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ELECTROSURGICAL INSTRUMENTS INCLUDING A JAW ANGLE DETECTION SYSTEM

Abstract

An electrosurgical instrument includes an elongated shaft, an end effector, a drive shaft, and a switch assembly. The end effector is coupled to a distal end portion of the elongated shaft and includes opposing first and second jaw members. The end effector is configured to move between an open configuration and a closed configuration. The drive shaft is operably coupled to the end effector to move the end effector between the open and closed configurations. The switch assembly includes a first electrical contact and a second electrical contact. The first electrical contact is coupled to the drive shaft and configured to move with the drive shaft. The first electrical contact is configured to engage the second electrical contact in response to a movement of the drive shaft to determine a first angle between the first and second jaw members.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a division of U.S. patent application Ser. No. 18/595,655, filed on Mar. 5, 2024, which is a division of U.S. patent application Ser. No. 16/944,367, filed on Jul. 31, 2020, now U.S. Pat. No. 11,931,097, which claims the benefit of the filing date of provisional U.S. Patent Application No. 62/888,235, filed on Aug. 16, 2019, the entire contents of each of which being incorporated herein by reference.

FIELD
[0002] The present technology is generally related to a surgical instrument, and more particularly to a surgical instrument with a jaw angle detection system.
BACKGROUND
[0003] End effectors utilize mechanical action to constrict, grasp, dissect, and/or clamp tissue. Electrosurgical end effectors utilize both mechanical clamping action and electrical energy to effect hemostasis by heating the tissue and blood vessels. By controlling the intensity, frequency, and duration of the electrosurgical energy applied through the jaw members to the tissue, the surgeon can coagulate, cauterize, and/or seal tissue.
[0004] In order to effect a proper seal with larger vessels or thick tissue, two predominant mechanical parameters should be accurately controlled: the pressure applied to the tissue; and the gap distance between the electrodes. Both of these parameters may be affected by the thickness of vessels or tissue. More particularly, accurate application of pressure is important for several reasons: to reduce the tissue impedance to a low enough value that allows enough electrosurgical energy through the tissue; to overcome the forces of expansion during tissue heating; and to contribute to the end tissue thickness, which is an indication of an effective seal.
SUMMARY
[0005] In one aspect, the present disclosure provides an electrosurgical instrument including an elongated shaft, an end effector, a drive shaft, and a switch assembly. The end effector is coupled to a distal end portion of the elongated shaft and includes opposing first and second jaw members. The end effector is configured to move between an open configuration, in which the first and second jaw members define a first gap therebetween. The end effector is configured to move between a closed configuration, in which the first and second jaw members define a second gap therebetween, smaller than the first gap. The drive shaft is operably coupled to the end effector to move the end effector between the open and closed configurations. Switch assembly includes a first electrical contact and a second electrical contact. The first electrical contact is coupled to the drive shaft and configured to move with the drive shaft. The second electrical contact is configured to be engaged by the first electrical contact in response to a movement of the drive shaft to determine a first angle between the first and second jaw members.
[0006] In aspects, the first electrical contact may be a coil spring.
[0007] In aspects, the coil spring may extend proximally from the drive shaft.
[0008] In aspects, the coil spring may have a distal end portion coupled to the drive shaft, and a

proximal end portion configured to engage the first electrical contact upon the end effector moving to a position between the open and closed configurations.

[0009] In aspects, the switch assembly may further include a third electrical contact coupled to the drive shaft. The third electrical contact may be configured to move with the drive shaft to engage the second electrical contact in response to movement of the drive shaft to determine a second angle between the first and second jaw members.

[0010] In aspects, the first and third electrical contacts may be coil springs and the third electrical contact may have a reduced length compared to the first electrical contact.

[0011] In aspects, the third electrical contact may be disposed within the first electrical contact.

[0012] In aspects, the first and third electrical contacts may extend proximally from the drive shaft.

[0013] In aspects, each of the first and third electrical contacts may have a distal end portion coupled to the drive shaft, and a proximal end portion. The proximal end portion of the first electrical contact may be configured to engage the second electrical contact upon the end effector moving to a first position between the open and closed configurations. The proximal end portion of the third electrical contact may be configured to engage the second electrical contact upon the end effector moving to a second position between the open and closed configurations.

[0014] In aspects, the electrosurgical instrument may further include a handle housing having the elongated shaft extending distally therefrom. The first electrical contact may be fixed within the handle housing.

[0015] In aspects, the second electrical contact may be disposed in the handle housing at a location distally of the first electrical contact.

[0016] In another aspect, the disclosure provides an electrosurgical instrument including an elongated shaft, an end effector, a drive shaft, a detecting circuit, and an electrical contact. The end effector is coupled to a distal end portion of the elongated shaft. The end effector includes opposing first and second jaw members configured to move between an open configuration, in which the first and second jaw members define a first gap therebetween. The end effector is configured to move between a closed configuration, in which the first and second jaw members define a second gap therebetween, smaller than the first gap. The drive shaft is operably coupled to the end effector to move the end effector between the open and closed configurations. The detecting circuit having a plurality of contacts. The electrical contact is coupled to the drive shaft and configured to move with the drive shaft, such that the electrical contact moves relative to the detecting circuit. Each discrete position of the electrical contact relative to a respective contact of the plurality of contacts of the detecting circuit corresponds to a discrete angle between the first and second jaw members.

[0017] In aspects, the plurality of contacts of the detecting circuit may be co-linear along an axis.

[0018] In aspects, the axis may be parallel with an axis defined by the drive shaft.

[0019] In aspects, the plurality of contacts of the detecting circuit may be disposed in a linear array.

[0020] In aspects, the plurality of contacts of the detecting circuit may be nested with one another.

[0021] In aspects, a first contact of the plurality of contacts of the detecting circuit may be generally L-shaped and a second contact of the plurality of contacts of the detecting circuit may be generally Z-shaped.

[0022] In aspects, the plurality of contacts of the detecting circuit may include an L-shaped first contact, a linear-shaped second contact, and a third contact. The L-shaped first contact may have a long leg and a short leg extending transversely from the long leg. The linear-shaped second contact may be nested with the first contact. The third contact may be aligned with and disposed distally of the long leg of the first contact.

[0023] In aspects, the plurality of contacts of the detecting circuit may include a first contact and a second contact axially spaced from the first contact.

[0024] In aspects, the first contact may be configured to send a first signal to the generator in response to the electrical contact moving to a position in overlapping alignment with the first contact, and the second contact may be configured to send a second signal to a generator in response to the electrical contact moving to a position in overlapping alignment with the second contact. The first and second signals correspond to a discrete angle between the first and second jaw members.

[0025] In aspects, the electrical contact may be a variable resistor.

[0026] In another aspect, the disclosure provides a method of controlling operation of an electrosurgical instrument. Method includes grasping tissue between the first and second jaw members; determining an impedance of the tissue grasped between the first and second jaw members; determining an angle between the first and second jaw members; and delivering electrosurgical energy to the tissue grasped between the first and second jaw member based on the determined impedance and the determined angle.

[0027] In aspects, the method may further include determining a location of the grasped tissue along a length of the first and second jaw members based on the determined impedance and the determined angle.

[0028] In aspects, determining the angle may include receiving a signal at a first electrical contact from a second electrical contact. Second electrical contact may move relative to the first electrical contact a distance proportionate to a change in angle between the first and second jaw members as the first and second jaw members are clamped about the portion of the tissue.

[0029] The details of one or more aspects of the disclosure are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the techniques described in this disclosure will be apparent from the description and drawings, and from the claims.

[0030] As used herein, the terms parallel and perpendicular are understood to include relative configurations that are substantially parallel and substantially perpendicular up to about + or −10 degrees from true parallel and true perpendicular.

[0031] As used herein, the term “about” means that the numerical value is approximate and small variations would not significantly affect the practice of the disclosed embodiments. Where a numerical limitation is used, unless indicated otherwise by the context, “about” means the numerical value can vary by +10% and remain within the scope of the disclosed embodiments.

[0032] For the purposes herein, the term “voltage divider network” relates to any suitable form of resistive, capacitive, or inductive switch closure (or the like) that determines the output voltage across a voltage source (e.g., one of two impedances) connected in series. A “voltage divider” as used herein relates to a number of resistors connected in series that are provided with taps at certain points to make available a fixed or variable fraction of the applied voltage.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0033] FIG. **1** is a side view illustrating a surgical system including a generator and an electrosurgical forceps according to an embodiment of the disclosure including a housing, a shaft assembly, and an end effector having a pair of jaw members in an approximated configuration;

[0034] FIG. **2** is a side view of the surgical system of FIG. **1** depicted with the pair of jaw members of the electrosurgical forceps in an expanded configuration;

[0035] FIG. **3** is an enlarged, perspective view of the proximal portion of the forceps of FIG. **1** with a portion of the housing removed revealing internal components including a switch assembly having a spring coil and an electrical contact;

[0036] FIG. **4** is a perspective view of the proximal portion of the forceps of FIG. **1**, with a portion of the housing removed, illustrating the spring coil and the electrical contact of the switch assembly in close proximity to one another;

[0037] FIGS. **5**A-**5**C are schematic illustrations of the switch assembly of FIG. **3**, including an

additional spring coil, depicted in different states;
[0038] FIG. **6** is a schematic illustration of another embodiment of a switch assembly for use in the forceps of FIG. **1** including an electrical contact and a detecting circuit having contacts axially spaced from one another;
[0039] FIG. **7** is a schematic illustration of another embodiment of a switch assembly for use in the forceps of FIG. **1**; and
[0040] FIG. **8** is a schematic illustration of another embodiment of a switch assembly for use in the forceps of FIG. **1**.
DETAILED DESCRIPTION
[0041] Embodiments of the presently disclosed electrosurgical instrument are described in detail with reference to the drawings, in which like reference numerals designate identical or corresponding elements in each of the several views. As used herein, the term “distal” refers to that portion of the surgical instrument or component thereof, farther from the user, while the term “proximal” refers to that portion of the surgical instrument, or component thereof, closer to the user.
[0042] With reference to FIGS. **1** and **2**, a surgical system **1** is provided in accordance with the present disclosure. Surgical system **1** includes an energy-based surgical instrument, such as, for example, an endoscopic forceps **10**, coupled to a generator **200**. Either a laparoscopic, an endoscopic, or an open instrument (not explicitly shown) may be utilized in accordance with the present disclosure, however, different electrical and mechanical connections and considerations apply to each particular type of instrument. As detailed below, surgical system **1** is configured to incorporate machine learning to facilitate the treatment of tissue, based on sensed data, thus providing more unique methods of treating tissue.
[0043] Forceps **10** defines a longitudinal axis “X” and includes a housing **20**, a handle assembly **30**, a rotating assembly **40**, a trigger assembly **50**, a switch **60**, a shaft **70** extending distally from housing **20**, and an end effector assembly **100**. Shaft **70** has a proximal end portion **72** that mechanically engages housing **20** and a distal end portion **74** configured to mechanically engage end effector assembly **100**. Housing **20** contains the internal working components of forceps **10**. Reference may be made to commonly-owned U.S. Pat. No. 7,156,846, the entire contents of which are incorporated herein by reference, for a detailed description of the internal working components of housing **20**.
[0044] End effector assembly **100** includes a pair of opposing jaw members **110** and **120** coupled to distal end portion **74** of shaft **70**. Jaw members **110**, **120** are moveable between a closed configuration (FIG. **1**) wherein jaw members **110**, **120** are approximated for grasping tissue therebetween and an open configuration (FIG. **2**) wherein jaw members **110**, **120** are spaced farther apart from one another. End effector assembly **100** is designed as a unilateral assembly, e.g., jaw member **120** is fixed relative to shaft **70**, and jaw member **110** is moveable about a pivot **103** relative to shaft **70** and fixed jaw member **120**. In some embodiments, end effector assembly **100** may be configured as a bilateral assembly, e.g., where both jaw member **110** and jaw member **120** are moveable about pivot **103** relative to one another and to shaft **70**.
[0045] Forceps **10** also includes an electrosurgical cable **80** that connects forceps **10** to generator **200** or other suitable power source. In some embodiments, forceps **10** may be configured as a battery-powered instrument. Cable **80** includes a wire or wires (not explicitly shown) extending therethrough that has sufficient length to extend through shaft **70** in order to provide electrical energy to at least one of jaw members **110** and **120** of end effector assembly **100**. Trigger **52** of trigger assembly **50** may be selectively depressed to advance a knife (not explicitly shown) between jaw members **110**, **120** to cut tissue grasped therebetween. Switch **60** is selectively activated to supply electrosurgical energy to jaw members **110**, **120**.
[0046] Handle assembly **30** includes a fixed handle **32** and a moveable handle **34**. Fixed handle **32** is integrally associated with housing **20** and moveable handle **34** is moveable relative to fixed

handle **32**. Rotating assembly **40** is rotatable in either direction about longitudinal axis “X” to rotate end effector **100** about longitudinal axis “X.” Moveable handle **34** of handle assembly **30** is coupled to a drive shaft **76** (FIG. **3**) that, together, mechanically cooperate to cause movement of one or both of jaw members **110** and **120** between the open configuration and the closed configuration to grasp tissue disposed between jaw members **110**, **120**. Moveable handle **34** is biased from fixed handle **32** and correspondingly biases jaw members **110**, **120** toward the open configuration. Moveable handle **34** is movable from an unactuated position (e.g., spaced from fixed handle **32**) to an actuated position (e.g., approximating fixed handle **32**) to move jaw members **110**, **120** from the open configuration to the closed configuration.

[0047] With reference to FIGS. **3** and **4**, in order to sense an angle between jaw members **110**, **120**, forceps **10** includes a switch assembly **90** having a first electrical contact **92** (e.g., a coil spring) and a second electrical contact **94** (e.g., a metal plate), each electrically coupled to generator **200**. In some embodiments, first and second electrical contacts **92**, **94** may communicate with generator **200** wirelessly.

[0048] Coil spring **92** of switch assembly **90** may be electrically coupled to generator **200** via a coil spring cable **82** which delivers a voltage source to coil spring **92**. Coil spring **92** has a distal end portion **92***a* and a proximal end portion **92***b*. Distal end portion **92***a* of coil spring **92** is coupled to proximal end portion **76***a* of drive shaft **76** and extends proximally from drive shaft **76**. Proximal end portion **92***b* of coil spring **92** is disposed in spaced relation from electrical contact **94** and is configured to engage electrical contact **94** in response to proximal movement of drive shaft **76**. Electrical contact **94** of switch assembly **90** may be disposed within proximal portion of housing **20** and electrically coupled to generator **200** via an electrical contact cable **84**.

[0049] With reference to FIGS. **5**A-**5**C, switch assembly **90** may further include a second electrical contact, such as, for example, an additional coil spring **95** disposed within first coil spring **92**. Coil spring **95** is electrically coupled to generator **200** via a cable (not shown) which delivers a voltage to coil spring **95**. Coil spring **95** has a distal end portion **95***a* and a proximal end portion **95***b*. Distal end portion **95***a* of coil spring **95** is coupled to proximal end portion **76***a* of drive shaft **76**. Coil spring **95** is nested within coil spring **92** and configured for independent contact with electrical contact **94**. Coil spring **95** extends proximally from drive shaft **76** and is spaced further from electrical plate **94** than is coil spring **92**. In aspects, switch assembly **90** may include any suitable number of coil springs, such as, for example, three or more. In other aspects, one or both of electrical contacts **92**, **95** may be any suitable biasing member, such as, for example, an accordion spring, a wave spring, etc.

[0050] With reference to FIGS. **1** and **2**, generator **200** generally includes a main controller **210**, a high voltage DC power supply (HVPS) **220** (or other suitable power supply), an RF output stage **230** (or other suitable output depending on the energy delivered to end effector assembly **100**), sensory circuitry **240**, and a user interface (not shown), e.g., a graphical user interface to enable the input and display of information such as settings, warnings, treatment complete indicators, etc.

[0051] Main controller **210** includes a microprocessor **212** connected to a computer-readable storage medium or memory **214**, which may be a volatile type memory, e.g., RAM, or a non-volatile type memory, e.g., flash media, disk media, etc. Main controller **210** is coupled to power supply **220** and/or RF output stage **230**, thus allowing microprocessor **212** to control the output of energy from generator **200** to end effector assembly **100**. Microprocessor **212** is further coupled to sensory circuitry **240** for receiving feedback signals from end effector assembly **100** to perform feedback-based control of the delivery of energy to forceps **10**, as detailed below. Memory **214** may store suitable instructions, to be executed by microprocessor **212**, for indicating the sequence, duration, and/or parameters associated with the energy delivery from generator **200** to end effector assembly **100** to treat tissue. In some embodiments, generator **200** is configured to supply energy to end effector assembly **100** according to a tissue sealing algorithm such that the supply of energy, together with the mechanical parameters of end effector assembly **100**, e.g., impedance of the tissue and jaw gap, enable the sealing of tissue grasped between jaw members **110**, **120**. However, other suitable tissue treatment effects are also contemplated.

[0052] Sensory circuitry **240** is coupled to suitable sensor components for measuring and providing feedback with respect to a variety of tissue and/or energy parameters, for example, switch assembly **90**. In addition to being coupled to switch assembly **90**, sensory circuitry **240** is coupled to electrical leads (not shown) for sensing additional properties of the tissue grasped between jaw members **110**, **120** or the energy conducted therethrough prior to or during tissue treatment. Sensory circuitry **240**, for example, may further be configured to sense the impedance of tissue grasped between jaw members **110**, **120** during the conduction of energy between tissue-contacting plates (not shown) and/or to sense power during the conduction of energy between tissue-contacting plates. For a detailed description of utilizing impedance-sensing during tissue treatment, reference may be made to commonly-owned U.S. Pat. Nos. 8,034,049, 9,186,200, and 8,591,506, the entire contents of each of which are incorporated herein by reference.

[0053] Machine learning unit **260** includes a microprocessor **262** connected to a computer-readable storage medium or memory **264**, which may be a volatile type memory, e.g., RAM, or a non-volatile type memory, e.g., flash media, disk media, etc. Memory **264** stores suitable instructions, to be executed by microprocessor **262**, for receiving the sensed data from sensory circuitry **240**, accessing storage device **266** of machine learning unit **260**, determining tissue information based upon the sensed data and information stored in storage device **266**, and providing feedback to main controller **210** based upon the determined tissue information. Although illustrated as part of generator **200**, it is also contemplated that machine learning unit **260** may be remote from generator **200**, e.g., on a remote server, and accessible by generator **200** via a wired or wireless connection. In embodiments where machine learning unit **260** is remote, it is contemplated that machine learning unit **260** may be accessible by and connected to multiple generators.

[0054] Storage device **266** of machine learning unit **260** stores one or more machine learning applications, e.g., algorithms and/or models, configured to determine tissue information based upon the sensed data received from sensory circuitry **240**. Machine learning application(s) are trained on and learn from experimental data and/or data from previous procedures initially input into the one or more machine learning applications in order to enable the machine learning application(s) to identify tissue information based upon such sensed data. Such sensed data may include tissue impedance data, power data, and/or any other suitable data. Suitable machine learning applications include, for example, Support Vector Machines (SVMs), applications employing Principle Component Analysis, Hidden Markov Models (HMMs), applications employing the Monte Carlo Method, etc.

[0055] In operation, referring to FIGS. **5**A-**5**C, prior to treatment of the tissue, moveable handle **34** (FIG. **1**) is biased from fixed handle **32** to bias jaw members **110**, **120** towards the open configuration such that tissue may be disposed between jaw members **110**, **120**. Moveable handle **34** is moved from the unactuated position towards the actuated position to pivot jaw members **110**, **120** from the open configuration to the closed configuration for grasping tissue therebetween.

[0056] Since moveable handle **34** of handle assembly **30** is coupled to drive shaft **76** (FIG. **3**), and coil springs **92**, **95** are coupled to drive shaft **76**, coil springs **92**, **95** move in response to movement of drive shaft **76**. In particular, as drive shaft **76** moves proximally towards electrical contact **94**, a distance indicated by “A” in FIG. **5**A, coil spring **92** first engages electrical contact **94**. Voltage delivered from generator **200** through coil spring **92** is received by electrical contact **94** to provide a feedback signal to sensory circuitry **240** (FIGS. **1** and **2**) of generator **200**. Using an algorithm stored in, for example, memory **214**, the jaw angle α between jaw members **110**, **120** is determined using the feedback signal. In some embodiments, sensory circuitry **240** delivers the feedback signal to machine learning unit **260**, which determines the jaw angle α between jaw members **110**, **120** based on the feedback signal received by sensory circuitry **240**.

[0057] To change the jaw angle α from a first jaw angle to a second jaw angle, a further actuation of moveable handle **34** further retracts drive shaft **76**, thereby compressing coil spring **92** against electrical contact **94** and approximating proximal end of coil spring **95** closer to electrical contact **94**. Upon moving coil spring **95** a distance indicate by "B" in FIG. **5**A, coil spring **95** contacts electrical contact **94**. Voltage source delivered from generator **200** through coil spring **95** is received by electrical contact **94** to provide a feedback signal to sensory circuitry **240** (FIGS. **1** and **2**) of generator **200**. Sensory circuitry **240** delivers the feedback signal to machine learning unit **260** which determines the second jaw angle between jaw members **110**, **120** based on the feedback signal received by sensory circuitry **240**.

[0058] Prior to tissue treatment, and with the tissue grasped between jaw members **110**, **120**, an impedance sensor in jaw members **110**, **120** may sense impedance of the tissue and send the detected impedance to sensory circuitry **240**. The jaw angle α and the impedance signals which are received by sensory circuitry **240** are relayed to machine learning unit **260**. Machine learning unit **260**, based upon the jaw angle α, the impedance, and any other sensed data received from sensory circuitry **240**, determines tissue information using the machine learning application(s) stored in storage device **266** of machine learning unit **260**. Tissue information may include, for example, where the tissue is placed within jaw members **110**, **120** (e.g., grasped at the tip or heel of the jaw members **110**, **120**), tissue density, tissue thickness (based on relative resistance to jaw closure), speed of jaw closure, jaw members **110**, **120** being in the appropriate configuration, a "re-grasp" condition, and/or overall adequacy of the tissue seal either prior to, during, or after activation.

[0059] Tissue information is relayed to main controller **210**, and main controller **210** may output an alert and/or warning regarding the jaw angle α, or implement a feedback-based control of the delivery of electrosurgical energy to end effector assembly **100**. In particular, power supply **220** and RF output stage **230**, based on control signals received from microprocessor **212** of main controller **210**, cooperate to deliver a selected amount of electrosurgical energy to tissue-contacting plates of jaw members **110**, **120** via electrical leads to treat tissue grasped between jaw members **110**, **120**. The amount of electrosurgical energy delivered is selected based on the tissue information determined by machine learning unit **260**.

[0060] Feedback-based control of the delivery of energy to forceps **10** may be implemented according to the parameter-based tissue grouping, e.g., tissue associated with a particular sensed parameter and/or similarity-based tissue grouping, e.g., separating tissue into groups based upon similarities and differences. For example, the feedback-based control may group together tissues with the same impedance, the same jaw angle α, the same impedance and jaw angle α, the same impedance and different jaw angle α, a different impedance and same jaw angle α, or any combination thereof, to deliver energy to forceps **10** according to each grouping. Other forms of feedback-based controls are contemplated, such as, for example treating tissue grasped at the tip differently than tissue grasped at the heel, treating tissue based on the determined state of diseased or challenged tissues without advanced sensors, adjusting energy delivery based on the monitored jaw angle α during tissue sealing accounting for changes in the jaw angle α, preventing delivery of energy based on potential errors during tissue sealing e.g., exceeding a jaw angle threshold.

[0061] FIGS. **6-8** illustrate alternative embodiments of a switch assembly for detecting a jaw angle of forceps **10**. With reference to FIG. **6**, forceps **10** includes a detecting circuit **190** and an electrical contact **196**. Detecting circuit **190** includes a plurality of contacts **192** disposed along an axis and in series, e.g., in a linear array. Each contact **192** is coupled to a variable resistor **194**, each representing a discrete angle of jaw members **110**, **120**, e.g., a voltage divider network, corresponding to the jaw angle α. Each variable resistor **194** delivers, to generator **200**, a feedback signal indicative of the discrete angle corresponding to the jaw angle α between jaw members **110**, **120**.

[0062] Electrical contact **196** has two conductive plates **198** in parallel and is disposed along drive shaft **76** (FIG. **4**). For example, electrical contact **196** may be attached to drive shaft **76**, such that movement of drive shaft **76** results in a corresponding movement of electrical contact **196**.

Electrical contact **196** receives the voltage delivered from generator **200** and the voltage is delivered via conductive plates **198** to detecting circuit **190**.

[0063] In operation, drive shaft **76** is retracted proximally in response to movement of moveable handle **34** toward the actuated position, thereby moving jaw members **110**, **120** from the open configuration to the closed configuration. Since electrical contact **196** is coupled to drive shaft **76**, electrical contact **196** moves with drive shaft **76** from a starting position, corresponding to the open configuration of jaw members **110**, **120**, toward detecting circuit **190**. Electrical contact **196** moves across plurality of contacts **192**, whereby the intensity of the feedback is varied. A feedback signal corresponding to the jaw angle α is produced upon movement of electrical contact **196** into parallel with contacts **192**. The feedback signal is then sent to sensory circuitry **240** for determination of the jaw angle α.

[0064] FIG. **7** illustrates another embodiment of a detecting circuit **290**, similar to detecting circuit **190** of FIG. **6**. Detecting circuit **290** includes a plurality of contacts **292** nested within one another to account for potential “dead spots.” “Dead spots” is the spacing between the plurality of contacts, thus the location between the spacing of the plurality of contacts would not be detectable due to the lack of contacts present. In particular, the plurality of contacts **292** includes generally “L-shaped” outer contacts **292***a*, **292***b* and complementary generally “Z-shaped” contacts **292***c* nested in series with “L-shaped” contacts **292***a*, **292***b*. As electrical contact **296** moves across detecting circuit **290**, the plurality of contacts **292** detect switch over points **293**. Due to the shapes of the plurality of contacts, the “dead spots” are replaced with portions of the plurality of contacts thus the switch over points provide the ability to determine location between the plurality of contacts where “dead spots” would otherwise be located. Thus, the detection of switch over points **293** provides a more precise detection of the jaw angle α as jaw members **110**, **120** move from the open configuration to the closed configuration, and vice versa.

[0065] FIG. **8** illustrates yet another embodiment of a detecting circuit **390**, similar to detecting circuit **290** of FIG. **7**. Detecting circuit **390** includes a plurality of contacts **392**. The plurality of contacts **392** includes two generally “L-shaped” outer contacts **394**, **396** each having a long leg **394***a*, **396***a* and a short leg **394***b*, **396***b* extending transversely from the long legs **394***a*, **396***a*, respectively. The plurality of contacts **392** also includes linear shaped contacts **392** that are cascaded and nested between outer contacts **394**, **396**. First linear contact **393** is disposed between long legs **394***a*, **396***a* of outer contacts **394**, **396**, and a pair of second linear contacts **395** is disposed between short legs **394***b*, **396***b* of outer contacts **394**, **396**.

[0066] Although the disclosure is directed towards sensing a jaw angle in conjunction with an electrosurgical instrument, the principles of the present disclosure may also be used in conjunction with any suitable type of instrument having jaws that open and close, such as ultrasonic instruments.

[0067] It should be understood that various aspects disclosed herein may be combined in different combinations than the combinations specifically presented in the description and accompanying drawings. It should also be understood that, depending on the example, certain acts or events of any of the processes or methods described herein may be performed in a different sequence, may be added, merged, or left out altogether (e.g., all described acts or events may not be necessary to carry out the techniques). In addition, while certain aspects of this disclosure are described as being performed by a single module or unit for purposes of clarity, it should be understood that the techniques of this disclosure may be performed by a combination of units or modules associated with, for example, a medical device.

[0068] In one or more examples, the described techniques may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored as one or more instructions or code on a computer-readable medium and executed by a hardware-based processing unit. Computer-readable media may include non-transitory computer-readable media, which corresponds to a tangible medium such as data storage media (e.g., RAM,

ROM, EEPROM, flash memory, or any other medium that can be used to store desired program code in the form of instructions or data structures and that can be accessed by a computer).
[0069] Instructions may be executed by one or more processors, such as one or more digital signal processors (DSPs), general purpose microprocessors, application specific integrated circuits (ASICs), field programmable logic arrays (FPGAs), or other equivalent integrated or discrete logic circuitry. Accordingly, the term "processor" as used herein may refer to any of the foregoing structure or any other physical structure suitable for implementation of the described techniques. Also, the techniques could be fully implemented in one or more circuits or logic elements.

Claims

1. A method of controlling operation of an electrosurgical instrument, the method comprising: grasping tissue between a first jaw member and a second jaw member; determining an impedance of the tissue grasped between the first and second jaw members; determining an angle between the first and second jaw members; and delivering electrosurgical energy to the tissue grasped between the first and second jaw members based on the determined impedance and the determined angle.
2. The method according to claim 1, further comprising: determining a location of the grasped tissue along a length of the first and second jaw members based on the determined impedance and the determined angle.
3. The method according to claim 1, wherein determining the angle includes receiving a signal at a first electrical contact from a second electrical contact, the second electrical contact moving relative to the first electrical contact a distance proportionate to a change in angle between the first and second jaw members as the first and second jaw members are clamped about the tissue.
4. The method according to claim 3, wherein the first electrical contact is a coil spring and the second electrical contact is a metal plate.
5. The method according to claim 3, wherein the first electrical contact is a metal plate and the second electrical contact is a coil spring.
6. The method according to claim 1, further comprising: receiving a measurement from an impedance sensor in at least one of the first or second jaw members.
7. The method according to claim 1, further comprising: input the angle and the impedance into a machine learning model trained to determine one or more tissue characteristics based on angle and impedance data; and determine electrosurgical energy settings based on the one or more tissue characteristics determined by the machine learning model.
8. An electrosurgical system comprising: an electrosurgical generator; an electrosurgical instrument comprising a first jaw member and a second jaw member moveable relative to each other between an open position and a closed position; one or more processors; and at least one memory coupled to the one or more processors, the at least one memory having instructions stored thereon which, when executed by the one or more processors, cause the electrosurgical system to: determine an impedance of tissue disposed between the first and second jaw members; determine an angle between the first and second jaw members; and delivery electrosurgical energy to the tissue grasped between the first and second jaw members based on the determined impedance and the determined angle.
9. The electrosurgical system of claim 8, wherein determine the impedance includes receiving a measurement from an impedance sensor in at least one of the first or second jaw members.
10. The electrosurgical system of claim 8, wherein the electrosurgical instrument further comprises: a first electrical contact configured to move as the first and second jaw members move between the open position and the closed position; and a second electrical contact configured to be placed into contact with the first electrical contact when the first and second jaw members are in a position corresponding to first angle.
11. The electrosurgical system of claim 10, wherein determining the angle includes receiving an

indication of the first electrical contact being in contact with the second electrical contact.

12. The electrosurgical system of claim 8, wherein the electrosurgical instrument further comprises: a first electrical contact configured to move when the first and second jaw members move between the open position and the closed position; a second electrical contact configured to move when the first and second jaw members move between the open position and the closed position; and a third electrical contact, wherein the third electrical contact is placed into contact with the first electrical contact when the first and second jaw members are in a first position associated with a first angle; and wherein the third electrical contact is placed into contact with the second electrical contact when the first and second jaw members are in a second position associated with a second angle.

13. The electrosurgical system of claim 12, wherein determining the angle includes determining whether the third electrical contact is in contact with the first electrical contact and/or the second electrical contact.

14. The electrosurgical system of claim 10, wherein the first electrical contact is a coil spring and the second electrical contact is a metal plate.

15. The electrosurgical system of claim 10, wherein the first electrical contact is a metal plate and the second electrical contact is a coil spring.

16. The electrosurgical system of claim 10, wherein the instructions stored, when executed by the one or more processors, further cause the electrosurgical system to: input the angle and the impedance into a machine learning model trained to determine one or more tissue characteristics based on angle and impedance data; and determine one or more electrosurgical energy settings based on the one or more tissue characteristics determined by the machine learning model.

17. A system for controlling electrosurgical energy, the system comprising: one or more processors; and at least one memory coupled to the one or more processors, the at least one memory having instructions stored thereon which, when executed by the one or more processors, cause the system to: determine an impedance of tissue disposed between a first jaw member and a second jaw member of an electrosurgical instrument; determine an angle between the first and second jaw members; and control delivery of electrosurgical energy to the tissue grasped between the first and second jaw members based on the determined impedance and the determined angle.

18. The system of claim 17, wherein determining the impedance includes receiving a measurement from an impedance sensor in at least one of the first or second jaw members.

19. The system of claim 17, wherein determining the angle includes: detecting a signal indicative of a first electrical contact in the electrosurgical instrument being in contact with a second electrical contact in the electrosurgical instrument.

20. The system of claim 17, wherein the instructions stored, when executed by the one or more processors, further cause the system to: input the angle and the impedance into a machine learning model trained to determine one or more tissue characteristics based on angle and impedance data; and determine one or more electrosurgical energy settings based on the one or more tissue characteristics determined by the machine learning model.