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### High torque threaded connections with external upset and multiple seals

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#### Abstract

A threaded connection includes a first tubular member having a box end defining an internal thread profile, and a second tubular member having a pin end defining an external thread profile threadably engageable with the internal thread profile of the box end. The external thread profile includes a first section that extends at a first taper angle relative to a longitudinal axis of the threaded connection, a second section extending from the first section at a second taper angle relative to the longitudinal axis, and an intermediate shoulder provided at a transition between the first and second sections and engageable with a corresponding intermediate shoulder provided on the internal thread profile. A cross-sectional area of the pin end increases at the intermediate shoulder.

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## **Background/Summary**

### **FIELD OF THE DISCLOSURE**

(1) The present disclosure relates generally to threaded pipes and, more particularly, to threaded connections between tubular members and including a thread profile defining at least two tapered sections and an intermediate shoulder provided at a transition between the tapered sections.

### **BACKGROUND OF THE DISCLOSURE**

(2) In the oil and gas industry, several types of tubing and pipe are used in exploration, completion, and production operations to extract hydrocarbons from subterranean hydrocarbon-bearing formations. Typical types of oilfield tubing include, among others, drill pipe, casing (or liner), and production tubing. Connected sections (lengths) of casing or liner pipe, for example, are used to encase the walls of a drilled wellbore and provide structural support for the well, and connected sections (lengths) of production pipe are used to convey the subsurface oil or gas to the well surface.

(3) Wellbore pipe typically has a threaded end configuration specially designed to meet its intended purpose as it structurally secures and seals the pipe ends together. Common threaded connections include a male threaded member or “pin” at the end of a tubing section, which engages a female threaded member or “box” at the end of an adjoining tubing section. The box may be formed as an integral part of the tubing section or it may comprise a coupling secured to a pin end of a tubular pipe section.

(4) Threaded connections of oilfield pipe and tubulars generally engage each other in an interference fit, a shouldering fit, or a combination of interference and shouldering fits. In an interference fit, tapered pin and box ends are tightly wedged together as the pin threadably advances into the box. The resulting interference fit provides both structural and sealing connections between the pin and box ends. In contrast, a shouldering connection engages an annular shoulder on the pin end with an annular shoulder provided on the box end. The threads of the shouldering connection provide the structure holding the pin and box ends together, and the engaged shoulders help facilitate a sealed engagement.

(5) Threaded connections tend to fail in areas of stress concentrations that occur during makeup and working of the connections. In particular, threaded connections can often exceed compression limits during deployment and production. A variety of thread designs, forms, and profiles have been suggested and introduced to change the distribution of torque stresses along the threaded connections of oilfield tubing, and thereby improve the long-term pipe integrity.

### **SUMMARY OF THE DISCLOSURE**

(6) Various details of the present disclosure are hereinafter summarized to provide a basic understanding. This summary is not an extensive overview of the disclosure and is neither intended to identify certain elements of the disclosure, nor to delineate the scope thereof. Rather, the primary purpose of this summary is to present some concepts of the disclosure in a simplified form prior to the more detailed description that is presented hereinafter.

(7) According to an embodiment, a threaded connection may include a first tubular member having a box end defining an internal thread profile, and a second tubular member having a pin end defining an external thread profile threadably engageable with the internal thread profile of the box

end, wherein the external thread profile includes a first section that extends at a first taper angle relative to a longitudinal axis of the threaded connection, a second section extending from the first section at a second taper angle relative to the longitudinal axis, and an intermediate shoulder provided at a transition between the first and second sections and engageable with a corresponding intermediate shoulder provided on the internal thread profile, wherein a cross-sectional area of the pin end increases at the intermediate shoulder.

(8) According to one or more additional embodiments, a thread profile for a tubular member may include a first section that extends from a first end of the thread profile at a first taper angle relative to a longitudinal axis of the tubular member, a second section extending from the first section at a second taper angle relative to the longitudinal axis, wherein the first taper angle is greater than the second taper angle, and an intermediate shoulder provided at a transition between the first and second sections, wherein a cross-sectional area of the tubular member increases at the intermediate shoulder.

(9) Any combinations of the various embodiments and implementations disclosed herein can be used in a further embodiment, consistent with the disclosure. These and other aspects and features can be appreciated from the following description of certain embodiments presented herein in accordance with the disclosure and the accompanying drawings and claims.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. 1 is a cross-sectional side view of an example threaded connection that may incorporate the principles of the present disclosure.

(2) FIG. 2 is an enlarged cross-sectional view of a portion of the threaded connection of FIG. 1, according to one or more embodiments.

(3) FIG. 3 is another enlarged cross-sectional view of a portion of the threaded connection of FIG. 1, according to one or more additional embodiments.

(4) FIG. 4 is another enlarged cross-sectional view of a portion of the threaded connection of FIG. 1, according to one or more additional embodiments.

(5) FIG. 5 is another enlarged cross-sectional view of a portion of the threaded connection of FIG. 1, according to one or more additional embodiments.

### DETAILED DESCRIPTION

(6) Embodiments of the present disclosure will now be described in detail with reference to the accompanying Figures. Wherever possible, like or identical reference numerals are used in the figures to identify common or the same elements. The figures are not necessarily to scale and certain features and certain views of the figures may be shown exaggerated in scale for purposes of clarification. Further, in the following detailed description of embodiments of the present disclosure, numerous specific details are set forth in order to provide a more thorough understanding of the claimed subject matter. However, it will be apparent to one of ordinary skill in the art that the embodiments disclosed herein may be practiced without these specific details. In other instances, well-known features have not been described in detail to avoid unnecessarily complicating the description.

(7) Embodiments in accordance with the present disclosure generally relate to threaded connections that include a first tubular member having a box end defining an internal thread profile, and a second tubular member having a pin end defining an external thread profile threadably engageable with the internal thread profile of the box end. The external thread profile can include a first section that extends at a first taper angle relative to a longitudinal axis of the threaded connection, a second section extends from the first section at a second taper angle relative to the longitudinal axis, and an intermediate external shoulder may be provided at a transition between the first and second sections

and engageable with a corresponding intermediate shoulder provided on the internal thread profile. A cross-sectional area of the pin end increases at the intermediate external shoulder.

(8) FIG. 1 is a cross-sectional side view of an example threaded connection **100** that may incorporate the principles of the present disclosure. The threaded connection **100** (also referred to as a “tool joint”) may form part of a string of multiple pipes (alternately referred to herein as “tubulars,” “tubular members,” or “tubes”) threadably connected together end-to-end. As illustrated, the threaded connection **100** may include a pin end or “pin” **102a** of a first tubular member **104a** and a box end or “box” **102b** of a second tubular member **104b**. The first and second tubular members **104a,b** may comprise any type of tubing, pipe, or tubulars commonly used in the oil and gas industry and capable of being threadably connected end-to-end. Examples of the tubular members **104a,b** include, but are not limited to, drill pipe, casing (or liner), production tubing, general tubular assemblies (e.g., a wellbore hanger, hydraulic fracturing tools, float equipment, etc.), and any combination thereof. In at least one embodiment, the tubular members **104a,b** may exhibit an external diameter of 5.5 inches or less, but could alternatively exhibit a diameter greater than 5.5 inches, without departing from the scope of the disclosure.

(9) During operation, it is desirable that the threaded connection **100** have sufficient strength to withstand all expected service loads (e.g., torsion, tension, compression, etc.). Particularly, it is desirable that the threaded connection **100** have sufficient torsional strength or “torque capacity,” which is a measure of the amount of torque applied about the centerline of the threaded connection **100** required to cause failure. In order to optimize the torque capacity of the threaded connection **100**, the threads must be designed to have sufficient bearing and shear strength to avoid the common failures resulting from elevated torsion. Bearing strength is a measure of the amount of force required to cause deformation (e.g., plastic deformation) of engaged surfaces (e.g., thread flanks) of the threaded connection **100**, and shear strength is a measure of the amount of force required to shear the threads between the thread flanks along a plane substantially parallel to the connection centerline. It is also desirable that the threaded connection **100** provide a gas-tight seal for the conveyance or preservation of gaseous hydrocarbons.

(10) As illustrated, the pin **102a** defines or otherwise provides a helically extending external thread profile **106a** threadably engageable with a helically extending internal thread profile **106b** provided by the box **102b**. The external thread profile **106a** includes a first or “distal” end **108a** at or near the distal end of the pin **102a**, and a second or “proximal” end **108b**. Each turn or “tooth” of the external thread profile **106a** includes a stab flank **110** and a load flank **112**, and each turn or “tooth” of the internal thread profile **106b** similarly includes a stab flank **114** and a load flank **116**. As the threaded connection **100** is made up (e.g., threaded or coupled together), the stab flanks **110**, **114** of adjacent teeth oppose each other, and the load flanks **112**, **116** of adjacent teeth oppose each other.

(11) As used herein, the term “thread profile” refers to the thread form or configuration of a thread in an axial plane and which is generally considered to include a crest, a root, and opposing stab and load flanks. The term “stab flank” is intended to designate those flanks of the pin and box threads that first engage as the pin **102a** is stabbed into the box **102b**, and the term “load flank” is intended to designate those contacting flanks of the pin and box threads that normally contact with an increasing bearing pressure in reaction to the load forces tending to separate the engaged pin **102a** and box **102b** axially.

(12) It is contemplated herein to match the internal thread profile **106b** of the box **102b** to the external thread profile **106a** of the pin **102a** such that the threaded connection **100** exhibits optimized torsional strength and a gas-tight seal. Accordingly, while the following discussion corresponds to the external thread profile **106a** of the pin **102a**, portions of the discussion are equally applicable to the internal thread profile **106b** of the box **102b**.

(13) In the illustrated embodiment, the external thread profile **106a** provides and otherwise defines a first or “nose” section **118a** extending from the distal end **108a**, and a second or “stress bearing” section **118b** extending from the nose section **118a** to the proximal end **108b**. The nose and stress

bearing sections **118a,b** collectively form the thread profile **106a** and extend contiguously in succession along the axial length of the thread profile **106a**. As described herein, the various differences in the nose and stress bearing sections **118a,b** may prove advantageous in easing the process of stabbing the pin **102a** into the box **102b**, as well as resulting in improved rotational capacity and compression ratings.

(14) The nose section **118a** extends or otherwise exhibits a first length  $L_{sub.1}$ , and the stress bearing section **118b** exhibits a second length  $L_{sub.2}$  extending from the nose section **118a**. In some embodiments, the first and second lengths  $L_{sub.1}$ ,  $L_{sub.2}$  may be the same; e.g.,  $L_{sub.1}=L_{sub.2}$ . In other embodiments, however, the first and second lengths  $L_{sub.1}$ ,  $L_{sub.2}$  may be different. In the illustrated example, for instance, the first length  $L_{sub.1}$  is greater than the second length  $L_{sub.2}$ ; e.g.,  $L_{sub.1}>L_{sub.2}$ . In other embodiments, however, the second length  $L_{sub.2}$  may be greater than the first length  $L_{sub.1}$  without departing from the scope of the disclosure. Those skilled in the art will readily appreciate that the magnitude of each length  $L_{sub.1}$ ,  $L_{sub.2}$  may be modified to meet specifications of particular applications.

(15) The nose section **118a** extends at a first taper angle **120a** relative to a longitudinal axis **122** of the threaded connection **100**, and the stress bearing section **118b** extends at a second taper angle **120b** relative to the longitudinal axis **122**. In some embodiments, the taper angles **120a,b** may be the same; e.g.,  $120a=120b$ . In such embodiments, the cross-sectional area of the pin **102a** will progressively increase at a constant rate between the distal and proximal ends **108a,b** of the external thread profile **106a**. In other embodiments, however, the taper angles **120a,b** may be different. In the illustrated example, for instance, the first taper angle **120a** is greater than the second taper angle **120b**; e.g.,  $120a>120b$ . Having the first taper angle **120a** greater than the second taper angle **120b** may help ease the stab-in process for the threaded connection **100**. More particularly, a steeper first taper angle **120a** may facilitate better and deep stabbing, especially in applications that do not include a stab-in guide.

(16) The thread profile **106a** across each section **118a,b** may provide the same or different thread pitches, where “thread pitch” is defined as the distance between corresponding points on axially adjacent threads of the thread profile **106a**. More specifically, the nose section **118a** provides a first thread pitch **124a**, and the stress bearing section **118b** provides a second thread pitch **124b**. In some embodiments, the thread pitches **124a,b** may be the same, but could alternatively be different. Accordingly, the thread profile **106a** may exhibit single or double thread pitches **124a,b**. In the illustrated example, the first thread pitch **124a** is greater than the second thread pitch **124b**; e.g.,  $124a>124b$ , which results in the nose section **118a** being more coarse as compared to the stress bearing section **118b**. This may prove advantageous in reducing the risk of cross-threading with the box **102b** during the connection make-up process. This may also provide enhanced torque capacity due to the increased cross-sectional area of the stress bearing section **118b**, and the increased torsional strength of the threaded connection **100** ensures improved performance during deployment in challenging well conditions, such as deep wells, horizontal wells, long reach wells, etc.

(17) In some embodiments, the external thread profile **106a** may provide and otherwise define an intermediate shoulder **126** located at a transition between the nose and stress bearing sections **118a,b**. The cross-sectional area of the pin **102a** increases at the intermediate shoulder **126**, which may help improve the torsional performance of the threaded connection **100**. The internal thread profile **106b** may provide or define a corresponding intermediate shoulder **128** configured to engage the intermediate shoulder **126** of the external thread profile **106a**. The double-taper thread with the intermediate shoulder **126** helps to ensure a deep stab-in with reduced risk of cross-threading.

(18) As indicated above, portions of the foregoing discussion related to the external thread profile **106a** of the pin **102a** are equally applicable to the internal thread profile **106b** of the box **102b**. Consequently, the internal thread profile **106b** may also include a double tapered profile that

matches the double tapered external thread profile **106a**. More specifically, the internal thread profile **106b** may include a first or “distal” end **130a**, a second or “proximal” end **130b** opposite the distal end **130a**, a first section (not labeled) that exhibits a first taper (or taper angle), and a second section (not labeled) that exhibits a second taper (or taper angle). The pitch(es) **124a,b** used on the pin **102a** may generally match corresponding pitch(es) of the box **102b** across the corresponding sections of the profiles **106a,b**.

(19) In some embodiments, as illustrated, the pin **102a** of the threaded connection **100** may further include an external upset **132** located proximal from the proximal end **108b** of the external thread profile **106a**. The external upset **132** increases the cross-sectional area of the threaded connection **100** as compared to the remaining portions of the first tubular **104a**, which helps improve the torsional capacity and ensures the tensile capacity of the threaded connection **100** exceeds the tensile capacity of the body of the first tubular **104a**. The upset **132** may also help to provide sufficient material to develop the double-taper structure described herein.

(20) The threaded connection **100** may also include one or more seals formed or otherwise provided between the opposing external and internal thread profiles **106a,b**, and such seals facilitate gas-tight sealing points along the threaded connection **100**. In some embodiments, as illustrated, the threaded connection **100** may include a first or “primary” seal **134a** arranged at or near the distal end **108a** of the external thread profile **106a** (i.e., also near the proximal end **130b** of the internal thread profile **106b**). In at least one embodiment, the primary seal **134a** may be positioned axially between the distal end of the pin **102a** (or the proximal end of the box **102b**) and an initial engaged thread **136** of the external thread profile **106a**.

(21) In some embodiments, the primary seal **134a** may comprise a metal-to-metal seal generated by the opposing engagement of the external and internal thread profiles **106a,b**. In such embodiments, for example, the primary seal **134a** may be formed between opposing tapered (but flat) surfaces of the external and internal thread profiles **106a,b**. In other embodiments, however, the primary seal **134a** may be formed between a tapered (but flat) surface of one of the external and internal thread profiles **106a,b** and an opposing spherical (or bulbous) projection provided by the other of external and internal thread profiles **106a,b**. In yet other embodiments, the primary seal **134a** may be formed between opposing spherical (or bulbous) projections provided by both the external and internal thread profiles **106a,b**.

(22) In some embodiments, the threaded connection **100** may further include a second or “secondary” seal **134b** arranged at the interface between the intermediate shoulders **126**, **128** and otherwise at the transition between the nose and stress bearing sections **118a,b**. The secondary seal **134b** may operate as a backup or redundant seal to the primary seal **134a**, which may prove advantageous in the event the primary seal **134a** is damaged during the stabbing or make-up process of the threaded connection **100**. Similar to the primary seal **134a**, in some embodiments, the secondary seal **134b** may also comprise a metal-to-metal seal generated by the opposing engagement of the external and internal thread profiles **106a,b**. In such embodiments, for example, the secondary seal **134b** may be formed between opposing tapered (but flat) surfaces of the external and internal thread profiles **106a,b** at the intermediate shoulder **126**. In other embodiments, however, the secondary seal **134b** may be formed between a tapered (but flat) surface of one of the external and internal thread profiles **106a,b** and an opposing spherical (or bulbous) projection provided by the other of external and internal thread profiles **106a,b**. In yet other embodiments, the secondary seal **134b** may be formed between opposing spherical (or bulbous) projections provided by both the external and internal thread profiles **106a,b**.

(23) In some embodiments, the threaded connection **100** may further include a tertiary seal **134c** that operates as an external seal or another metal-to-metal seal that functions as an external seal. In the illustrated embodiment, the tertiary seal **134c** may be arranged between the external and internal thread profiles **106a,b** at or near the proximal end **108b** of the external threaded profile **106a** (or the distal end **130a** of the internal threaded profile **106b**). For example, the tertiary seal

**134c** may be positioned at the stress contact area at or near the last engaged thread **138** of the threaded connection **100**.

(24) In at least one embodiment, the tertiary seal **134c** may include or otherwise comprise a resilient seal, such as a seal ring, positioned within a groove **140** defined in the threaded connection **100**. In such embodiments, the tertiary seal **134c** may be made of a variety of pliable materials including, but not limited to, a polymer and an elastomer. In some embodiments, the tertiary seal **134c** may be made of a material that is water swellable, but may alternatively be made of a non-water swellable seal material, depending on the application.

(25) The groove **140** that receives the tertiary seal **134c** may be defined in one or both of the pin **102a** and the box **102b**. The groove **140** may exhibit sufficient tolerances to generate an interference fit with or without the volumetric strain of the tertiary seal **134c**, where applicable. The specific dimensions of the groove **140** may be dependent on the size of the tubular(s) **104a,b**. In some embodiments, the cross-sectional shape of the groove **140** may be rectangular. In such embodiments, the base dimension of the groove **140** may match or may be slightly smaller than the cross-sectional size of the tertiary seal **134c** to help facilitate an interference fit within the groove **140**. Moreover, in such embodiments, the top dimension (e.g., opening) of the groove **140** may be smaller than the base dimension, which may prove advantageous in helping retain the tertiary seal **134c** in the groove **140**. In other embodiments, however, the cross-sectional shape of the groove **140** may include other shapes besides rectangular, such as, but not limited to, rounded or oval, without departing from the scope of the disclosure.

(26) FIG. 2 is an enlarged cross-sectional view of a portion of the threaded connection **100**, according to one or more embodiments. As illustrated, the pin **102a** provides an extended lip **202** that terminates in a distal end **204**, which forms the distal end of the pin **102a**. In some embodiments, the primary seal **134a** may be positioned on or along the extended lip **202** and otherwise arranged at or near the distal end **204** of the pin **102a**. In such embodiments, the primary seal **134a** may be positioned between the distal end **204** and the initial engaged thread or “tooth” **136** of the external thread profile **106a**.

(27) As mentioned above, the primary seal **134a** may comprise a metal-to-metal seal generated by the opposing engagement of the external and internal thread profiles **106a,b**. In the illustrated embodiment, the primary seal **134a** includes a spherical (or bulbous) projection **206** defined by the internal thread profile **106b** of the box **102b** and is engageable with an opposing tapered (but flat) surface **208** of the external thread profile **106a** of the pin **102a**. In other embodiments, however, the projection **206** may alternatively be defined by the external thread profile **106a** and the opposing tapered (but flat) surface **208** may be provided by the internal thread profile **106b**. In yet other embodiments, each of the external and internal thread profiles **106a,b** may define or provide complimentary opposing spherical (or bulbous) projections **206** engageable with each other to form the primary seal **134a**, without departing from the scope of the disclosure.

(28) The distal end **204** may be configured to axially engage a load shoulder **210** of the opposing box **102b** and thereby provide a metal-to-metal seal at the interface between the distal end **204** and the load shoulder **210**. The extended lip **202** of the pin **102a** may define an inner surface **212a**, and the load shoulder **210** of the box **102b** may also define an inner surface **212b**. In some embodiments, as illustrated, the inner surfaces **212a,b** may align, thus providing a flush inner diameter of the threaded connection **100** at the interface between the distal end **204** and the load shoulder **210**. The flush inner diameter across the interface between the inner surfaces **212a,b** may prove advantageous in reducing the risk of erosion and abrasion within the threaded connection **100** at that location.

(29) In some embodiments, the distal end **204** may provide and otherwise define a reverse angle portion or surface **214** that extends from the inner surface **212a** of the pin **102a** at an angle **216**. In some embodiments, the angle **216** may be about 105° from the inner surface **212a**. Stated differently, the reverse angle surface **214** may extend at a reverse angle **218** of about 15°, where the



reverse angle **218** is measured from a line **220** perpendicular to the inner surface **212a**. The reverse angle surface **214** helps provide a positive contact with the opposing load shoulder **210** of the box **102b**, which provides a correspondingly angled surface **221**, which helps improve compression efficiency and sealing capabilities.

(30) In some embodiments, the threaded connection **100** may further provide or otherwise define a pocket **222** at the interface between the external and internal thread profiles **106a,b** and located along the extended lip **202**. In the illustrated embodiment, for example, the pocket **222** is located axially between the primary seal **134a** and the distal end **204** of the pin **102a**. The pocket **222** may provide a location to accommodate excess thread dope (e.g., lubricant), which is commonly used to help ease the make-up process of the threaded connection **100**. In the illustrated embodiment, the pocket **222** comprises a concave section defined in the internal thread profile **106b** and opposing the tapered (but flat) surface **208** of the external thread profile **106a**. In other embodiments, however, the pocket **222** may alternatively be defined in the external thread profile **106a**, or the pocket **222** could be defined jointly by the external and internal thread profiles **106a,b**, without departing from the scope of the disclosure.

(31) FIG. 3 is another enlarged cross-sectional view of a portion of the threaded connection **100** of FIG. 1, according to one or more embodiments. As illustrated, the internal thread profile **106b** of the box **102b** provides a thread or “tooth” **300** that defines a crest **302** and roots **304**, and the stab and load flanks **114**, **116** extend between the crest **302** and the corresponding root **304**. The stab flank **114** may transition to the crest **302** at a transition surface **306**.

(32) In some embodiments, as illustrated, the stab flank **114** and the crest **302** may each be substantially flat surfaces, and the transition surface **306** may comprise an arcuate or curved surface extending from the crest **302** to the stab flank **114**. In at least one embodiment, the radius of the transition surface **306** may be about  $30^\circ$ , but could be more or less than  $30^\circ$ , without departing from the scope of the disclosure. The transition surface **306** may prove advantageous in providing an anti-galling characteristic and otherwise mitigating galling between the thread profiles **106a,b** and, more particularly, between the crest **302** of one profile **106a,b** and the roots **304** of the other profile **106a,b** during the connection make-up process.

(33) FIG. 4 is another enlarged cross-sectional view of a portion of the threaded connection **100** of FIG. 1, according to one or more additional embodiments. As illustrated, the external thread profile **106a** of the pin **102a** provides first and second threads or “teeth” **400a** and **400b** sequentially aligned along the external thread profile **106a**. Each tooth **400a,b** defines a crest **402** and a root **404**, and the stab and load flanks **110**, **112** extend between the crest **302** and the corresponding root **404**.

(34) In some embodiments, the geometry of the teeth **400a,b**, and therefore the overall geometry of the external thread profile **106a**, may be modified to reduce the risk of thread “jump out” under increased tensile load or excessive torque during the connection make-up process. Thread jump-out is a connection failure mode resulting from the formation of a gap between opposing thread flanks, and can promote the total separation of the tubular string. It can occur as a result of excessive torque during make-up or improper make-up, and the risk of thread jump-out increases with increasing tension. In the illustrated embodiment, the load flank **112** of one or both of the teeth **400a,b** may extend at an angle  $\beta$  from the inner surface **212a** of the pin **102a** (or the longitudinal axis **122** of FIG. 1), where the angle  $\beta$  is about  $85^\circ$ . Expressed differently, the load flank **112** may extend at an angle  $\theta$  as measured relative to a line **406** perpendicular to the inner surface **212a** (or the longitudinal axis **122**), and the angle  $\theta$  may be about  $-5^\circ$ , and ranging between about  $-4.5^\circ$  and about  $-5.5^\circ$ . Accordingly, the load flank **112** may be described as extending at a “negative load angle,” and having the load flank **112** extend at the negative load angle may help improve tensile capacity, and reduce relative sliding and radial separation between the pin **102a** and the box **102b**, which minimizes the risk of thread jump-out.

(35) In other embodiments, or in addition thereto, the stab flank **110** of one or both of the teeth

**400a,b** may extend at an angle  $\Delta$  from the inner surface **212a** of the pin **102a** (or the longitudinal axis **122** of FIG. 1), where the angle  $\Delta$  is about  $80^\circ$ . Expressed differently, the stab flank **110** may extend at an angle  $\alpha$  measured relative to a line **408** perpendicular to the inner surface **212a** (or the longitudinal axis **122**), and the angle  $\alpha$  may be about  $-10^\circ$ . Providing the stab flank **110** at angle  $\Delta$  or  $\alpha$  may help improve the efficiency of the connection make-up process.

(36) FIG. 5 is another enlarged cross-sectional view of a portion of the threaded connection **100** of FIG. 1, according to one or more additional embodiments. The turns or “teeth” in the external thread profile **106a** may exhibit the same or different thread height, where “thread height” is defined as the distance between the crest and the root of a given thread or “tooth”. In one or more embodiments, the last engaged thread or “tooth” **138** of the external thread profile **106a** may exhibit a first thread height **502a** and one or more of the remaining teeth **504** of the external thread profile **106a** may exhibit a second thread height **502b** different from the first thread height **502a**. In at least one embodiment, for example, the first thread height **502a** may be less than the second thread height **502b** such that there is a height difference **506** between the thread heights **502a,b**.

(37) The last engaged thread or tooth **138** is often an incomplete thread, and providing the last engaged tooth **138** with a decreased (lesser) thread height **502a** as compared to the remaining teeth **504** may prove advantageous in reducing the risk of plastic deformation at the load flank **112** and ultimately thread jump out. Those skilled in the art will readily appreciate that deformation can be more severe at the last engaged tooth **138** mainly due to the increased height of the incomplete thread of the pin connection. Moreover, the risk of deformation can be higher in applications where the load flank **112** extends at a negative load angle (as provided in FIG. 5), which can result in loss of reusability as well as an increase in the risk of galling, especially when the tubular is used as a work string or a landing string.

(38) The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, for example, the singular forms “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “contains”, “containing”, “includes”, “including,” “comprises”, and/or “comprising,” and variations thereof, when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

(39) Terms of orientation are used herein merely for purposes of convention and referencing and are not to be construed as limiting. However, it is recognized these terms could be used with reference to an operator or user. Accordingly, no limitations are implied or to be inferred. In addition, the use of ordinal numbers (e.g., first, second, third, etc.) is for distinction and not counting. For example, the use of “third” does not imply there must be a corresponding “first” or “second.” Also, as used herein, the terms “coupled” or “coupled to” or “connected” or “connected to” or “attached” or “attached to” may indicate establishing either a direct or indirect connection, and is not limited to either unless expressly referenced as such.

(40) While the disclosure has described several exemplary embodiments, it will be understood by those skilled in the art that various changes can be made, and equivalents can be substituted for elements thereof, without departing from the spirit and scope of the invention. In addition, many modifications will be appreciated by those skilled in the art to adapt a particular instrument, situation, or material to embodiments of the disclosure without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed, or to the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

## Claims

1. A threaded connection, comprising: a first tubular member having a box end, the first tubular member having an internal surface defining an internal thread profile at the box end; and a second tubular member having a pin end defining an external thread profile threadably engageable with the internal thread profile, wherein the external thread profile includes: a first section that extends at a first taper angle relative to a longitudinal axis of the threaded connection; a second section extending from the first section at a second taper angle relative to the longitudinal axis; an intermediate shoulder provided at a transition between the first and second sections and engageable with a corresponding intermediate shoulder provided on the internal thread profile; an external upset defined on the pin end proximal to a proximal end of the external thread profile, wherein the external upset has a groove, wherein the external upset increases a cross-sectional area of the second tubular member as compared to remaining portions of the second tubular member, wherein a distal end of the first tubular member extends over at least a portion of the external upset such that a gap separates the external upset from the internal surface of the first tubular member, wherein a maximum outer diameter of the external upset is less than a maximum outer diameter of the first section, and wherein the maximum outer diameter of the external upset is greater than a maximum outer diameter of the second section; a first seal provided at or near a distal end of the external thread profile and facilitating a sealed interface between the external and internal thread profiles, the first seal comprising a bulbous projection defined on at least one of the external and internal thread profiles; and a second seal disposed in the groove of the external upset and disposed in the gap, wherein the second seal is engaged with the external upset and the internal surface of the first tubular member, wherein a cross-sectional area of the pin end increases at the intermediate shoulder.
2. The threaded connection of claim 1, wherein the first taper angle is greater than the second taper angle.
3. The threaded connection of claim 1, wherein the first section provides a first thread pitch and the second section provides a second thread pitch less than the first thread pitch.
4. The threaded connection of claim 1, further comprising a pocket provided at an interface between the external and internal thread profiles and located axially between the first seal and the distal end.
5. The threaded connection of claim 1, further comprising a third seal provided at an interface between the intermediate shoulder and the corresponding intermediate shoulder of the internal thread profile.
6. The threaded connection of claim 5, wherein the third seal comprises a bulbous projection defined on at least one of the external and internal thread profiles.
7. The threaded connection of claim 1, wherein the pin end includes an extended lip that extends past the external thread profile and terminates in a distal end of the second tubular member, and wherein the distal end of the second tubular member provides a reverse angle surface engageable with a load shoulder of the box end.
8. The threaded connection of claim 1, wherein the internal thread profile provides a tooth that defines a crest, a root, and a stab flank that extends between the crest and the root, and wherein a curved transition surface extends between the stab flank and the crest and exhibits a radius of about  $30^\circ$ .
9. The threaded connection of claim 1, wherein the external thread profile provides a tooth that defines a crest, a root, and a load flank that extends between the crest and the root at a negative load angle of about  $-5^\circ$  measured relative to a line perpendicular to the internal surface of the second tubular member.
10. The threaded connection of claim 1, wherein the external thread profile provides a last engaged tooth that exhibits a first thread height, and wherein adjacent teeth of the external thread profile exhibit a second thread height greater than the first thread height.

11. The threaded connection of claim 1, wherein the first and second sections extend contiguously in succession along an axial length of the external thread profile and interposed only by the intermediate shoulder.

12. The threaded connection of claim 1, wherein a last engaged tooth of the second section exhibits a thread height that is less than a thread height of remaining teeth of the second section.

13. The threaded connection of claim 1, wherein: the internal surface of the first tubular member includes a first portion and a second portion, wherein the first portion includes the internal thread profile and the second portion defines a first bore having a first inner diameter; and the second tubular member includes an external surface and an internal surface opposite of the external surface of the second tubular member, the internal surface of the second tubular member defining a second bore having a second inner diameter that is the same as the first inner diameter, wherein the second bore has a first bore portion opposite the bulbous projection and a second bore portion opposite the first and second sections that both have the second inner diameter, and wherein the second portion of the internal surface of the first tubular member is flush with the internal surface of the second tubular member when the external thread profile is threadably engaged with the internal thread profile.

14. A thread profile for a tubular member, comprising: a first section including first threads that extends from a first end of the thread profile at a first taper angle relative to a longitudinal axis of the tubular member, wherein the first end includes an end surface; a second section including second threads that extends from the first section at a second taper angle relative to the longitudinal axis, wherein the first taper angle is greater than the second taper angle; an intermediate shoulder provided at a transition between the first and second sections, wherein a cross-sectional area of the tubular member increases at the intermediate shoulder; an external upset extending proximally from the second section, wherein the external upset increases a cross-sectional area of the thread profile as compared to remaining portions of the tubular member; and a bulbous projection located between the end surface and the first threads, wherein a maximum outer diameter of the external upset is less than a maximum outer diameter of the second section and greater than an outer maximum diameter of the first section.

15. The thread profile of claim 14, wherein a last tooth of the second section exhibits a thread height that is less than a thread height of remaining teeth of the second section.

16. The thread profile of claim 14, wherein the thread profile is formed on the external surface of a pin end of the tubular member, wherein the tubular member has an internal surface opposite the external surface that defines a bore of the tubular member, wherein a first portion of the bore opposite the bulbous projection has the same inner diameter as a second portion of the bore opposite the first and second sections.

17. A tubular connection, comprising: a first tubular member including an internal surface defining an internal thread profile at a box end of the first tubular member and a bore of the first tubular member, wherein the internal surface includes a first angled end surface at the transition between the internal thread profile and the bore of the first tubular member; and a second tubular member including an exterior surface defining an external thread profile on a pin end of the second tubular that is threadably engageable with the internal thread profile, an internal surface opposite of the exterior surface of the second tubular member defining a bore of the second tubular member, and a second angled end surface at a distal end of pin engageable with the first angled end surface, wherein the external thread profile includes: a first threaded section that extends at a first taper angle relative to a longitudinal axis of the threaded connection; a second threaded section extending from the first threaded section at a second taper angle relative to the longitudinal axis; an intermediate shoulder provided at a transition between the first and second threaded sections and engageable with a corresponding intermediate shoulder provided on the internal thread profile; and a lip extending between the second threaded section and the second angled end surface, the lip including a bulbous projection configured to seal against the internal thread profile, wherein a first

portion of the bore of the second tubular member that is opposite the bulbous projection has the same inner diameter as a second portion of the bore of the second tubular member that is opposite the first and second threaded sections, and wherein the internal surface of the first tubular member is flush with the internal surface of the second tubular member when the external thread profile is threadably engaged with the internal thread profile; and an external upset on the second tubular member, wherein the external thread profile is disposed between the external upset and the second angled end surface at the distal end of the pin, wherein a maximum outer diameter of the external upset is less than a maximum outer diameter of the first threaded section, and wherein the maximum outer diameter of the external upset is greater than a maximum outer diameter of the second threaded section.

18. The tubular connection of claim 17, wherein the external upset interposes the external thread profile and a first tubular portion that extends between the pin end and another end of the second tubular, wherein the maximum outer diameter of the external upset is greater than an outer diameter of the first tubular portion of the second tubular member, and wherein the internal surface of the first tubular member overlaps a portion of the external upset such that a gap separates the external upset from the internal surface of the first tubular member; and a seal disposed in a groove formed in the external upset, the seal extending across the gap being engaged with the external upset and the box end.

19. The tubular connection of claim 17, wherein the first angled surface extends at a first angle relative to the internal surface of the first tubular member, wherein the second angled surface extends at a second angle relative to the internal surface of the second tubular member, and wherein a sum of the first and second angles is 180 degrees.

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