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(54) **POSITIONING DEVICE**

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(57) **ABSTRACT**

A positioning device including a plurality of finger portions formed so as to be movable in a radial direction perpendicular to the axial direction and a wedge-shaped pressing member disposed so as to contact the plurality of finger portions. The positioning device further includes a moving device that moves the pressing member in the axial direction. By the moving device moving the pressing member in a state in which the finger portions are inserted into a plurality of hole portions of a workpiece, the finger portions are moved outward in the radial direction, thereby positioning the plurality of hole portions of the workpiece.

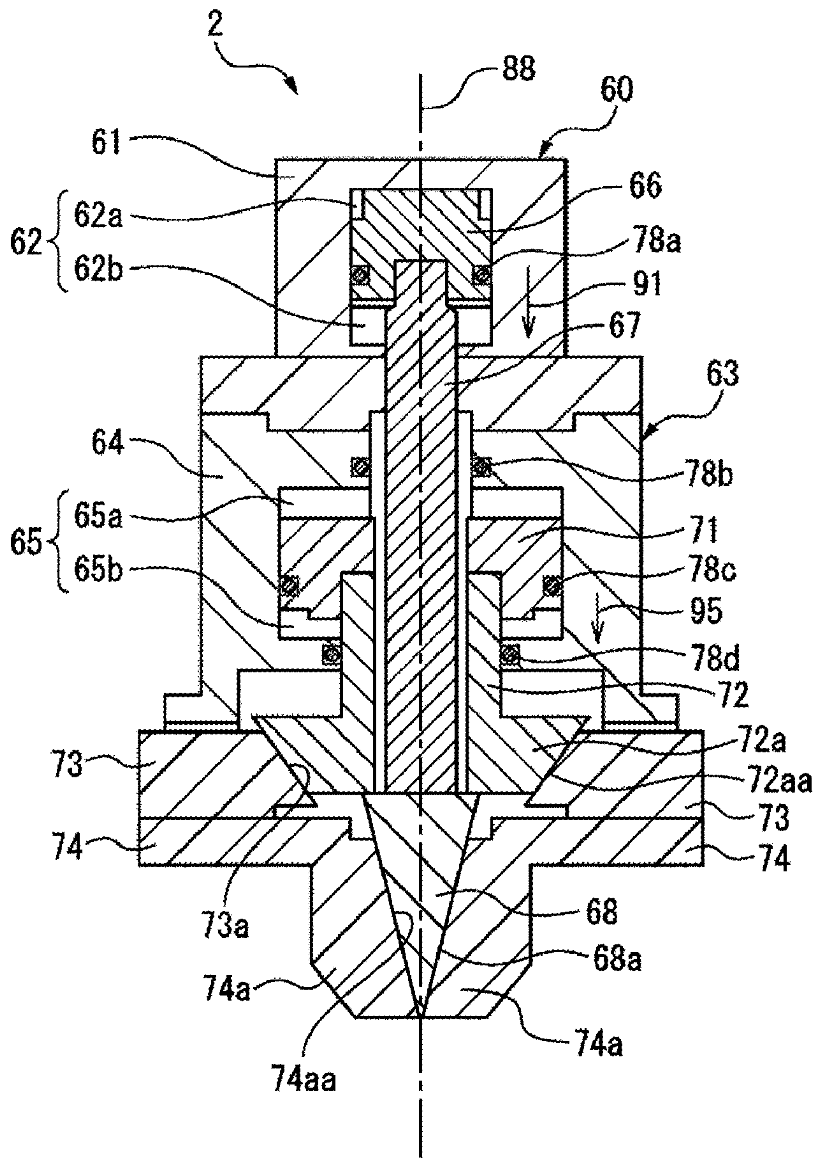
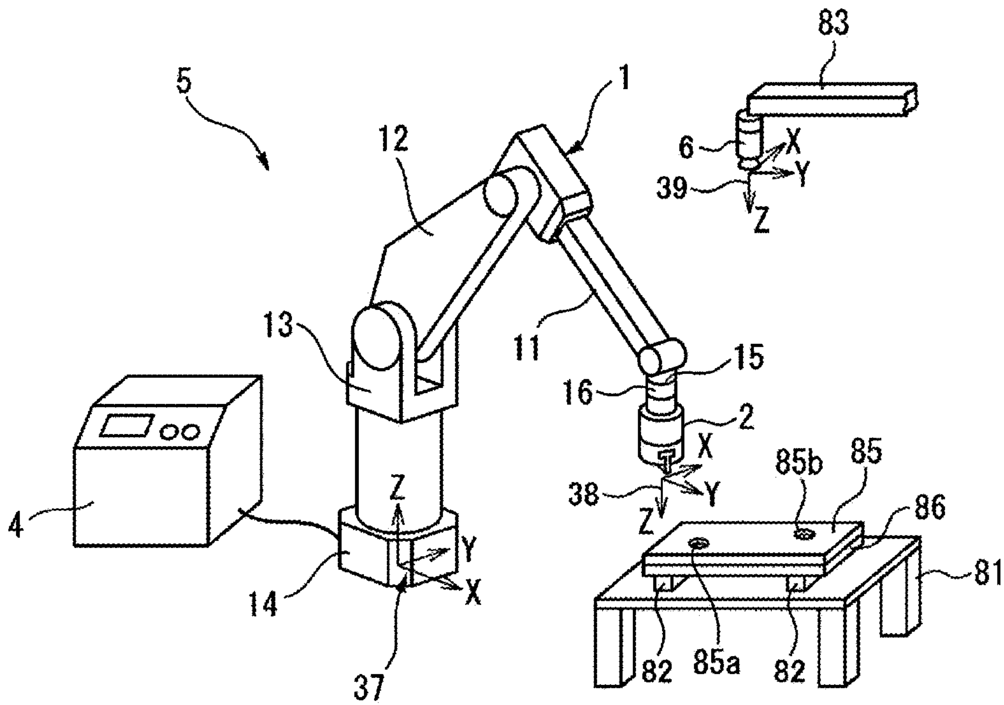


Fig. 1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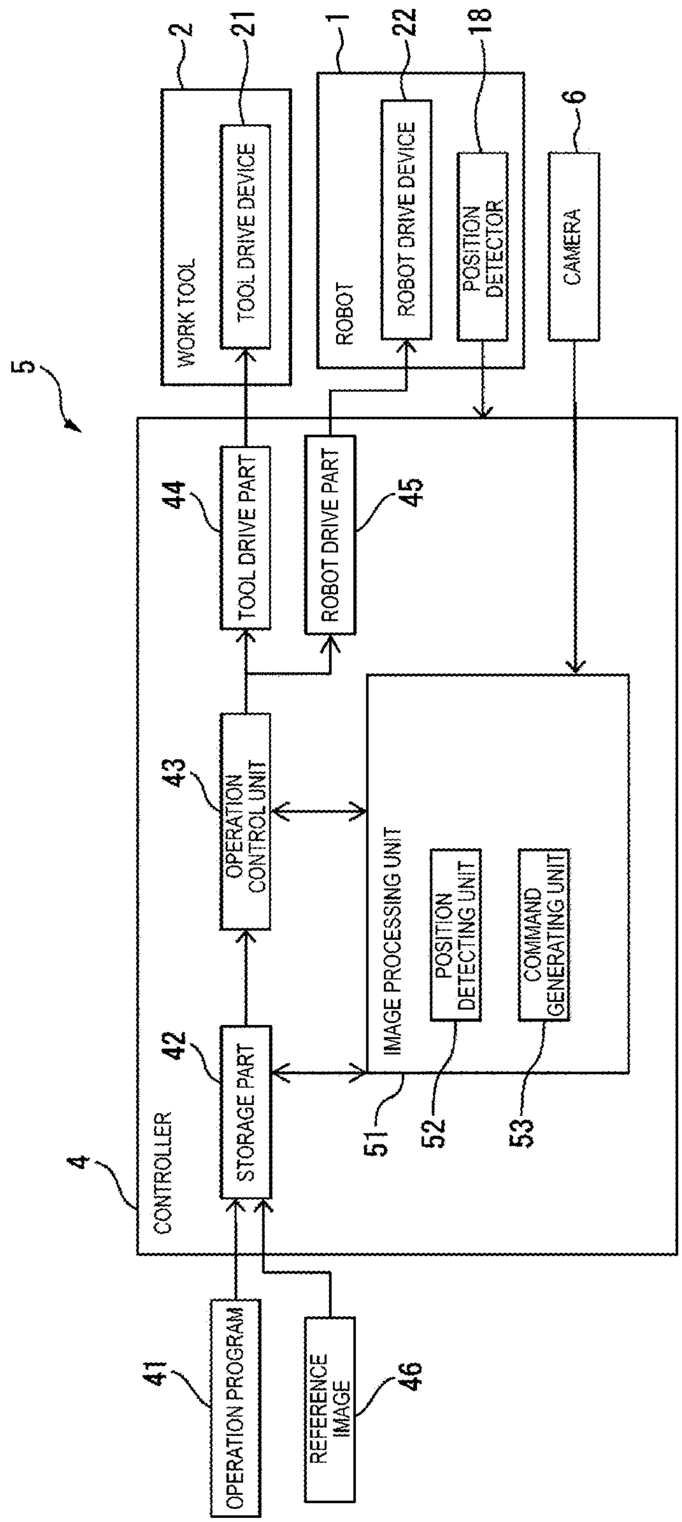
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TOOL DRIVE DEVICE
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CONTROLLER
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TOOL DRIVE PART
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ROBOT DRIVE PART
43
OPERATION CONTROL UNIT
42
STORAGE PART
IMAGE PROCESSING UNIT
POSITION DETECTING UNIT
COMMAND GENERATING UNIT
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OPERATION PROGRAM
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REFERENCE IMAGE

Fig. 2

Fig. 3

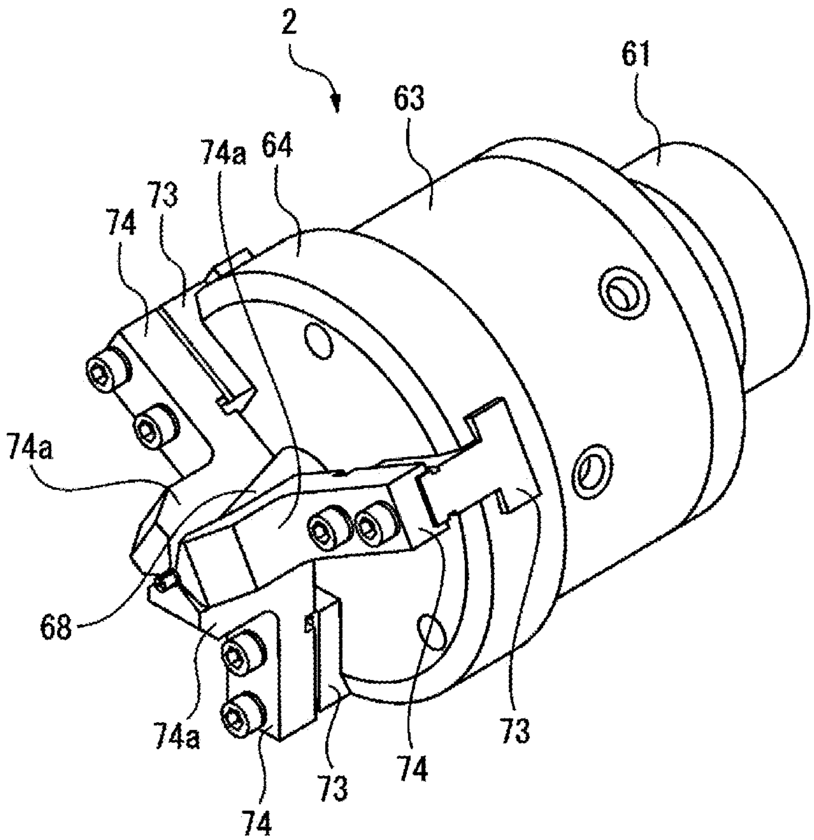

Fig. 4

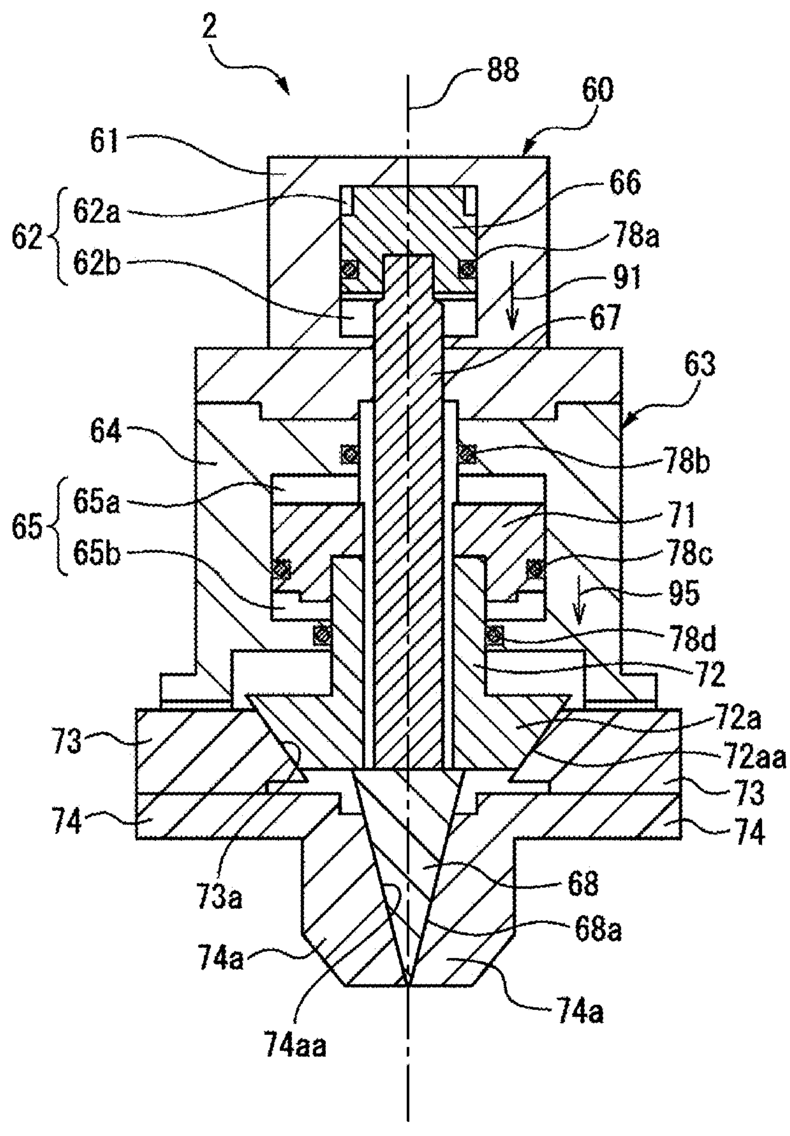
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Fig. 5

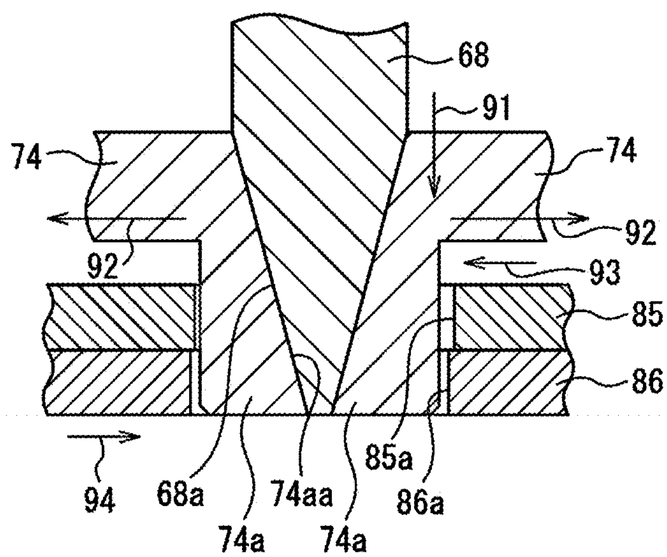

Fig. 6

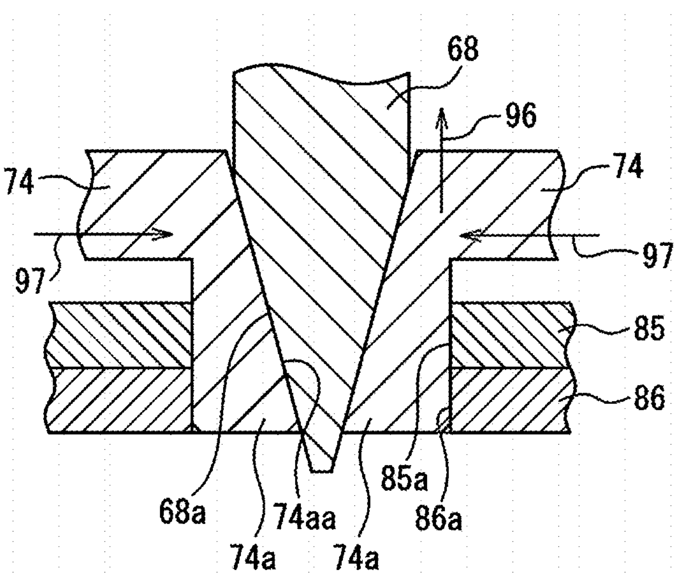

Fig. 7

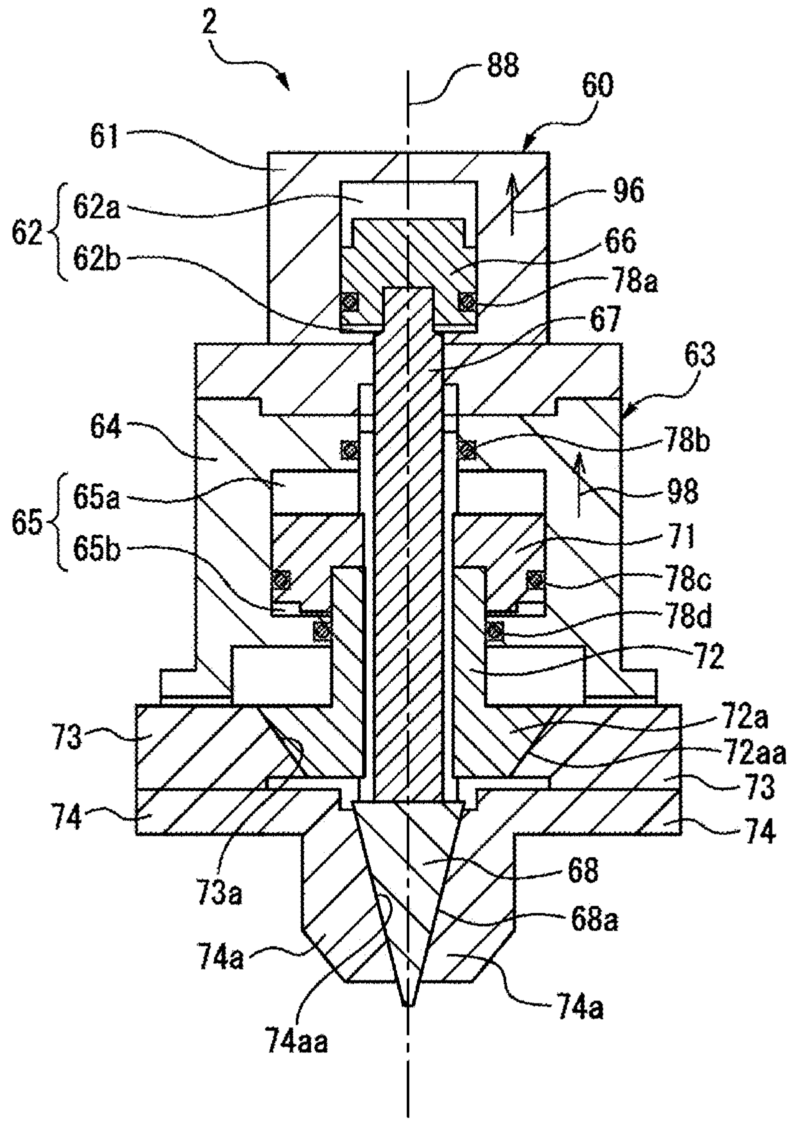
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Fig. 8

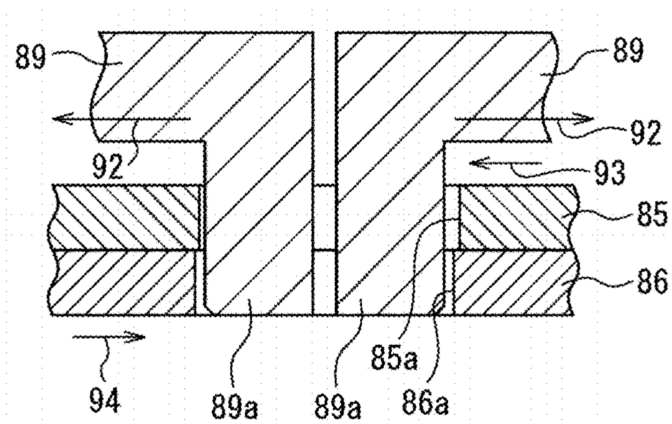


Fig. 9

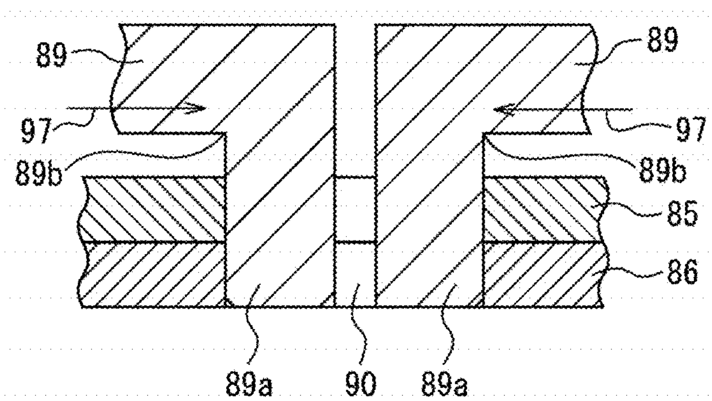


Fig. 10

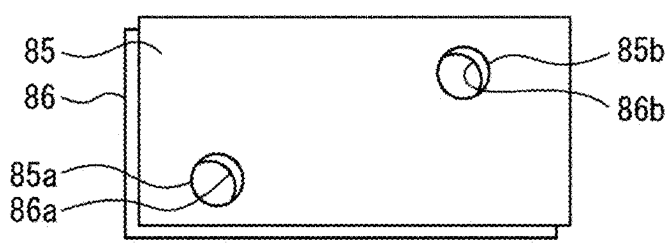


Fig. 11

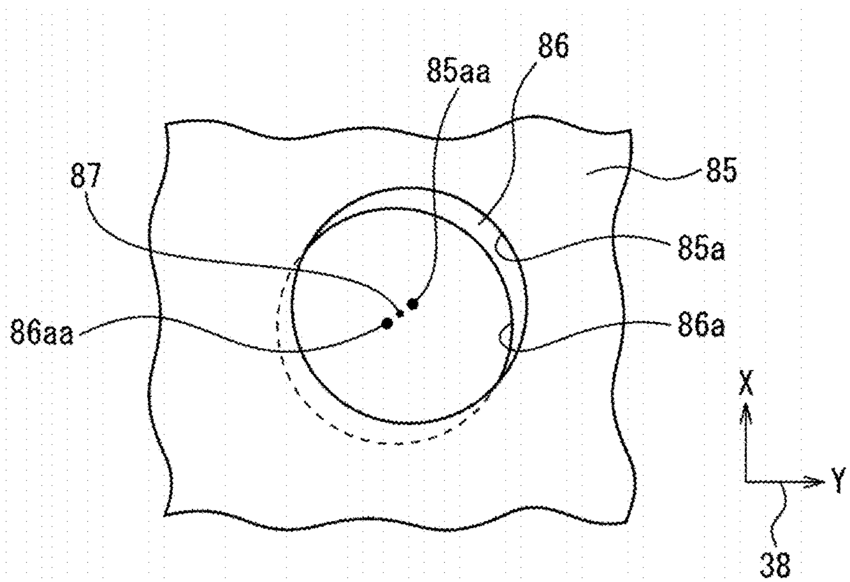
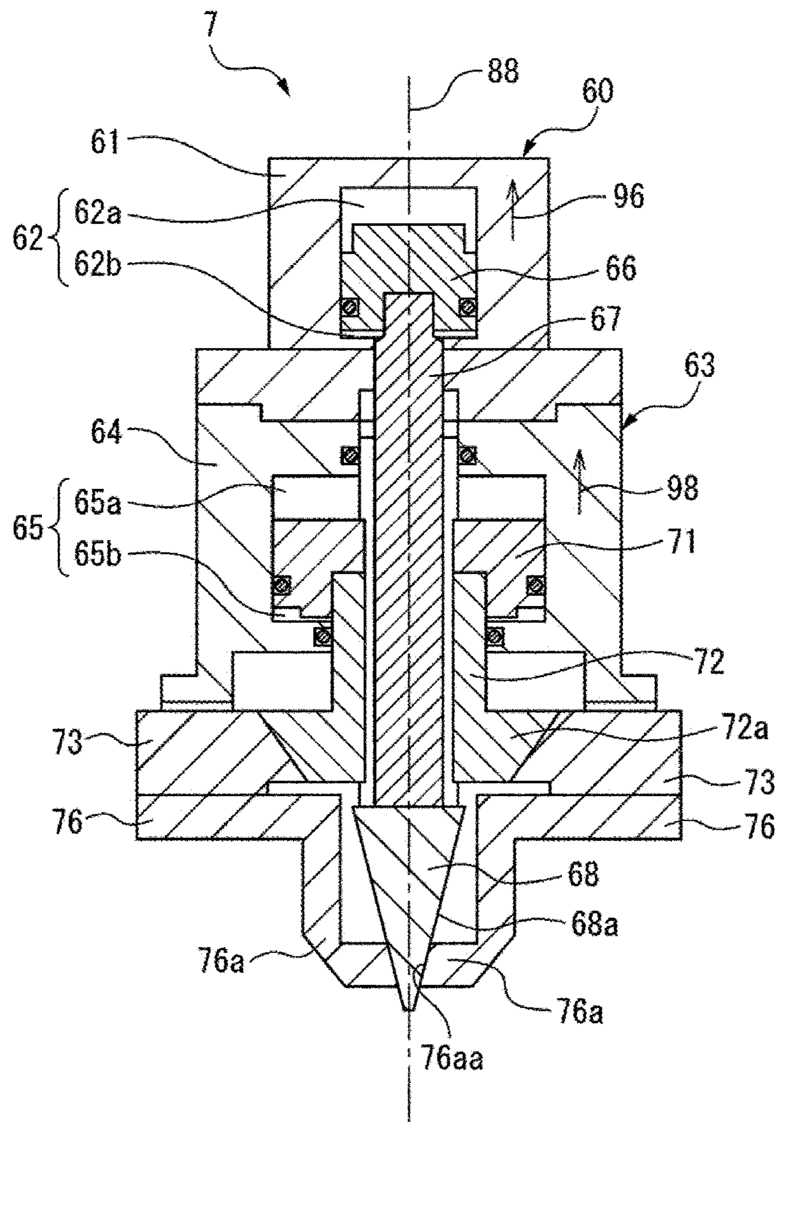


Fig. 12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POSITIONING DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a bypass continuation application of International Application No. PCT/JP2022/045345 filed Dec. 8, 2022.

BACKGROUND

Field

[0002] The present disclosure relates to a positioning device.

Discussion of the Related Art

[0003] In a process of manufacturing a product, there is a step in which, after stacking a plurality of workpieces, holes formed in the workpieces are positioned. For example, there is a case in which a plurality of workpieces are fixed to each other by inserting a bolt into holes after positioning of the holes. Alternatively, there is a case in which the positions of the holes are aligned with each other, and then a rod-shaped member such as a pin or a shaft is inserted into the holes of the workpieces.

[0004] When the positions of the plurality of holes are displaced from each other, a member such as a bolt or a shaft cannot be smoothly inserted into the holes in some cases. For this reason, when the holes are viewed from an axial direction, the positions of the plurality of holes need to coincide exactly with each other.

[0005] In the prior art, in order to align the positions of holes of a plurality of workpieces, there is known a device in which a hole clamp for holding the holes is inserted into the holes so as to align the positions of the holes with the clamping force. However, when the hole clamp is large, there is a case where the hole clamp may not be able to be inserted into the holes. Alternatively, there is known a method of using an air chuck in order to align the positions of holes of a plurality of workpieces. Fingers of the air chuck are inserted into the holes. Accordingly, there is known a device for positioning of holes by opening a plurality of such fingers.

[0006] In a device for aligning the positions of holes with each other by opening fingers of an air chuck, there is a case in which, when the diameter of the hole is small, a finger may be deformed or broken because the rigidity of the finger cannot be increased. Alternatively, also in a case where a large opening force of the air chuck is required, a finger may be deformed or broken. When a finger is broken, it needs to be replaced. As explained above, in the case where the air chuck is used as a device for positioning of the holes, there is a problem in that the durability of the device is low.

SUMMARY

[0007] A positioning device according to an aspect of the present disclosure includes a plurality of fingers formed to be movable in a radial direction perpendicular to an axial direction, and a pressing member having a wedge shape and disposed so as to be in contact with the plurality of fingers. The positioning device further includes a movement device configured to move the pressing member in the axial direction. When the movement device moves the pressing member in a state in which the fingers are inserted into holes of a plurality of workpieces, the fingers move outward in the radial direction to align positions of the holes of the plurality of workpieces.

BRIEF DESCRIPTION OF DRAWINGS

[0008] FIG. **1** is a schematic perspective view of a robot apparatus according to an embodiment.

[0009] FIG. **2** is a block diagram of the robot apparatus according to the embodiment.

[0010] FIG. **3** is a perspective view of a work tool according to the embodiment.

[0011] FIG. **4** is a schematic cross-sectional view of the work tool according to the embodiment.

[0012] FIG. **5** is an enlarged schematic cross-sectional view of a first step of aligning hole positions in the work tool according to the embodiment.

[0013] FIG. **6** is an enlarged schematic cross-sectional view of a second step of aligning hole positions in the work tool according to the embodiment.

[0014] FIG. **7** is an enlarged schematic cross-sectional view when the work tool according to the embodiment has adjusted the positions of the holes.

[0015] FIG. **8** is an enlarged schematic cross-sectional view of a first step of aligning hole positions in a positioning device according to a comparative example.

[0016] FIG. **9** is an enlarged schematic cross-sectional view of a second step of aligning hole positions in the positioning device according to the comparative example.

[0017] FIG. **10** is a plan view when two plate-shaped workpieces are stacked.

[0018] FIG. **11** is an enlarged view of an image of holes when two workpieces are stacked.

[0019] FIG. **12** is a schematic cross-sectional view of another positioning device according to the embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0020] A positioning device and a robot apparatus including the positioning device and a robot in the embodiment will be described with reference to FIG. **1** to FIG. **12**. The positioning device of the present embodiment adjusts relative positions of a plurality of workpieces so that the positions of holes formed in the workpieces are aligned with each other when the plurality of workpieces are stacked and arranged.

[0021] FIG. **1** is a perspective view of a robot apparatus in the present embodiment. A robot apparatus **5** of the present embodiment includes a robot **1** and a work tool **2**. The robot apparatus **5** includes a controller **4** configured to control the robot **1** and the work tool **2**. In the present embodiment, the work tool **2** attached to the robot **1** corresponds to a positioning device. The robot apparatus **5** changes the position and orientation of the positioning device, and inserts a finger of the positioning device into holes of a plurality of workpieces **85**, **86**. The positioning device then aligns the positions of the holes with each other.

[0022] The robot **1** of the present embodiment is an articulated robot including a plurality of joints. The robot **1** includes an upper arm **11** and a lower arm **12**. The lower arm **12** is supported by a swivel base **13**. The swivel base **13** is supported by a base **14**. The robot **1** includes a wrist **15**

connected to an end portion of the upper arm **11**. The wrist **15** includes a flange **16** attached with the work tool **2** and formed to be rotatable.

[0023] These constituent members of the robot **1** are each formed so as to rotate about a predetermined rotation axis. The robot of the present embodiment has six drive axes, but is not limited to this configuration. The robot may employ any robot that can change the position and orientation of the work tool.

[0024] The work tool **2** of the present embodiment functions as a positioning device for aligning the positions of holes formed in a plurality of workpieces. The workpieces **85** and **86** of the present embodiment are each formed in a plate shape. The workpieces **85** and **86** are set on platforms **81** and **82**. The workpieces **85** and **86** are each arranged so that an area-maximum surface having the largest area extends in a horizontal direction. As will be described later, holes **85***a* and **85***b* are formed in the workpiece **85**. Holes **86***a* and **86***b* are formed in the workpiece **86**.

[0025] In the present embodiment, the workpiece **85** and the workpiece **86** have the same shape. When the two workpieces **85** and **86** are stacked and viewed in a plan view, the position of the hole **85***a* and that of the hole **86***a* substantially coincide with each other. The hole **85***a* and the hole **86***a* have the same shape. The position of the hole **85***b* and the position of the hole **86***b* substantially coincide with each other. The hole **85***b* and the hole **86***b* have the same shape. However, the positions of the holes are slightly displaced from each other in a plan view in some cases.

[0026] The robot apparatus **5** of the present embodiment performs an operation of aligning a relative position of the workpiece **86** with respect to the workpiece **85** by using the work tool **2** so that the positions of the holes are coincident with each other in a plan view. Thereafter, an operation of inserting a member such as a bolt or a pin into the holes is performed by, for example, another robot apparatus.

[0027] The robot apparatus **5** of the present embodiment includes a camera **6** as a vision sensor for detecting the positions of the holes of the workpieces **85** and **86**. The position of the camera **6** of the present embodiment is fixed by a support member **83**. The camera **6** of the present embodiment is a two-dimensional camera. The camera **6** is controlled by a controller **4**. The camera **6** of the present embodiment captures an image of the workpieces **85** and **86**. The camera **6** is disposed so as to capture an image of an object located just under the camera. In other words, the camera **6** is fixed such that an optical axis extends in the vertical direction.

[0028] The distances from the workpieces **85** and **86** to the camera **6** are measured in advance. Because of this, a three-dimensional position can be detected based on a position in a two-dimensional image that the camera **6** captures. For example, a reference image **46** of the hole **85***a* can be stored in a storage part **42**. Then, the three-dimensional position of the hole **85***a* can be detected by pattern matching of the image captured by the camera **6**.

[0029] A reference coordinate system **37**, which is immovable when a change in the position and orientation of the robot **1** occurs, is set in the robot apparatus **5** of the present embodiment. In the example illustrated in FIG. **1**, the reference coordinate system **37** has the origin arranged at the base **14** of the robot **1**. The reference coordinate system **37** is also referred to as a world coordinate system.

[0030] In the robot apparatus **5**, a tool coordinate system **38** having the origin set at an arbitrary position of the work tool **2** is set. The tool coordinate system **38** changes the position and orientation together with the work tool **2**. In the present embodiment, the origin of the tool coordinate system **38** is set at a tool center point.

[0031] When the position and the orientation of the robot **1** change, the position of the origin and the orientation of the tool coordinate system **38** change. The position of the robot **1** corresponds to the position of the tool center point (the position of the origin of the tool coordinate system **38**). The orientation of the robot **1** corresponds to the orientation of the tool coordinate system **38** with respect to the reference coordinate system **37**.

[0032] Further, in the robot apparatus **5**, a camera coordinate system **39** is set with respect to the camera **6**. The camera coordinate system **39** is a coordinate system in which the origin is fixed to the camera **6**. In the present embodiment, since the position of the camera **6** is fixed, the position of the camera coordinate system **39** is likewise fixed. In the present embodiment, the camera coordinate system **39** is set such that the Z axis of the camera coordinate system **39** coincides with the optical axis.

[0033] Each of the coordinate systems has X axis, Y axis, and Z axis orthogonal to each other as the coordinate axes. In addition, W axis serving as a coordinate axis around the X axis, P axis serving as a coordinate axis around the Y axis, and R axis serving as a coordinate axis around the Z axis may be set.

[0034] FIG. **2** is a block diagram of the robot apparatus according to the present embodiment. Referring to FIG. **1** and FIG. **2**, the robot **1** includes a robot drive device **22** configured to change the position and the orientation of the robot **1**. The robot drive device **22** includes drive motors configured to drive constituent members such as the arm, the wrist, and the like. A direction of each constituent member is changed by driving the robot drive device **22**.

[0035] The robot apparatus **5** includes a tool drive device **21** configured to drive the work tool **2**. The work tool **2** of the present embodiment is driven by air pressure. The tool drive device **21** of the present embodiment includes a cylinder, an electromagnetic valve, and the like.

[0036] The controller **4** controls operations of the robot **1** and the work tool **2**. The controller **4** has an arithmetic processing device (computer) including a central processing unit (CPU) as a processor. The arithmetic processing device includes a random access memory (RAM), a read only memory (ROM), and the like, which are mutually connected to the CPU via a bus. The robot apparatus **5** of the present embodiment adjusts the relative positions of the holes of the workpiece **86** with respect to the holes of the workpiece **85** based on an operation program **41**. The robot drive device **22** and the tool drive device **21** are controlled by the controller **4**.

[0037] The controller **4** includes the storage part **42** for storing information relating to the control of the robot apparatus **5**. The storage part **42** may be constituted by a non-transitory storage medium capable of storing information. For example, the storage part **42** may be constituted by a storage medium such as a volatile memory, a nonvolatile memory, a magnetic storage medium, or an optical storage medium. The operation program **41** is stored in the storage part **42**.

[0038] An operation control unit **43** transmits an operation command for driving the robot **1** to a robot drive part **45** based on the operation program **41**. The robot drive part **45** includes an electric circuit configured to drive the robot drive device **22**. The robot drive part **45** supplies electricity to the robot drive device **22**, based on the operation command.

[0039] Moreover, the operation control unit **43** transmits, to a tool drive part **44**, an operation command for driving the work tool **2** based on the operation program **41**. The tool drive part **44** includes an electric circuit configured to drive the tool drive device **21**. The tool drive part **44** supplies electricity to the tool drive device **21**, based on the operation command. The operation control unit **43** transmits, to the camera **6**, an operation command for driving the camera **6**, based on the operation program **41**. The camera **6** captures an image based on the operation command.

[0040] The operation control unit **43** is equivalent to a processor driven in accordance with the operation program **41**. The processor is configured to be able to read information stored in the storage part **42**. The processor functions as the operation control unit **43** by reading the operation program **41** and performing control defined in the operation program **41**.

[0041] The robot **1** includes a state detector for detecting the position and orientation of the robot **1**. The state detector in the present embodiment includes a position detector **18** attached to the drive motor of the robot drive device **22** corresponding to the drive axis of the constituent member such as the arm. The position and the orientation of the robot **1** are calculated, based on the output of the position detector **18**.

[0042] The controller **4** in the present embodiment includes an image processing unit **51** configured to process an image that is captured by the camera **6**. The image processing unit **51** includes a position detecting unit **52** for detecting a three-dimensional position of a target portion based on the image acquired by the camera **6**.

[0043] The position detecting unit **52** in the present embodiment detects the positions of the holes of the workpieces. As a position of the hole of the workpiece, for example, it is possible to detect the position of the center of a planar shape of the hole in a surface including the top face of the workpiece. In the present embodiment, the reference image **46** of the workpiece is stored in advance in the storage part **42**. Alternatively, the reference image **46** of the hole of the workpiece is stored in advance in the storage part **42**. The position detecting unit **52** can detect the position of the hole in the image by performing pattern matching on the image captured by the camera **6** by using the reference image **46**.

[0044] In this case, a distance from the camera **6** to the workpiece **85** is measured in advance. Accordingly, the position detecting unit **52** can detect a three-dimensional position of the hole based on the position in the two-dimensional image that is captured by the camera **6**. For example, in the camera coordinate system **39**, the position of the center of the planar shape of the hole **85***a* of the workpiece **85** can be calculated. The camera coordinate system **39** of the present embodiment is fixed. The position and the orientation of the camera coordinate system **39** in the reference coordinate system **37** are predetermined. Therefore, the position detecting unit **52** can convert the position and orientation of the hole in the camera coordinate system **39** into the position and orientation of the hole in the reference coordinate system **37**.

[0045] The image processing unit **51** includes a command generating unit **53** configured to generate an operation command for the robot **1** based on the position of the hole detected by the position detecting unit **52**. For example, the command generating unit **53** generates an operation command so as to move the tool center point in the vertical direction after arranging the tool center point at the center position of the hole. The operation command generated by the command generating unit **53** is transmitted to the operation control unit **43**. The operation control unit **43** drives the robot **1** and the work tool **2** based on the operation commands generated by the command generating unit **53**.

[0046] Each of the image processing unit **51**, the position detecting unit **52**, and the command generating unit **53** is equivalent to a processor that is driven in accordance with a predetermined program. The processor functions as each unit by reading the program and performing control defined in the program.

[0047] FIG. **3** illustrates a perspective view of the work tool in the present embodiment. FIG. **4** illustrates an enlarged schematic cross-sectional view of the work tool in the present embodiment. FIG. **4** is a cross-sectional view taken along a radial direction at the positions of a plurality of fingers. FIG. **4** illustrates a state of the work tool before the positioning of the holes is performed. In the present embodiment, a direction in which the pressing member **68** moves is referred to as an axial direction. A direction in which an axis **88** of a center axis extends is referred to as the axial direction. Further, a direction perpendicular to the axial direction is referred to as the radial direction.

[0048] The work tool **2** includes a plurality of fingers **74** formed to be movable in the radial direction. In the present embodiment, three fingers **74** are disposed. The finger **74** is fixed to a slide member **73**. The slide member **73** is formed to be slidable in the radial direction relative to a second cylinder case **64**. The finger **74** moves integrally with the slide member **73**.

[0049] The work tool **2** includes the pressing member **68** for moving the plurality of fingers **74** in the radial direction. The pressing member **68** has a wedge-shaped cross section. The pressing member **68** in the present embodiment is formed in a conical shape. The pressing member **68** is disposed so as to be in contact with inner surfaces of the plurality of fingers **74**.

[0050] Each finger **74** has an erected part **74***a* extending along the axis **88**. The erected part **74***a* has an inclined surface **74***aa* on the inner side. The inclined surface **74***aa* is in close contact with an inclined surface **68***a*, which is an outer circumferential surface of the pressing member **68**. The pressing member **68** has a shape that tapers in a direction toward a distal end of the erected part **74***a*. In this way, the pressing member **68** is pinched between the plurality of fingers **74** and is formed so as to be in close contact with inner circumferential surfaces of the plurality of fingers **74**.

[0051] The work tool **2** is configured such that the fingers **74** open or close as the pressing member **68** moves in the direction of the axis **88**. The work tool **2** includes a first cylinder **60** for moving the pressing member **68** in the axial direction and a second cylinder **63** for biasing the fingers **74**. The first cylinder **60** includes a first cylinder case **61** having a hollow part **62** therein. A first piston **66** is disposed inside the hollow part **62**. The first cylinder **60** functions as a movement device that moves the pressing member **68** in the axial direction.

[0052] The first piston **66** is connected to a first shaft **67**. The pressing member **68** is fixed to the first shaft **67**. Air chambers **62***a* and **62***b* for moving the first piston **66** are formed in the hollow part **62**. When compressed air is supplied to one of the air chamber **62***a* and the air chamber **62***b* and air is discharged from the other air chamber (the air chamber is opened), the first piston **66** moves along the axis **88**. The first piston **66**, the first shaft **67**, and the pressing member **68** move integrally.

[0053] The second cylinder **63** functions as a biasing device that biases the fingers **74** inward in the radial direction. The second cylinder **63** includes the second cylinder case **64** having a hollow part **65** therein. A second piston **71** is disposed inside the hollow part **65**. A second shaft **72** is fixed to the second piston **71**. The second piston **71** and the second shaft **72** are formed to be slidable in the axial direction relative to the first shaft **67**. A distal end part **72***a* is formed at a distal end of the second shaft **72**. The distal end part **72***a* of the present embodiment is formed in a truncated cone shape. The distal end part **72***a* has an inclined surface **72***aa*, which is an outer circumferential surface.

[0054] The second piston **71** and the second shaft **72** are formed so as to integrally move in the axial direction. The slide member **73** has an inclined surface **73***a* on the inner side in the radial direction. The inclined surface **72***aa* of the distal end part **72***a* is formed so as to be in contact with the inclined surface **73***a* of the slide member **73**. The distal end part **72***a* includes a mechanism configured to catch the slide member **73** and bias the slide member **73** inward in the radial direction when the distal end part **72***a* moves in a direction away from the finger **74**. In other words, the inclined surface **72***aa* of the distal end part **72***a* is formed to slide relative to the inclined surface **73***a* of the slide member **73** and engage with the inclined surface **73***a* so as to pull the slide member **73** inward in the radial direction.

[0055] In the hollow part **65** of the second cylinder case **64**, when air is supplied to an air chamber **65***b* and air is discharged from an air chamber **65***a*, the second piston **71** and the second shaft **72** move in a direction away from the fingers **74**. The slide members **73** and the fingers **74** are biased inward in the radial direction. In this way, the second piston **71** moves along the axial direction so that the fingers **74** can be biased.

[0056] A sealing member **78***a* configured to block the flow of air is disposed on the outer circumferential surface of the first piston **66**. A sealing member **78***b* is disposed on the outer circumferential surface of the first shaft **67**, a sealing member **78***c* is disposed on the outer circumferential surface of the second piston **71**, and a sealing member **78***d* is disposed on the outer circumferential surface of the second shaft **72**.

[0057] In a state illustrated in FIG. **4**, compressed air is supplied to the air chamber **62***b*. The air chamber **62***a* is opened. Compressed air is supplied to the air chamber **65***b*. The air chamber **65***a* is opened. The first piston **66** moves in a direction away from the fingers **74**. The pressing member **68** is disposed at a retracted position.

[0058] The second piston **71** is biased in a direction away from the fingers **74**. The slide member **73** is pulled by the inclined surface **72***aa* of the distal end part **72***a* of the second shaft **72** and is biased inward in the radial direction. The finger **74** is biased inward together with the slide member **73** in the radial direction. The plurality of fingers **74** are in a closed state. The inclined surface **74***aa* of the erected part **74***a* is in close contact with the inclined surface **68***a* of the pressing member **68**. In this state, the robot **1** is driven and inserts the erected parts **74***a* of the fingers **74** into the holes **85***a* and **86***a*.

[0059] FIG. **5** illustrates an enlarged schematic cross-sectional view for explaining a step of aligning the positions of the holes. FIG. **5** corresponds to the state of the work tool in FIG. **4**. The position of the hole **85***a* of the workpiece **85** and the position of the hole **86***a* of the workpiece **86** are slightly displaced from each other in the radial direction. In this example, the position of the hole **85***a* and the position of the hole **86***a* are displaced from each other in the horizontal direction.

[0060] The controller **4** inserts the erected parts **74***a* of the fingers **74** into the hole **85***a* and the hole **86***a*. As described above, the position detecting unit **52** of the controller **4** can detect the position of the hole **85***a* by analyzing the image of the top face of the workpiece **85** captured by the camera **6**. Then, the command generating unit **53** drives the robot **1** so that the tool center point of the work tool **2** is arranged at the position of the hole **85***a*. For example, the distal end point of the pressing member **68** is arranged at the center position of the hole **85***a* on the top face of the workpiece **85**. Subsequently, the command generating unit **53** can insert the erected parts **74***a* of the fingers **74** into the holes **85***a* and **86***a* by moving the work tool **2** downward in the vertical direction.

[0061] Alternatively, in the present embodiment, positions at which the workpieces **85** and **86** are arranged with respect to the platforms **81** and **82** are determined in advance. Accordingly, the positions of the holes **85***a* and **86***a* are determined in advance although errors are included. The storage part **42** of the controller **4** can store the position and the orientation of the robot when the erected parts **74***a* of the work tool **2** are inserted into the holes **85***a* and **86***a*. Then, by the controller **4** driving the robot **1**, the erected parts **74***a* at the distal end of the work tool **2** are inserted into the holes **85***a* and **86***a*.

[0062] Referring to FIG. **4**, in a state where the fingers **74** are inserted into the holes **85***a* and **86***a* of the plurality of workpieces **85**, **86**, the tool drive device **21** removes air from the air chamber **62***b* and supplies compressed air to the air chamber **62***a* of the first cylinder **60**. The tool drive device **21** performs control for removing air from the air chamber **65***b* of the second cylinder **63**. By performing this control, the first piston **66**, the first shaft **67**, and the pressing member **68** move in a direction indicated by an arrow **91**. The second piston **71** and the second shaft **72** move in a direction indicated by an arrow **95**.

[0063] Referring to FIG. **5**, the pressing member **68** moves in the direction indicated by the arrow **91**. The inclined surface **68***a* of the pressing member **68** presses the inclined surface **74***aa* of the finger **74**. The finger **74** moves outward in the radial direction as indicated by an arrow **92**. In this way, the plurality of fingers **74** perform an opening operation.

[0064] When the finger **74** moves in the direction indicated by the arrow **92**, the outer surface in the radial direction of the erected part **74***a* comes into contact with the holes **85***a* and **86***a*. In this example, the workpiece **85** moves in a direction indicated by an arrow **93**. The workpiece **86**

moves in a direction indicated by an arrow **94**. The workpieces **85** and **86** are not fixed to an anchoring member but are set on the platforms. Therefore, the relative position of the workpiece **86** with respect to the workpiece **85** changes in accordance with the movement of the fingers **74**.

[0065] FIG. **6** illustrates an enlarged schematic cross-sectional view when the fingers are opened. When the fingers **74** are opened, the outer circumferential surfaces of the fingers **74** come into contact with the holes **85***a* and **86***a*. Since the fingers **74** are driven by a predetermined driving force, the opening operation of the fingers **74** is stopped. The position of the hole **85***a* and the position of the hole **86***a* are aligned along the axial direction. In other words, in a plan view, the position of the hole **85***a* and the position of the hole **86***a* match each other. Alignment of the positions of the holes with each other is completed.

[0066] FIG. **7** is a schematic cross-sectional view of the work tool when the alignment of the positions of the holes with each other is completed. Referring to FIG. **6** and FIG. **7**, when compressed air is supplied to the air chamber **62***a* of the first cylinder **60**, the first piston **66**, the first shaft **67**, and the pressing member **68** are arranged at the positions causing the pressing member **68** to protrude most. When the air chamber **65***b* of the second cylinder **63** is opened, the positions of the second piston **71** and the second shaft **72** are changed as the fingers **74** move outward in the radial direction.

[0067] Referring to FIG. **6** and FIG. **7**, after the alignment of the positions of the holes with each other is completed, the tool drive device **21** performs an operation of supplying compressed air to the air chamber **62***b* of the first cylinder **60** and removing air from the air chamber **62***a*. This operation causes the first piston **66**, the first shaft **67**, and the pressing member **68** to move in a direction indicated by an arrow **96**.

[0068] In the second cylinder **63**, by removing air from the air chamber **65***a* and supplying compressed air to the air chamber **65***b*, the second piston **71** and the second shaft **72** are biased in a direction indicated by an arrow **98**. The slide member **73** and the finger **74** are moved inward in the radial direction as indicated by an arrow **97** by the movement of the second shaft **72**. The slide member **73** and the finger **74** are biased inward in the radial direction by the movement of the second shaft **72**. By performing the control, the plurality of fingers **74** are closed and separated from the inner circumferential surfaces of the holes **85***a* and **86***b*.

[0069] After the fingers **74** are separated from the inner circumferential surfaces of the holes **85***a* and **86***a*, the controller **4** controls the position and the orientation of the robot **1** such that the work tool **2** is retracted from the workpieces **85** and **86**. After the holes **85***a* and **86***a* are subjected to position alignment, a bolt, a pin, or the like can be inserted into the holes **85***a* and **86***a*.

[0070] FIG. **8** illustrates an enlarged schematic cross-sectional view of a distal end part of a positioning device of a comparative example. The positioning device of the comparative example includes fingers **89**, which move together in the radial direction. The fingers **89** are formed to be moved by a chuck device. In other words, the finger **89** is not pressed by a wedge-shaped pressing member but is connected to a cylinder or the like and moved in the radial direction.

[0071] In the positioning device of the comparative example, the chuck device is driven so as to move the finger **89** in the direction indicated by the arrow **92**. Then, an erected part **89***a* is brought into contact with the holes **85***a* and **85***b*, thereby making it possible to align the positions of the holes **85***a* and **86***a*.

[0072] FIG. **9** is an enlarged schematic cross-sectional view when the position alignment of the holes is completed in the positioning device of the comparative example. In the positioning device of the comparative example, a space **90** is formed between a plurality of the fingers **89**. Referring to FIG. **8** and FIG. **9**, the finger **89** is driven in the direction indicated by the arrow **92**.

[0073] When the erected part **89***a* of the finger **89** comes into contact with the inner circumferential surfaces of the holes **85***a* and **86***a*, stress is applied in a direction in which the finger **89** bends. In particular, the stress is applied to a portion **89***b* of the finger **89** in the direction in which the finger **89** bends. For this reason, there is a problem that the durability of the finger **89** is lowered. When the finger **89** is deformed, broken, or the like, the finger **89** needs to be replaced. Alternatively, there is a problem that a force larger than an allowable bending moment cannot be applied to a guide part supporting the finger **89** of the chuck device.

[0074] Referring to FIG. **5** and FIG. **6**, on the other hand, in the positioning device of the present embodiment, the pressing member **68** is disposed in a region surrounded by the plurality of fingers **74**. The finger **74** is in contact with the pressing member **68**. Because of this, when the finger **74** is driven, it is possible to suppress a situation in which bending stress is applied to the finger **74**. As a result, the positioning device of the present embodiment is unlikely to be broken. In other words, the durability of the positioning device is improved.

[0075] In the present embodiment, the plurality of fingers **74** are formed so as to move outward in the radial direction when the movement device including the first cylinder **60** pushes the pressing member **68**, but the present disclosure is not limited thereto. The movement device may be configured such that, by pulling the pressing member **68**, the pressing member **68** moves in the direction indicated by the arrow **91**.

[0076] In the present embodiment, the pressing member **68** is configured to be moved by the first cylinder **60**, but the present disclosure is not limited thereto. The movement device may be formed so as to move the pressing member **68** by a member such as a motor or a spring. The biasing device configured to bias the finger **74** inward in the radial direction is not limited to the second cylinder **63**. The biasing device may be configured to bias the finger inward in the radial direction by a member such as a motor or a spring.

[0077] Next, another control for inserting fingers of a work tool into holes of workpieces will be described. Referring to FIG. **1** and FIG. **2**, the controller **4** includes the image processing unit **51** configured to process an image of the camera **6**. In the case of the aforesaid another control, the camera **6** images the workpiece **85** and the workpiece **86** so as to detect the position of the hole **85***a* and the position of the hole **86***a*.

[0078] FIG. **10** illustrates a plan view of a plurality of workpieces of the present embodiment. When two workpieces **85** and **86** are set on the top face of the platform **82**, the positions of the two workpieces **85** and **86** may be slightly displaced from each other. In this example, the position of the hole **86***a* is displaced relative to the hole **85***a*. In addition, the position of the hole **86***b* is displaced relative to the hole **85***b*.

[0079] FIG. **11** illustrates an enlarged view of holes in an image that is captured by a camera. FIG. **11** illustrates an enlarged view of the image of the hole **85***a* and the hole **86***a*. Referring to FIG. **2**, FIG. **10**, and FIG. **11**, the position detecting unit **52** of the image processing unit **51** detects a center point **85***aa* of the hole **85***a* in a plan view by pattern matching of the hole **85***a*. The image of the camera **6** includes an arc of the hole **86***a* of the workpiece **86**. The position detecting unit **52** can detect a center point **86***aa* of the hole **86***a* in the image by detecting the arc.

[0080] The position detecting unit **52** converts the coordinate values of the camera coordinate system **39** into the coordinate values of the reference coordinate system **37**. On the top face of the workpiece **85**, the position of the center point **85***aa* and the position of the center point **86***aa* can be calculated. The command generating unit **53** calculates a midpoint **87** between the center point **85***aa* and the center point **86***aa*. Then, the command generating unit **53** can control the position and orientation of the robot **1** so that the tool center point of the work tool **2** is arranged at the position of the midpoint **87** on the top face of the workpiece **85**. Subsequently, the position and orientation of the robot can be controlled so that the tool center point of the work tool **2** moves downward in the vertical direction. By performing the control, the erected part **74***a* of the finger **74** of the work tool **2** can be reliably inserted into the plurality of holes **85***a*, **86***a*.

[0081] FIG. **12** illustrates a schematic cross-sectional view of another work tool in the present embodiment. In the above-described work tool **2**, most of the inner surface of the finger **74** is in contact with the outer circumferential surface of the pressing member **68**, but the present disclosure is not limited thereto. Another work tool **7** of the present embodiment includes a finger **76** having an erected part **76***a*. Most of the inner circumferential surface of the erected part **76***a* is not in contact with the pressing member **68**. Part of an inclined surface **76***aa* of the erected part **76***a* is formed so as to be in contact with the inclined surface **68***a* of the pressing member **68**.

[0082] With the configuration of the aforesaid another work tool **7** as well, since the pressing member **68** is disposed in a portion surrounded by a plurality of the fingers **76**, it is possible to avoid a situation in which bending stress is applied to the fingers **76**. As a result, the durability of the work tool **7** can be improved.

[0083] The positioning device of the present embodiment has three fingers, but the present disclosure is not limited thereto. The positioning device may be constituted by the plurality of fingers. The pressing member of the present embodiment has a conical shape, but the shape of the pressing member is not limited thereto. The pressing member may have a pyramid shape corresponding to the number of fingers.

[0084] The camera **6** as a vision sensor of the present embodiment is fixed to the support member **83**, but the present disclosure is not limited thereto. The vision sensor can be disposed such that the image of the workpiece can be captured. For example, the vision sensor may be fixed to the wrist so as to move integrally with the wrist of the robot. In this case, the position and orientation in the camera coordinate system of the robot can be calculated in advance. Then, based on the position and orientation of the robot, information on the position of the hole detected in the camera coordinate system can be converted into information on the position of the hole in the reference coordinate system.

[0085] The camera **6** of the present embodiment is a two-dimensional camera, but is not limited thereto. The vision sensor may be a three-dimensional camera capable of acquiring three-dimensional position information. The vision sensor may be, for example, a stereo camera including two two-dimensional cameras.

[0086] In the present embodiment, the controller includes the image processing unit, but the present disclosure is not limited thereto. The image processing unit may be constituted by an arithmetic processing device (computer) different from the controller that controls the operations of the robot. For example, a computer that functions as the image processing unit may be formed so as to communicate with the controller that controls the robot.

[0087] In the present embodiment, the control for aligning the positions of the holes of two workpieces has been described as an example. However, the present disclosure is not limited thereto, and a case of hole position alignment of three or more workpieces can also be implemented similarly to the control of the present embodiment.

[0088] According to at least one of the embodiments described above, it is possible to provide a positioning device for aligning the positions of holes of a plurality of workpieces with each other.

[0089] The present disclosure has been described in detail thus far, but the present disclosure is not limited to the individual embodiments described above. Various additions, replacements, changes, partial deletions, and the like can be made to these embodiments without departing from the gist of the present disclosure or without departing from the gist of the present disclosure derived from the contents described in the claims and equivalents thereof. Further, these embodiments can also be combined and implemented. For example, in the above-described embodiment, the order of the operations and the order of the processes are given as examples, and are not limited thereto. The same applies to a case where a numerical value or a mathematical expression is used in the description of the above-described embodiment.

[0090] The following supplementary notes are disclosed with regard to the above-described embodiment and modified examples.

Supplementary Note 1

[0091] A positioning device including:

- **[0092]** the plurality of fingers **74**, **76** formed to be movable in a radial direction perpendicular to an axial direction;
- **[0093]** the pressing member **68** having a wedge shape and disposed so as to be in contact with the plurality of fingers; and
- **[0094]** the movement device **60** configured to move the pressing member in the axial direction, wherein
- **[0095]** when the movement device moves the pressing member in a state in which the fingers are inserted into the holes **85***a* and **86***a* of the plurality of workpieces **85**, **86**, the fingers move outward in a radial direction to align positions of the holes of the plurality of workpieces.

Supplementary Note 2

[0096] The positioning device of Supplementary Note 1, wherein

[0097] each of the plurality of fingers includes the erected part **74***a*, **76***a* extending in the axial direction,

[0098] the pressing member is formed to taper in a direction toward a distal end of the erected part, and

[0099] the plurality of fingers move outward in the radial direction when the movement device pushes the pressing member.

Supplementary Note 3

[0100] The positioning device of Supplementary Note 1 or Supplementary Note 2, further including the biasing device **63** configured to bias each of the plurality of fingers inward in the radial direction.

REFERENCE SIGNS LIST

[0101] **2**, **7** Work tool

[0102] **60** First cylinder

[0103] **63** Second cylinder

[0104] **66** First piston

[0105] **67** First shaft

[0106] **68** Pressing member

[0107] **71** Second piston

[0108] **72** Second shaft

[0109] **74**, **76** Finger

[0110] **74***a*, **76***a* Erected part

[0111] **85**, **86** Workpiece

[0112] **85***a*, **85***b*, **86***a*, **86***b* Hole

[0113] **88** Axis

What is claimed is:

1. A positioning device comprising:

a plurality of fingers formed to be movable in a radial direction perpendicular to an axial direction;

a pressing member having a wedge shape and disposed so as to be in contact with the plurality of fingers; and

a movement device configured to move the pressing member in the axial direction, wherein

when the movement device moves the pressing member in a state in which the fingers are inserted into holes of a plurality of workpieces, the fingers move outward in a radial direction to align positions of the holes of the plurality of workpieces.

2. The positioning device of claim **1**, wherein

each of the plurality of fingers includes an erected part extending in the axial direction,

the pressing member is formed to taper in a direction toward a distal end of the erected part, and

the plurality of fingers move outward in the radial direction when the movement device pushes the pressing member.

3. The positioning device of claim **1**, comprising a biasing device configured to bias each of the plurality of fingers inward in the radial direction.

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