect the rotations of the first jaw operating bar **6122** and the rotation of the pitch operating bar **6112** together.

(492) Likewise, the first J**1**P additional pulley **616***a* and a second J**1**P additional pulley **616***b* connected therewith rotate along with the first jaw operating pulley **6123** when the first jaw operating bar **6122** rotates, and rotate along with the pitch operating pulley **6113** when the pitch operating bar **6112**, and the first operator **612** and the second operator **613** connected therewith rotate around the pitch operating axis **6111**. That is, the first J**1**P additional pulley **616***a* and the second J**1**P additional pulley **616***b* may be considered as pulleys that reflect the rotation of the first jaw operating bar **6122** and the rotation of the pitch operating bar **6112** together.

(493) Herein, the rotation directions of the first J1P pulley **615***a* and the first J1P additional pulley **616***a* are opposite to each other. This is because unlike the first jaw operating wire **635J1** connecting the first jaw operating pulley **6123** and the first J1P pulley **615***a*, the first additional jaw operating wire **635J1′** connecting the first jaw operating pulley **6123** and the first J1P additional pulley **616***a* is twisted one time. That is, since the rotating force transmission directions of the first jaw operating wire **635J1** and the first additional jaw operating wire **635J1′** are opposite to each other, the rotation directions of the first J1P pulley **615***a* and the first J1P additional pulley **616***a* are opposite to each other.
(494) Although it is illustrated that the first J2P pulley **614***a* is connected to the second J2P pulley **614***b*, and the second J2P pulley **614***b* is connected to a first input unit **6311** of the first differential member **631** and a second input unit **6322** of the second differential member **632**, this is merely for convenience of description, and the first J2P pulley **614***a* may be directly connected to the first input unit **6311** of the first differential member **631** and the second input unit **6322** of the second differential member **632**, without using the second J2P pulley **614***b*.
(495) Likewise, although it is illustrated that the first J1P pulley **615***a* is connected to the second J1P pulley **615***b*, and the second J1P pulley **615***b* is connected to a first input unit **6321** of the second differential member **632**, this is merely for convenience of description, and the first J1P pulley **615***a* may be directly connected to the first input unit **6321** of the second differential member **632**, without using the second J1P pulley **615***b*.
(496) Likewise, although it is illustrated that the first J1P additional pulley **616***a* is connected to the second J1P additional pulley **616***b*, and the second J1P additional pulley **616***b* is connected to a second input unit **6312** of the first differential member **631**, this is merely for convenience of description, and the first J1P additional pulley **616***a* may be directly connected to the second input unit **6312** of the first differential member **631**, without using the second J1P additional pulley **616***b*.
Overall Operation of Sixth Embodiment
(497) Hereinafter, an overall configuration for the pitch operation, the yaw operation, and the actuation operation of the surgical instrument **600** according to the sixth embodiment of the present invention will be summarized with reference to the above descriptions.
(498) In the surgical instrument **600** according to the sixth embodiment of the present invention, the first differential member **631** includes the first input unit **6311**, the second input unit **6312**, an output unit **6313**, a first differential control member **6314**, a second differential control member **6315**, and a differential control wire **6316**, and the second differential member **632** includes the first input unit **6321**, the second input unit **6322**, an output unit **6323**, a first differential control member **6324**, a second differential control member **6325**, and a differential control wire **6326**.
(499) In detail, for the configuration of the end tool **620** of the present embodiment, the operating force transmitter **630** capable of dividing the operation input of the operator **610** into a pitch operation, a yaw operation, and an actuation operation is necessary to perform the pitch, yaw, and actuation operations of the end tool **620**. The pitch operator **611** includes the first jaw operator **612** and the second jaw operator **613**, and divides the operation inputs thereof into a pitch operation component, a yaw operation component, and an actuation operation component. The rotation operation of the pitch operating bar may be directly connected to the pitch operation of the end tool. However, the yaw and actuation operations of the end tool **620** reconstructs the operation inputs of the first jaw and the second jaw. This may be expressed as the following equation:
$Y=J1+J2$ (two jaws rotate in the same direction in the yaw operation)
$A=J1-J2$ (two jaws rotate in opposite directions in the actuation operation)
(500) To this end, the operation inputs of the two jaws are connected to the first J1P pulley **615***a* and the first J2P pulley **614***a*, and the first J1P additional pulley **616***a* is provided to transmit the operation input of the first jaw reversely. This may be expressed as the following equation:

$$J1_P = J1 + P$$
(501) 0 $J1_{P2} = -J1 + P$
$$J2_P = J2 + P$$
(502) (where J**1**.sub.P denotes the rotation of the J**1**.sub.P pulley, J**1**.sub.P2 denotes the rotation of the J**1**P additional pulley, J**2**.sub.P denotes the rotation of the J**2**.sub.P pulley, J**1** denotes the rotation of the first jaw operating pulley, J**2** denotes the rotation of the second jaw operating pulley, and P denotes the rotation of the pitch operating pulley.)
(503) Thus, in order to transmit the output of the operator **610** as only the Y and A components to the end tool **620**, the operating force transmitter **630** extracts the following components:
(504) $$Y = J1 + J2 = J2_P - J1_{P2}$$ $$A = J1 - J2 = J1_P - J2_P$$
(505) To this end, the operating force transmitter **630** includes a differential pulley that receives an input of J**2**.sub.P and J**1**.sub.P2 and outputs only the difference (Y component) between J**2**.sub.P and J**1**.sub.P2, and a differential pulley that receives an input of J**1**.sub.P and J**2**.sub.P and outputs only the difference (A component) between J**1**.sub.P and J**2**.sub.P.
(506) The first input unit **6311** of the first differential member **631** is connected with the first J**2**P pulley **614***a* (or the second J**2**P pulley **614***b* connected therewith) to rotate when the second jaw operating pulley **6133** rotates and also rotate when the pitch operating pulley **6113** rotates. The second input unit **6312** of the first differential member **631** is connected with the first J**1**P additional pulley **616***a* (or the second J**1**P additional pulley **616***b* connected therewith) to rotate when the first jaw operating pulley **6123** rotates and also rotate when the pitch operating pulley **6113** rotates. Also, the output unit **6313** of the first differential member **631** is connected with the yaw wire **635**Y to control the yaw operation of the end tool **620**.
(507) The first input unit **6321** of the second differential member **632** is connected with the first J**1**P pulley **615***a* (or the second J**1**P pulley **615***b* connected therewith) to rotate when the first jaw operating pulley **6123** rotates and also rotate when the pitch operating pulley **6113** rotates. The second input unit **6322** of the second differential member **632** is connected with the first J**2**P pulley **614***a* (or the second J**2**P pulley **614***b* connected therewith) to rotate when the second jaw operating pulley **6133** rotates and also rotate when the pitch operating pulley **6113** rotates. Also, the output unit **6323** of the second differential member **632** is connected with the actuation wire **635**A to control the actuation operation of the end tool **620**.
(508) The pitch operating pulley **6113** is connected with the pitch wire **635**P to control the pitch operation of the end tool **620**.
(509) First, the pitch operation will be described below.
(510) As described above, when the user grips the pitch operating bar **6112** of the pitch operator **611** of the operator **610** and rotates the pitch operating bar **6112** around the pitch operating axis **6111** in the direction of an arrow P of FIG. **39**, the pitch operating pulley **6113** rotates along with the pitch operating axis **6111**. Then, the pitch pulley **623** connected with the pitch operating pulley **6113** by the pitch wire **635**P, the yaw pulley **624** connected therewith, the first jaw **621**, and the second jaw **622** rotate around the pitch rotating axis **420**PX (see FIG. **32**) to perform a pitch operation.
(511) In this case, the pitch operation does not affect the first and second differential pulleys **631** and **632** of the operating force transmitter **630** which determine the yaw and actuation operations of the end tool **620**. In more detail, when the first J**2**P pulley **614***a*, the first J**1**P pulley **615***a*, and the first J**1**P additional pulley **616***a* rotate around the pitch operating axis **6111** according to the pitch operation, the first input unit **6311** of the first differential member **631** that is connected with the second J**2**P pulley **614***b* and the second input unit **6312** of the first differential member **631** that is connected with the second J**1**P additional pulley **616***b* rotate; however, since the rotations are offset in the first differential member **631**, the output unit **6313** of the first differential member **631** does

not rotate. Likewise, the first input unit **6321** of the second differential member **632** that is connected with the second J**1**P pulley **615***b* and the second input unit **6322** of the second differential member **632** that is connected with the second J**2**P pulley **614***b* rotate; however, since the rotations are offset in the second differential member **632**, the output unit **6323** of the second differential member **632** does not rotate. Thus, the pitch operation may be performed independently of the yaw operation and the actuation operation.
(512) The yaw operation and the actuation operation of the present embodiment will be described below.
(513) For a yaw operation, the user holds and rotates the first jaw operating bar **6122** with the thumb finger in the direction of an arrow J**1** of FIG. **39**, and holds and rotates the second jaw operating bar **6132** with the index finger in the direction of an arrow J**2** of FIG. **39** (that is, rotates the first jaw operating bar **6122** and the second jaw operating bar **6132** in the same direction). For an actuation operation, the user rotates the first jaw operating bar **6122** in a direction opposite to the direction of the arrow J**1** of FIG. **39**, and rotates the second jaw operating bar **6132** in the direction of the arrow J**2** of FIG. **39** (that is, rotates the first jaw operating bar **6122** and the second jaw operating bar **6132** in opposite directions).
(514) Then, the first jaw operating pulley **6123** connected with the first jaw operating bar **6122** rotates around the first jaw operating axis (i.e., the pitch operating bar), and the resulting rotating force is transmitted through the first jaw operating wire **635J1** to the first J**1**P pulley **615***a* and the second J**1**P pulley **615***b* connected therewith, to rotate the second J**1**P pulley **615***b*. When the second J**1**P pulley **615***b* rotates, the first input unit **6321** of the second differential member **632** connected therewith and the output unit **6323** of the second differential member **632** connected therewith rotate. In addition, the rotating force of the first jaw operating pulley **6123** is transmitted through the first additional jaw operating wire **635J1′** to the first J**1**P additional pulley **616***a* and the second J**1**P additional pulley **616***b* connected therewith, to rotate the second J**1**P additional pulley **616***b*. When the second J**1**P additional pulley **616***b* rotates, the second input unit **6312** of the first differential member **631** connected therewith and the output unit **6313** of the first differential member **631** connected therewith rotate.
(515) At the same time, the second jaw operating pulley **6133** connected with the second jaw operating bar **6132** rotates around the second jaw operating axis (i.e., the pitch operating bar), and the resulting rotating force is transmitted through the second jaw operating wire **635J2** to the first J**2**P pulley **614***a* and the second J**2**P pulley **614***b* connected therewith, to rotate the second J**2**P pulley **614***b*. When the second J**2**P pulley **614***b* rotates, the first input unit **6311** of the first differential member **631** connected therewith and the output unit **6313** of the first differential member **631** connected therewith rotate. In addition, when the second J**2**P pulley **614***b* rotates, the second input unit **6322** of the second differential member **632** connected therewith and the output unit **6323** of the second differential member **632** connected therewith rotate.
(516) As described above, the first J**2**P pulley **614***a* and the second J**2**P pulley **614***b* connected therewith rotate along with the second jaw operating pulley **6133** when the second jaw operating pulley **6133** rotates, and rotate along with the pitch operating pulley **6113** when the pitch operating pulley **6113** rotates. The first J**1**P pulley **615***a* and the second J**1**P pulley **615***b* connected therewith rotate along with the first jaw operating pulley **6123** when the first jaw operating pulley **6123** rotates, and rotate along with the pitch operating pulley **6113** when the pitch operating pulley **6113** rotates. Likewise, the first J**1**P additional pulley **616***a* and the second J**1**P additional pulley **616***b* connected therewith rotate along with the first jaw operating pulley **6123** when the first jaw operating pulley **6123** rotates, and rotate along with the pitch operating pulley **6113** when the pitch operating pulley **6113** rotates.
(517) Consequently, when the second J**2**P pulley **614***b* and the second J**1**P additional pulley **616***b* are connected respectively to the two input units of the first differential member **631**, only a pure yaw operation control component may be extracted from the rotation of the pitch operating pulley

6113, the rotation of the first jaw operating pulley **6123**, and the rotation of the second jaw operating pulley **6133**.

(518) Likewise, when the second J**1**P pulley **615***b* and the second J**2**P additional pulley **614***b* are connected respectively to the two input units of the second differential member **632**, only a pure actuation operation control component may be extracted from the rotation of the pitch operating pulley **6113**, the rotation of the first jaw operating pulley **6123**, and the rotation of the second jaw operating pulley **6133**.

(519) Consequently, for a yaw operation, when the first jaw operating bar **6122** is rotated in the direction of the arrow J**1** of FIG. **39** and the second jaw operating bar **6132** is rotated in the direction of the arrow J**2** of FIG. **39**, the first J**2**P pulley **614***a* and the second J**2**P pulley **614***b* connected therewith rotate in the counterclockwise direction in FIG. **39**, the first J**1**P pulley **615***a* and the second J**1**P pulley **615***b* connected therewith rotate in the counterclockwise direction in FIG. **39**, and the first J**1**P additional pulley **616***a* and the second J**1**P additional pulley **616***b* rotate in the clockwise direction in FIG. **39**. Also, the first input unit **6311** of the first differential member **631** that is connected with the second J**2**P pulley **614***b* rotates in the counterclockwise direction, and the second input unit **6312** of the first differential member **631** that is connected with the second J**1**P additional pulley **616***b* rotates in the clockwise direction. Accordingly, the output unit **6313** of the first differential member **631** rotates in the counterclockwise direction, and the yaw wire **635**Y connected with the output unit **6313**, the yaw pulley **624** connected with the yaw wire **635**Y, and the first and second jaws **621** and **622** connected with the yaw pulley **624** rotate around the yaw rotating axis **420**YX (see FIG. **32**) to perform a yaw operation.

(520) Likewise, for an actuation operation, when the first jaw operating bar **6122** is rotated in a direction opposite to the direction of the arrow J**1** of FIG. **39** and the second jaw operating bar **6132** is rotated in the direction of the arrow J**2** of FIG. **39**, the first J**2**P pulley **614***a* and the second J**2**P pulley **614***b* connected therewith rotate in the counterclockwise direction in FIG. **39**, the first J**1**P pulley **615***a* and the second J**1**P pulley **615***b* connected therewith rotate in the clockwise direction in FIG. **39**, and the first J**1**P additional pulley **616***a* and the second J**1**P additional pulley **616***b* rotate in the counterclockwise direction in FIG. **39**. Also, the first input unit **6321** of the second differential member **632** that is connected with the second J**1**P pulley **615***b* rotates in the clockwise direction, and the second input unit **6322** of the second differential member **632** that is connected with the second J**2**P pulley **614***b* rotates in the counterclockwise direction. Accordingly, the output unit **6323** of the second differential member **632** rotates in the clockwise direction, the actuation wire **635**A connected to the output unit **6313** moves linearly in the direction of an arrow A of FIG. **39**, and the actuation axis **420**AX (see FIG. **32**) connected with the actuation wire **635**A translates, to perform an actuation operation of the first jaw **621** and the second jaw **622**.

(521) Thus, according to the present invention, the yaw operation and the actuation operation of the end tool may be extracted from the rotation of the first jaw operating pulley **6123** and the rotation of the second jaw operating pulley **6133**.

(522) Thus, as described above, the pitch, first jaw, and second jaw operations of the operator are independently divided into the pitch, yaw, and actuation operations of the end tool. Also, even when the pitch, first jaw, and second jaw operations of the operator occur simultaneously or not, the pitch, yaw, and actuation operations of the operator may be independently divided into the pitch, yaw, and actuation operations of the end tool.

(523) Any combination of various configurations of the operator described with reference to FIG. **3**A, various configurations of the operating force transmitter described with reference to FIGS. **4**A and **15** to **27**, and various modifications described with reference to FIGS. **7** to **14** may be applied to the surgical instrument **600** according to the sixth embodiment of the present invention.

<End Tools of Seventh to Ninth Embodiments of Surgical Instrument> (E2)

(524) Hereinafter, surgical instruments **700**, **800**, and **900** according to seventh, eighth, and ninth embodiments of the present invention will be described. The surgical instruments **700**, **800**, and

900 according to the seventh, eighth, and ninth embodiments of the present invention are substantially identical to the surgical instruments **100**, **200**, and **300** according to the first, second, and third embodiments of the present invention and are different from the surgical instruments **100**, **200**, and **300** according to the first, second, and third embodiments of the present invention in terms of the configuration of an end tool. Thus, the configuration of the end tool applied in common to the seventh, eighth, and ninth embodiments will be described first.
(525) FIGS. **40** to **43** are schematic views illustrating an end tool included in a surgical instrument **700** according to a seventh embodiment of the present invention. FIG. **40** is an XZ-plane side view of the end tool, FIG. **41** is an XY-plane plan view of the end tool, FIG. **42** is a plan view illustrating a yaw motion of the end tool of FIG. **41**, and FIG. **43** is a plan view illustrating an actuation motion of the end tool of FIG. **41**. Although FIGS. **41** to **43** schematically illustrate that the first jaw and the second jaw rotate around different axes, the present invention is not limited thereto, and the first jaw and the second jaw may rotate around the same axis.
(526) Referring to FIGS. **40** to **43**, an end tool **720** included in the surgical instrument **700** according to the seventh embodiment of the present invention includes a first jaw **721**, a second jaw **722**, a pitch pulley **723**, a first jaw pulley **724**, and a second jaw pulley **725**. An operating force transmitter **730** included in the surgical instrument **700** according to the seventh embodiment of the present invention includes a pitch wire **735**P, a first jaw wire **735**J**1**, and a second jaw wire **735**J**2**.
(527) In the present embodiments, a pitch operation is performed by the rotation of the pitch wire wound around the pitch pulley, the two jaw wires are formed to intersect the pitch pulley and extend toward the end tool, and the two jaw wires are wound around their respective jaw pulleys to perform rotation operations for the yaw and actuation operations of their respective jaws. Since the jaw wires are formed to intersect the pitch pulley, the jaw wires are minimally affected by the rotation of the pitch pulley according to the pitch operation.
(528) In detail, at one end portion of a connector (not illustrated), the pitch pulley **723** is formed to rotate around a pitch rotating axis **720**PX with respect to the connector. Also, on one side of the pitch pulley **723**, the first jaw pulley **724** and the second jaw pulley **725** are formed around a jaw rotating axis **720**JX. Thus, the pitch pulley **723** may rotate around the pitch rotating axis **720**PX, and the first jaw pulley **724** and the second jaw pulley **725** coupled therewith rotate along with the pitch pulley **723**.
(529) The first jaw **721** is coupled with the first jaw pulley **724** to rotate along with the first jaw pulley **724**, and the second jaw **722** is coupled with the second jaw pulley **725** to rotate along with the second jaw pulley **725**.
(530) In the end tool **720** of the surgical instrument **700** according to the seventh embodiment of the present invention, the pulley/wire for a pitch operation, the pulley/wire for an operation of the first jaw, and the pulley/wire for an operation of the second jaw are separately formed such that one operation does not affect other operations. This will be described below in more detail.
(531) First, the pitch operation of the present embodiment will be described below.
(532) The pitch wire **735**P of the operating force transmitter **730** for a pitch operation of the end tool **720** connects a pitch operator (not illustrated) of an operator (not illustrated) and the pitch pulley **723** of the end tool **720**. Thus, when the pitch operator rotates around a pitch operating axis (not illustrated) in the counterclockwise direction in FIG. **40**, the pitch wire **735**P connected therewith moves in the direction of an arrow P**2** of FIG. **40**. Accordingly, the pitch pulley **723** connected with the pitch wire **735**P, the first jaw pulley **724** connected therewith, the first jaw **721**, and the second jaw **722** rotate around the pitch rotating axis **720**PX in the direction of an arrow P of FIG. **40** to perform a pitch operation. On the other hand, when the pitch operator rotates around the pitch operating axis in the clockwise direction in FIG. **40**, the pitch wire **735**P connected therewith moves in the direction of an arrow P**1** of FIG. **40**. Accordingly, the pitch pulley **723** connected with the pitch wire **735**P, the first jaw pulley **724** connected therewith, the first jaw **721**, and the second jaw **722** rotate around the pitch rotating axis **720**PX in a direction opposite to the direction of the

arrow P of FIG. **40** to perform a pitch operation.
(533) The yaw operation and the actuation operation of the present embodiment will be described below.
(534) The first jaw wire **735J1** of the operating force transmitter **730** for the operation of the first jaw **721** of the end tool **720** connects a yaw operator (not illustrated), an actuation operator (not illustrated), or a first jaw operator (not illustrated) of an operator (not illustrated) and the first jaw pulley **724** of the end tool **720**. Accordingly, when the yaw operator, the actuation operator, or the first jaw operator of the operator rotates, the first jaw wire **735J1** connected therewith, the first jaw pulley **724** connected therewith, and the first jaw **721** rotate around the jaw rotating axis **720**JX.
(535) The second jaw wire **735J2** of the operating force transmitter **730** for the operation of the second jaw **722** of the end tool **720** connects a yaw operator (not illustrated), an actuation operator (not illustrated), or a second jaw operator (not illustrated) of an operator (not illustrated) and the second jaw pulley **725** of the end tool **720**. Accordingly, when the yaw operator, the actuation operator, or the second jaw operator of the operator rotates, the second jaw wire **735J2** connected therewith, the second jaw pulley **725** connected therewith, and the second jaw **722** rotate around the jaw rotating axis **720**JX.
(536) As illustrated in FIG. **42**, when the first jaw pulley **724** and the second jaw pulley **725** rotate around the jaw rotating axis **720**JX in the same direction, a yaw operation is performed. As illustrated in FIG. **43**, when the first jaw pulley **724** and the second jaw pulley **725** rotate around the jaw rotating axis **720**JX in opposite directions, an actuation operation is performed.
<Seventh Embodiment of Surgical Instrument> (E2+H**1**+D)
(537) Hereinafter, the surgical instrument **700** according to the seventh embodiment of the present invention will be described. In the surgical instrument **700** according to the seventh embodiment of the present invention, the end tool **720** has the configuration described with reference to FIGS. **40** to **43**, and an operator **710** has a yaw operator and an actuation operator formed independently of each other as in the surgical instrument **100** according to the first embodiment of the present invention (illustrated in FIG. **2**), so that a rotation of a yaw operating axis and a rotation of an actuation operating axis are performed independently of each other.
(538) FIG. **44** is a view illustrating the surgical instrument **700** according to the seventh embodiment of the present invention. Referring to FIG. **44**, the surgical instrument **700** according to the seventh embodiment of the present invention includes the operator **710**, the end tool **720**, an operating force transmitter **730**, and a connector (not illustrated).
(539) The end tool **720** includes the first jaw **721**, the second jaw **722**, the pitch pulley **723**, the first jaw pulley **724**, and the second jaw pulley **725**, and the operating force transmitter **730** includes the pitch wire **735**P, the first jaw wire **735J1**, and the second jaw wire **735J2**. In the end tool **720**, the pulley/wire for a pitch operation, the pulley/wire for an operation of the first jaw, and the pulley/wire for an operation of the second jaw are separately formed such that one operation does not affect other operations. The end tool **720** is the same as described above with reference to FIGS. **40** to **43** and thus a detailed description thereof will be omitted herein.
(540) The operating force transmitter **730** includes a first differential member **731** and a second differential member **732**. The first differential member **731** and the second differential member **732** each include two or more input units and one input unit, receive an input of rotating forces from the two or more input units, extract a desired rotating force from the sum of (or the difference between) the input rotating forces, and output the desired rotating force through the output unit. The first and second differential members **731** and **732** may include various differential pulleys and differential gears, such as, the differential pulley of the surgical instrument **100** according to the first embodiment illustrated in FIGS. **4**A and **4**B, the first modification of the differential pulley illustrated in FIG. **15**, the second modification of the differential pulley illustrated in FIG. **18**, and the third modification of the differential pulley illustrated in FIG. **22**. That is, although the differential pulley of FIG. **21**E is illustrated as the first and second differential members **731** and

732 of the surgical instrument **700** according to the seventh embodiment in FIG. **44**, the present invention is not limited thereto, and various differential pulleys and differential gears may be used in the present embodiment.

(541) Hereinafter, the operator **710** of the surgical instrument **700** according to the seventh embodiment of the present invention will be described in more detail.

(542) Referring to FIG. **44**, the operator **710** of the surgical instrument **700** according to the seventh embodiment of the present invention includes a pitch operator **711** controlling a pitch motion of the end tool **720**, a yaw operator **712** controlling a yaw motion of the end tool **720**, and an actuation operator **713** controlling an actuation motion of the end tool **720**.

(543) The pitch operator **711** includes a pitch operating axis **7111**, a pitch operating bar **7112**, and a pitch operating pulley **7113**. Herein, the pitch operating axis **7111** may be formed in a direction parallel to the Y axis, and the pitch operating bar **7112** may be connected with the pitch operating axis **7111** to rotate along with the pitch operating axis **7111**. For example, when the user grips and rotates the pitch operating bar **7112**, the pitch operating axis **7111** connected with the pitch operating bar **7112** and the pitch operating pulley **7113** connected therewith rotate together. Then, the resulting rotating force is transmitted to the end tool **720** through the operating force transmitter **730**, so that the end tool **720** rotates in the same direction as the rotation direction of the pitch operating axis **7111**. That is, when the pitch operator **711** rotates in the clockwise direction around the pitch operating axis **7111**, the end tool **720** also rotates in the clockwise direction around a pitch pulley operating axis (not illustrated), and when the pitch operator **711** rotates in the counterclockwise direction around the pitch operating axis **7111**, the end tool **720** also rotates in the counterclockwise direction around the pitch pulley operating axis. The pitch operating pulley **7113** is integrated with the pitch operating axis **7111** to rotate along with the pitch operating axis **7111**.

(544) The yaw operator **712** includes a yaw operating axis, a yaw operating bar **7122**, and a yaw operating pulley **7123**. Although it is illustrated that the yaw operating axis is formed to extend from the pitch operating bar **7112** and the pitch operating bar **7112** is inserted into the yaw operating pulley **7123**, the present invention is not limited thereto. For example, the pitch operating bar **7112** and the yaw operating axis may be formed as separate members on different axes. In this case, the yaw operating axis may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **710**.

(545) A yaw operating wire **735**Y may be connected to the yaw operating pulley **7123**. The yaw operating bar **7122** and the yaw operating pulley **7123** are formed to rotate around the yaw operating axis. For example, when the user holds and rotates the yaw operating bar **7122** with the index finger, the yaw operating pulley **7123** connected with the yaw operating bar **7122** rotates around the yaw operating axis. Then, the resulting rotating force is transmitted to the end tool **720** through the operating force transmitter **730**, so that the first and second jaws **721** and **722** of the end tool **720** horizontally rotate in the same direction as the rotation direction of the yaw operating pulley **7123**.

(546) The actuation operator **713** includes an actuation operating axis, an actuation operating bar **7132**, and an actuation operating pulley **7133**. Herein, the actuation operating axis may be formed to extend from the pitch operating bar **7112**, and may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **710**. An actuation operating wire **735**A and an actuation additional operating wire **735**A′ may be connected to the actuation operating pulley **7133**. In this case, any one of the actuation operating wire **735**A and the actuation additional operating wire **735**A′ may be twisted one time such that the rotating force transmission directions of the actuation operating wire **735**A and the actuation additional operating wire **735**A′ are opposite to each other. The actuation operating axis is formed to extend from the pitch operating bar **7112** and may be formed in the direction parallel to the Z axis or in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **710**. The actuation operating bar **7132** and the actuation operating pulley **7133** are formed

to rotate around the actuation operating axis. For example, when the user holds and rotates the actuation operating bar **7132** with the thumb finger, the actuation operating pulley **7133** connected with the actuation operating bar **7132** rotates around the actuation operating axis. Then, the resulting rotating force is transmitted to the end tool **720** through the operating force transmitter **730**, so that the first and second jaws **721** and **722** of the end tool **720** perform an actuation operation.

(547) The pitch operating axis **7111** is inserted into a first YP pulley **714***a*, a first AP pulley **715***a*, and a first AP additional pulley **716***a* such that the first YP pulley **714***a*, the first AP pulley **715***a*, and the first AP additional pulley **716***a* may rotate around the pitch operating axis **7111**.

(548) When the yaw operating pulley **7123** rotates, the first YP pulley **714***a* and a second YP pulley **714***b* connected therewith rotate along with the yaw operating pulley **7123**; and when the pitch operating bar **7112** and the yaw operator **712** and the actuation operator **713** connected therewith rotate together around the pitch operating axis **7111**, the first YP pulley **714***a* and the second YP pulley **714***b* connected therewith rotate along with the pitch operating pulley **7113**. That is, the first YP pulley **714***a* and the second YP pulley **714***b* may be considered as pulleys that reflect the rotations of the yaw operating bar **7122** and the rotation of the pitch operating bar **7112** together.

(549) In detail, when the yaw operating bar **7122** rotates, the yaw operating pulley **7123** connected with the yaw operating bar **7122** rotates along with the yaw operating bar **7122**, and thus the yaw operating wire **735**Y moves to rotate the first YP pulley **714***a* and the second YP pulley **714***b* connected therewith. When the pitch operating axis **7111** and the pitch operating bar **7112** rotate in the direction of an arrow P of FIG. **44**, the yaw operating axis and the yaw operating pulley **7123** also rotate around the pitch operating axis **7111**. Then, the yaw operating wire **735**Y rotates around the pitch operating axis **7111** in the direction of the arrow P of FIG. **44** according to the rotation of the operator **710**, and the first YP pulley **714***a* connected therewith also rotates accordingly. Consequently, the first YP pulley **714***a* and the second YP pulley **714***b* rotate when the yaw operating pulley **7123** rotates, and also rotate when the pitch operating pulley **7113** rotates. This means that a yaw operation input and a pitch operation input are added together by the first YP pulley **714***a* and the second YP pulley **714***b* of the operator **710** to output the sum of the yaw operation input and the pitch operation input.

(550) When the actuation operating bar **7132** rotates, the first AP pulley **715***a* and a second AP pulley **715***b* connected therewith rotate along with the actuation operating pulley **7133**; and when the actuation operating bar **7112** and the yaw operator **712** and the actuation operator **713** connected therewith rotate together around the pitch operating axis **7111**, the first AP pulley **715***a* and the second AP pulley **715***b* connected therewith rotate along with the pitch operating pulley **7113**. That is, the first AP pulley **715***a* and the second AP pulley **715***b* may be considered as pulleys that reflect the rotations of the actuation operating pulley **7133** and the rotation of the pitch operating pulley **7113** together.

(551) Likewise, when the actuation operating bar **7132** rotates, the first AP additional pulley **716***a* and a second AP additional pulley **716***b* connected therewith rotate along with the actuation operating pulley **7133**; and when the pitch operating bar **7112** and the yaw operator **712** and the actuation operator **713** connected therewith rotate together around the pitch operating axis **7111**, the first AP additional pulley **716***a* and the second AP additional pulley **716***b* connected therewith rotate along with the pitch operating pulley **7113**. That is, the first AP additional pulley **716***a* and the second AP additional pulley **716***b* may be considered as pulleys that reflect the rotations of the actuation operating bar **7132** and the rotation of the pitch operating bar **7112** together.

(552) Herein, the rotation directions of the first AP pulley **715***a* and the first AP additional pulley **716***a* are opposite to each other. This is because unlike the actuation operating wire **735**A connecting the actuation operating pulley **7133** and the first AP pulley **715***a*, the actuation additional operating wire **735**A′ connecting the actuation operating pulley **7133** and the first AP additional pulley **716***a* is twisted one time. That is, since the rotating force transmission directions

of the actuation operating wire **735**A and the actuation additional operating wire **735**A′ are opposite to each other, the rotation directions of the first AP pulley **715***a* and the first AP additional pulley **716***a* are opposite to each other.

(553) Although it is illustrated that the first YP pulley **714***a* is connected to the second YP pulley **714***b*, and the second YP pulley **714***b* is connected to a first input unit **7311** of the first differential member **731** and a first input unit **7321** of the second differential member **732**, this is merely for convenience of description, and the first YP pulley **714***a* may be directly connected to the first input unit **7311** of the first differential member **731** and first input unit **7321** of the second differential member **732**, without using the second YP pulley **714***b*.

(554) Likewise, although it is illustrated that the first AP pulley **715***a* is connected to the second AP pulley **715***b*, and the second AP pulley **715***b* is connected to the first input unit **7321** of the second differential member **732**, this is merely for convenience of description, and the first AP pulley **715***a* may be directly connected to the first input unit **7321** of the second differential member **732**, without using the second AP pulley **715***b*.

(555) Also, although it is illustrated that the first AP additional pulley **716***a* is connected to the second AP additional pulley **716***b*, and the second AP additional pulley **716***b* is connected to the first input unit **7311** of the first differential member **731**, this is merely for convenience of description, and the first AP additional pulley **716***a* may be directly connected to the first input unit **7311** of the first differential member **731**, without using the second AP additional pulley **716***b*.

Overall Operation of Seventh Embodiment

(556) Hereinafter, an overall configuration for the pitch operation, the yaw operation, and the actuation operation of the surgical instrument **700** according to the seventh embodiment of the present invention will be summarized with reference to the above descriptions.

(557) In the surgical instrument **700** according to the seventh embodiment of the present invention, the first differential member **731** includes the first input unit **7311**, a second input unit **7312**, an output unit **7313**, a first differential control member **7314**, a second differential control member **7315**, and a differential control wire **7316**, and the second differential member **732** includes the first input unit **7321**, a second input unit **7322**, an output unit **7323**, a first differential control member **7324**, a second differential control member **7325**, and a differential control wire **7326**.

(558) For the configuration of the end tool **720** of the present embodiment, the operating force transmitter **730** capable of dividing the operation input of the operator **710** into a pitch operation, a first jaw operation, and a second jaw operation is necessary to perform the pitch, yaw, and actuation operations of the end tool **720**. The rotation operation of the pitch operating bar may be directly connected to the pitch operation of the end tool. However, since the end tool needs to include the operation component of the first jaw and the operation component of the second jaw but the input of the operator is the yaw component and the actuation component, the operation component of the first jaw and the operation component of the second jaw have to include the yaw component and the actuation component as follows: This may be expressed as the following equation:

$J1=Y+A$ (the first jaw rotates in the same direction in both the yaw operation and the actuation operation.)

$J2=Y-A$ (the second jaw rotates in the same direction in the yaw operation and rotates in an opposite direction in the actuation operation.)

(559) To this end, the yaw operator **712** and the actuation operator **713** of the operator **710** are connected to the first YP pulley **714***a* and the first AP pulley **715***a*, and the first AP additional pulley **716***a* is provided to transmit the actuation operation input reversely. This may be expressed as the following equation:

$$Y_P = Y + P$$

(560) $A_P = A + P$

$$A_{P'} = -A + P$$

(561) Thus, in order to transmit the output of the operator **710** as only the components of the first and second jaws to the end tool **720**, the operating force transmitter **730** extracts the following components:

(562) $$J1 = Y + A = Y_P - A_{P'}$$
$$J2 = Y - A = Y_P - A_P$$

(563) To this end, the operating force transmitter **730** includes a differential pulley that receives an input of YP and AP′ and outputs only the difference (J**1** component) between YP and AP′, and a differential pulley that receives an input of YP and AP and outputs only the difference (J**2** component) between YP and AP.

(564) (where Y denotes the rotation of the yaw operating pulley, A denotes the rotation of the actuation operating pulley, YP denotes the rotation of the YP pulley, AP denotes the rotation of the AP pulley, AP′ denotes the rotation of the AP additional pulley, J**1** denotes the rotation of the first jaw operating pulley, and J**2** denotes the rotation of the second jaw operating pulley.)

(565) This will be described below in more detail.

(566) The first input unit **7311** of the first differential member **731** is connected with the first YP pulley **714***a* (or the second YP pulley **714***b* connected therewith) to rotate when the yaw operating pulley **7123** rotates and also rotate when the pitch operating pulley **7113** rotates. The second input unit **7312** of the first differential member **731** is connected with the first AP additional pulley **716***a* (or the second AP additional pulley **716***b* connected therewith) to rotate when the actuation operating pulley **7133** rotates and also rotate when the pitch operating pulley **7113** rotates. Also, the output unit **7313** of the first differential member **731** is connected with the first jaw wire **735J1** to control the operation of the first jaw **721** of the end tool **720**.

(567) The first input unit **7321** of the second differential member **732** is connected with the first YP pulley **714***a* (or the second YP pulley **714***b* connected therewith) to rotate when the yaw operating pulley **7123** rotates and also rotate when the pitch operating pulley **7113** rotates. The second input unit **7322** of the second differential member **732** is connected with the first AP pulley **715***a* (or the second AP pulley **715***b* connected therewith) to rotate when the actuation operating pulley **7133** rotates and also rotate when the pitch operating pulley **7113** rotates. Also, the output unit **7323** of the second differential member **732** is connected with the second jaw wire **735J2** to control the operation of the second jaw **722** of the end tool **720**.

(568) The pitch operating pulley **7113** is connected with the pitch wire **735**P to control the pitch operation of the end tool **720**.

(569) First, the pitch operation will be described below.

(570) As described above, when the user grips the pitch operating bar **7112** of the pitch operator **711** of the operator **710** and rotates the pitch operating bar **7112** around the pitch operating axis **7111** in the direction of the arrow P of FIG. **44**, the pitch operating pulley **7113** rotates along with the pitch operating axis **7111**. Then, the pitch pulley **723** connected with the pitch operating pulley **7113** by the pitch wire **735**P, the first jaw pulley **724** connected therewith, the second jaw pulley **725**, the first jaw **721**, and the second jaw **722** rotate around the pitch rotating axis **720**PX (see FIG. **40**) to perform a pitch operation.

(571) In this case, the pitch operation does not affect the output units of the first and second differential pulleys **731** and **732** of the operating force transmitter **730** which determine the operations of the first and second jaws **721** and **722** of the end tool **720**. In more detail, when the first YP pulley **714***a*, the first AP pulley **715***a*, and the first AP additional pulley **716***a* rotate around the pitch operating axis **7111** according to the pitch operation, the first input unit **7311** of the first differential member **731** that is connected with the second YP pulley **714***b* and the second input

unit **7312** of the first differential member **731** that is connected with the second AP additional pulley **716***b* rotate; however, since the rotations are offset in the first differential member **731**, the output unit **7313** of the first differential member **731** does not rotate. Likewise, the first input unit **7321** of the second differential member **732** that is connected with the second YP pulley **714***b* and the second input unit **7322** of the second differential member **732** that is connected with the second AP pulley **715***b* rotate; however, since the rotations are offset in the second differential member **732**, the output unit **7323** of the second differential member **732** does not rotate. Thus, the pitch operation may be performed independently of the yaw operation and the actuation operation.
(572) The yaw operation and the actuation operation of the present embodiment will be described below.
(573) For a yaw operation, the user holds the yaw operating bar **7122** with the index finger and rotates the yaw operating bar **7122** in the direction of an arrow Y of FIG. **44**.
(574) Then, the yaw operating pulley **7123** connected with the yaw operating bar **7122** rotates around the yaw operating axis (i.e., the pitch operating bar), and the resulting rotating force is transmitted through the yaw operating wire **735**Y to the first YP pulley **714***a* and the second YP pulley **714***b* connected therewith, to rotate the second YP pulley **714***b*. When the second YP pulley **714***b* rotates, the first input unit **7311** of the first differential member **731** connected therewith and the output unit **7313** of the first differential member **731** connected therewith rotate. In addition, when the second YP pulley **714***b* rotates, the first input unit **7321** of the second differential member **732** connected therewith and the output unit **7323** of the second differential member **732** connected therewith rotate.
(575) For an actuation operation, the user holds the actuation operating bar **7132** with the thumb finger and rotates the actuation operating bar **7132** in the direction of an arrow A of FIG. **44**.
(576) Then, the actuation operating pulley **7133** connected with the actuation operating bar **7132** rotates around the actuation operating axis (i.e., the pitch operating bar), and the resulting rotating force is transmitted through the actuation operating wire **735**A to the first AP pulley **715***a* and the second AP pulley **715***b* connected therewith, to rotate the second AP pulley **715***b*. When the second AP pulley **715***b* rotates, the second input unit **7322** of the second differential member **732** that is connected therewith and the output unit **7323** of the second differential member **732** connected therewith rotate. In addition, the rotating force of the actuation operating pulley **7133** is transmitted through the actuation additional operating wire **735**A′ to the first AP additional pulley **716***a* and the second AP additional pulley **716***b* connected therewith, to rotate the second AP additional pulley **716***b*. When the second AP additional pulley **716***b* rotates, the second input unit **7312** of the first differential member **731** that is connected therewith and the output unit **7313** of the first differential member **731** connected therewith rotate.
(577) As described above, the second YP pulley **714***a* and the second YP pulley **714***b* connected therewith rotate along with the yaw operating pulley **7123** when the yaw operating pulley **7123** rotates, and rotate along with the pitch operating pulley **7113** when the pitch operating pulley **7113** rotates. The first AP pulley **715***a* and the second AP pulley **715***b* connected therewith rotate along with the actuation operating pulley **7133** when the actuation operating pulley **7133** rotates, and rotate along with the pitch operating pulley **7113** when the pitch operating pulley **7113** rotates. Likewise, the first AP pulley **716***a* and the second AP pulley **716***b* connected therewith rotate along with the actuation operating pulley **7133** when the actuation operating pulley **7133** rotates, and rotate along with the pitch operating pulley **7113** when the pitch operating pulley **7113** rotates.
(578) Referring to the above equation, when the second YP pulley **714***b* and the second AP additional pulley **716***b* are connected respectively to the two input units of the first differential member **731**, only a pure operation control component of the first jaw **721** may be extracted from the rotation of the pitch operating pulley **7113**, the rotation of the yaw operating pulley **7123**, and the rotation of the actuation operating pulley **7133**.
(579) Likewise, when the second YP pulley **714***b* and the second AP pulley **715***b* are connected

respectively to the two input units of the second differential member **732**, only a pure operation control component of the second jaw **722** may be extracted from the rotation of the pitch operating pulley **7113**, the rotation of the yaw operating pulley **7123**, and the rotation of the actuation operating pulley **7133**.

(580) Consequently, for a yaw operation, when the yaw operating bar **7122** is rotated in the direction of the arrow Y of FIG. **44**, the first YP pulley **714***a* and the second YP pulley **714***b* connected therewith rotate in the counterclockwise direction in FIG. **44**. Then, the first input unit **7311** of the first differential member **731** that is connected with the second YP pulley **714***b* rotates in the counterclockwise direction. Accordingly, the output unit **7313** of the first differential member **731** rotates in the counterclockwise direction, and the first jaw wire **735J1** connected with the output unit **7313**, the first jaw pulley **724** connected with the first jaw wire **735J1**, and the first jaw **721** connected with the first jaw pulley **724** rotate around the jaw rotating axis **720**JX (see FIG. **40**) in the counterclockwise direction. Likewise, the first input unit **7321** of the second differential member **732** that is connected with the second YP pulley **714***b* rotates in the counterclockwise direction. Accordingly, the output unit **7323** of the second differential member **732** rotates in the counterclockwise direction, and the second jaw wire **735J2** connected with the output unit **7323**, the second jaw pulley **725** connected with the second jaw wire **735J2**, and the second jaw **722** connected with the second jaw pulley **725** rotate around the jaw rotating axis **720**JX (see FIG. **40**) in the counterclockwise direction. In this manner, the first jaw **721** and the second jaw **722** rotate in the same direction to perform a yaw operation.

(581) Similarly, for an actuation operation, when the actuation operating bar **7132** is rotated in the direction of the arrow A of FIG. **44**, the first AP pulley **715***a* and the second AP pulley **715***b* connected therewith rotate in the clockwise direction in FIG. **44**, and the first AP additional pulley **716***a* and the second AP additional pulley **716***b* rotate in the counterclockwise direction in FIG. **44**. Then, the second input unit **7322** of the second differential member **732** that is connected with the second AP pulley **715***b* rotates in the clockwise direction. Accordingly, the output unit **7323** of the second differential member **732** rotates in the counterclockwise direction, and the second jaw wire **735J2** connected with the output unit **7323**, the second jaw pulley **725** connected with the second jaw wire **735J2**, and the second jaw **722** connected with the second jaw pulley **725** rotate around the jaw rotating axis **720**JX (see FIG. **40**) in the counterclockwise direction. Likewise, the second input unit **7312** of the first differential member **731** that is connected with the second AP additional pulley **716***b* rotates in the counterclockwise direction. Accordingly, the output unit **7313** of the first differential member **731** rotates in the clockwise direction, and the first jaw wire **735J1** connected with the output unit **7313**, the first jaw pulley **724** connected with the first jaw wire **735J1**, and the first jaw **721** connected with the first jaw pulley **724** rotate around the jaw rotating axis **720**JX (see FIG. **40**) in the clockwise direction. In this manner, the first jaw **721** and the second jaw **722** rotate in opposite directions to perform an actuation operation.

(582) Thus, according to the present invention, the pitch operation of the end tool, the rotation operation of the first jaw, and the rotation operation of the second jaw may be extracted respectively from the rotation of the pitch operating pulley **7113**, the rotation of the yaw operating pulley **7123**, and the rotation of the actuation operating pulley **7133**. Accordingly, even when the pitch, yaw, and actuation operations of the operator occur simultaneously or not, the pitch, yaw, and actuation operations of the operator may be independently divided into the pitch operation component of the end tool, the rotation operation component of the first jaw, and the rotation operation component of the second jaw.

(583) Any combination of various configurations of the operator described with reference to FIG. **3**A, various configurations of the operating force transmitter described with reference to FIGS. **4**A and **15** to **27**, and various modifications described with reference to FIGS. **7** to **14** may be applied to the surgical instrument **700** according to the seventh embodiment of the present invention.

<Eighth Embodiment of Surgical Instrument> (E2+H**2**+D)

(584) Hereinafter, the surgical instrument **800** according to the eighth embodiment of the present invention will be described. In the surgical instrument **800** according to the eighth embodiment of the present invention, an end tool **820** has the configuration described with reference to FIGS. **40** to **43**, and an actuation operator formed is formed on an yaw operator such that the actuation operator rotates together when the yaw operator rotates, as in the surgical instrument **200** according to the second embodiment illustrated in FIG. **28**.
(585) FIG. **45** is a view illustrating the surgical instrument **800** according to the eighth embodiment of the present invention. Referring to FIG. **45**, the surgical instrument **800** according to the eighth embodiment of the present invention includes an operator **810**, the end tool **820**, an operating force transmitter **830**, and a connector (not illustrated).
(586) The end tool **820** includes a first jaw **821**, a second jaw **822**, a pitch pulley **823**, a first jaw pulley **824**, and a second jaw pulley **825**, and the operating force transmitter **830** includes a pitch wire **835**P, a first jaw wire **835**J1, and a second jaw wire **835**J2. In the end tool **820**, the pulley/wire for a pitch operation, the pulley/wire for an operation of the first jaw, and the pulley/wire for an operation of the second jaw are separately formed such that one operation does not affect other operations. Since the end tool **820** is substantially identical to the end tool **720** described with reference to FIGS. **40** to **43**, a detailed description thereof will be omitted herein.
(587) The operating force transmitter **830** includes a first differential member **831** and a second differential member **832**. The first differential member **831** and the second differential member **832** each include two or more input units and one input unit, receive an input of rotating forces from the two or more input units, extract a desired rotating force from the sum of (or the difference between) the input rotating forces, and output the desired rotating force through the output unit. The first and second differential members **831** and **832** may include various differential pulleys and differential gears, such as, the differential pulley of the surgical instrument **100** according to the first embodiment illustrated in FIGS. **4**A and **4**B, the first modification of the differential pulley illustrated in FIG. **15**, the second modification of the differential pulley illustrated in FIG. **18**, and the third modification of the differential pulley illustrated in FIG. **22**. That is, although the differential pulley of FIG. **21**E is illustrated as the first and second differential members **831** and **832** of the surgical instrument **800** according to the eighth embodiment in FIG. **44**, the present invention is not limited thereto, and various differential pulleys and differential gears may be used in the present embodiment.
(588) Hereinafter, the operator **810** of the surgical instrument **800** according to the eighth embodiment of the present invention will be described in more detail.
(589) Referring to FIG. **45**, the operator **810** of the surgical instrument **800** according to the eighth embodiment of the present invention includes a pitch operator **811** controlling a pitch motion of the end tool **820**, a yaw operator **812** controlling a yaw motion of the end tool **820**, and an actuation operator **813** controlling an actuation motion of the end tool **820**.
(590) The pitch operator **811** includes a pitch operating axis **8111**, a pitch operating bar **8112**, and a pitch operating pulley **8113**. Herein, the pitch operating axis **8111** may be formed in the direction parallel to the Y axis, and the pitch operating bar **8112** may be connected with the pitch operating axis **8111** to rotate along with the pitch operating axis **8111**. For example, when the user grips and rotates the pitch operating bar **8112**, the pitch operating axis **8111** connected with the pitch operating bar **8112** and the pitch operating pulley **8113** connected therewith rotate together therewith. Then, the resulting rotating force is transmitted to the end tool **820** through the operating force transmitter **830**, so that the end tool **820** rotates in the same direction as the rotation direction of the pitch operating axis **8111**. That is, when the pitch operator **811** rotates in the clockwise direction around the pitch operating axis **8111**, the end tool **820** also rotates in the clockwise direction around a pitch pulley operating axis (not illustrated), and when the pitch operator **811** rotates in the counterclockwise direction around the pitch operating axis **8111**, the end tool **820** also rotates in the counterclockwise direction around the pitch pulley operating axis. The pitch operating

pulley **8113** is integrated with the pitch operating axis **8111** to rotate along with the pitch operating axis **8111**.
(591) The yaw operator **812** includes a yaw operating axis **8121** and a yaw operating bar **8122**. Although it is illustrated that the yaw operating axis **8121** is formed to extend from the pitch operating bar **8112**, the present invention is not limited thereto. For example, the pitch operating bar **8112** and the yaw operating axis **8121** may be formed as separate members on different axes. In this case, the yaw operating axis **8121** may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **810**.
(592) When the pitch operator **811** rotates, a coordinate system of the yaw operator **812** may change relatively. The yaw operating bar **8122** is formed to rotate around the yaw operating axis **8121**. For example, when the user holds and rotates the yaw operating bar **8122** with the index finger, the yaw operating bar **8122** rotates around the yaw operating axis **8122**. Then, the resulting rotating force is transmitted to the end tool **820** through a first yaw-actuation operating wire **835**AY**1** and a second yaw-actuation operating wire **835**AY**2**, so that the first and second jaws **821** and **822** of the end tool **820** horizontally rotate in the same direction as the rotation direction of the yaw operator **812**.
(593) The actuation operator **813** includes an actuation operating axis **8131**, an actuation operating bar **8132**, a first actuation operating pulley **8133***a*, and a second actuation operating pulley **8133***b*. Herein, the actuation operating bar **8132**, the first actuation operating pulley **8133***a*, and the second actuation operating pulley **8133***b* are formed to rotate around the actuation operating axis **8131**. For example, when the user holds and rotates the actuation operating bar **8132** with the thumb finger, the first actuation operating pulley **8133***a* and the second actuation operating pulley **8133***b* connected with the actuation operating bar **8132** rotate around the actuation operating axis **8131**. Then, the resulting rotating force is transmitted to the end tool **820** through the operating force transmitter **830**, so that the first and second jaws **821** and **822** of the end tool **820** perform an actuation operation. In this case, the actuation operator **813** may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **810**.
(594) The actuation operator **813** is formed on a yaw-actuation connector **8124** extending from the yaw operator **812**. Thus, when the yaw operating bar **8122** of the yaw operator **812** rotates, the actuation operator **813** also rotates along with the yaw operating bar **8122**. A first yaw-actuation operating pulley **814**P**1** and a second yaw-actuation operating pulley **814**P**2** are formed to rotate around the yaw operating axis **8121**. The first actuation operating pulley **8133***a* and the first yaw-actuation operating pulley **814**P**1** are connected by a first yaw-actuation connecting wire **814**W**1**, and the first yaw-actuation operating wire **835**AY**1** is connected to the first yaw-actuation operating pulley **814**P**1**. Likewise, the second actuation operating pulley **8133***b* and the second yaw-actuation operating pulley **814**P**2** are connected by a second yaw-actuation connecting wire **814**W**2**, and the second yaw-actuation operating wire **835**AY**2** is connected to the second yaw-actuation operating pulley **814**P**2**.
(595) Thus, when the yaw operating bar **8122** rotates, the yaw-actuation connector **8124** extending therefrom and the actuation operator **813** rotate around the yaw operating axis **8121**, the first yaw-actuation connecting wire **814**W**1** connected to the first actuation operating pulley **8133***a* and the second yaw-actuation connecting wire **814**W**2** connected to the second actuation operating pulley **8133***b* also rotate around the yaw operating axis **8121**, and consequently, the first yaw-actuation operating pulley **814**P**1** and the second yaw-actuation operating pulley **814**P**2** rotate around the yaw operating axis **8121**.
(596) Consequently, the first yaw-actuation operating pulley **814**P**1** and the second yaw-actuation operating pulley **814**P**2** are formed to rotate when the yaw operator **812** rotates and also rotate when the actuation operator **813** rotates.
(597) The pitch operating axis **8111** is inserted into a first actuation-yaw-pitch (AY**1**P) pulley **815***a* and a first actuation-yaw-pitch (AY**2**P) pulley **816***a* such that the first AY**1**P pulley **815***a* and the

first AY**2**P pulley **816***a* rotate around the pitch operating axis **8111**; and the first AY**1**P pulley **815***a* and the first AY**2**P pulley **816***a* are connected to the first yaw-actuation operating pulley **814**P and the second yaw-actuation operating pulley **814**P**2** by the first yaw-actuation operating wire **835**AY**1** and the second yaw-actuation operating wire **835**AY**2**, respectively.

(598) The first AY**1**P pulley **815***a* and a second AY**1**P pulley **815***b* connected therewith rotate along with the actuation operator **813** when the actuation operator **813** rotates, rotate along with the yaw operator **812** when the yaw operator **812** rotates, and rotate along with the pitch operator **811** when the pitch operator **811** rotates. That is, the first AY**1**P pulley **815***a* and the second AY**1**P pulley **815***b* may be considered as pulleys that reflect the rotation of the actuation operator **813**, the rotation of the yaw operator **812**, and the rotations of the pitch operator **811** together.

(599) In detail, when the actuation operating bar **8132** rotates, the first actuation operating pulley **8133***a* connected with the actuation operating bar **8132** rotates along with the first actuation operating bar **8132**, and thus the first yaw-actuation connecting wire **814**W**1** moves to rotate the first yaw-actuation operating pulley **814**P**1**. When the first yaw-actuation operating pulley **814**P**1** rotates, the first yaw-actuation operating wire **835**AY**1** connected therewith rotates to rotate the first AY**1**P pulley **815***a* and the second AY**1**P pulley **815***b* connected therewith. When the yaw operating bar **8122** rotates, the actuation operator **813** connected with the yaw operating bar **8122** rotates along with the yaw operating bar **8122**, and thus the first actuation operating pulley **8133***a* of the actuation operator **813** and the first yaw-actuation connecting wire **814**W**1** connected therewith rotate around the yaw operating axis **8121** to rotate the first yaw-actuation operating pulley **814**P**1**. When the first yaw-actuation operating pulley **814**P**1** rotates, the first yaw-actuation operating wire **835**AY**1** connected therewith rotates to rotate the first AY**1**P pulley **815***a* and the second AY**1**P pulley **815***b* connected therewith. When the pitch operating axis **8111** and the pitch operating bar **8112** rotate in the direction of an arrow P of FIG. **45**, the actuation operator **813** also rotate around the pitch operating axis **8111**. Then, the first yaw-actuation operating wire **835**AY**1** rotates according to the rotation of the operator **810**, and the first AY**1**P pulley **815***a* connected therewith also rotates accordingly. Consequently, the first AY**1**P pulley **815***a* and the second AY**1**P pulley **815***b* rotate when the actuation operator **813** rotates, rotate when the yaw operator **812** rotates, and rotate when the pitch operator **811** rotates.

(600) Likewise, when the first AY**2**P pulley **816***a* and a second AY**2**P pulley **815***b* connected therewith rotate along with the actuation operator **816** when the actuation operator **813** rotates, rotate along with the yaw operator **812** when the yaw operator **812** rotates, and rotate along with the pitch operator **811** when the pitch operator **811** rotates. That is, the first AY**2**P pulley **816***a* and the second AY**2**P pulley **816***b* may be considered as pulleys that reflect the rotations of the actuation operator **813**, the rotation of the yaw operator **812**, and the rotation of the pitch operator **811** together.

(601) Although it is illustrated that the first AY**1**P pulley **815***a* is connected to the second AY**1**P pulley **815***b*, and the second AY**1**P pulley **815***b* is connected to a first input unit **8311** of the first differential member **831**, this is merely for convenience of description, and the first AY**1**P pulley **815***a* may be directly connected to the first input unit **8311** of the first differential member **831**, without using the second AY**1**P pulley **815***b*.

(602) Likewise, although it is illustrated that the first AY**2**P pulley **816***a* is connected to the second AY**2**P pulley **816***b*, and the second AY**2**P pulley **816***b* is connected to a first input unit **8321** of the second differential member **832**, this is merely for convenience of description, and the first AY**2**P pulley **816***a* may be directly connected to the first input unit **8321** of the second differential member **832**, without using the second AY**2**P pulley **816***b*.

(603) Likewise, although it is illustrated that the pitch operating pulley **8113** is connected to a second pitch operating pulley **8113***b*, and the second pitch operating pulley **8113***b* is connected to a second input unit **8312** of the first differential member **831** and a second input unit **8322** of the second differential member **832**, this is merely for convenience of description, and the pitch

operating pulley **8113** may be directly connected to the second input unit **8312** of the first differential member **831** and the second input unit **8322** of the second differential member **832**, without using the second pitch operating pulley **8113***b*.

Overall Operation of Eighth Embodiment

(604) Hereinafter, an overall configuration for the pitch operation, the yaw operation, and the actuation operation of the surgical instrument **800** according to the eighth embodiment of the present invention will be summarized with reference to the above descriptions.

(605) In the surgical instrument **800** according to the eighth embodiment of the present invention, the first differential member **831** includes the first input unit **8311**, the second input unit **8312**, an output unit **8313**, a first differential control member **8314**, a second differential control member **8315**, and a differential control wire **8316**, and the second differential member **832** includes the first input unit **8321**, the second input unit **8322**, an output unit **8323**, a first differential control member **8324**, a second differential control member **8325**, and a differential control wire **8326**.

(606) For the configuration of the end tool **820** of the present embodiment, the operating force transmitter **830** capable of dividing the operation input of the operator **810** into a pitch operation, a first jaw operation, and a second jaw operation is necessary to perform the pitch, yaw, and actuation operations of the end tool **820**. The rotation operation of the pitch operating bar may be directly connected to the pitch operation of the end tool **820**. However, since the end tool **820** needs to include the operation component of the first jaw and the operation component of the second jaw but the input of the operator **810** is the yaw component and the actuation component, the operation component of the first jaw and the operation component of the second jaw have to include the yaw component and the actuation component as follows:

$J1=Y+A$ (the first jaw rotates in the same direction in both the yaw operation and the actuation operation.)

$J2=Y-A$ (the second jaw rotates in the same direction in the yaw operation and rotates in an opposite direction in the actuation operation.)

(607) Particularly, in the present embodiment, since the actuation operator **813** is disposed on the yaw operator **812**, the output of the operator **810** is the sum of the yaw operation input, the actuation operation input, and the pitch operation input. As described above, the output of the operator **810** may be expressed as the following equation:

(608)
$$A_{Y1P}=A_{Y1}+P=A+Y+P$$
$$A_{Y2P}=A_{Y2}+P=-A+Y+P$$

(609) Thus, in order to transmit the output of the operator **810** as only the components of the first and second jaws to the end tool **820**, the operating force transmitter **830** extracts the following components:

(610)
$$J1=Y+A=A_{Y1P}-P$$
$$J2=Y-A=A_{Y2P}-P$$

(611) To this end, the operating force transmitter **830** includes a differential pulley that receives an input of A.sub.Y1P and P and outputs only the difference (J**1** component) between A.sub.Y1P and P, and a differential pulley that receives an input of A.sub.Y2P and P and outputs only the difference (J**2** component) between A.sub.Y2P and P. (where Y denotes the rotation of the yaw operating pulley, A denotes the rotation of the actuation operating pulley, A.sub.Y1 denotes the rotation of the A.sub.Y1 pulley, A.sub.Y2 denotes the rotation of the A.sub.Y2 pulley, A.sub.Y1P denotes the rotation of the A.sub.Y1 pulley, A.sub.Y2 denotes the rotation of the A.sub.Y2P pulley, P denotes the rotation of the pitch operating pulley, J**1** denotes the rotation of the first jaw operating pulley, and J**2** denotes the rotation of the second jaw operating pulley.)

(612) This will be described below in more detail.

(613) First, the pitch operation will be described below.

(614) As described above, when the user grips the pitch operating bar **8112** of the pitch operator

811 of the operator **810** and rotates the pitch operating bar **8112** around the pitch operating axis **8111** in the direction of the arrow P of FIG. **45**, the pitch operating pulley **8113** rotates along with the pitch operating axis **8111**. Then, the pitch pulley **823** connected with the pitch operating pulley **8113** by the pitch wire **835**P, the first jaw pulley **824** connected therewith, the second jaw pulley **825**, the first jaw **821**, and the second jaw **822** rotate around a pitch rotating axis **820**PX to perform a pitch operation.

(615) In this case, the pitch operation does not affect the output units of the first and second differential pulleys **831** and **832** of the operating force transmitter **830**, which determine the operations of the first and second jaws **821** and **822** of the end tool **820**. In more detail, when the first AY**1**P pulley **815***a* and the first AY**2**P pulley **816***a* rotate around the pitch operating axis **8111** according to the pitch operation, the first input unit **8311** of the first differential member **831** that is connected with the second AY**1**P pulley **815***b* and the second input unit **8312** of the first differential member **831** that is connected with the pitch operating pulley **8113** rotate; however, since the rotations are offset in the first differential member **831**, the output unit **8313** of the first differential member **831** does not rotate. Likewise, the first input unit **8321** of the second differential member **832** that is connected with the second AY**2**P pulley **816***b* and the second input unit **8322** of the second differential member **832** that is connected with the pitch operating pulley **8113** rotate; however, since the rotations are offset in the second differential member **832**, the output unit **8323** of the second differential member **832** does not rotate. Thus, the pitch operation may be performed independently of the yaw operation and the actuation operation.

(616) The yaw operation and the actuation operation of the present embodiment will be described below.

(617) In the surgical instrument **800**, the first differential member **831** includes the first input unit **8311**, the second input unit **8312**, the output unit **8313**, the first differential control member **8314**, the second differential control member **8315**, and the differential control wire **8316**, and the second differential member **832** includes the first input unit **8321**, the second input unit **8322**, the output unit **8323**, the first differential control member **8324**, the second differential control member **8325**, and the differential control wire **8326**.

(618) The first input unit **8311** of the first differential member **831** is connected with the second AY**1**P pulley **815***b* to rotate when the actuation operator **813** rotates, rotate when the yaw operator **812** rotates, and rotate when the pitch operator **811** rotates. Also, the second input unit **8312** of the first differential member **831** is connected with the second pitch operating pulley **8113***b* to rotate when the pitch operator **811** rotates. Also, the output unit **8313** of the first differential member **831** is connected with the first jaw wire **835**J1 to control the operation of the first jaw **821** of the end tool **820**.

(619) The first input unit **8321** of the second differential member **832** is connected with the second AY**2**P pulley **816***b* to rotate when the actuation operator **816** rotates, rotate when the yaw operator **812** rotates, and rotate when the pitch operator **811** rotates. Also, the second input unit **8322** of the second differential member **832** is connected with the second pitch operating pulley **8113***b* to rotate when the pitch operator **811** rotates. Also, the output unit **8323** of the second differential member **832** is connected with the second jaw wire **835**J2 to control the operation of the second jaw **822** of the end tool **820**.

(620) As described above, the first AY**1**P pulley **815***a*, the second AY**1**P pulley **815***b* connected therewith, the first AY**2**P pulley **816***a*, and the second AY**2**P pulley **816***b* connected therewith rotate along with the actuation operator **813** when the actuation operator **813** rotates, rotate along with the yaw operator **812** when the yaw operator **812** rotates, and rotate along with the pitch operator **811** when the pitch operator **811** rotates.

(621) Referring to the above equation, when the second AY**1**P pulley **815***b* and the pitch operating pulley **8113** are connected respectively to the two input units of the first differential member **831**, only a pure operation control component of the first jaw **821** may be extracted from the rotation of

the pitch operator **811**, the rotation of the yaw operator **812**, and the rotation of the actuation operator **813**.

(622) Similarly, when the second AY**2**P pulley **816***b* and the pitch operating pulley **8113** are connected respectively to the two input units of the second differential member **832**, only a pure operation control component of the second jaw **822** may be extracted from the rotation of the pitch operator **811**, the rotation of the yaw operator **812**, and the rotation of the actuation operator **813**.

(623) Consequently, for a yaw operation, when the user holds and rotates the yaw operating bar **8122** with the index finger in the direction of an arrow Y of FIG. **45**, the actuation operator **813** connected with the yaw operator **812** rotates around the yaw operating axis **8121**. Then, the resulting rotating force is transmitted to the first AY**1**P pulley **815***a* and the second AY**1**P pulley **815***b* connected therewith through the first yaw-actuation connecting wire **814**W**1**, the first yaw-actuation operating pulley **814**P**1**, and the first yaw-actuation operating wire **835**AY**1**, to rotate the second AY**1**P pulley **815***b* in the counterclockwise direction. Then, the first input unit **8311** of the first differential member **831** that is connected with the second AY**1**P pulley **815***b* rotates in the counterclockwise direction, and thus the output unit **8313** of the first differential member **831** rotates in the counterclockwise direction. Then, the first jaw wire **835**J**1** connected with the output unit **8313**, the first jaw pulley **824** connected therewith, and the first jaw **821** connected therewith rotate around a jaw rotating axis **820**JX in the counterclockwise direction.

(624) At the same time, when the yaw operating bar **8122** is rotated in the direction of the arrow Y of FIG. **45**, the actuation operator **813** connected with the yaw operator **812** rotates around the yaw operating axis **8121**. Then, the resulting rotating force is transmitted to the first AY**2**P pulley **816***a* and the second AY**2**P pulley **816***b* connected therewith through the second yaw-actuation connecting wire **814**W**2**, the second yaw-actuation operating pulley **814**P**2**, and the second yaw-actuation operating wire **835**AY**2**, to rotate the second AY**2**P pulley **816***b* in the counterclockwise direction. Then, the first input unit **8321** of the second differential member **832** that is connected with the second AY**2**P pulley **816***b* rotates in the counterclockwise direction, and thus the output unit **8323** of the second differential member **832** rotates in the counterclockwise direction. Then, the second jaw wire **835**J**2** connected with the output unit **8323**, the second jaw pulley **825** connected therewith, and the second jaw **822** connected therewith rotate around the jaw rotating axis **820**JX in the counterclockwise direction.

(625) Consequently, when the yaw operator **812** rotates in the direction of the arrow Y of FIG. **45**, the first jaw **821** and the second jaw **822** rotate around the jaw rotating axis **820**JX in the same direction to perform a yaw operation.

(626) The actuation operation of the present embodiment will be described below.

(627) For an actuation operation, when the user holds and rotates the actuation operating bar **8132** with the thumb finger in the direction of an arrow A of FIG. **45**, the actuation operator **813** rotates around the actuation operating axis **8131**. Then, the resulting rotating force is transmitted to the first AY**1**P pulley **815***a* and the second AY**1**P pulley **815***b* connected therewith through the first yaw-actuation connecting wire **814**W**1**, the first yaw-actuation operating pulley **814**P**1**, and the first yaw-actuation operating wire **835**AY**1**, to rotate the second AY**1**P pulley **815***b* in the clockwise direction. Then, the first input unit **8311** of the first differential member **831** that is connected with the second AY**1**P pulley **815***b* rotates in the clockwise direction, and thus the output unit **8313** of the first differential member **831** rotates in the clockwise direction. Then, the first jaw wire **835**J**1** connected with the output unit **8313**, the first jaw pulley **824** connected therewith, and the first jaw **821** connected therewith rotate around the jaw rotating axis **820**JX in the clockwise direction.

(628) At the same time, when the actuation operating bar **8132** is rotated in the direction of the arrow A of FIG. **45**, the actuation operator **813** rotates around the actuation operating axis **8131**. Then, the resulting rotating force is transmitted to the first AY**2**P pulley **816***a* and the second AY**2**P pulley **816***b* connected therewith through the second yaw-actuation connecting wire **814**W**2**, the second yaw-actuation operating pulley **814**P**2**, and the second yaw-actuation operating wire

835AY**2**, to rotate the second AY**2**P pulley **816***b* in the counterclockwise direction. Then, the first input unit **8321** of the second differential member **832** that is connected with the second AY**2**P pulley **816***b* rotates in the counterclockwise direction, and thus the output unit **8323** of the second differential member **832** rotates in the counterclockwise direction. Then, the second jaw wire **835**J**2** connected with the output unit **8323**, the second jaw pulley **825** connected therewith, and the second jaw **822** connected therewith rotate around the jaw rotating axis **820**JX in the counterclockwise direction.

(629) Consequently, when the yaw operator **812** rotates in the direction of the arrow A of FIG. **45**, the first jaw **821** and the second jaw **822** rotate around the jaw rotating axis **820**JX in opposite directions to perform an actuation operation.

(630) Thus, according to the present invention, the pitch operation of the end tool, the rotation operation of the first jaw, and the rotation operation of the second jaw may be extracted respectively from the rotation of the pitch operator **811**, the rotation of the yaw operator **812**, and the rotation of the actuation operator **813**. Accordingly, even when the pitch, yaw, and actuation operations of the operator occur simultaneously or not, the pitch, yaw, and actuation operations of the operator may be independently divided into the pitch operation component of the end tool, the rotation operation component of the first jaw, and the rotation operation component of the second jaw.

(631) Any combination of various configurations of the operator described with reference to FIG. **3**A, various configurations of the operating force transmitter described with reference to FIGS. **4**A and **15** to **27**, and various modifications described with reference to FIGS. **7** to **14** may be applied to the surgical instrument **800** according to the eighth embodiment of the present invention.

<Modification of Operator of Eighth Embodiment of Surgical Instrument> (E2+H**2**+D4)

(632) FIG. **46** is a view illustrating a surgical instrument **800***a* according to a modification of the operator of the eighth embodiment illustrated in FIG. **45**. Since the surgical instrument **800***a* according to a modification of the operator of the eighth embodiment of the present invention is similar to the surgical instrument **800** (see FIG. **45**) according to the eighth embodiment of the present invention and is different from the surgical instrument **100** in terms of the configuration of the operator, the configuration of the operator will be mainly described below.

(633) Referring to FIG. **46**, an operator **810***a* of the surgical instrument **800***a* according to a modification of the operator **810** of the eighth embodiment of the present invention uses the third modification of the differential pulley illustrated in FIGS. **22** and **23**.

(634) In detail, in the operator **810** of the eighth embodiment, the actuation operator **813** is disposed on the yaw operator **812**. The sum of the actuation operation input and the yaw operation input is output from the operator **810**, and the first jaw and the second jaw of the end tool **820** need the sum of and the difference between the yaw operation input and the actuation operation input in the eighth embodiment. Therefore, a differential pulley capable of outputting the sum of the yaw operation and the actuation operation may be used in the configuration of the operator.

(635) However, in the configuration of the operator **810** of the eighth embodiment, since the actuation operator **813** is disposed on the yaw operator **812**, the third modification (see FIGS. **22** and **23**) of the differential pulley in which one input unit is not independent of but is formed on another input unit may be used.

(636) Referring to FIG. **46**, the third modification (see FIGS. **22** and **23**) of the differential pulley including a yaw input unit and an actuation input unit may be applied to the operator **810** such that the operator **810** is modified to have the output of AYP=A+Y+P, AYP**2**=−A+Y+P.

(637) Since the modification of the eighth embodiment are the same in other configurations except for the configuration of the operator **810***a*, it may also use the other configurations of the eight embodiment.

(638) That is, as described above, an operating force transmitter **830** of the surgical instrument **800***a* according to the this modification includes a first differential pulley **838** and a second

differential pulley **839**, and the first differential pulley **838** includes a first input unit **8381**, a second input unit **8382**, an output unit, and a connector **8384**. The output unit of the first differential pulley **838** may be substantially identical to the first AY**2**P pulley **816***a*. The second differential pulley **839** includes a first input unit **8391**, a second input unit **8392**, an output unit, and a connector **8394**. The output unit of the second differential pulley **839** may be substantially identical to the first AY**1**P pulley **815***a*.

(639) By the first differential pulley **838** and the second differential pulley **839**, when one of two or more input units rotates, only the output unit may be rotated without other input units rotating, and when two or more input units rotate simultaneously, a single rotating force equal to the sum or (the difference between) the rotating forces of two input units may be output through the output unit.

<Ninth Embodiment of Surgical Instrument> (E2+H**3**+D)

(640) Hereinafter, a surgical instrument **900** according to a ninth embodiment of the present invention will be described. In the surgical instrument **900** according to the ninth embodiment of the present invention, an end tool **920** has the configuration described with reference to FIGS. **40** to **43**, and an operator **910** includes a first jaw operator and a second jaw operator that operate a first jaw and second jaw independently instead of a yaw operator and an actuation operator as in the surgical instrument **300** according to third second embodiment illustrated in FIG. **30**.

(641) FIG. **47** is a view illustrating the surgical instrument **900** according to the ninth embodiment of the present invention. Referring to FIG. **47**, the surgical instrument **900** according to the ninth embodiment of the present invention includes an operator **910**, an end tool **920**, an operating force transmitter **930**, and a connector (not illustrated).

(642) The end tool **920** includes a first jaw **921**, a second jaw **922**, a pitch pulley **923**, a first jaw pulley **924**, and a second jaw pulley **925**, and the operating force transmitter **930** includes a pitch wire **935**P, a first jaw wire **935**J1, and a second jaw wire **935**J2. In the end tool **920**, the pulley/wire for a pitch operation, the pulley/wire for an operation of the first jaw, and the pulley/wire for an operation of the second jaw are separately formed such that one operation does not affect other operations. Since the end tool **920** is substantially identical to the end tool **720** described with reference to FIGS. **40** to **43**, a detailed description thereof will be omitted herein.

(643) The operating force transmitter **930** includes a first differential member **931** and a second differential member **932**. The first differential member **931** and the second differential member **932** includes two or more input units and one input unit, receives an input of rotating forces from the two or more input units, extracts a desired rotating force from the sum of (or the difference between) the input rotating forces, and outputs the desired rotating force through the output unit. The first and second differential members **931** and **932** may include various differential pulleys and differential gears, such as, the differential pulley of the surgical instrument **100** according to the first embodiment illustrated in FIGS. **4**A and **4**B, the first modification of the differential pulley illustrated in FIG. **15**, the second modification of the differential pulley illustrated in FIG. **18**, and the third modification of the differential pulley illustrated in FIG. **22**. That is, although the differential pulley of FIG. **21**E is illustrated as the first and second differential members **931** and **932** of the surgical instrument **900** according to the ninth embodiment in FIG. **47**, the present invention is not limited thereto, and various differential pulleys and differential gears may be used in the present embodiment.

(644) Hereinafter, the operator **910** of the surgical instrument **900** according to the ninth embodiment of the present invention will be described in more detail.

(645) Referring to FIG. **47**, the operator **910** of the surgical instrument **900** according to the ninth embodiment of the present invention includes a pitch operator **911** controlling a pitch motion of the end tool **920**, a first jaw operator **912** controlling a motion of the first jaw **921** of the end tool **920**, and a second jaw operator **913** controlling a motion of the second jaw **922** of the end tool **920**.

(646) The pitch operator **911** includes a pitch operating axis **9111**, a pitch operating bar **9112**, and a pitch operating pulley **9113**. Herein, the pitch operating axis **9111** may be formed in the direction

parallel to the Y axis, and the pitch operating bar **9112** may be connected with the pitch operating axis **9111** to rotate along with the pitch operating axis **9111**. The pitch operating pulley **9113** is integrated with the pitch operating axis **9111** to rotate along with the pitch operating axis **9111**.
(647) The first jaw operator **912** includes a first jaw operating axis **9121**, a first jaw operating bar **9122**, and a first jaw operating pulley **9123**. A first jaw operating wire **935**J**11** may be connected to the first jaw operating pulley **9123**. In this case, the first jaw operating axis **9121** may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **910**. The first jaw operating bar **9122** and the first jaw operating pulley **9123** are formed to rotate around the first jaw operating axis **9121**. For example, when the user holds and rotates the first jaw operating bar **9122** with the thumb finger, the first jaw operating pulley **9123** connected with the first jaw operating bar **9122** rotates around the first jaw operating axis **9121**. Then, the resulting rotating force is transmitted to the end tool **920** through the operating force transmitter **930**, so that the first jaw **921** of the end tool **920** horizontally rotates in the same direction as the rotation direction of the first jaw operating pulley **9123**.
(648) The second jaw operator **913** includes a second jaw operating axis **9131**, a second jaw operating bar **9132**, and a second jaw operating pulley **9133**. Although it is illustrated that the second jaw operating axis **9131** is formed to extend from the pitch operating bar **9112**, the present invention is not limited thereto. For example, the pitch operating bar **9112** and the second jaw operating axis **9131** may be formed as separate members on different axes. In this case, the second jaw operating axis **9131** may be formed in various directions by ergonomic design according to the structure of the hand of the user gripping the operator **910**. A second jaw operating wire **935**J**21** may be connected to the second jaw operating pulley **9133**. The second jaw operating bar **9132** and the second jaw operating pulley **9133** are formed to rotate around the second jaw operating axis **9131**. For example, when the user holds and rotates the second jaw operating bar **9132** with the index finger, the second jaw operating pulley **9133** connected with the second jaw operating bar **9132** rotates around the second jaw operating axis **9131**. Then, the resulting rotating force is transmitted to the end tool **920** through the operating force transmitter **930**, so that the second jaw **922** of the end tool **920** horizontally rotates in the same direction as the rotation direction of the second jaw operating pulley **9133**.
(649) The pitch operating axis **9111** is inserted into a first second yaw-pitch (Y**2**P) pulley **914***a* and a first first actuation-pitch (J**1**P) pulley **915***a* such that the first Y**2**P pulley **914***a* and the first J**1**P pulley **915***a* rotate around the pitch operating axis **9111**.
(650) The first J**2**P pulley **914***a* and a second J**2**P pulley **914***b* connected therewith rotate along with the second jaw operating pulley **9133** when the second jaw operating pulley **9133** rotates, and rotate along with the pitch operating pulley **9113** when the pitch operating pulley **9113** rotates. That is, the first J**2**P pulley **914***a* and the second J**2**P pulley **914***b* may be considered as pulleys that reflect the rotations of the second jaw operating pulley **9133** and the rotation of the pitch operating pulley **9113** together.
(651) In detail, when the second jaw operating bar **9132** rotates, the second jaw operating pulley **9133** connected with the second jaw operating bar **9132** rotates along with the second jaw operating bar **9132**, and thus the second jaw operating wire **935**J**21** connected therewith moves to rotate the first J**2**P pulley **914***a* and the second J**2**P pulley **914***b* connected therewith. When the pitch operating axis **9111** and the pitch operating bar **9112** rotate in the direction of an arrow P of FIG. **47**, the second jaw operating axis **9131** and the second jaw operating pulley **9133** also rotate around the pitch operating axis **9111**. Then, the second jaw operating wire **935**J**21** rotates around the pitch operating axis **9111** in the direction of the arrow P of FIG. **47** according to the rotation of the operator **910**, and the first J**2**P pulley **914***a* connected therewith also rotates accordingly. Consequently, the first J**2**P pulley **914***a* and the second J**2**P pulley **914***b* rotate when the second jaw operating pulley **9133** rotates, and rotate when the pitch operating pulley **9113** rotates.
(652) Likewise, the first J**1**P pulley **915***a* and a second J**1**P pulley **915***b* connected therewith rotate

along with the first jaw operating pulley **9123** when the first jaw operating pulley **9123** rotates, and rotate along with the pitch operating pulley **9113** when the pitch operating pulley **9113** rotates. That is, the first J**1**P pulley **915***a* and the second J**1**P pulley **915***b* may be considered as pulleys that reflect the rotation of the first jaw operating pulley **9123** and the rotations of the pitch operating pulley **9113** together.
(653) Although it is illustrated that the first J**2**P pulley **914***a* is connected to the second J**2**P pulley **914***b*, and the second J**2**P pulley **914***b* is connected to a first input unit **9321** of the second differential member **932**, this is merely for convenience of description, and the first J**2**P pulley **914***a* may be directly connected to the first input unit **9321** of the second differential member **932**, without using the second J**2**P pulley **914***b*.
(654) Likewise, although it is illustrated that the first J**1**P pulley **915***a* is connected to the second J**1**P pulley **915***b*, and the second J**1**P pulley **915***b* is connected to a first input unit **9311** of the first differential member **931**, this is merely for convenience of description, and the first J**1**P pulley **915***a* may be directly connected to the first input unit **9311** of the first differential member **931**, without using the second J**1**P pulley **915***b*.
(655) Likewise, although it is illustrated that the pitch operating pulley **9113** is connected to a second pitch operating pulley **913***b*, and the second pitch operating pulley **913***b* is connected to a second input unit **9312** of the first differential member **931** and a second input unit **9322** of the second differential member **932**, this is merely for convenience of description, and the pitch operating pulley **9113** may be directly connected to the second input unit **9312** of the first differential member **931** and the second input unit **9322** of the second differential member **932**, without using the second pitch operating pulley **913***b*.
Overall Operation of Ninth Embodiment
(656) Hereinafter, an overall configuration for the pitch operation, the yaw operation, and the actuation operation of the surgical instrument **900** according to the ninth embodiment of the present invention will be summarized with reference to the above descriptions.
(657) In the surgical instrument **900** according to the ninth embodiment of the present invention, the first differential member **931** includes a first input unit **9311**, a second input unit **9312**, an output unit **9313**, a first differential control member **9314**, a second differential control member **9315**, and a differential control wire **9316**, and the second differential member **932** includes the first input unit **9321**, the second input unit **9322**, an output unit **9323**, a first differential control member **9324**, a second differential control member **9325**, and a differential control wire **9326**.
(658) For the configuration of the end tool **920** of the present embodiment, the operating force transmitter **930** capable of dividing the operation input of the operator **910** into a pitch operation, a first jaw operation, and a second jaw operation is necessary to perform the pitch, yaw, and actuation operations of the end tool **920**. The rotation operation of the pitch operating bar may be directly connected to the pitch operation of the end tool. The operator includes the first jaw operator and the second jaw operator, and the output of the operator may be expressed as the following equation:
(659) $$\begin{gathered} J1P = J1 + P \\ J2P = J2 + P \end{gathered}$$
(660) Thus, in order to transmit the output of the operator **910** as only the components of the first and second jaws to the end tool **920**, the operating force transmitter **930** extracts the following components:
(661) $$\begin{gathered} J1 = J1P - P \\ J2 = J2P - P \end{gathered}$$
(662) To this end, the operating force transmitter **930** includes a differential pulley that receives an input of J1P and P and outputs only the difference (J**1** component) between J1P and P, and a differential pulley that receives an input of J2P and P and outputs only the difference (J**2** component) between J2P and P. (where J1P denotes the rotation of the J**1**P pulley, J2P denotes the

rotation of the J2P pulley, J1 denotes the rotation of the first jaw operating pulley, J2 denotes the rotation of the second jaw operating pulley, and P denotes the rotation of the pitch operating pulley.)
(663) The first input unit **9311** of the first differential member **931** is connected with the second J1P pulley **915***b* to rotate when the first jaw operating pulley **9123** rotates and also rotate when the pitch operating pulley **9113** rotates. Also, the second input unit **9312** of the first differential member **931** is connected with the pitch operating pulley **9113** to rotate when the pitch operating pulley **9113** rotates. Also, the output unit **9313** of the first differential member **931** is connected with the first jaw wire **935**J1 to control the operation of the first jaw **921** of the end tool **920**.
(664) The first input unit **9321** of the second differential member **932** is connected with the second J2P pulley **914***b* to rotate when the second jaw operating pulley **9133** rotates and also rotate when the pitch operating pulley **9113** rotates. Also, the second input unit **9322** of the second differential member **932** is connected with the pitch operating pulley **9113** to rotate when the pitch operating pulley **9113** rotates. Also, the output unit **9323** of the second differential member **932** is connected with the second jaw wire **935**J2 to control the operation of the second jaw **922** of the end tool **920**.
(665) The pitch operating pulley **9113** is connected with the pitch wire **935**P to control the pitch operation of the end tool **920**.
(666) First, the pitch operation will be described below.
(667) As described above, when the user grips the pitch operating bar **9112** of the pitch operator **911** of the operator **910** and rotates the pitch operating bar **9112** around the pitch operating axis **9111** in the direction of an arrow P (pitch) of FIG. **47**, the pitch operating pulley **9113** rotates along with the pitch operating axis **9111**. Then, the pitch pulley **923** connected with the pitch operating pulley **9113** by the pitch wire **935**P, the first jaw pulley **924** connected therewith, the second jaw pulley **925**, the first jaw **921**, and the second jaw **922** rotate around a pitch rotating axis **920**PX to perform a pitch operation.
(668) In this case, the first J2P pulley **914***a* and the first J1P pulley **915***a* rotate around the pitch operating axis **9111**. Then, the first input unit **9311** of the first differential member **931** that is connected with the second J1P pulley **915***b* and the second input unit **9312** of the first differential member **931** that is connected with the pitch operating pulley **9113** rotate; however, since the rotations are offset in the first differential member **931**, the output unit **9313** of the first differential member **931** does not rotate. Likewise, the first input unit **9321** of the second differential member **932** that is connected with the second J2P pulley **914***b* and the second input unit **9322** of the second differential member **932** that is connected with the pitch operating pulley **9113** rotate; however, since the rotations are offset in the second differential member **932**, the output unit **9323** of the second differential member **932** does not rotate. Thus, the pitch operation may be performed independently of the yaw operation and the actuation operation.
(669) The yaw operation and the actuation operation of the present embodiment will be described below.
(670) For a yaw operation, the user holds and rotates the first jaw operating bar **9122** with the thumb finger in the direction of an arrow J1 of FIG. **47**, and holds and rotates the second jaw operating bar **9132** with the index finger in the direction of an arrow J2 of FIG. **47** (that is, rotates the first jaw operating bar **9122** and the second jaw operating bar **9132** in the same direction). For an actuation operation, the user rotates the first jaw operating bar **9122** in a direction opposite to the direction of the arrow J1 of FIG. **47**, and rotates the second jaw operating bar **9132** in the direction of the arrow J2 of FIG. **47** (that is, rotates the first jaw operating bar **9122** and the second jaw operating bar **9132** in opposite directions).
(671) Then, the first jaw operating pulley **9123** connected with the first jaw operating bar **9122** rotates around the first jaw operating axis **9121**, and the resulting rotating force is transmitted through the first jaw operating wire **935**J11 to the first J1P pulley **915***a* and the second J1P pulley **915***b* connected therewith, to rotate the second J1P pulley **915***b*. When the second J1P pulley **915***b*

rotates, the first input unit **9311** of the first differential member **931** connected therewith and the output unit **9313** of the first differential member **931** connected therewith rotate.
(672) At the same time, the second jaw operating pulley **9133** connected with the second jaw operating bar **9132** rotates around the second jaw operating axis **9131**, and the resulting rotating force is transmitted through the second jaw operating wire **935**J**21** to the first J**2**P pulley **914***a* and the second J**2**P pulley **914***b* connected therewith, to rotate the second J**2**P pulley **914***b*. When the second J**2**P pulley **914***b* rotates, the first input unit **9321** of the second differential member **932** connected therewith and the output unit **9323** of the second differential member **932** connected therewith rotate.
(673) As described above, the first J**2**P pulley **914***a* and the second J**2**P pulley **914***b* connected therewith rotate along with the second jaw operating pulley **9133** when the second jaw operating pulley **9133** rotates, and rotate along with the pitch operating pulley **9113** when the pitch operating pulley **9113** rotates. The first J**1**P pulley **915***a* and the second J**1**P pulley **915***b* connected therewith rotate along with the first jaw operating pulley **9123** when the first jaw operating pulley **9123** rotates, and rotate along with the pitch operating pulley **9113** when the pitch operating pulley **9113** rotates.
(674) Consequently, when the second J**1**P pulley **915***b* and the pitch operating pulley **9113** are connected respectively to the two input units of the first differential member **931**, only a pure operation control component of the first jaw **921** may be extracted from the rotation of the pitch operating pulley **9113** and the rotation of the first jaw operating pulley **9123**.
(675) Similarly, when the second J**2**P pulley **914***b* and the pitch operating pulley **9113** are connected respectively to the two input units of the second differential member **932**, only a pure operation control component of the second jaw **922** may be extracted from the rotation of the pitch operating pulley **9113** and the rotation of the second jaw operating pulley **9133**.
(676) Consequently, for a yaw operation, when the first jaw operating bar **9122** is rotated in the direction of the arrow J**1** of FIG. **47** and the second jaw operating bar **9132** is rotated in the direction of the arrow J**2** of FIG. **47**, the first J**2**P pulley **914***a* and the second J**2**P pulley **914***b* connected therewith rotate in the counterclockwise direction in FIG. **47** and the first J**1**P pulley **915***a* and the second J**1**P pulley **915***b* rotate in the counterclockwise direction in FIG. **47**. Then, the first input unit **9311** of the first differential member **931** connected with the second J**1**P pulley **915***b* rotates in the counterclockwise direction. Accordingly, the output unit **9313** of the first differential member **931** rotates in the counterclockwise direction, and the first jaw wire **935**J**1** connected with the output unit **9313**, the first jaw pulley **924** connected with the first jaw wire **935**J**1**, and the first jaw **921** connected with the first jaw pulley **924** rotate around a jaw rotating axis **920**JX in the counterclockwise direction. Likewise, the first input unit **9321** of the second differential member **932** connected with the second J**2**P pulley **914***b* rotates in the counterclockwise direction. Accordingly, the output unit **9323** of the second differential member **932** rotates in the counterclockwise direction, and the second jaw wire **935**J**2** connected with the output unit **9323**, the second jaw pulley **925** connected with the second jaw wire **935**J**2**, and the second jaw **922** connected with the second jaw pulley **925** rotate around the jaw rotating axis **920**JX in the counterclockwise direction. In this manner, the first jaw **921** and the second jaw **922** rotate in the same direction to perform a yaw operation.
(677) Similarly, for an actuation operation, when the first jaw operating bar **9122** is rotated in the direction of the arrow J**1** of FIG. **47** and the second jaw operating bar **9132** is rotated in the direction of the arrow J**2** of FIG. **47**, the first J**2**P pulley **914***a* and the second J**2**P pulley **914***b* connected therewith rotate in the counterclockwise direction in FIG. **47** and the first J**1**P pulley **915***a* and the second J**1**P pulley **915***b* rotate in the counterclockwise direction in FIG. **47**. Then, the first input unit **9311** of the first differential member **931** that is connected with the second J**1**P pulley **915***b* rotates in the clockwise direction. Accordingly, the output unit **9313** of the first differential member **931** rotates in the clockwise direction, and the first jaw wire **935**J**1** connected

with the output unit **9313**, the first jaw pulley **924** connected with the first jaw wire **935**J**1**, and the first jaw **921** connected with the first jaw pulley **924** rotate around the jaw rotating axis **920**JX in the clockwise direction. Likewise, the first input unit **9321** of the second differential member **932** that is connected with the second J**2**.sub.P pulley **914***b* rotates in the counterclockwise direction. Accordingly, the output unit **9323** of the second differential member **932** rotates in the counterclockwise direction, and the second jaw wire **935**J**2** connected with the output unit **9323**, the second jaw pulley **925** connected with the second jaw wire **935**J**2**, and the second jaw **922** connected with the second jaw pulley **925** rotate around the jaw rotating axis **920**JX in the counterclockwise direction. In this manner, the first jaw **921** and the second jaw **922** rotate in opposite directions to perform an actuation operation.
(678) Thus, according to the present invention, the yaw operation and the actuation operation of the end tool may be extracted respectively from the rotation of the first jaw operating pulley **9123** and the rotation of the second jaw operating pulley **9133**.
(679) According to the present invention, the pitch operation of the end tool, the rotation operation of the first jaw, and the rotation operation of the second jaw may be extracted respectively from the rotation of the pitch operating pulley **9113**, the rotation of the first jaw operating pulley **9123**, and the rotation of the second jaw operating pulley **9133**. Thus, even when the pitch, first jaw, and second jaw operations of the operator occur simultaneously or not, the pitch, yaw, and actuation operations of the operator may be independently divided into the pitch operation component of the end tool, the rotation operation component of the first jaw, and the rotation operation component of the second jaw.
(680) Any combination of various configurations of the operator described with reference to FIG. **3**A, various configurations of the operating force transmitter described with reference to FIGS. **4**A and **15** to **27**, and various modifications described with reference to FIGS. **7** to **14** may be applied to the surgical instrument **900** according to the ninth embodiment of the present invention.
(681) While the present invention has been described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The exemplary embodiments should be considered in descriptive sense only and not for purposes of limitation. Therefore, the scope of the invention is defined not by the detailed description of the invention but by the appended claims, and all differences within the scope will be construed as being included in the present invention.
INDUSTRIAL APPLICABILITY
(682) The present invention relates to surgical instruments and may be applied to surgical instruments that may be manually operated to perform laparoscopic operations or various surgical operations.

Claims

1. An end tool for a surgical instrument, the end tool comprising: a first jaw and a second jaw configured to operate independently of each other; and an end tool control member including: a first pulley coupled with the first jaw and rotatable around a first axis; a second pulley and a fourth pulley each being rotatable around an end tool pitch operating axis making a first predetermined angle with the first axis, the second pulley and the fourth pulley being arranged on both sides of the end tool pitch operating axis to face each other; a third pulley and a fifth pulley each being rotatable around a second axis making a second predetermined angle with the first axis, the third pulley and the fifth pulley facing each other; a sixth pulley coupled with the second jaw and facing the first pulley; a seventh pulley and a ninth pulley each being rotatable around the end tool pitch operating axis making the first predetermined angle with the first axis, the seventh pulley and the ninth pulley being arranged on both sides of the end tool pitch operating axis to face each other; a

eighth pulley and a tenth pulley each being rotatable around a third axis making a third predetermined angle with the first axis, the eighth pulley and the tenth pulley facing each other; a first jaw operating wire, at least a portion of the first jaw operating wire being configured to sequentially contact the third pulley, the second pulley, the first pulley, the fourth pulley, and the fifth pulley to rotate the first pulley, the second pulley, the third pulley, the fourth pulley, and the fifth pulley; and a second jaw operating wire, at least a portion of the second jaw operating wire being configured to sequentially contact the eighth pulley, the seventh pulley, the sixth pulley, the ninth pulley, and the tenth pulley to rotate the sixth pulley, the seventh pulley, the eighth pulley, the ninth pulley, and the tenth pulley, wherein the end tool control member further includes a pitch pulley that is configured to rotate around the end tool pitch operating axis making the first predetermined angle with the first axis, and a pitch wire that is wound around the pitch pulley, the pitch wire being configured to transmit a pitch motion of an operator to the pitch pulley, wherein the end tool control member further includes a wire guide disposed between the first axis and the end tool pitch operating axis to contact at least a portion of one of the first jaw operating wire and the second jaw operating wire, wherein based on a first plane extending between the first pulley and the second pulley and being perpendicular to the first axis, the first jaw operating wire is configured to: contact the third pulley on one side of the first plane, contact the second pulley on another side of the first plane, contact the fourth pulley on the one side of the first plane, and contact the fifth pulley on the another side of the first plane, wherein based on the first plane extending between the first pulley and the second pulley and being perpendicular to the first axis, the second jaw operating wire is configured to: contact the eighth pulley on the one side of the first plane, contact the seventh pulley on the another side of the first plane, contact the ninth pulley on the one side of the first plane, and contact the tenth pulley on the another side of the first plane.
2. The end tool of claim 1, wherein with respect to a second plane being perpendicular to the first axis and including a rotating axis of each of the third pulley, the second pulley, the fourth pulley, and the fifth pulley, the first jaw operating wire is configured to sequentially contact an upper side of the third pulley, a lower side of the second pulley, an upper side of the fourth pulley, and a lower side of the fifth pulley, and wherein with respect to a third plane being perpendicular to the first axis and including a rotating axis of each of the eighth pulley, the seventh pulley, the ninth pulley, and the tenth pulley, the second jaw operating wire is configured to sequentially contact a lower side of the eighth pulley, an upper side of the seventh pulley, a lower side of the ninth pulley, and an upper side of the tenth pulley.
3. The end tool of claim 1, wherein with respect to a fourth plane that is perpendicular to the first axis and passes through a center of the third pulley, the first jaw operating wire is configured to enter from one side, either an upper side or a lower side, of the fourth plane, and wherein with respect to a fifth plane that is perpendicular to the first axis and passes through a center of the fifth pulley, the first jaw operating wire, after entering from the one side of the fourth plane, is configured to exit from another side, either an upper side or a lower side, of the fifth plane, which is a side relatively opposite to the one side from which the first jaw operating wire enters.
4. The end tool of claim 3, wherein the first jaw operating wire, after entering from the one side of the fourth plane, is configured to pass through a sixth plane passing through a center of the first axis and a center of the second pulley.
5. The end tool of claim 1, wherein with respect to a seventh plane that is perpendicular to the first axis and passes through a center of the eighth pulley, the second jaw operating wire is configured to enter from one side, either an upper side or a lower side, of the seventh plane, and wherein with respect to an eighth plane that is perpendicular to the first axis and passes through a center of the tenth pulley, the second jaw operating wire, after entering from the one side of the seventh plane, is configured to exit from another side, either an upper side or a lower side, of the eighth plane, which is a side relatively opposite to the one side from which the second jaw operating wire enters.
6. The end tool of claim 5, wherein the second jaw operating wire, after entering from the one side

of the seventh plane, is configured to pass through a plane passing through a center of the first axis and the center of the eighth pulley.

7. An end tool for a surgical instrument, the end tool comprising: a first jaw and a second jaw configured to operate independently of each other; and an end tool control member including: a first pulley coupled with the first jaw and rotatable around a first axis; a second pulley and a fourth pulley each being rotatable around an end tool pitch operating axis making a first predetermined angle with the first axis, the second pulley and the fourth pulley being arranged on both sides of the end tool pitch operating axis to face each other; a third pulley and a fifth pulley each being rotatable around a second axis making a second predetermined angle with the first axis, the third pulley and the fifth pulley facing each other; a sixth pulley coupled with the second jaw and facing the first pulley; a seventh pulley and a ninth pulley each being rotatable around the end tool pitch operating axis making the first predetermined angle with the first axis, the seventh pulley and the ninth pulley being arranged on both sides of the end tool pitch operating axis to face each other; an eighth pulley and a tenth pulley each being rotatable around a third axis making a third predetermined angle with the first axis, the eighth pulley and the tenth pulley facing each other; a first jaw operating wire, at least a portion of the first jaw operating wire being configured to sequentially contact the third pulley, the second pulley, the first pulley, the fourth pulley, and the fifth pulley to rotate the first pulley, the second pulley, the third pulley, the fourth pulley, and the fifth pulley; and a second jaw operating wire, at least a portion of the second jaw operating wire being configured to sequentially contact the eighth pulley, the seventh pulley, the sixth pulley, the ninth pulley, and the tenth pulley to rotate the sixth pulley, the seventh pulley, the eighth pulley, the ninth pulley, and the tenth pulley, wherein based on one plane extending between the first pulley and the second pulley and being perpendicular to the first axis, the first jaw operating wire or the second jaw operating wire is configured to enter the end tool control member from one side of the one plane and exit from the one side of the one plane, wherein based on the one plane extending between the first pulley and the second pulley and being perpendicular to the first axis, the first jaw operating wire is further configured to: contact the third pulley on one side of the one plane, contact the second pulley on another side of the one plane, contact the fourth pulley on the one side of the one plane, and contact the fifth pulley on the another side of the one plane, and wherein based on the one plane extending between the first pulley and the second pulley and being perpendicular to the first axis, the second jaw operating wire is further configured to: contact the eighth pulley on the one side of the one plane, contact the seventh pulley on the another side of the one plane, contact the ninth pulley on the one side of the one plane, and contact the tenth pulley on the another side of the one plane.

8. The end tool of claim 7, wherein based on the one plane, the first jaw operating wire is configured to: contact the third pulley on the one side of the one plane, sequentially contact the second pulley, the first pulley, and the fourth pulley on another side of the one plane, and contact the fifth pulley on the one side of the one plane.

9. The end tool of claim 7, wherein based on the one plane, the second jaw operating wire is configured to: contact the eighth pulley on another side of the one plane, sequentially contact the seventh pulley, the sixth pulley, and the ninth pulley on the one side of the one plane, and contact the tenth pulley on the another side of the one plane.

10. The end tool of claim 7, wherein the first jaw operating wire and the second jaw operating wire are only wires that are configured to control a pitch motion, a yaw motion, and an actuation motion of the end tool.

11. The end tool of claim 10, wherein the pitch motion of the end tool is performed when opposite sides of a wire of one or more of the first jaw operating wire and the second jaw operating wire, which is wound around the end tool, are pulled simultaneously.

12. The end tool of claim 10, wherein the yaw motion or the actuation motion of the end tool is performed when one side of a wire of one or more of the first jaw operating wire and the second

jaw operating wire, which is wound around the end tool, is pulled and another side of the wire is pushed.

13. The end tool of claim 7, further comprising a pitch pulley configured to rotate around the end tool pitch operating axis of each of the second pulley and the fourth pulley.

14. An end tool for a surgical instrument, the end tool comprising: a first jaw and a second jaw configured to operate independently of each other; and an end tool control member including: a first pulley coupled with the first jaw and rotatable around a first axis; a second pulley and a fourth pulley each being rotatable around an end tool pitch operating axis making a first predetermined angle with the first axis, the second pulley and the fourth pulley being arranged on both sides of the end tool pitch operating axis to face each other; a third pulley and a fifth pulley each being rotatable around a second axis making a second predetermined angle with the first axis, the third pulley and the fifth pulley facing each other; a sixth pulley coupled with the second jaw and facing the first pulley; a seventh pulley and a ninth pulley each being rotatable around the end tool pitch operating axis making the first predetermined angle with the first axis, the seventh pulley and the ninth pulley being arranged on both sides of the end tool pitch operating axis to face each other; an eighth pulley and a tenth pulley each being rotatable around a third axis making a third predetermined angle with the first axis, the eighth pulley and the tenth pulley facing each other; a first jaw operating wire, at least a portion of the first jaw operating wire being configured to sequentially contact the third pulley, the second pulley, the first pulley, the fourth pulley, and the fifth pulley to rotate the first pulley, the second pulley, the third pulley, the fourth pulley, and the fifth pulley; and a second jaw operating wire, at least a portion of the second jaw operating wire being configured to sequentially contact the eighth pulley, the seventh pulley, the sixth pulley, the ninth pulley, and the tenth pulley to rotate the sixth pulley, the seventh pulley, the eighth pulley, the ninth pulley, and the tenth pulley, wherein with respect to one plane being perpendicular to the first axis and including a rotating axis of each of the third pulley, the second pulley, the fourth pulley, and the fifth pulley, the first jaw operating wire is configured to sequentially contact an upper side of the third pulley, a lower side of the second pulley, a lower side of the fourth pulley, and an upper side of the fifth pulley, and with respect to another plane being perpendicular to the first axis and including a rotating axis of each of the eighth pulley, the seventh pulley, the ninth pulley, and the tenth pulley, the second jaw operating wire is configured to sequentially contact a lower side of the eighth pulley, an upper side of the seventh pulley, an upper side of the ninth pulley, and a lower side of the tenth pulley, wherein based on the one plane extending between the first pulley and the second pulley and being perpendicular to the first axis, the first jaw operating wire is further configured to: contact the third pulley on one side of the one plane, contact the second pulley on another side of the one plane, contact the fourth pulley on the one side of the one plane, and contact the fifth pulley on the another side of the one plane, wherein based on the another plane extending between the first pulley and the second pulley and being perpendicular to the first axis, the second jaw operating wire is further configured to: contact the eighth pulley on the one side of the another plane, contact the seventh pulley on the another side of the another plane, contact the ninth pulley on the one side of the another plane, and contact the tenth pulley on the another side of another plane.

15. The end tool of claim 14, further comprising a pitch pulley configured to rotate around the end tool pitch operating axis of each of the second pulley and the fourth pulley.