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LOCKING THREADED CONNECTION ASSEMBLY

Abstract

A connection assembly enabling torque transfer between coaxially-aligned components includes: an upper component carrying an upper spline; a lower component threadedly engageable with the upper component and carrying a lower spline: a coupling ring having first and second splines; and means for axially moving the coupling ring, relative to the upper and lower components, between a free position in which the coupling ring is freely rotatable relative to the connected upper and lower components, and a seated position in which the coupling ring is rotationally coupled to the upper component by engagement of the first coupling ring spline with the upper spline, and rotationally coupled to the lower component by engagement of the second coupling ring spline with the lower spline. The upper and lower splines have different numbers of evenly-spaced spline ridges, which on at least one of the upper spline and the lower spline are axially tapered.

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Background/Summary

FIELD

[0001] The present disclosure relates in general to helically-threaded connections between axially-aligned components, and relates in particular to apparatus for preventing relative rotation between two such connected components.

BACKGROUND

[0002] A rotary shouldered connection (also known as an “RSC”) is a type of helically-threaded connection commonly used to connect drill string components (e.g., pipe sections) and drilling tools (including an assembly of drilling tools for connection to a top drive of a drilling rig) for rotary drilling of subterranean wells. A typical RSC involves engagement of an external thread on a first component with an internal thread on a second component where the first and second components have respective annular shoulders that come into mating engagement as the threaded connection is made up. After these shoulders have come into contact, relative rotation between the two components will either increase or decrease the axial contact force acting between the shoulders, depending on the direction of rotation.

[0003] As used in this document: the phrasal verb “make up” means to tighten or assemble a threaded connection; the noun “makeup” refers to the process of tightening or assembling a threaded connection; the phrasal verb “break out” means to loosen or disassemble a threaded connection; and the noun “breakout” refers to the process of loosening or disassembling a threaded connection.

[0004] Common RSCs rely on frictional resistance, between the mating shoulders and between the two components' matingly engaged threads, to transfer torque between the components without either loosening or further tightening the connection. If an RSC is not made up to a torque sufficiently higher than the “breakout” torque (i.e., the minimum torque required to loosen the connection), it may unintentionally loosen (or “back off”) when relative rotation is applied in the breakout direction. Such unintentional loosening can result in a drill string dropping into the wellbore, making it necessary to “fish” the drill string out of the wellbore, typically at great expense. The consequences of unintentional “backing off” can be even more severe in the case of an RSC above the drill floor, such as an RSC in an assembly of heavy drilling tools mounted to a top drive, in which case personnel on the drill floor could be seriously or fatally injured by the falling tools and/or auxiliary components.

[0005] Other drawbacks of conventional RSCs include the need for power tongs or other heavy equipment to make up and break out the RSCs, plus the related need for the connected components to provide a significant axial length for gripping by the tongs. Moreover, the tongs or other gripping equipment can cause significant surface damage to the connected components, making the components more susceptible to metal fatigue and consequently reduce their service life.

[0006] A further drawback of conventional RSCs is the risk of thread damage (also referred to as “galling”) resulting from repeated application of the high torque necessary to make up and break out the RSCs. To mitigate the cost of repairing such damage, it is common for tools and other components with shouldered connections to be made longer than operationally necessary to allow for multiple repairs (removing damaged threads and machining new ones) before it becomes necessary to scrap the components.

[0007] Yet another drawback of conventional RSCs is their inherent inefficiency in transferring torque via frictional resistance between the two joined components' mating shoulders, which typically provide a comparatively small annular contact area with a comparatively small effective radius (or moment arm). The primary ways to increase the torque resistance of a shouldered connection are to increase the annular contact area and/or to increase the effective moment arm, which in either case would entail larger and/or differently configured components.

BRIEF SUMMARY

[0008] The present disclosure describes embodiments of threaded connection assemblies that are capable of bi-directional torque transfer while providing advantages over conventional RSCs that transfer torque by means of friction (or mechanical interference) between the annular shoulders of the connected components. Such advantages may include, without limitation, one or more of the following: [0009] substantial reduction of the torque levels needed to induce shoulder interference for connection makeup, and to relieve shoulder interference for connection breakout; [0010] prevention of relative rotation between the connected components during use, independent of the makeup torque (i.e., the torque applied to make up the connection); [0011] provision of a fluid seal independent of the metal-to-metal seal induced between the mating load shoulders of the connected components by the applied makeup torque; and [0012] provision of higher combined torque and axial load rating than provided by equivalently-sized conventional oilfield tool joint connections.

[0013] As used in this patent document, the term “torque transfer element” denotes an annular element having a plurality of uniformly-spaced teeth engageable with teeth of a complementarily-configured torque transfer element. In this context, the terms “teeth” and “tooth” are to be understood in a broad sense and not as being limited to teeth of any particular configuration. Accordingly, and by way of non-limiting example only, the term “torque transfer element” is intended to cover a spline (as defined below), and the term “teeth” is intended to cover the uniformly-spaced ridges of such a spline. As a further non-limiting example, the mating components of a dog clutch (a term that will be familiar to persons skilled in the art) would be considered to be torque transfer elements in the context of the present disclosure.

[0014] As used in this patent document, the term “spline” denotes an annular arrangement of uniformly-spaced vertical spline ridges and intervening vertical spline grooves, and is intended to include, without limitation, splines in which the spline ridges have tapered, helical, or curvilinear flanks.

[0015] In broad terms, the present disclosure teaches embodiments of a threaded connection assembly comprising: an upper component having an upper torque transfer element comprising a plurality of uniformly-spaced teeth; a lower component threadingly engageable with the upper component and having a lower torque transfer element comprising a plurality of uniformly-spaced teeth; a coupling ring having a first coupling ring torque transfer element engageable with the upper torque transfer element, and a second coupling ring torque transfer element engageable with the lower torque transfer element, said coupling ring being axially movable between: [0016] a free position in which the coupling ring is freely rotatable relative to both the upper component and the lower component; and [0017] a seated position in which the first coupling ring torque transfer element engages the upper torque transfer element, and the second coupling ring torque transfer element engages the lower torque transfer element, such that the coupling ring prevents relative rotation between the upper component and the lower component; and [0018] axial force means for urging the coupling ring from the free position toward the seated position.

[0019] The upper component, the lower component, and the coupling ring are coaxial about a longitudinal connection axis, and the upper torque transfer element and the lower torque transfer element have different numbers of teeth. Each tooth of the lower torque transfer element has an axially-tapered flank that is slidingly engageable with an axially-tapered flank on a tooth of the second coupling ring torque transfer element, such that when the teeth of the lower torque transfer element are rotationally misaligned (i.e., out of phase) with the teeth of the second coupling ring torque transfer element, movement of the coupling ring from the free position toward the seated

position will urge relative rotation between the upper and lower components as a result of sliding engagement of the axially-tapered flanks of the teeth of the lower torque transfer element and the second coupling ring torque transfer element. When the coupling ring is in the free position, the coupling ring is rotatable to one or more selectable rotational positions in which the teeth of the lower torque transfer element are rotationally out of phase with the teeth of the second coupling ring torque transfer element.
[0020] In some embodiments, the upper torque transfer element comprises an external spline, and the first coupling ring torque transfer element comprises an internal spline.
[0021] In some embodiments, the lower torque transfer element comprises an external spline, and the second coupling ring torque transfer element comprises an internal spline.
[0022] In some embodiments, the lower torque transfer element and the second coupling ring torque transfer element are configured for engagement in the manner of a dog clutch.
[0023] In some embodiments, the teeth of the lower torque transfer element and the second coupling ring torque transfer element are at least partially of curvilinear configuration.
[0024] Optionally, the threaded connection assembly may comprise locking means for preventing relative rotation between the drive ring and a selected one of the upper and lower components. In such embodiment, the locking means may be provided by one or more locking lugs insertable through holes in the drive ring and into holes in the selected one of the upper and lower components, but this is by way of non-limiting example only.
[0025] Optionally, the threaded connection assembly may incorporate drive ring rotation means to facilitate rotation of the drive ring. By way of non-limiting example, such drive ring rotation means may be provided by forming one or more drive tool sockets in the drive ring, enabling manual rotation of the drive ring using a steel rod or other suitable tool inserted into one of the drive tool sockets.
[0026] In a variant embodiment, the coupling ring may be coaxially coupled to the upper component so as to follow a helically-rotating path (i.e., axial force applied to the coupling ring will induce both rotation and axial displacement of the coupling ring relative to the upper component).
[0027] In a first exemplary and non-limiting embodiment, a locking threaded connection assembly in accordance with the present disclosure has a longitudinal connection axis and comprises: [0028] (a) an upper component having: [0029] a lower portion carrying an external helical connection thread; [0030] a downward-facing external annular connection shoulder above the external helical thread of the upper component; and [0031] an upper torque transfer element in the form of an external spline located above the external helical thread, with said external spline comprising a selected number n.sub.U vertical spline ridges and n.sub.U vertical spline grooves each being parallel to the longitudinal connection axis; [0032] (b) a lower component having an upper end and: [0033] an upper portion carrying an internal helical connection thread matingly engageable with the external helical connection thread of the upper component; [0034] an upward-facing annular shoulder on an upper end of the lower component matingly engageable with the downward-facing annular connection shoulder of the upper component; and [0035] a lower torque transfer element in the form of an external spline on an upper portion of the lower component, said external spline having a selected number n.sub.L vertical spline ridges and n.sub.L vertical spline grooves, wherein n.sub.L is not equal to n.sub.U, and wherein the flanks of the vertical spline ridges of the external spline are axially tapered (alternatively referred to as having a helix angle) such that the circumferential width of each vertical spline groove of the external spline decreases toward its lower end; [0036] (c) a coupling ring having a coupling ring throughbore defining: [0037] a first coupling ring torque transfer element in the form of an upper internal spline having n.sub.U vertical spline ridges and n.sub.U vertical spline grooves, with the vertical spline ridges of said upper internal spline being slidingly engageable within the vertical spline grooves of the external spline on the upper component; and [0038] a second coupling ring torque transfer element

in the form of a lower internal spline having a selected number n.sub.L vertical spline ridges and n.sub.L vertical spline grooves, wherein the flanks of the vertical spline ridges of the lower internal spline are axially tapered such that the circumferential width of each vertical spline ridge of the lower internal spline decreases in width toward its lower end so as to be matingly engageable with a tapered vertical spline groove of the external spline of the lower component, and [0039] (d) means for urging axial movement of the coupling ring relative to the upper and lower components, between a free position and a seated position, when the upper and lower components are threadingly connected with their annular connection shoulders in contact and the coupling ring is mounted around the connected upper and lower components;
wherein: [0040] (e) when the coupling ring is in the free position, the coupling ring will be freely rotatable relative to the connected upper and lower components; [0041] (f) when the coupling ring is in the seated position, the coupling ring will be: [0042] rotationally coupled to the upper component by engagement of the upper internal spline of the coupling ring and the external spline on the upper component; and [0043] rotationally coupled to the lower component by engagement of the lower internal spline of the coupling ring and the external spline on the lower component; and [0044] (g) the axial taper angle of the flanks of the vertical spline ridges of the external spline on the lower component and the axial taper angle of the vertical ridges of the lower internal spline of the coupling ring are selected such that movement of the coupling ring from the free position to the seated position will urge relative rotation of the upper and lower components in a first rotational direction as a result of vertically-sliding engagement of the tapered flanks of the vertical spline ridges of the lower internal spline of the coupling ring with the tapered flanks the vertical spline ridges of the external spline on the lower component.
[0045] In variant embodiments, the external helical thread could be on the lower component instead of on the upper component as in the above-described embodiment. Also, the shouldering surfaces could be located at either end of the helical thread. In further variant embodiments, the ridges of the external spline on the lower component and the lower internal spline of the coupling ring could have tapered flanks on one side only (with the opposite flanks being parallel to the connection axis), thus enabling incremental relative rotation of the upper and lower components in one rotational direction only. More typically, however, the flanks on both sides of the spline ridges are tapered to enable incremental relative rotation in either direction (i.e., for either connection makeup or connection breakout). In embodiments having tapered flanks on both sides of the spline ridges, the taper angle (relative to the longitudinal connection axis) could be different on either side of the flanks.
[0046] Threaded connections that employ two spline pairs in a manner similar to a vernier scale are known in the prior art, such as in U.S. Pat. No. 7,104,345 (Eppink), U.S. Pat. No. 7,493,960 (Leising et al.), U.S. Pat. No. 7,887,098 (Aas), and U.S. Pat. No. 105,153,891 (Daigle et al.). Embodiments of threaded connection assemblies in accordance with the present disclosure also comprise two spline pairs in a manner similar to a vernier scale. In the first exemplary embodiment described above, the phase alignment between the lower internal spline of the coupling ring and the external spline on the lower component will vary according to the coupling ring's rotational position relative to the lower component.
[0047] Additionally, in embodiments of locking threaded connection assemblies in accordance with the present disclosure, the rotational position of the coupling ring may be selected such that movement of the coupling ring from the free position to the seated position will urge relative rotation of the upper and lower components in a first rotational direction (e.g., tending to further tighten the threaded connection of the upper and lower components). In some embodiments, the rotational position of the coupling ring may also be selected such that movement of the coupling ring from the free position to the seated position will urge relative rotation of the upper and lower components in a second rotational direction (e.g., tending to loosen the threaded connection).
[0048] Optionally, one or both of the axially-tapered flanks of the vertical spline ridges of the lower

internal spline of the coupling ring and the external spline on the lower component may follow a helical profile.
[0049] Optionally, the flanks of the vertical spline ridges of the external spline on the upper component may be axially tapered such that the circumferential width of each vertical spline groove of the external spline decreases toward its lower end, and the flanks of the vertical spline ridges of the upper internal spline on the coupling ring are axially tapered such that the circumferential width of each vertical spline ridge of the upper internal spline decreases toward its lower end so as to be matingly engageable with a tapered vertical spline groove of the external spline of the upper component.
[0050] The axially-tapered spline ridge flanks provide a mechanical advantage converting the axial force to circumferentially tangential force urging relative rotation between the upper and lower components. The means for urging axial movement of the coupling ring relative to the upper and lower components may also provide an additional mechanical advantage in generating an axial force on the coupling ring.
[0051] In some embodiments, the means for urging axial movement of the coupling ring relative to the upper and lower components may comprise a drive ring threadingly engageable with the coupling ring and having an annular shoulder configured for mating engagement with an annular shoulder on a selected one of the upper component and the lower component. Rotation of the drive ring relative to the coupling ring will urge axial movement of the coupling ring relative to the upper and lower components.
[0052] In alternative embodiments, the drive ring may have an annular shoulder configured for mating engagement with an annular shoulder on the coupling ring, with the drive ring being threadingly engageable with a selected one of the upper component and the lower component. Rotation of the drive ring relative to the selected component will urge axial movement of the coupling ring relative to the upper and lower components.
[0053] In further alternative embodiments, the means for urging axial displacement of the coupling ring relative to the upper and lower components may comprise a plurality of jackscrews threadingly engaging a plate, wherein: [0054] the plate has an axial surface contacting an axial shoulder surface on a selected one of the upper component and the lower component, and [0055] the jackscrews bear against the coupling ring;
such that rotation of the jack screws relative to the plate will urge axial movement of the coupling ring relative to the upper and lower components.
[0056] The upper and lower components may be cylindrical components having respective internal bores, in which case the coupling ring may be coaxially aligned with the upper and lower components and may be located within the internal bore of one or both the upper and lower tubular components.
[0057] Optionally, rotary shouldered threaded connection assemblies in accordance with the present disclosure may further comprise an elastomeric seal element configured to prevent fluid leakage at the connection between the internal bores of the upper and lower components.
[0058] In variant embodiments, the configuration of the threaded connection assembly may be reversed—. i.e., with the coupling ring engaging axially-tapered splines provided on the upper component (rather than on the lower component as in the embodiments described above), and with the drive ring shouldering against the lower component.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0059] An embodiment in accordance with the present disclosure will now be described with reference to the accompanying Figures, in which numerical references denote like parts, and in

which:

[0060] FIG. **1** is an exploded isometric view of a first embodiment of a locking threaded connection assembly in accordance with the present disclosure.

[0061] FIG. **2** is exploded elevation of the connection assembly in FIG. **1**, with the coupling ring and the drive ring shown in cross-section.

[0062] FIG. **2**A is an axially-upward view of the coupling ring shown in FIGS. **1** and **2**.

[0063] FIG. **3** is an elevation view of the (partially assembled) connection assembly in FIG. **1** in preparation for a connection makeup operation.

[0064] FIGS. **4**A and **4**B, respectively, are elevation and partial cross-section views of the connection assembly in FIG. **1** with an external thread on the upper component engaged to an internal thread on the lower component at a hand-tight position in the connection makeup operation.

[0065] FIGS. **5**A and **5**B, respectively, are elevation and partial cross-section views of the connection assembly in FIG. **1** with coupling and drive rings rotated and then axially translated to a position where a tapered internal spline on the coupling ring is partially misaligned from a tapered external spline on the lower component.

[0066] FIGS. **6**A and **6**B, respectively, are elevation and partial cross-section views of the connection assembly in FIG. **1** with the drive ring partially axially extended from the coupling ring such that a shoulder of the drive ring contacts a shoulder of the upper component.

[0067] FIGS. **7**A and **7**B, respectively, are elevation and partial cross-section views of the connection assembly in FIG. **1** with the drive and coupling rings further axially extended from each other such that the tapered spline of the coupling ring has been urged into full alignment with the tapered spline of the lower component and, simultaneously, the lower component has been urged to rotate relative to the upper component.

[0068] FIG. **8** is an exploded isometric view of a second embodiment of a locking threaded connection assembly in accordance with the present disclosure.

[0069] FIG. **9** is exploded elevation of the connection assembly in FIG. **8**, with the lower component, the coupling ring, and the drive ring shown in cross-section.

[0070] FIG. **10** is an elevation view of the (partially assembled) connection assembly in FIG. **8** in preparation for a connection makeup operation.

[0071] FIGS. **11**A and **11**B, respectively, are elevation and partial cross-section views of the connection assembly in FIG. **8** with an external thread on the upper component engaged to an internal thread on the lower component at a hand-tight position in the connection makeup operation

[0072] FIGS. **12**A and **12**B, respectively, are elevation and partial cross-section views of the connection assembly in FIG. **8** with coupling ring rotated and axially translated to a position where a tapered downward-facing spline on the coupling ring is partially misaligned from a tapered upward-facing spline on the lower component.

[0073] FIGS. **13**A and **13**B, respectively, are elevation and partial cross-section views of the connection assembly in FIG. **8** with the drive ring partially axially extended from the upper component such that a shoulder of the drive ring contacts a shoulder of the coupling ring.

[0074] FIGS. **14**A and **14**B, respectively, are elevation and partial cross-section views of the connection assembly in FIG. **8** with the drive ring further axially extended from the upper component such that the tapered spline of the coupling ring has been urged into full alignment with the tapered spline of the lower component and, simultaneously, the lower component has been urged to rotate relative to the upper component.

[0075] FIGS. **15**A and **15**B, respectively, are elevation and partial cross-section views of the connection assembly in FIG. **8** fully engaged and secured with locking lugs.

[0076] FIG. **16** is an exploded elevation of a third embodiment of a locking threaded connection assembly in accordance with the present disclosure, in which a jack screw arrangement is used to apply axial force to the coupling ring (instead of a drive ring as in the first and second

embodiments).
[0077] FIG. **17** is an exploded elevation of the connection assembly in FIG. **16**, with the upper component, the coupling ring, and the drive ring assembly shown in cross-section.
[0078] FIGS. **18**A and **18**B, respectively, are elevation and partial cross-section views of the connection assembly in FIG. **16**, shown with the coupling ring rotated and then axially translated to a position in which the teeth of the second coupling ring torque transfer element are partially misaligned from the teeth of the lower torque transfer element, and with jackscrews partially axially extended downward from the drive plate such that the jackscrews bear on the coupling ring.
[0079] FIGS. **19**A and **19**B, respectively, are elevation and partial cross-section views of the connection assembly in FIG. **16**, shown with the jackscrews further axially extended downward from the drive plate such that the second coupling ring torque transfer element has been urged into alignment with the lower torque transfer element and, simultaneously, the lower component has been urged to rotate relative to the upper component.
DETAILED DESCRIPTION
First Exemplary Embodiment
[0080] FIGS. **1-7**B illustrate a first exemplary embodiment **100** of a locking threaded connection assembly in accordance with the present disclosure. As shown in FIGS. **1-3**, connection assembly **100** has a longitudinal connection axis A.sub.C and comprises an upper component **110**, a lower component **120** having an upper end **120**U and an axial bore **120**B extending downward from upper end **120**U, a coupling ring **130** having a lower end **130**L and a throughbore **130**B, and a drive ring **140** having a throughbore **140**B.
[0081] Upper component **110** has an external connection thread **111** configured for engagement with an internal connection thread **121** in axial bore **120**B of lower component **120**. In this particular illustrated embodiment, and by way of non-limiting example only, connection threads **111** and **121** are shown as right-handed threads, and for drawing simplicity, are represented in FIGS. **1-7**B as a set of circumferential grooves and ridges.
[0082] Upper component **110** has a downward-facing connection shoulder **112** configured for contact with an upward-facing connection shoulder **122** on lower component **120**.
[0083] Upper component **110** has an external upper spline **113** having a selected number n.sub.U spline ridges **113**R and a corresponding number of spline grooves **113**G, with each spline ridge **113**R being configured to have a zero helical angle relative to longitudinal connection axis A.sub.C, with spline **113** being configured for axial sliding engagement with an internal upper spline **133** in throughbore **130**B of coupling ring **130**. Similar to external spline **113**, spline **133** has n.sub.U spline ridges **133**R and a corresponding number of spline grooves **133**G as shown in FIG. **2**A, with each spline ridge **133**R being configured to have a zero helical angle. Each spline ridge **113**R on upper spline **113** has a first ridge flank **113***f* configured for sliding engagement with a first ridge flank **133***f* on upper spline **133**, plus a second ridge flank **113***s* configured for sliding engagement with a second ridge flank **133***s* of a spline ridge **133**R on upper spline **133**. In the illustrated embodiment (and by way of non-limiting example only), the value of n.sub.U=19.
[0084] Upper component **110** has a downward-facing drive shoulder **114** configured for contact with an upward-facing drive shoulder **144** on drive ring **140**.
[0085] Upper end **120**U of lower component **120** defines an external lower spline **125** having a selected number n.sub.L of spline ridges **125**R and a corresponding number of spline grooves **125**G, with the value of n.sub.L being different from the value of n.sub.U. Spline **125** is configured for engagement with an internal lower spline **135** in throughbore **130**B of coupling ring **130**, below internal upper spline **133**. Similar to lower spline **125**, internal lower spline **135** has n.sub.L spline ridges **135**R and a corresponding number of spline grooves **135**G as shown in FIG. **2**A. Each spline ridge **125**R also has a first flank **125***f* configured for engagement with a first flank **135***f* of a spline ridge **135**R on lower spline **135**. First flanks **125***f* and **135***f* are axially tapered, with the tapered flank surfaces preferably (but not necessarily) following fully mating helical profiles. Each spline

ridge **125**R also has a second flank **125***s* configured for engagement with a second flank **135***s* of a spline ridge **135**R on lower spline **135**. Second flanks **125***s* and **135***s* are axially tapered, with the tapered flank surfaces preferably (but not necessarily) following fully mating helical profiles. In the embodiment shown in FIGS. **1**-**7**B (and by way of non-limiting example only), the value of n.sub.L=18. Although n.sub.L is less than n.sub.U and the difference between n.sub.L and n.sub.U is one in this particular example, it is to be understood that n.sub.L could be greater than equal to n.sub.U in alternative embodiments, and that the difference between n.sub.L and n.sub.U could be greater than one.
[0086] The taper angle of first flanks **125***f* and **135***f* and the taper angle of second flanks **125***s* and **135***s* may be (but are not necessarily) the same. The value of the taper angles, otherwise understood as helix angles, of the flank surfaces is shown in the illustrated embodiment as being approximately 15 degrees relative to connection axis A.sub.C. However, this is by way of non-limiting example only, and selection of the taper angle will typically be based on whether the user wants the spline engagement to be self-releasing or locking. More specifically, the included angle between the helix or taper angle of external upper spline **113** on upper component **110** (which will be zero when the flanks of upper spline **113** are parallel to connection axis A.sub.C) and the helix or taper angle of lower spline **125** on lower component **120** must exceed a threshold value in order for the spline engagement to be self-releasing and non-locking, and this threshold value can be readily determined in accordance with methods familiar to persons of ordinary skill in the art, taking into consideration relevant variables such as material properties and friction coefficients.
[0087] Coupling ring **130** has an external drive thread **136** configured for engagement with an internal drive thread **146** on drive ring **140**.
[0088] FIG. **3** is an elevation view of assembly **100** partially assembled in preparation for a connection makeup operation. Prior to making up connection threads **111** and **121**, rings **130** and **140** are threaded together (via drive threads **136** and **146**) to a minimum combined axial length (retracted length). Drive shoulder **144** and throughbore **140**B of drive ring **140** are profiled so that drive ring **140** may axially pass over upper spline **113** on upper component **110**. Rings **130** and **140** are slidingly mounted around upper component **110** with drive shoulders **114** and **144** in contact.
Connection Makeup Procedure
[0089] FIGS. **4**A and **4**B, respectively, are elevation and partial cross-section views of assembly **100** at a hand-tight position in the connection makeup operation. Connection threads **111** and **121** are engaged and connection shoulders **112** and **122** are in contact with a small contact force. Upper splines **113** and **133** are not engaged, and splines **125** and **135** are also not engaged. Coupling ring **130** is in a free position and may rotate freely, together with drive ring **140**, on upper component **110**. There are n.sub.U=19 rotational positions that may be selected at which rings **130** and **140** may be axially lowered together to engage upper spline **113** with upper spline **133**. The phase difference (amount of misalignment) between lower splines **125** and **135** will depend on the selected rotational position of coupling ring **130**, similar to a vernier scale.
[0090] FIGS. **5**A and **5**B, respectively, are elevation and partial cross-section views of connection assembly **100** with rings **130** and **140** shown rotated to a selected rotational position and lowered, engaging upper splines **113** and **133**. At the selected rotational position, lower splines **125** and **135** are misaligned (i.e., out of phase) such that axially-tapered first ridge flanks **125***f* and **135***f* are only partially engaged.
[0091] In the next step of the connection makeup operation, drive ring **140** is rotated relative to coupling ring **130** causing rings **130** and **140** to extend in combined length until drive shoulders **144** and **114** come into contact. FIGS. **6**A and **6**B, respectively, are elevation and partial cross-section views showing connection assembly **100** after this step of the makeup operation.
[0092] In the final step of the connection makeup operation, drive ring **140** is further rotated relative to coupling ring **130**, urging coupling ring **130** downward. As coupling ring **130** moves downward, tapered splines **135** and **125** move toward in-phase alignment as a result of the sliding

engagement of the corresponding contacting spline ridge flanks (**125***f* and **135***f*), and lower component **120** incrementally rotates relative to upper component **110**, thus tightening the threaded connection of upper and lower components **110** and **120**. FIGS. **7**A and **7**B, respectively, are elevation and partial cross-section views of connection assembly **100** at the end of the connection makeup operation. Coupling ring **130** is in a seated position.

[0093] The torque required to rotate drive ring **140** relative to coupling ring **130** during the final makeup step is substantially less than the resulting torque that urges relative rotation between lower component **120** and upper component **110**, due to the mechanical advantage provided by the relative sliding action of drive threads **136** and **146**; and the relative sliding action of first ridge flanks **125***f* and **135***f*. The magnitude of mechanical advantage will vary according to factors including the lead angle of drive threads **136** and **146**, the taper angle of first ridge flanks **125***f* and **135***f*, and the friction forces between the sliding surfaces.

[0094] When desired, the threaded connection of upper and lower components **110** and **120** may be tightened further by performing the additional steps of: [0095] 1. rotating drive ring **140** relative to coupling ring **130** to axially retract rings **130** and **140** relative to each other; [0096] 2. raising rings **130** and **140** together until drive shoulders **144** and **114** contact and coupling ring **130** is in a free position where upper splines **133** and **113** are disengaged, lower splines **135** and **125** are disengaged, and rings **130** and **140** are free to rotate around upper component **110**; [0097] 3. rotating rings **130** and **140** together and selecting a new position of the n.sub.U=19 rotational positions at which rings **130** and **140** may be axially lowered together to engage upper splines **113** and **133** and wherein lower splines **125** and **135** partially engage axially-tapered first ridge flanks **125***f* and **135***f*; and [0098] 4. rotating drive ring **140** relative to coupling ring **130** to axially extend rings **130** and **140** relative to each other until coupling ring **130** is in a seated position, tapered lower splines **135** and **125** are in-phase aligned, and lower component **120** has rotated relative to upper component **110** to further incrementally tighten the threaded connection therebetween. Steps 1-4 above may be repeated as many times as necessary to achieve a desired tightness of the threaded connection.

[0099] After the connection makeup operation, assembly **100** is locked from further relative rotation between upper component **110** and lower component **120** by rings **130** and **140**. Torque transmitted between upper component **110** and lower component **120** in excess of the torque resisted by friction between connection threads **111** and **121** and between connection shoulders **112** and **122** will flow through coupling ring **130** via upper splines **113** and **133** and via lower splines **125** and **135**.

[0100] Coupling ring **130** is held axially in place, with both upper splines **113** and **133** engaged and lower splines **125** and **135** engaged, by drive ring **140**. Unintentional rotation of drive ring **140** relative to coupling ring **130** (and upper component **110**) will be resisted by friction between drive threads **136** and **146** and between drive shoulders **114** and **144**.

[0101] The torque required to rotate drive ring **140** to urge axial movement of coupling ring **130** and resultant incremental rotation between upper component **110** and lower component **120** is much less than the torque required to directly urge incremental rotation between upper component **110** and lower component **120** due to the mechanical advantage provided by the helical sliding engagement of first flanks **125***f* and **135***f* and the additional mechanical advantage provided by the helical sliding engagement of internal drive thread **146** and external drive thread **136**. In this first exemplary embodiment, the total combined mechanical advantage provided by first flanks **125***f* and **135***f* and by drive threads **146** and **136** is 10 to 1 (i.e., the torque required to rotate drive ring **140** is 1/10 of the torque required to directly urge incremental rotation between components **110** and **120**).

Connection Breakout Procedure

[0102] Rings **130** and **140** may also be used to loosen the threaded connection of upper and lower components **110** and **120** by performing the steps of. [0103] 1. rotating drive ring **140** relative to coupling ring **130** to axially retract rings **130** and **140** relative to each other; [0104] 2. raising rings

130 and **140** together until drive shoulders **144** and **114** contact and coupling ring **130** is in a free position where upper splines **133** and **113** are disengaged, lower splines **135** and **125** are disengaged, and rings **130** and **140** are free to rotate around upper component **110**; [0105] 3. rotating rings **130** and **140** together and select a new position of the n.sub.U=19 rotational positions at which rings **130** and **140** may be axially lowered together to engage upper splines **113** and **133** and wherein lower splines **125** and **135** partially engage axially-tapered second ridge flanks **125***s* and **135***s*; and [0106] 4. rotating drive ring **140** relative to coupling ring **130** to axially extend rings **130** and **140** relative to each other until coupling ring **130** is in a seated position, tapered lower splines **135** and **125** are in-phase aligned, and lower component **120** a has rotated relative to upper component **110** to incrementally loosen the threaded connection therebetween.
[0107] FIGS. **1**, **2**, **3**, and **4**A-**7**B show an optional circumferential reference line RL that may be marked by any suitable means on an upper portion of upper component **110** to provide a visual indication of axial movement of drive ring **140** relative to upper component **110**, and thereby to assist a user in determining the state of connection assembly **100** during a connection makeup or breakout operation. By way of non-limiting example only, reference line RL is shown as being coincident with an upper cylindrical edge of drive ring **140** in FIGS. **3**, **4**A, **4**B, and **6**A-**7**B.
Second Exemplary Embodiment
[0108] FIGS. **8**-**15**B illustrate a second exemplary embodiment **200** of a locking threaded connection assembly in accordance with the present disclosure. As shown in FIGS. **8** and **9**, connection assembly **200** has a longitudinal connection axis A.sub.C and comprises an upper component **210**, a lower component **220** having an upper end **220**U and an axial bore **220**B extending downward from upper end **220**U, a coupling ring **230** having an axial throughbore **230**B and a lower end **230**L, a drive ring **240** having an axial throughbore **240**B, and one or more locking lugs **250**.
[0109] Upper component **210** has an external connection thread **211** configured for engagement with an internal connection thread **221** in bore **220**B of lower component **220**. In this particular illustrated embodiment, and by way of non-limiting example only, connection threads **211** and **221** are shown as mating tapered right-handed helical threads. For drawing simplicity, connection threads **211** and **221** are represented in FIGS. **8** to **15**B as a set of circumferential grooves and ridges.
[0110] Upper component **210** has a downward-facing connection shoulder **217** configured for contact with an upward-facing connection shoulder **223** on lower component **220**.
[0111] Upper component **210** has an external spline **213** having a selected number n.sub.U of spline ridges **213**R and a corresponding number of spline grooves **213**G, with each spline ridge **213**R being configured to have a zero helical angle relative to longitudinal connection axis A.sub.C, with spline **213** being configured for axial sliding engagement with an internal spline **232** in throughbore **230**B of coupling ring **230**. Similar to external spline **213**, internal spline **232** has ny spline ridges **232**R and a corresponding number of spline grooves **232**G as shown in FIG. **9**A, with each spline ridge **232**R being configured to have a zero helical angle. Each spline ridge **213**R on external spline **213** has a first ridge flank **213***f* configured for sliding engagement with a first ridge flank **232***f* on internal spline **232**, plus a second ridge flank **213***s* configured for sliding engagement with a second ridge flank **232***s* on internal spline **232**. In the illustrated embodiment (and by way of non-limiting example only), the value of n.sub.U=15.
[0112] Upper end **220**U of lower component **220** defines an upward-facing spline **222** having a selected number n.sub.L of spline ridges **222**R and a corresponding number of spline grooves **222**G, with the value of n.sub.L being different from the value of n.sub.U. Spline **222** is configured for engagement with a downward-facing spline **231** on lower end **230**L of coupling ring **230**. Similar to upward-facing spline **222**, downward-facing spline **231** has ng spline ridges **231**R and a corresponding number of spline grooves **231**G as shown in FIG. **9**B. Each spline ridge **222**R has a first flank **222***f* configured for engagement with a first flank **231***f* of a spline ridge **231**R on

downward-facing spline **231**. First flanks **222***f* and **231***f* are axially tapered, with the tapered flank surfaces preferably (but not necessarily) following fully mating helical profiles. Each spline ridge **222**R also has a second flank **222***s* configured for engagement with a second flank **231***s* of a spline ridge **231**R on downward-facing spline **231**. Second flanks **222***s* and **231***s* are axially tapered, with the tapered flank surfaces preferably (but not necessarily) following fully mating helical profiles. In the embodiment shown in FIGS. **8-15**B (and by way of non-limiting example only), the value of n.sub.L=14. Although n.sub.L is less than n.sub.U and the difference between n.sub.L and n.sub.U is one in this particular example, it is to be understood that ng could be greater than equal to n.sub.U in alternative embodiments, and that the difference between n.sub.L and n.sub.U could be greater than one.

[0113] The taper angle of first flanks **222***f* and **231***f* and the taper angle of second flanks **222***s* and **231***s* may be (but are not necessarily) the same. The value of the taper angles, otherwise understood as helix angles, of the flank surfaces is shown in the illustrated embodiment as being approximately 20 degrees relative to connection axis A.sub.C. However, this is by way of non-limiting example only, and selection of the taper angle will typically be based on whether the user wants the spline engagement to be self-releasing or locking. More specifically, the included angle between the helix or taper angle of external spline **213** on upper component **210** (which will be zero when the flanks of external spline **213** are parallel to connection axis A.sub.C) and the helix or taper angle of upward-facing spline **222** on lower component **220** must exceed a threshold value in order for the spline engagement to be self-releasing and non-locking, and this threshold value can be readily determined in accordance with methods familiar to persons of ordinary skill in the art, taking into consideration relevant variables such as material properties and friction coefficients.

[0114] Drive ring **240** has an internal drive thread **243** in throughbore **240**B, configured for engagement with external drive thread **216** on upper component **210**. Locking lug holes **241** in drive ring **240** may be aligned with locking lug holes **215** on upper component **210**, whereupon locking lugs **250** may be threaded into locking lug holes **241** to secure connection assembly **200** by preventing rotation of drive ring **240** relative to upper component **210**.

[0115] FIG. **10** is an elevation view of assembly **200** partially assembled in preparation for a connection makeup operation. Prior to makeup of connection threads **211** and **221**, drive ring **240** is passed over external spline **213** on upper component **210** and mounted on upper component **210** by engagement of drive threads **243** and **216**. Coupling ring **230** is slidingly mounted around upper component **210**. Coupling ring **230** may be rotationally oriented to axially pass over external spline **213** to reach a free position where splines **213** and **232** are not engaged and coupling ring **230** is free to rotate.

Connection Makeup Procedure

[0116] FIGS. **11**A and **11**B, respectively, are elevation and partial cross-section views of assembly **200** at a hand-tight position in the connection makeup operation. Connection threads **211** and **221** are engaged and connection shoulders **217** and **223** are in contact with a small contact force. Splines **213** and **232** are not engaged, and splines **231** and **222** are also not engaged. Coupling ring **230** is in a free position and may rotate freely. Drive ring **240** is engaged with upper component **210** by external drive thread **216** and internal drive thread **243**. There are n.sub.U=15 rotational positions that may be selected at which ring **230** may be axially lowered to engage external spline **213** with internal spline **232**. The phase difference (amount of misalignment) between downward-facing spline **231** and upward-facing spline **222** will depend on the selected rotational position of coupling ring **230**, similar to a vernier scale.

[0117] FIGS. **12**A and **12**B, respectively, are elevation and partial cross-section views of connection assembly **200** with coupling ring **230** shown rotated to a selected rotational position and lowered, engaging splines **213** and **232**. At the selected rotational position, upward-facing spline **222** and downward-facing spline **231** are misaligned (i.e., out of phase) such that axially-tapered first ridge flanks **222***f* and **231***f* are only partially engaged.

[0118] In the next step of the connection makeup operation, drive ring **240** is rotated relative to upper component **210** causing drive ring **240** to move axially down relative to upper component **210**, and causing downward-facing drive shoulder **242** on drive ring **240** to contact upward-facing drive shoulder **233** on coupling ring **230**, as shown in FIGS. **13**A and **13**B. In the final connection makeup step, drive ring **240** is further rotated relative to upper component **210**, urging coupling ring **230** downward. As coupling ring **230** moves downward, tapered splines **231** and **222** move toward in-phase alignment as a result of the sliding engagement of the corresponding contacting spline ridge flanks (**231***f* and **222***f*), and lower component **220** incrementally rotates relative to upper component **210**, thus tightening the threaded connection of upper and lower components **210** and **220**.
[0119] FIGS. **14**A and **14**B, respectively, are elevation and partial cross-section views of connection assembly **200** at the end of the connection makeup operation, with coupling ring **230** shown in a seated position. FIGS. **15**A and **15**B, respectively, are elevation and partial cross-section views showing connection assembly **200** with locking lugs **250** installed into locking lug holes **241** and **215** to prevent unintended rotation of coupling ring **230**.
[0120] The torque required to rotate drive ring **240** during the final connection makeup step is substantially less than the resulting torque that urges relative rotation between lower component **220** and upper component **210**, due to the mechanical advantage provided by the relative sliding action of drive threads **216** and **243**; and the relative sliding action of first ridge flanks **222***f* and **231***f*. The magnitude of mechanical advantage will vary according to factors including the lead angle of drive threads **216** and **243**, the taper angle of first ridge flanks **222***f* and **231***f*, and the friction forces between the sliding surfaces.
[0121] When desired, the threaded connection of upper and lower components **210** and **120** may be tightened further by performing the additional steps of: [0122] 1. rotating drive ring **240** relative to upper component **210** to axially raise drive ring **240**; [0123] 2. raising coupling ring **230** to a free position where splines **213** and **232** are disengaged, splines **231** and **222** are disengaged, and coupling ring **230** is free to rotate around upper component **210**; [0124] 3. rotating coupling ring **230** and selecting a new position of the n.sub.U=15 rotational positions at which coupling ring **230** may be axially lowered to engage splines **213** and **232** and wherein lower splines **231** and **222** partially engage axially-tapered first ridge flanks **222***f* and **231***f*; and [0125] 4. rotating drive ring **240** relative to upper component **210** to axially lower drive ring **240** and urge coupling ring **230** into a seated position, wherein tapered lower splines **231** and **222** are in-phase aligned, and lower component **220** has rotated relative to upper component **210** to further incrementally tighten the threaded connection therebetween.
Steps 1-4 above may be repeated as many times as necessary to achieve a desired tightness of the threaded connection. Optionally, and as shown in FIGS. **11**A, **12**A, **13**A, and **14**A, one or more drive tool sockets **245** may be provided in drive ring **240** to facilitate manual rotation of drive ring **240** relative to upper component **210** with the aid of a steel bar or other suitable tool inserted in drive tool socket **245**.
[0126] After the connection makeup operation, assembly **200** is locked from further relative rotation between upper component **210** and lower component **220** by rings **230** and **240** and locking lugs **250**. Torque transmitted between upper component **210** and lower component **220** in excess of the torque resisted by friction between connection threads **211** and **221** and between connection shoulders **217** and **223** will flow through coupling ring **230** via splines **213** and **232** and via splines **231** and **222**.
[0127] Coupling ring **230** is held axially in place, with both splines **213** and **232** engaged and splines **231** and **222** engaged, by drive ring **240**. Unintentional rotation of drive ring **240** relative to coupling ring **230** (and upper component **210**) will be resisted by friction between drive threads **216** and **243** and locking lugs **250**.
Connection Breakout Procedure

[0128] Rings **230** and **240** may also be used to loosen the threaded connection of upper and lower components **210** and **220** by performing the steps of: [0129] 1. rotating drive ring **240** relative to upper component **210** to axially raise drive ring **240**; [0130] 2. raising coupling ring **230** to a free position where splines **213** and **232** are disengaged, splines **231** and **222** are disengaged, and coupling ring **230** is free to rotate around upper component **210**; [0131] 3. rotating coupling ring **230** and selecting a new rotational position at which coupling ring **230** may be axially lowered to engage splines **213** and **232** and wherein splines **231** and **222** partially engage axially-tapered second ridge flanks **222***s* and **231***s*; and [0132] 4. rotating drive ring **240** relative to upper component **210** to axially lower ring **240** and urge coupling ring **230** into a seated position, tapered splines **231** and **222** are in-phase aligned, and lower component **220** a has rotated relative to upper component **210** to incrementally loosen the threaded connection therebetween.

Third Exemplary Embodiment

[0133] FIGS. **16-19**B illustrate a third exemplary embodiment **300** of a locking threaded connection assembly in accordance with the present disclosure. As shown in FIGS. **16** and **17**, connection assembly **300** has a longitudinal connection axis A.sub.C and comprises an upper component **310**, a lower component **320**, and a coupling ring **330**.

[0134] Lower component **320** has an external connection thread **321** threadingly engageable with an internal connection thread **311** on upper component **310**. In this particular illustrated embodiment, and by way of non-limiting example only, connection threads **311** and **321** are shown as right-handed threads and, for drawing simplicity, are represented in FIGS. **16-19**B as a set of circumferential grooves and ridges.

[0135] Lower component **320** has an upward-facing connection shoulder **322** configured for contact with a downward-facing connection shoulder **312** on upper component **110**.

[0136] Coupling ring **330** has a first coupling ring torque transfer element **331** engageable with an upper torque transfer element **313** on upper component **310**, and a second coupling ring torque transfer element **332** engageable with a lower torque transfer element **323** on lower component **320**. Coupling ring **330** is axially movable between: [0137] a free position in which coupling ring **330** is freely rotatable relative to both upper component **310** and lower component **320**; and [0138] a seated position in which first coupling ring torque transfer element **331** engages upper torque transfer element **313**, and second coupling ring torque transfer element **332** engages lower torque transfer element **323**, such that coupling ring **330** prevents relative rotation between upper component **310** and lower component **320**.

[0139] In the illustrated embodiment (and by way of non-limiting example only), upper torque transfer element **313** and first coupling ring torque transfer element **331** each have n.sub.U=24 uniformly-spaced teeth, and lower torque transfer element **323** and second coupling ring torque transfer element **332** each have n.sub.L=21 uniformly-spaced teeth. Each tooth of lower torque transfer element **323** has an axially-tapered flank slidingly engageable with an axially-tapered flank on a tooth of second coupling ring torque transfer element **332**.

[0140] Connection assembly **300** further comprises axial force means for urging coupling ring **330** from the free position toward the seated position in the form of a drive plate **341** with a plurality of jackscrews **345**. Drive plate **341** has a threaded screw hole **342** for each jackscrew **345**, and an upward-facing drive shoulder **342** configured for contact with a downward-facing drive shoulder **314** on upper component **110**. Jackscrews **345** may be turned to apply axial force to coupling ring **330**.

[0141] When coupling ring **340** is in the free position, coupling ring **340** is rotatable to one or more selectable rotational positions in which the teeth of lower torque transfer element **323** are rotationally out of phase with the teeth of second coupling ring torque transfer element **332**. FIGS. **18**A and **18**B, respectively, are elevation and partial cross-section views of connection assembly **300** with coupling ring **330** rotated and then axially translated to a position where second coupling ring torque transfer element **332** is partially misaligned from lower torque transfer element **323**, and with jackscrews **345** partially axially extended downward from drive plate **340** such that jackscrews **345** bear on coupling ring **340**.

[0142] Movement of coupling ring **340** from the free position toward the seated position will urge relative rotation between upper component **310** and lower component **320** as a result of sliding engagement of the axially-tapered flanks of the teeth of lower torque transfer element **323** and second coupling ring torque transfer element **332**. FIGS. **19**A and **19**B, respectively, are elevation and partial cross-section views of connection assembly **300** with jackscrews **345** further axially extended downward from drive plate **340** such that an upward-facing drive shoulder **342** of drive plate **340** bears on a downward facing drive shoulder **314** of upper component **310**, and second torque transfer element **332** has been urged into full alignment with lower torque transfer element **323** and, simultaneously, lower component **320** has been urged to rotate relative to upper component **310**, tightening connection threads **311** and **321**. [0143] #####

[0144] It will be readily appreciated by persons skilled in the art that various modifications to embodiments in accordance with the present disclosure may be devised without departing from the scope of the present teachings, including modifications that use equivalent structures or materials hereafter conceived or developed.

[0145] It is especially to be understood that the scope of the present disclosure is not intended to be limited to described or illustrated embodiments, and that the substitution of a variant of any claimed or illustrated element or feature, without any substantial resultant change in functionality, will not constitute a departure from the scope of the disclosure.

[0146] In this patent document, any form of the word “comprise” is to be understood in its non limiting sense to mean that any element or feature following such word is included, but elements or features not specifically mentioned are not excluded. A reference to an element or feature by the indefinite article “a” does not exclude the possibility that more than one such element or feature is present, unless the context clearly requires that there be one and only one such element or feature.

[0147] Any use herein of any form of the terms “connect”, “engage”, “couple”, “attach”, or any other term describing an interaction between elements is not meant to limit the interaction to direct interaction between the subject elements, and may also include indirect interaction between the elements such as through secondary or intermediary structure.

[0148] Relational and conformational terms such as (but not limited to) “parallel”, “vertical”, “axial”, “coaxial”, and “helical” are not intended to denote or require absolute mathematical or geometrical precision. Accordingly, such terms are to be understood as denoting or requiring substantial precision only (e.g., “substantially parallel” or “generally helical”) unless the context clearly requires otherwise. Unless the context clearly indicates otherwise, the term “vertical” as used herein is intended to mean parallel to the longitudinal connection axis. As used herein, the term “cylindrical” is intended to cover not only purely cylindrical elements but also elements that are cylindrical in cross-section but their cross-sectional configurations may vary along their axial lengths.

[0149] Wherever used in this document, the terms “typical” and “typically” are to be understood and interpreted in the sense of being representative of common usage or practice, and are not intended to be understood or interpreted as implying essentiality or invariability.

LIST OF COMPONENTS AND FEATURES

[0150] Feature Number Description [0151] **100** Locking threaded connection assembly [0152] **110** Upper component [0153] **111** External connection thread [0154] **112** Downward-facing connection shoulder on **110** [0155] **113** External upper spline on **110** [0156] **113**G Spline groove on **113** [0157] **113**R Spline ridge on **113** [0158] **113*f*** First ridge flank on **113**R [0159] **113*s*** Second ridge flank on **113**R [0160] **114** Downward-facing drive shoulder on **110** [0161] **120** Lower component [0162] **120**B Bore of **120** [0163] **120**U Upper end of **120** [0164] **121** Internal connection thread on **120** [0165] **122** Upward-facing connection shoulder on **120** [0166] **125** External lower spline on **120** [0167] **125**G Spline groove on **125** [0168] **125**R Spline ridge on **125** [0169] **125*f*** First ridge flank on **125**R [0170] **125***s* Second ridge flank on **125**R [0171] **130** Coupling ring [0172] **130**L Lower end of **130** [0173] **130**B Coupling ring throughbore [0174] **133** Internal upper spline on **130** [0175] **133**G Spline groove on **133** [0176] **133**R Spline ridge on **133** [0177] **133***f* First ridge flank on **133**R [0178] **133***s* Second ridge flank on **133**R [0179] **135** Internal lower spline on **130** [0180] **135**G Spline groove on **135** [0181] **135**R Spline ridge on **135** [0182] **135***f* First ridge flank on **135**R [0183] **135***s* Second ridge flank on **135**R [0184] **136** External drive thread on **130** [0185] **140** Drive ring [0186] **140**B Drive ring throughbore [0187] **144** Upward-facing drive shoulder on **140** [0188] **146** Internal drive thread on **140** [0189] **200** Locking threaded connection assembly [0190] **210** Upper component [0191] **211** External connection thread [0192] **217** Downward-facing connection shoulder on **210** [0193] **213** External spline on **210** [0194] **213**G Spline groove on **213** [0195] **213**R Spline ridge on **213** [0196] **213***f* First ridge flank on **213**R [0197] **213***s* Second ridge flank on **213**R [0198] **215** Locking lug holes on **210** [0199] **216** External drive thread on **210** [0200] **220** Lower component [0201] **220**B Bore of **220** [0202] **220**U Upper end of **220** [0203] **221** Internal connection thread on **220** [0204] **222** Upward-facing spline on **220** [0205] **222**G Spline groove on **222** [0206] **222**R Spline ridge on **222** [0207] **222***f* First ridge flank on **222**R [0208] **222***s* Second ridge flank on **222**R [0209] **223** Upward-facing connection shoulder on **220** [0210] **230** Coupling ring [0211] **230**B Throughbore of **230** [0212] **230**L Lower end of **230** [0213] **231** Downward-facing spline on **230** [0214] **231***f* First ridge flank on **231**R [0215] **231***s* Second ridge flank on **212**R [0216] **231***f* First ridge flank on **231** [0217] **231***s* Second ridge flank on **231** [0218] **232** Internal spline on **230** [0219] **232**G Spline groove on **232** [0220] **232**R Spline ridge on **232** [0221] **232***f* First ridge flank on **232**R [0222] **232***s* Second ridge flank on **232**R [0223] **233** Upward-facing drive shoulder on **230** [0224] **240** Drive ring [0225] **240**B Throughbore of **240** [0226] **241** Locking lug holes on **240** [0227] **242** Downward-facing drive shoulder on **240** [0228] **243** Internal drive thread on **240** [0229] **245** Drive tool socket on **240** [0230] **250** Locking lugs [0231] **300** Locking threaded connection assembly [0232] **310** Upper component [0233] **311** Internal connection thread [0234] **312** Downward-facing connection shoulder [0235] **313** Upper torque transfer element [0236] **314** Downward-facing drive shoulder on **310** [0237] **320** Lower component [0238] **321** External connection thread [0239] **322** Upward-facing connection shoulder [0240] **323** Lower torque transfer element [0241] **330** Coupling ring [0242] **331** First coupling ring torque transfer element [0243] **332** Second coupling ring torque transfer element [0244] **340** Drive plate [0245] **341** Threaded screw hole [0246] **342** Upward-facing drive shoulder on **340** [0247] **345** Jackscrew [0248] A.sub.C Longitudinal connection axis of connection assembly **100**, **200**, or **300** [0249] RL Reference line on upper component **110** of assembly **100**

Claims

1. A threaded connection assembly comprising: (a) an upper component having an upper torque transfer element comprising a plurality of uniformly-spaced teeth; (b) a lower component threadingly engageable with the upper component and having a lower torque transfer element comprising a plurality of uniformly-spaced teeth; (c) a coupling ring having a first coupling ring torque transfer element engageable with the upper torque transfer element, and a second coupling ring torque transfer element engageable with the lower torque transfer element, said coupling ring being axially movable between: a free position in which the coupling ring is freely rotatable relative to both the upper component and the lower component; and a seated position in which the first coupling ring torque transfer element engages the upper torque transfer element, and the second coupling ring torque transfer element engages the lower torque transfer element, such that the coupling ring prevents relative rotation between the upper component and the lower component; and (d) axial force means for urging the coupling ring from the free position toward the seated position; wherein: (e) the upper component, the lower component, and the coupling ring are coaxial about a longitudinal connection axis; (f) the upper torque transfer element and the lower torque transfer element have different numbers of teeth; (g) each tooth of the lower torque transfer element has an axially-tapered flank slidingly engageable with an axially-tapered flank on a tooth of the second coupling ring torque transfer element, such that when the teeth of the lower torque transfer element are rotationally out of phase with the teeth of the second coupling ring torque transfer element, movement of the coupling ring from the free position toward the seated position will urge relative rotation between the upper and lower components as a result of sliding engagement of the axially-tapered flanks of the teeth of the lower torque transfer element and the second coupling ring torque transfer element; and (h) when the coupling ring is in the free position, the coupling ring is rotatable to one or more selectable rotational positions in which the teeth of the lower torque transfer element are rotationally out of phase with the teeth of the second coupling ring torque transfer element.

2. The threaded connection assembly as in claim 1 wherein both flanks of each tooth of the lower torque transfer element and the second coupling ring torque transfer element are axially tapered.

3. The threaded connection assembly as in claim 2 wherein both flanks of each tooth of the lower torque transfer element and the second coupling ring torque transfer element have axial taper angles of equal magnitude.

4. The threaded connection assembly as in claim 1 wherein: (a) the upper and lower components are cylindrical components having respective internal bores; and (b) the coupling ring is coaxially aligned with the upper and lower components and is located within the internal bore of a selected one, or both, of the upper and lower components.

5. The threaded connection assembly as in claim 1 wherein the upper torque transfer element comprises an external spline, and the first coupling ring torque transfer element comprises an internal spline.

6. The threaded connection assembly as in claim 1 wherein the lower torque transfer element comprises an external spline, and the second coupling ring torque transfer element comprises an internal spline.

7. The threaded connection assembly as in claim 1 wherein the lower torque transfer element and the second coupling ring torque transfer element are configured for engagement in the manner of a dog clutch.

8. The threaded connection assembly as in claim 7 wherein the teeth of the torque transfer element and the second coupling ring torque transfer element are at least partially of curvilinear configuration.

9. The threaded connection assembly as in claim 1 wherein when the coupling ring is in one of the one or more selectable rotational positions, movement of the coupling ring from the free position to the seated position will urge relative rotation of the upper and lower components in a rotational direction tending to tighten the threaded connection.

10. The threaded connection assembly as in claim 1 wherein when the coupling ring is in one of the one or more selectable rotational positions, movement of the coupling ring from the free position to the seated position will urge relative rotation of the upper and lower components in a rotational direction tending to loosen the threaded connection.

11. The threaded connection assembly as in any one of claim 1 wherein the axially-tapered flanks of the teeth of the lower torque transfer element and the second coupling ring torque transfer element follow a helical profile.

12. The threaded connection assembly as in claim 1 wherein the axial force means comprises a drive ring threadingly engageable with the coupling ring, and having an annular shoulder configured for sliding contact with an annular shoulder on a selected one of the upper and lower components, such that rotation of the drive ring relative to the coupling ring will urge axial movement of the coupling ring relative to the upper and lower components.

13. The threaded connection assembly as in claim 1 wherein the axial force means comprises a drive ring having an annular shoulder configured for sliding contact with an annular shoulder on the coupling ring, with the drive ring being threadingly engageable with a selected one of the upper and lower components, such that rotation of the drive ring relative to the selected one of the upper and lower components will urge axial movement of the coupling ring relative to the upper and lower components.

14. The threaded connection assembly as in claim 12, further comprising locking means for preventing relative rotation between the drive ring and the selected one of the upper and lower components.

15. The threaded connection assembly as in claim 14 wherein the locking means is provided by one or more locking lugs insertable through holes in the drive ring and into holes in the selected one of the upper and lower components.

16. The threaded connection assembly as in claim 12, further comprising drive ring rotation means for rotating the drive ring.

17. The threaded connection assembly as in claim 16 wherein the drive ring rotation means is provided by one or more drive tool sockets formed in the drive ring.

18. The threaded connection assembly as in claim 1 wherein the axial force means comprises a plurality of jackscrews threadingly engaging a plate, wherein: (a) the plate has an axial surface contacting an axial shoulder surface on a selected one of the upper and lower components; and (b) the jackscrews bear against the coupling ring; such that rotation of the jack screws relative to the plate will urge axial movement of the coupling ring relative to the upper and lower components.

Upon entry of the current amendments, the claims pending in the application will be claims **1-18**.