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ENGAGEMENT FEATURES AND METHODS FOR ATTACHING A DRIVE ROD TO A KNIFE BLADE IN AN ARTICULATING SURGICAL INSTRUMENT

Abstract

A knife assembly for use with a surgical instrument includes a knife having proximal and distal ends, the proximal end including an aperture defined therein having a series of spaced apart fins extending thereacross. A knife drive rod is included and is configured to operably engage the fins to secure the knife drive rod to the knife. A retention mechanism is operably disposed at a distal end of the knife drive rod and is configured to secure the knife drive rod in engagement between the fins.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. patent application Ser. No. 17/982,124, filed on Nov. 7, 2022, which is a continuation of U.S. patent application Ser. No. 16/832,782, filed on Mar. 27, 2020, now U.S. Pat. No. 11,490,916, which claims the benefit of and priority to U.S. Provisional Patent Application No. 62/825,882, filed on Mar. 29, 2019, the entire contents of each of which is incorporated by reference herein.

BACKGROUND

Technical Field

[0002] The present disclosure relates surgical instruments, and more particularly, to various engagement features and methods for attaching a drive rod to a knife blade to facilitate actuation thereof.

Background of Related Art

[0003] A surgical forceps is a pliers-like instrument that relies on mechanical action between its jaw members to grasp, clamp, and constrict tissue. Electrosurgical forceps utilize both mechanical clamping action and energy to heat tissue to treat, e.g., coagulate, cauterize, or seal, tissue. Typically, once tissue is treated, the surgeon has to accurately sever the treated tissue. Accordingly, many electrosurgical forceps are designed to incorporate a knife or cutting member utilized to effectively sever the treated tissue.

[0004] Many electrosurgical forceps include various actuators to orient the jaw members for tissue treatment. For example, many forceps include rotational wheels (or the like) disposed in proximity to a surgeon's hands to enable the surgeon to selectively rotate the jaw members as needed during an operation. A trigger (or similar) may be disposed on the forceps housing to allow a surgeon to selectively deploy a knife or cutting element as needed during surgery. Other actuators include articulating mechanisms disposed in proximity to the surgeon's hands to allow the surgeon to selectively articulate (e.g., pitch and yaw) the jaw members as needed during surgery.

[0005] With particular respect to articulating forceps that include a deployable knife, one important feature of these types of forceps is the knife drive rod which typically needs to be both sufficiently flexible to allow articulation of the jaw members while also being strong enough to advance and retract a knife blade through tissue.

SUMMARY

[0006] As used herein, the term “distal” refers to the portion that is being described which is further from a user, while the term “proximal” refers to the portion that is being described which is closer to a user. Further, to the extent consistent, any or all of the aspects detailed herein may be used in conjunction with any or all of the other aspects detailed herein.

[0007] In accordance with aspects of the present disclosure, a knife assembly for use with a surgical instrument is provided and includes a knife having proximal and distal ends. The proximal end of the knife includes an aperture defined therein having a series of spaced apart fins extending thereacross. A knife drive rod is configured to operably engage the fins to secure the knife drive rod to the knife, and a retention mechanism is operably disposed at a distal end of the knife drive rod and is configured to secure the knife drive rod in engagement between the fins.
[0008] In aspects according to the present disclosure, the retention mechanism is a cap or any other type of enlarged area at a distal end thereof, e.g., forged head, molten bubble, additional material via welding, crimping, swaging, etc. In other aspects according to the present disclosure, the retention mechanism includes the knife having a second aperture defined therein configured to receive a bent end of the knife drive rod.
[0009] In aspects according to the present disclosure, one or more of the fins includes a recess defined therein configured to receive at least a portion of an outer periphery of the knife drive rod. In still other aspects according to the present disclosure, the knife drive rod is configured to engage the fins in a weave-like manner from a proximal end of the aperture to a distal end of the aperture.
[0010] In accordance with additional aspects of the present disclosure, a knife assembly for use with a surgical instrument is provided and includes a knife having proximal and distal ends, the proximal end including an aperture defined therein. A knife drive rod includes a tube operably engaged to a distal end thereof. The tube is configured to operably engage the aperture to lock the knife drive rod in engagement with the knife. In aspects according to the present disclosure, a weld operably engages the tube to the knife. In other aspects according to the present disclosure, the distal end of the knife drive rod threadably engages the tube. In still other aspects according to the present disclosure, the knife and the tube are made from similar metals to increase the strength of the weld.
[0011] In yet other aspects according to the present disclosure, the tube is dimensioned to seat within the aperture and, once seated, provides a first mechanical engagement between the tube and the knife, and a weld provides a second mechanical engagement between the tube and the knife. Other methods of mechanical engagement are contemplated, e.g., crimping and swaging.
[0012] In still other aspects according to the present disclosure, the knife includes a second aperture defined therein configured to receive a bent end of the knife drive rod to provide a second mechanical engagement between the knife and the knife drive rod. In other aspects according to the present disclosure, the second aperture is a slot and the bent end of the knife includes a locking feature to secure the distal end of the knife drive rod within the slot once engaged therein. In yet other aspects according to the present disclosure, the locking feature is a twist lock, a tab lock, a button snap, a crimp, or a rivet.
[0013] In accordance with additional aspects of the present disclosure, a knife assembly for use with a surgical instrument includes a knife having proximal and distal ends. The proximal end includes an aperture defined therein including a pair of tubes operably engaged thereto. A knife drive rod is configured to operably engage the pair of tubes disposed within the aperture. A knife tube is operably engaged to the knife drive rod between the pair of tubes. The knife tube is dimensioned larger than the pair of tubes to lock the knife drive rod within the pair of tubes and in operable engagement with the knife.
[0014] In aspects according to the present disclosure, a weld secures each tube of the pair of tubes to the knife, and a knife weld secures the knife tube to the knife drive rod. In yet other aspects according to the present disclosure, the pair of tubes and the knife are made from similar metals, and the knife tube and the knife drive rod are made from similar materials to increase the strength of the welds.
[0015] In accordance with additional aspects of the present disclosure, a knife assembly for use with a surgical instrument includes a knife having proximal and distal ends. The proximal end includes an aperture defined therein having one or more capture tabs disposed therein. A tube is

configured to operably engage the one or more capture tabs disposed within the aperture. A knife drive rod is configured to operably engage the tube disposed within the aperture.
[0016] In aspects according to the present disclosure, the knife drive rod threadably engages the tube. In other aspects according to the present disclosure, the tube is dimensioned to seat within the aperture and, once seated, provides a first mechanical engagement between the tube and the knife, and a weld provides a second mechanical engagement between the tube and the knife. In aspects according to the present disclosure, the aperture includes a pair of opposing capture tabs each configured to engage an end of the tube.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0017] The above and other aspects and features of the present disclosure will become more apparent in view of the following detailed description when taken in conjunction with the accompanying drawings wherein like reference numerals identify similar or identical elements and:
[0018] FIG. **1**A is a perspective view of endoscopic surgical forceps exemplifying the aspects and features of the present disclosure, wherein the shaft of the endoscopic surgical forceps is disposed in a non-articulated position and wherein the jaw members of the endoscopic surgical forceps are disposed in a spaced-apart position;
[0019] FIG. **1**B is a perspective view of the endoscopic surgical forceps of FIG. **1**A, wherein the shaft of the endoscopic surgical forceps is disposed in an articulated position and wherein the jaw members of the endoscopic surgical forceps are disposed in an approximated position;
[0020] FIGS. **2**A and **2**B are enlarged schematic views of one embodiment of an engagement feature for coupling a knife blade to a knife drive rod exemplifying the aspects and features of the present disclosure;
[0021] FIGS. **3**A, **3**B and **3**C are enlarged schematic views of another embodiment of an engagement feature for coupling a knife blade to a knife drive rod exemplifying the aspects and features of the present disclosure;
[0022] FIGS. **4**A and **4**B are enlarged schematic views of another embodiment of an engagement feature for coupling a knife blade to a knife drive rod exemplifying the aspects and features of the present disclosure;
[0023] FIGS. **5**A, **5**B and **5**C are enlarged schematic views of another embodiment of an engagement feature for coupling a knife blade to a knife drive rod exemplifying the aspects and features of the present disclosure;
[0024] FIGS. **6**A, **6**B and **6**C are enlarged schematic views of another embodiment of an engagement feature for coupling a knife blade to a knife drive rod exemplifying the aspects and features of the present disclosure;
[0025] FIGS. **7**A, **7**B and **7**C are enlarged schematic views of another embodiment of an engagement feature for coupling a knife blade to a knife drive rod exemplifying the aspects and features of the present disclosure;
[0026] FIGS. **8**A, **8**B and **8**C are enlarged schematic views of another embodiment of an engagement feature for coupling a knife blade to a knife drive rod exemplifying the aspects and features of the present disclosure;
[0027] FIGS. **9**A, **9**B and **9**C are enlarged schematic views of another embodiment of an engagement feature for coupling a knife blade to a knife drive rod exemplifying the aspects and features of the present disclosure; and
[0028] FIG. **10** is an enlarged schematic view of another embodiment of an engagement feature for coupling a knife blade to a knife drive rod exemplifying the aspects and features of the present disclosure.

DETAILED DESCRIPTION

[0029] Referring generally to FIGS. **1**A and **1**B, an endoscopic surgical forceps exemplifying the aspects and features of the present disclosure is shown generally identified by reference numeral **10**. For the purposes herein, endoscopic surgical forceps **10** is generally described. Aspects and features of endoscopic surgical forceps **10** not germane to the understanding of the present disclosure are omitted to avoid obscuring the aspects and features of the present disclosure in unnecessary detail.

[0030] Forceps **10** includes a housing **20**, a handle assembly **30**, a trigger assembly **60**, a rotating assembly **70**, a plurality of articulation actuators **80**, an activation switch **4**, and an end effector assembly **100**. Forceps **10** further includes a shaft **12** having a distal end **12***a* configured to mechanically engage end effector assembly **100** and a proximal end **12***b* that mechanically engages housing **20**. Forceps **10** also includes cable **2** that connects forceps **10** to an energy source (not shown), e.g., a generator or other suitable power source, although forceps **10** may alternatively be configured as a battery-powered device. Cable **2** includes a wire (or wires) (not shown) extending therethrough that has sufficient length to extend through shaft **12** in order to provide energy to one or both tissue-treating plates **114**, **124** of jaw members **110**, **120**, respectively, of end effector assembly **100**. Activation switch **4** is coupled to tissue-treating plates **114**, **124** and the source of energy for selectively activating the supply of energy to jaw members **110**, **120** for treating, e.g., cauterizing, coagulating/desiccating, and/or sealing, tissue.

[0031] Shaft **12** of forceps **10** defines a distal segment **13** positioned towards distal end **12***a* thereof, a proximal segment **14** positioned towards proximal end **12***b* thereof, and an articulating section **15** disposed between the distal and proximal segments **13**, **14**, respectively. Articulating section **15** includes a plurality of articulating links **16** having a plurality of articulation cables **17** extending therethrough. Each cable **17** is operably engaged at a distal end thereof to distal segment **13** and at a proximal end thereof to one of the articulation actuators **80** to enable articulation of distal segment **13** and, thus, end effector assembly **100**, relative to proximal segment **14** upon actuation of one or more of articulation actuators **80**. Rotating assembly **70** operably couples shaft **12** to housing **20** to enable selective rotation of shaft **12** and, thus, end effector assembly **100**, relative to housing **20**.

[0032] Handle assembly **30** of forceps **10** includes a fixed handle **50** and a movable handle **40**. Fixed handle **50** is integrally associated with housing **20** and handle **40** is movable relative to fixed handle **50**. Movable handle **40** of handle assembly **30** is operably coupled to a drive assembly (not shown) that, together, mechanically cooperate to impart movement of one or both of jaw members **110**, **120** of end effector assembly **100** about a pivot **103** between a spaced-apart position (FIG. **1**A) and an approximated position (FIG. **1**B) to grasp tissue between jaw members **110**, **120**. As shown in FIG. **1**A, movable handle **40** is initially spaced-apart from fixed handle **50** and, correspondingly, jaw members **110**, **120** of end effector assembly **100** are disposed in the spaced-apart position. Movable handle **40** is compressible from this initial position to a compressed position corresponding to the approximated position of jaw members **110**, **120** (FIG. **1**B).

[0033] Trigger assembly **60** includes a trigger **62** coupled to housing **20** and movable relative thereto between an un-actuated position and an actuated position. Trigger **62** is operably coupled to a cutting mechanism **85**, various embodiments of which are detailed below, to actuate the cutting mechanism **85** to cut tissue grasped between jaw members **110**, **120** of end effector assembly **100** upon actuation of trigger **62**. As an alternative to a pivoting trigger **62**, a slide trigger, push-button, toggle switch, or other suitable actuator may be provided.

[0034] End effector assembly **100**, as noted above, includes first and second jaw members **110**, **120**. Each jaw member **110**, **120** includes a proximal flange portion **111**, **121**, an outer insulative jaw housing **112**, **122** disposed about the distal portion (not explicitly shown) of each jaw member **110**, **120**, and a tissue-treating plate **114**, **124**, respectively. Proximal flange portions **111**, **121** are pivotably coupled to one another about pivot **103** for moving jaw members **110**, **120** between the

spaced-apart and approximated positions, although other suitable mechanisms for pivoting jaw members **110**, **120** relative to one another are also contemplated. The distal portions (not explicitly shown) of the jaw members **110**, **120** are configured to support jaw housings **112**, **122**, and tissue-treating plates **114**, **124**, respectively, thereon.

[0035] Outer insulative jaw housings **112**, **122** of jaw members **110**, **120** support and retain tissue-treating plates **114**, **124** on respective jaw members **110**, **120** in opposed relation relative to one another. Tissue-treating plates **114**, **124** are formed from an electrically conductive material, e.g., for conducting electrical energy therebetween for treating tissue, although tissue-treating plates **114**, **124** may alternatively be configured to conduct any suitable energy, e.g., thermal, microwave, light, ultrasonic, etc., through tissue grasped therebetween for energy-based tissue treatment. As mentioned above, tissue-treating plates **114**, **124** are coupled to activation switch **4** and the source of energy (not shown), e.g., via the wires (not shown) extending from cable **2** through forceps **10**, such that energy may be selectively supplied to tissue-treating plate **114** and/or tissue-treating plate **124** and conducted therebetween and through tissue disposed between jaw members **110**, **120** to treat tissue.

[0036] One or both of jaw members **110**, **120** may further define a longitudinally-extending channel **125** (only the channel **125** of jaw member **120** is shown) for allowing reciprocation of the cutting mechanism **85** upon actuation of trigger **62**. A ctuation of the trigger **62** reciprocates a knife drive bar, e.g., knife drive rod **280** of FIG. **2**B, operably coupled to the cutting mechanism, e.g., knife **285**. As explained below, the term “rod” is generally utilized herein but is meant to denote any type of drive member or element. Together and as used herein, the knife, e.g., knife **285** and knife drive bar, e.g., knife drive rod **280**, form a knife assembly **250**. Knife drive rod **280** is made from a flexible material of sufficient strength to allow the knife drive rod **280** to both push and pull the knife **285** through tissue disposed between jaw members **110**, **120**. Moreover, the flexibility of the knife drive rod **280** allows the knife drive rod **280** to flex as needed during articulation of the jaw members **110**, **120**. The knife drive rod **280** may be made from a variety of flexible materials such as Nitinol that exhibit the necessary strength and flexibility to allow smooth translation of the knife drive rod **280** through one or more articulating joints of articulating section **15**, e.g., Stainless Steel, High Carbon Steel, Iconel, Monel, Nimonic, Nitronic, Hastelloy (Nickel-based alloys other than Nitonol), Elgiloy (Cobalt-Nickel), Brass, Phosphor Brass, Beryllium Copper, Chrome-Vanadium, Chrome Silicone, Titanium and Braided Cable made of steel or Tungsten.

[0037] The knife drive rod **280** generally refers to a drive member that may be in the shape of a rod, cable, braided cable, tube, piece of sheet metal or plastic, screw and the like. It is envisioned that the term “rod” covers all of these and other commonly known types of drive members made from a variety of different materials so long as it is strong enough, durable enough and/or stiff enough to advance and retract the knife **285**.

[0038] Knife **285** is typically made from a stronger, harder, stiffer and/or more durable material, e.g., stainless steel, to allow the knife **285** to easily translate through tissue on a repeated basis. Other materials are also contemplated such as Stainless Steel or High Carbon Steel, Tool Steel, High Speed Steel, Chrome Steel, Tungston Carbide, Titanium, Vanadium Alloys, Ceramic or Glass and/or Plastic.

[0039] Since it is often difficult to assure a consistent and strong weld between two dissimilar metals, i.e., utilizing a flexible first material, e.g., Nitinol, for the knife drive rod **280** with a second stronger material for the knife **285**, e.g., stainless steel, various welding and mechanical capture techniques are described below with respect to FIGS. **2**A-**10**.

[0040] FIGS. **2**A and **2**B show one embodiment of a knife **285** for engagement to a knife drive rod **280**. More particularly, knife **285** includes a knife body **284** having a distal end **286** and a proximal end **282**, the distal end **286** including a sharpened edge for cutting tissue and the proximal end **282** including an aperture **287** defined therein for capturing the knife drive rod **280**. Together the knife **285** and knife drive rod **280** form a knife assembly **250**. A series of fins **283** are etched from the

proximal end **282** into the aperture **287** that include one or more recessed portions **283′** defined therein configured to partially receive the outer periphery of the knife drive rod **280** to mechanically capture the knife drive rod **280** on opposing sides along the length thereof. During assembly, the knife drive rod **280** is weaved through the various fins **283** to engage the recesses **283′** and secure the knife drive rod **280** to the knife **285**. Weaving the knife drive rod **280** through the fins **283** provides lateral stability to the knife **285** and knife drive rod **280** during use. Once the knife drive rod **280** is weaved through the fins **283**, a retention mechanism, e.g., a cap **281**, is secured (e.g., welded, crimped, etc.) to the end of the knife drive rod **280** to lock the knife drive rod **280** in place within aperture **287** of knife **285**. Other types of enlarged areas may be utilized as a retention mechanism, e.g., forged head, molten bubble, additional material via welding, crimping, swaging, etc. The dimensions of the cap **281** are sized greater than the dimensions of the recesses **283′** to prevent slippage of the mechanical connection during use. The knife **285** may be made from stainless steel, e.g., surgical stainless steel (**316** SS) or other surgical metal, and the knife drive rod **280** may be made from Nitinol or other flexible metal or a metal hybrid (Nitinol inner rod and helical hollow strand HHS outer casing).

[0041] FIGS. **3**A-**3**C show another embodiment of a knife **385** for engagement to a knife drive rod **380**. M ore particularly, knife **385** includes a knife body **384** having a distal end **386** and a proximal end **382**, the distal end **386** including a sharpened edge for cutting tissue and the proximal end **382** including an aperture **387** defined therein for capturing the knife drive rod **380**. Together the knife **385** and knife drive rod **380** form a knife assembly **350**. A series of fins **383** are etched from the proximal end **382** into the aperture **387** that include one or more recessed portions **383′** defined therein configured to partially receive the outer periphery of the knife drive rod **380** to mechanically capture the knife drive rod **380** on opposing sides along the length thereof.

[0042] During assembly, the knife drive rod **380** is weaved through the various fins **383** to engage the recesses **383′** and secure the knife drive rod **380** to the knife **385**. As mentioned above, weaving the knife drive rod **380** through the fins **383** provides lateral stability to the knife **385** and knife drive rod **380** during use. Once the knife drive rod **380** is weaved through the fins **383**, a retention mechanism, e.g., a bent end **381** disposed at the distal end of the knife drive rod **380**, is secured within a corresponding aperture **389** defined within the proximal end **382** of the knife body **384** (FIG. **3**B) to lock the knife drive rod **380** in place within aperture **389** of knife body **384** (FIG. **3**C).

[0043] FIGS. **4**A and **4**B show another embodiment of a knife **485** for engagement to a knife drive rod **480**. M ore particularly, knife **485** includes a knife body **484** having a distal end **486** and a proximal end **482**, the distal end **486** including a sharpened edge for cutting tissue and the proximal end **482** including an aperture **487** defined therein for capturing the knife drive rod **480**. Together the knife **485** and knife drive rod **480** form a knife assembly **450**. A pair of opposing capture tabs **481***a* and **481***b* are etched from the proximal end **482** into the aperture **487** and are configured to capture and secure a tube **483** therebetween. The inner periphery of the tube **483** is configured to engage, e.g., threadably engage, the knife drive rod **480**. During assembly, the tube **483** and the knife drive rod **480** may be spot-welded or crimped after engagement within the tube **483** to provide additional engagement of the knife drive rod **480** therein.

[0044] Since the knife drive rod **480** needs to be flexible to accommodate articulation of the jaw members **110**, **120**, and the knife body **484** needs to be sufficiently strong to cut through tissue on a repeated basis, the knife drive rod **480** and the knife body **484** are typically made from dissimilar materials and any such weld or bond may be weaker than desired. Thus, additional mechanical engagement between the two elements, e.g., the knife drive rod **480** and knife body **484**, is needed to prevent mechanical failure. Tube **483** may be made from any type of metal, e.g., stainless steel, that will provide a secure weld to knife body **484**. In embodiments, the knife body **484** and the tube **483** are made from the same material, e.g., stainless steel, to assure a good weld.

[0045] By providing a strong mechanical connection between the knife drive rod **480** and the tube **483** and a strong mechanical connection between the tube **483** and the knife body **484**, the chances

of mechanical failure are greatly reduced.
[0046] FIGS. **5**A-**5**C show another embodiment of a knife **585** for engagement to a knife drive rod **580**. M ore particularly, knife **585** includes a knife body **584** having a distal end **586** and a proximal end **582**, the distal end **586** including a sharpened edge for cutting tissue and the proximal end **582** including an aperture **587** defined therein for capturing the knife drive rod **580**. Together the knife **585** and knife drive rod **580** form a knife assembly **550**. A capture tab **581** is etched from the proximal end **582** into the aperture **587** and is configured to capture and secure a tube **583** therein. The inner periphery of the tube **583** is configured to engage, e.g., threadably engage, the knife drive rod **580**. During assembly, the tube **583** and the knife drive rod **580** may be spot-welded or crimped after engagement within the tube **583** to provide additional engagement of the knife drive rod **580** therein.
[0047] Since the knife drive rod **580** needs to be flexible to accommodate articulation of the jaw members **110**, **120**, and the knife body **584** needs to be sufficiently strong to cut through tissue on a repeated basis, the knife drive rod **580** and the knife body **584** are typically made from dissimilar materials and any such weld or bond may be weaker than desired. Thus additional mechanical engagement between the two elements, e.g., the knife drive rod **580** and knife body **584**, is needed to prevent mechanical failure. Tube **583** may be made from any type of metal, e.g., stainless steel, that will provide a secure weld to knife body **584**.
[0048] In embodiments, the knife body **584** and the tube **583** are made from the same material, e.g., stainless steel, to assure a good weld. The tube **583** may be dimensioned to securely seat within aperture **587** after assembly of the knife drive rod **580** within aperture **587** and about capture tab **586** to provide additional mechanical engagement between the knife body **584** and the knife drive rod **580**. By providing a strong mechanical connection between the knife drive rod **580** and the tube **583** and a strong mechanical connection between the tube **583** and the knife body **584**, the chances of mechanical failure are greatly reduced.
[0049] FIGS. **6**A-**6**C show another embodiment of a knife **685** for engagement to a knife drive rod **680**. M ore particularly, knife **685** includes a knife body **684** having a distal end **686** and a proximal end **682**, the distal end **686** including a sharpened edge for cutting tissue and the proximal end **682** including an aperture **687** defined therein for capturing the knife drive rod **680**. Together the knife **685** and knife drive rod **680** form a knife assembly **650**. A pair of capture tubes **681***a* and **681***b* is welded (or otherwise formed) into aperture **687** of proximal end **682** and is configured to capture and secure a knife drive rod **680** therein. The inner periphery of the capture tubes **681***a*, **681***b* are configured to engage, e.g., threadably engage, the knife drive rod **680**. Opposing capture tabs (not shown but see FIG. **4***a*-capture tabs **481***a*, **481***b*) may be utilized to mechanically capture tubes **681***a*, **681***b*.
[0050] During assembly, the knife drive rod **680** is threaded through the pair of capture tubes **681***a*, **681***b* and a second tube **689** (FIG. **6**C) is spot welded to the exposed portion of the knife drive rod **680** between the pair of capture tubes **681***a*, **681***b* to secure the knife drive rod **680** in place between the two capture tubes **681***a*, **681***b*. The second tube **689** is made from the same material, e.g., Nitinol, as the knife drive rod **680** to assure a strong weld and secure mechanical engagement between the knife drive rod **680** and the capture tubes **681***a*, **681***b* of the knife body **684**.
[0051] FIGS. **7**A-**7**C show another embodiment of a knife **785** for engagement to a knife drive rod **780**. M ore particularly, knife **785** includes a knife body **784** having a distal end **786** and a proximal end **782**, the distal end **786** including a sharpened edge for cutting tissue and the proximal end **782** including a slot **787** defined therein and configured to capture a tube **781** crimped, threaded or welded onto a portion of the knife drive rod **780**. Together the knife **785** and knife drive rod **780** form a knife assembly **750**.
[0052] Since the knife drive rod **780** needs to be flexible to accommodate articulation of the jaw members **110**, **120**, and the knife body **784** needs to be sufficiently strong to cut through tissue on a repeated basis, the knife drive rod **780** and the knife body **784** are typically made from dissimilar

materials and any such weld or bond may be weaker than desired. Thus additional mechanical engagement between the two elements, e.g., the knife drive rod **780** and knife body **784**, is needed to prevent mechanical failure. Tube **781** may be made from any type of metal, e.g., stainless steel, that will provide a secure weld to knife body **784**.

[0053] In embodiments, the knife body **784** and the tube **781** are made from the same material, e.g., stainless steel, to assure a good weld. The proximal end **782** of the knife body **780** also includes an aperture **789** defined therein configured to receive the distal end **783** of the knife drive rod **780**. More particularly, the distal end **783** of the knife rod **780** is bent at an angle, e.g., 90°, such that during assembly the distal end **783** may be inserted into aperture **789** to secure the knife drive rod **780** to the knife body **784**. In addition and during assembly the tube **781** is seated within slot **787** to capture the tube **781** therein and provide additional mechanical engagement between the knife drive rod **780** and the knife body **784** (See FIG. **7**C).

[0054] FIGS. **8**A-**8**C show another embodiment of a knife **885** for engagement to a knife drive rod **880**. M ore particularly, knife **885** includes a knife body **884** having a distal end **886** and a proximal end **882**, the distal end **886** including a sharpened edge for cutting tissue and the proximal end **882** including a slot **887** defined therein and configured to capture a tube **881** crimped, threaded or welded onto a portion of the knife drive rod **880**. Together the knife **885** and knife drive rod **880** form a knife assembly **850**.

[0055] Since the knife drive rod **880** needs to be flexible to accommodate articulation of the jaw members **110**, **120**, and the knife body **884** needs to be sufficiently strong to cut through tissue on a repeated basis, the knife drive rod **880** and the knife body **884** are typically made from dissimilar materials and any such weld or bond may be weaker than desired. Thus additional mechanical engagement between the two elements, e.g., the knife drive rod **880** and knife body **884**, is needed to prevent mechanical failure. Tube **881** may be made from any type of metal, e.g., stainless steel, that will provide a secure weld to knife body **884**.

[0056] In embodiments, the knife body **884** and the tube **881** are made from the same material, e.g., stainless steel, to assure a good weld. The proximal end **882** of the knife body **880** also includes an aperture or keyway **883** defined therein configured to receive the distal end **889** of the knife drive rod **880**. M ore particularly, the distal end **889** of the knife rod **880** is bent at an angle, e.g., 90°, such that during assembly the distal end **889** may be inserted into aperture **883** to secure the knife drive rod **880** to the knife body **884**. The distal end **889** includes a locking feature **889′** that is enabled once the distal end **889** is inserted into the aperture **883** during assembly.

[0057] The locking feature **889′** may be a twist lock, tab lock, button snap, crimp, rivet or the like that is dimensioned to securely engage the distal end **889** within aperture **883** upon actuation, e.g., twisting, snapping, crimping, hammering, etc. thereof (FIG. **8**C). In addition and during assembly the tube **881** is seated within slot **887** to capture the tube **881** therein and provide additional mechanical engagement between the knife drive rod **880** and the knife body **884** (See FIG. **8**C).

[0058] FIGS. **9**A and **9**B show another embodiment of a knife **985** for engagement to a knife drive rod **980**. M ore particularly, knife **985** includes a knife body **984** having a distal end **986** and a proximal end **982**, the distal end **986** including a sharpened edge for cutting tissue and the proximal end **982** including a slot **987** defined therein and configured to capture a tube **981** crimped, threaded or welded onto a portion of the knife drive rod **980**. Together the knife **985** and knife drive rod **980** form a knife assembly **950**.

[0059] Since the knife drive rod **980** needs to be flexible to accommodate articulation of the jaw members **110**, **120**, and the knife body **984** needs to be sufficiently strong to cut through tissue on a repeated basis, the knife drive rod **980** and the knife body **984** are typically made from dissimilar materials and any such weld or bond may be weaker than desired. Thus additional mechanical engagement between the two elements, e.g., the knife drive rod **980** and knife body **984**, is needed to prevent mechanical failure. Tube **981**, on the other hand, may be made from any type of metal, e.g., stainless steel, that will provide a secure weld to knife body **984**.

[0060] In embodiments, the knife body **984** and the tube **981** are made from the same material, e.g., stainless steel, to assure a good weld. In addition and during assembly the tube **981** is seated within slot **987** to capture the tube **981** therein and provide additional mechanical engagement between the knife drive rod **980** and the knife body **984** (See FIG. **9**C). As mentioned above, the knife drive rod **980** and the tube **980** are typically made from dissimilar metals, e.g., Nitinol and stainless steel, respectively, and, when welded, may produce a weaker weld.

[0061] In the particular embodiment of FIGS. **9**A and **9**B, if the weaker weld between the knife drive rod **980** and the tube **981** fails, the stronger bond between the knife body **984** and the tube **981** will remain intact thereby preventing the possibility of the blade **985** coming out of one or both jaw members, e.g., jaw member **120**.

[0062] FIG. **10** shows another embodiment of a knife **1085** for engagement to a knife drive rod (not shown). More particularly, knife **1085** includes a knife body **1084** having a distal end **1086** and a proximal end **1082**, the distal end **1086** including a sharpened edge for cutting tissue and the proximal end **1082** configured to mechanically engage a tube **1081** which may be crimped, threaded or welded onto the proximal end **1082** along a lower edge **1087** of the knife body **1084**. Together the knife **1085** and knife drive rod (not shown) form a knife assembly **1050**. Tube **1081** may be made from any type of metal, e.g., stainless steel, that will provide a secure weld to knife body **1084**.

[0063] In embodiments, the knife body **1084** and the tube **1081** are made from the same material, e.g., stainless steel, to assure a good weld. The knife drive rod is secured within the tube **1081** during assembly via crimping, welding or threadable engagement. Engaging the knife drive rod to the tube **1081** which is secured to the lower edge **1087** of the knife body **1084** facilitates a more balanced actuation of the knife **1085** during translation since the mechanical engagement of the knife body **1084** and the tube **1081** is along the centerline (lower edge **1087**) of the knife **1085**.

[0064] The present disclosure also describes various methods of engaging a knife drive rod, e.g., knife drive rod **280**, **380**, **480**, **580**, **680**, **780**, **880**, and **980**, to a respective knife, e.g., knife **285**, **385**, **485**, **585**, **685**, **785**, **885**, **985**, **1085**. For example, one such method is described with reference to FIGS. **2**A and **2**B. The method includes: forming a knife **285** (e.g., stamping, etching, cutting, pressing, rolling (hot or cold), extruding, etc.) having proximal **282** and distal ends **286**, the distal end **286** including a sharpened edge; etching (or otherwise forming) an aperture **287** within the proximal end **282** of the knife **285**, the aperture **287** including a series of fins **283** disposed therein; weaving a distal end of a knife rod **280** through the series of fins **283** in an alternating manner; and engaging a cap **281** onto the distal end of the knife drive rod **280** to secure the knife drive rod **280** within the aperture **287** of the knife **285**. One or more fins **283** may include a recess **283′** formed therein configured to laterally secure the knife drive rod **285** within the aperture **287**. The distal end of the drive rod **280** may be weaved through the fins **283** and recesses **283′**. The aperture **287** may be formed within knife **285** via etching, cutting, stamping or any other method known in the art.

[0065] FIGS. **3**A-**3**C show another method of engaging a knife drive rod **380** to a knife **385** according the present disclosure. Similar to the embodiment shown in FIGS. **2**A and **2**B, the method includes: forming a knife **385** having proximal **382** and distal ends **386**, the distal end **386** including a sharpened edge; etching (or otherwise forming) an aperture **387** within the proximal end **382** of the knife **385**, the aperture **387** including a series of fins **383** disposed therein; etching or otherwise forming a second aperture **389** within the proximal end **382** of the knife **385**; weaving a distal end of a knife rod **380** through the series of fins **383** in an alternating manner; bending a distal end **381** of the knife drive rod **380**; and engaging the bent distal end **381** into the second aperture **389** formed within the proximal end **382** of the knife **385** to secure the knife drive rod **380** within the aperture **387** of the knife **385**.

[0066] FIGS. **4**A and **4**B show another method of engaging a knife drive rod **480** to a knife **485** according the present disclosure. Similar to the embodiments shown above, the method includes: forming a knife **485** having proximal **482** and distal ends **486**, the distal end **486** including a

sharpened edge; etching (or otherwise forming) an aperture **487** within the proximal end **482** of the knife **485**, the aperture **487** including a pair of opposing capture tabs **481***a*, **481***b* disposed therein; engaging (threading, crimping or otherwise capturing) a tube **483** onto a distal end of a knife drive rod **480**; engaging the tube **483** between the two opposing capture tabs **481***a*, **481***b* to seat the tube **483** within the aperture **487**; and securing (welding, crimping, or otherwise) the tube **483** to the proximal end **482** of the knife **485** to secure the knife drive rod **480** and tube **483** to the knife **485**.

[0067] FIGS. **5**A-**5**C show another method of engaging a knife drive rod **580** to a knife **585** according the present disclosure. Similar to the embodiment shown above with respect to FIGS. **4**A and **4**B, the method includes: forming a knife **585** having proximal **582** and distal ends **586**, the distal end **586** including a sharpened edge; etching (or otherwise forming) an aperture **587** within the proximal end **582** of the knife **585**, the aperture **587** including a capture tab **581** disposed therein; engaging (threading, crimping or otherwise capturing) a tube **583** onto a distal end of a knife drive rod **580**; engaging the tube **583** to the capture tab **581** to seat the tube **583** within the aperture **587**; and securing (welding, crimping, or otherwise) the tube **583** to the proximal end **582** of the knife **585** to secure the knife drive rod **580** and tube **583** to the knife **585**.

[0068] FIGS. **6**A-**6**C show another method of engaging a knife drive rod **680** to a knife **685** according the present disclosure. The method includes: forming a knife **685** having proximal **682** and distal ends **686**, the distal end **686** including a sharpened edge; etching (or otherwise forming) an aperture **687** within the proximal end **682** of the knife **685**; engaging (e.g., welding) a pair of opposing tubes **681***a*, **681***b* within the aperture **687**; feeding the knife drive rod **680** through the pair of tubes **681***a*, **681***b*; and engaging (e.g., welding or crimping) a second tube **689** to the exposed portion of the knife drive rod **680** between the pair of tubes **681***a*, **681***b* to secure the knife drive rod **680** in place between the tubes **681***a*, **681***b*. K nife drive rod **680** and the second tube **689** may be made from the same material to provide a strong weld. The knife drive rod **680** may also be threaded through the pair of tubes **681***a*, **681***b* to enhance the mechanical connection. The tubes **681***a*, **681***b* may be made from the same material as the knife **685** to enhance the weld and provide additional strength, stiffness, and/or durability.

[0069] FIGS. **7**A-**7**C show another method of engaging a knife drive rod **780** to a knife **785** according the present disclosure. Similar to the embodiments shown above with respect to FIGS. **4**A and **4**B and FIGS. **3**A-**3**C, the method includes: forming a knife **785** having proximal **782** and distal ends **786**, the distal end **786** including a sharpened edge; etching (or otherwise forming) an aperture **787** within the proximal end **782** of the knife **785**; etching or otherwise forming a second aperture **789** within the proximal end **782** of the knife **785**; engaging (threading, crimping or otherwise capturing) a tube **781** onto a distal end **783** of a knife drive rod **780**; bending the distal end **783** of the knife drive rod **780**; seating the tube **781** within the aperture **787**; and engaging the bent distal end **783** into the second aperture **789** formed within the proximal end **782** of the knife **785** to secure the tube **781** within the aperture **787** of the knife **785** and secure the bent distal end **783** to the proximal end **782** of the knife **785**.

[0070] FIGS. **8**A-**8**C show another method of engaging a knife drive rod **880** to a knife **885** according the present disclosure. Similar to the embodiments shown above with respect to FIGS. **7**A-**7**C, the method includes: forming a knife **885** having proximal **882** and distal ends **886**, the distal end **886** including a sharpened edge; etching (or otherwise forming) an aperture **887** within the proximal end **882** of the knife **885**; etching or otherwise forming a slot **883** within the proximal end **882** of the knife **885**; engaging (threading, crimping or otherwise capturing) a tube **881** onto a distal end **889** of a knife drive rod **880**; bending the distal end **889** of the knife drive rod **880**; seating the tube **881** within the aperture **887**; engaging the bent distal end **889** into the slot **883** formed within the proximal end **882** of the knife **885**; actuating a locking feature **889′** (e.g., twist lock, tab lock, button snap, crimp, rivet or the like) to engage and secure (via twisting, snapping, crimping, hammering, etc.) the distal end **889** within the slot **883** and secure the tube **881** within the aperture **887** of the knife **885**.

[0071] FIGS. **9**A-**9**C show another method of engaging a knife drive rod **980** to a knife **985** according the present disclosure. Similar to many of the above-described embodiments shown above with respect to the various figures, the method includes: forming a knife **985** having proximal **982** and distal ends **986**, the distal end **986** including a sharpened edge; etching (or otherwise forming) an aperture **987** within the proximal end **982** of the knife **985**; engaging (threading, crimping or otherwise capturing) a tube **981** onto a distal end of a knife drive rod **980**; seating the tube **981** within the aperture **987**; and securing the tube **981** within the aperture **987** via welding, crimping, etc. As mentioned above, the knife body **984** and the tube **981** are made from the same material, e.g., stainless steel, to assure a good weld.
[0072] In addition and during assembly the tube **981** is seated within slot **987** to capture the tube **981** therein and provide additional mechanical engagement between the knife drive rod **980** and the knife body **984** (See FIG. **9**C). As mentioned above, the knife drive rod **980** and the tube **980** are typically made from dissimilar metals, e.g., Nitinol and stainless steel, respectively, and, when welded, may produce a weaker weld. If the weaker weld between the knife drive rod **980** and the tube **981** fails, the stronger bond between the knife body **984** and the tube **981** will remain intact thereby preventing the possibility of the blade **985** coming out of one or both jaw members, e.g., jaw member **120**.
[0073] FIG. **10** shows another method of engaging a knife drive rod **1080** to a knife **1085** according the present disclosure. The method includes forming a knife **1085** having proximal **1082** and distal ends **1086**, the distal end **1086** including a sharpened edge; engaging (e.g., welding or other mechanical attachment) a tube **1081** to a lower edge **1087** of the knife **1085**; and engaging (threading, crimping or otherwise capturing) a distal end of a knife drive rod (not shown) within the tube **1081**. Tube **1081** may be made from any type of metal, e.g., stainless steel, that will provide a secure weld to knife body **1084** (which is also made from a similar material, e.g., stainless steel) to assure a good weld.
[0074] Engaging the knife drive rod to the tube **1081** (which is secured to the lower edge **1087** of the knife body **1084**) facilitates a more balanced actuation of the knife **1085** during translation since the mechanical engagement of the knife body **1084** and the tube **1081** is along the centerline (lower edge **1087**) of the knife **1085**.
[0075] The various embodiments disclosed herein may also be configured to work with robotic surgical systems and what is commonly referred to as “Telesurgery.” Such systems employ various robotic elements to assist the clinician and allow remote operation (or partial remote operation) of surgical instrumentation. Various robotic arms, gears, cams, pulleys, electric and mechanical motors, etc. may be employed for this purpose and may be designed with a robotic surgical system to assist the clinician during the course of an operation or treatment. Such robotic systems may include remotely steerable systems, automatically flexible surgical systems, remotely flexible surgical systems, remotely articulating surgical systems, wireless surgical systems, modular or selectively configurable remotely operated surgical systems, etc.
[0076] The robotic surgical systems may be employed with one or more consoles that are next to the operating theater or located in a remote location. In this instance, one team of clinicians may prep the patient for surgery and configure the robotic surgical system with one or more of the instruments disclosed herein while another clinician (or group of clinicians) remotely controls the instruments via the robotic surgical system. As can be appreciated, a highly skilled clinician may perform multiple operations in multiple locations without leaving his/her remote console which can be both economically advantageous and a benefit to the patient or a series of patients.
[0077] For a detailed description of exemplary medical work stations and/or components thereof, reference may be made to U.S. Patent Application Publication No. 2012/0116416, and PCT Application Publication No. WO2016/025132, the entire contents of each of which are incorporated by reference herein.
[0078] Persons skilled in the art will understand that the structures and methods specifically

described herein and shown in the accompanying figures are non-limiting exemplary embodiments, and that the description, disclosure, and figures should be construed merely as exemplary of particular embodiments. It is to be understood, therefore, that the present disclosure is not limited to the precise embodiments described, and that various other changes and modifications may be effected by one skilled in the art without departing from the scope or spirit of the disclosure. Additionally, the elements and features shown or described in connection with certain embodiments may be combined with the elements and features of certain other embodiments without departing from the scope of the present disclosure, and that such modifications and variations are also included within the scope of the present disclosure. Accordingly, the subject matter of the present disclosure is not limited by what has been particularly shown and described.
[0079] While several embodiments of the disclosure have been shown in the drawings, it is not intended that the disclosure be limited thereto, as it is intended that the disclosure be as broad in scope as the art will allow and that the specification be read likewise. Therefore, the above description should not be construed as limiting, but merely as exemplifications of particular embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto. For example, the knife body and tube do not necessarily have to be made from the exact same materials. Similar materials, or any two materials that can be welded together to allow for a durable weld joint could be used.

Claims

1. A surgical instrument, comprising: an end effector assembly; and a knife assembly comprising: a knife extending along a longitudinal centerline, the knife including a knife body and a distal end portion including a knife blade; a tube having an outer surface engaged with the knife body, wherein the tube is laterally centered with respect to the knife body, and wherein the distal end portion of the knife extends distally beyond the tube; and a knife drive rod disposed in the tube to secure the knife drive rod to the tube, the knife drive rod extending proximally beyond the tube and the knife, wherein the knife drive rod is actuatable to translate the knife blade through tissue grasped by the end effector assembly.
2. The surgical instrument of claim 1, wherein the tube is engaged with a bottom surface of the knife body.
3. The surgical instrument of claim 2, wherein the tube is crimped, threaded, or welded to the knife body.
4. The surgical instrument of claim 1, wherein the tube is engaged with the knife body along the longitudinal centerline.
5. The surgical instrument of claim 1, further comprising a retention mechanism operably disposed at a distal end of the knife drive rod to secure the knife drive rod to the knife.
6. The surgical instrument of claim 5, wherein the retention mechanism is a cap.
7. The surgical instrument of claim 5, wherein the retention mechanism includes a bent end of the knife drive rod.
8. A surgical instrument, comprising: an end effector assembly; and a knife assembly, comprising: a knife extending along a centerline, the knife having a lower edge, a distal end portion including a sharpened edge, and a proximal end portion; a tube having an outer surface secured to the lower edge of the knife; and a knife drive rod disposed in the tube to secure the knife drive rod to the tube, the knife drive rod extending proximally beyond the tube and the knife, wherein the knife drive rod is actuatable to translate the sharpened edge through tissue grasped by the end effector assembly.
9. The surgical instrument of claim 8, wherein the tube is laterally centered with respect to the centerline.
10. The surgical instrument of claim 9, wherein the tube is engaged with the knife along the

centerline.
11. The surgical instrument of claim 8, wherein the tube is crimped, threaded, or welded to the knife.
12. The surgical instrument of claim 8, further comprising a retention mechanism operably disposed at a distal end of the knife drive rod to secure the knife drive rod to the knife.
13. The surgical instrument of claim 12, wherein the retention mechanism is a cap.
14. The surgical instrument of claim 12, wherein the retention mechanism includes a bent end of the knife drive rod.
15. A knife assembly for use with a surgical instrument, comprising: a knife body having a proximal end portion, a first lateral side, a second lateral side, a top side, a bottom side, and a distal end portion including a sharpened edge; and a tube engaged with the knife body at the bottom side of the knife body, the tube laterally centered with respect to the knife body.
16. The knife assembly of claim 15, wherein the knife body has a centerline, and the tube is engaged with the knife body along centerline.
17. The knife assembly of claim 15, wherein the tube is crimped, threaded, or welded to the knife body.
18. The knife assembly of claim 15, further comprising: a knife drive rod disposed in the tube to secure the knife drive rod to the tube, the knife drive rod extending proximally beyond the tube, wherein the knife drive rod is configured to move the knife assembly for cutting tissue.
19. The knife assembly of claim 18, further comprising a retention mechanism operably disposed at a distal end of the knife drive rod to secure the knife drive rod to the tube.
20. The knife assembly of claim 19, wherein the retention mechanism includes a cap or a bent end of the knife drive rod.