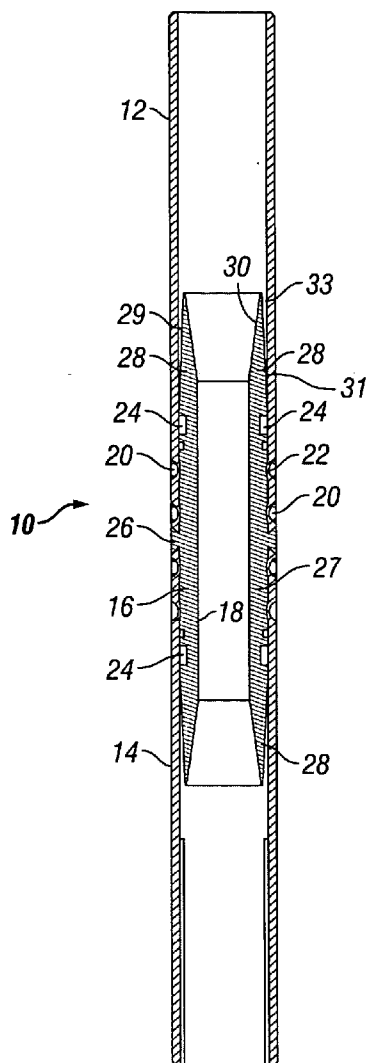


(43) **Pub. Date:** **Nov. 2, 2006**

(57) **ABSTRACT**



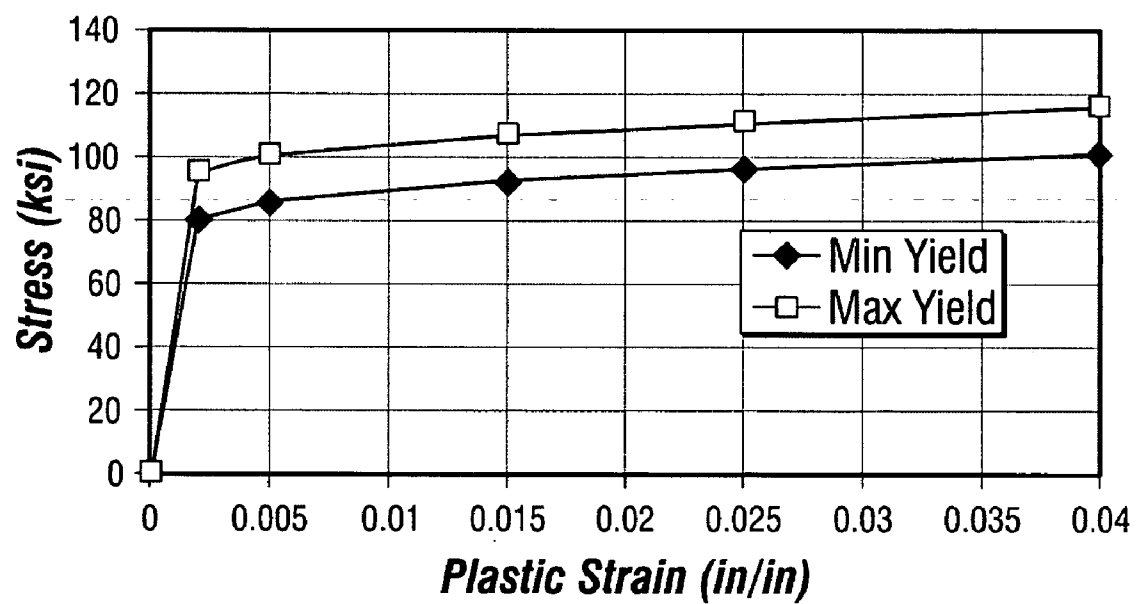


FIG. 1
(Prior Art)

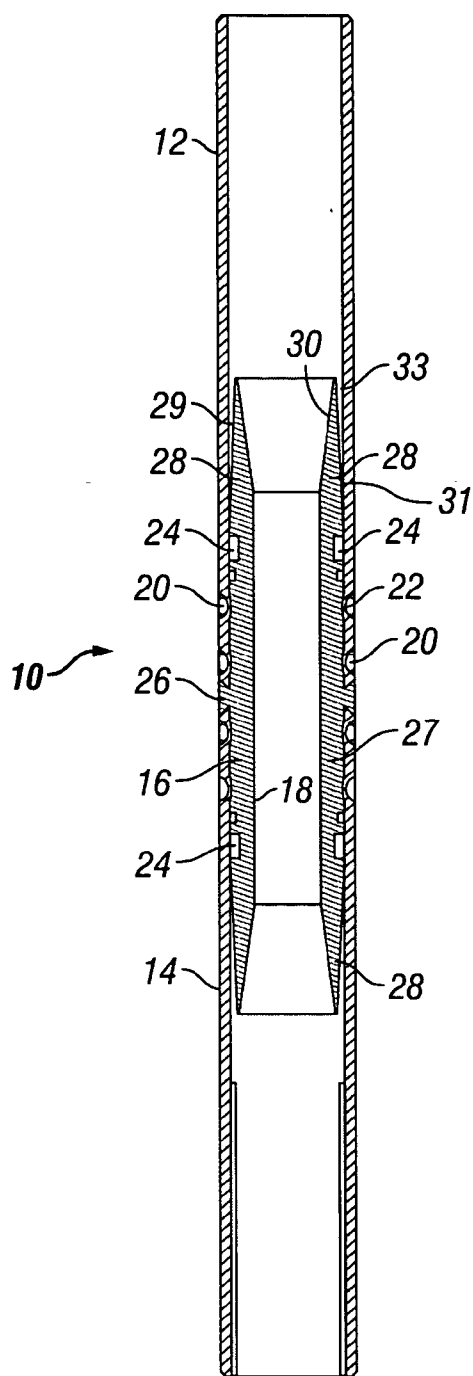


FIG. 2

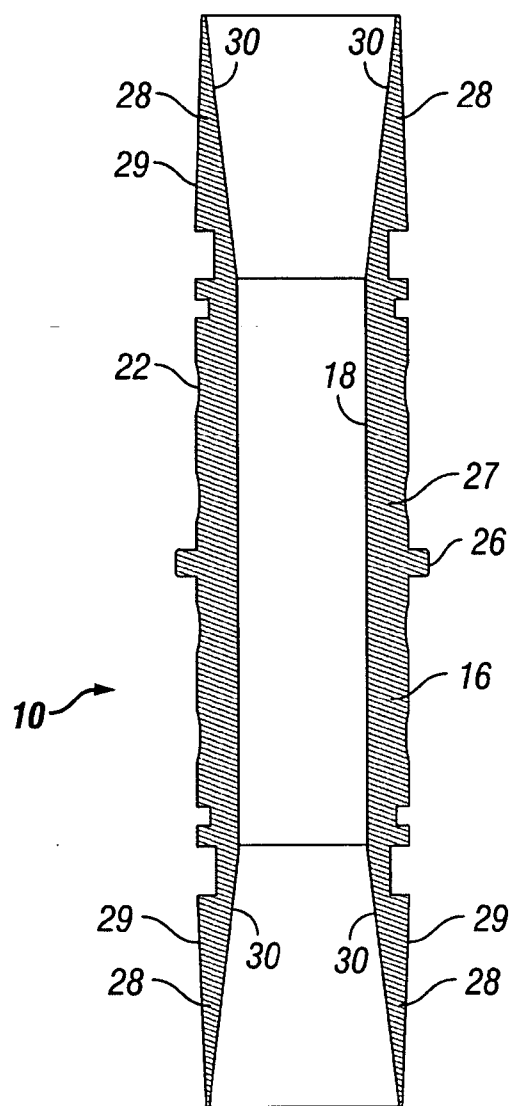


FIG. 3A

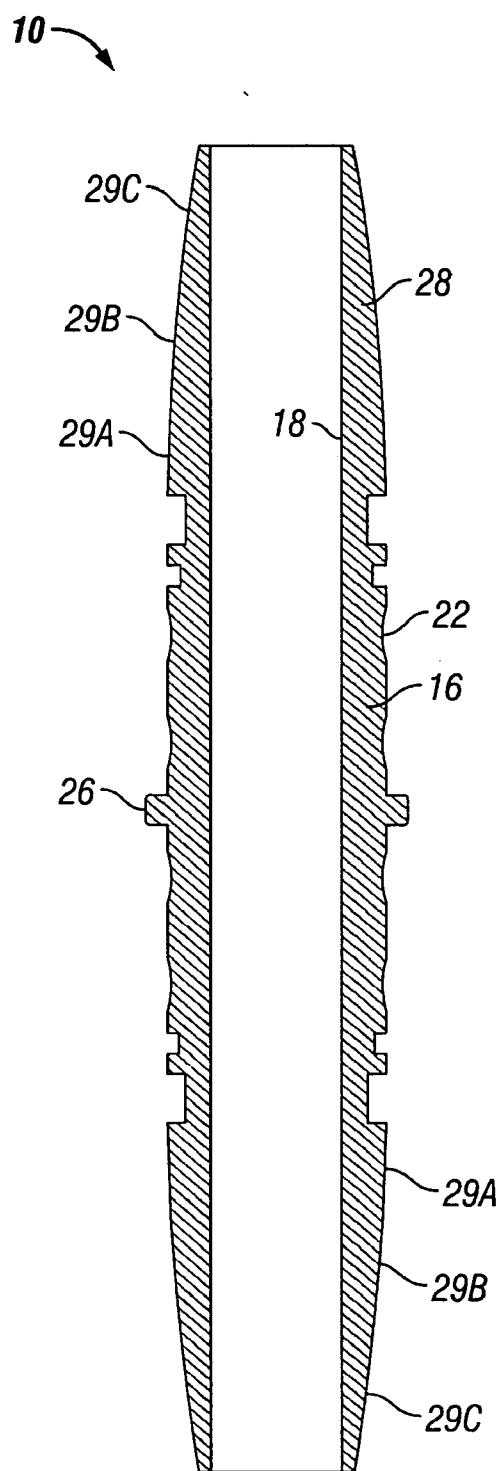


FIG. 3B

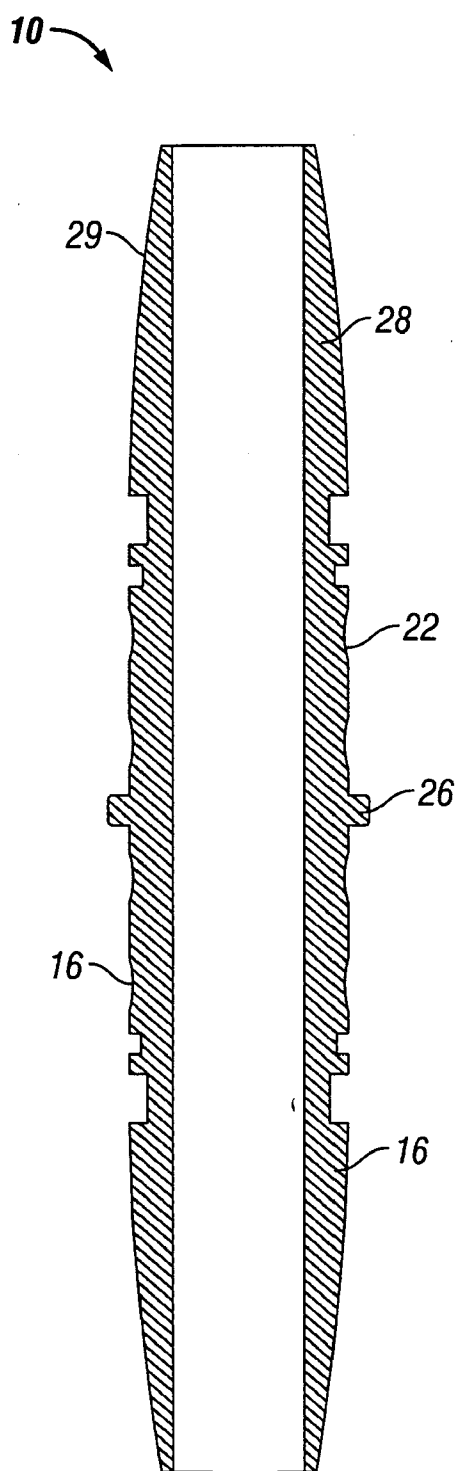


FIG. 3C

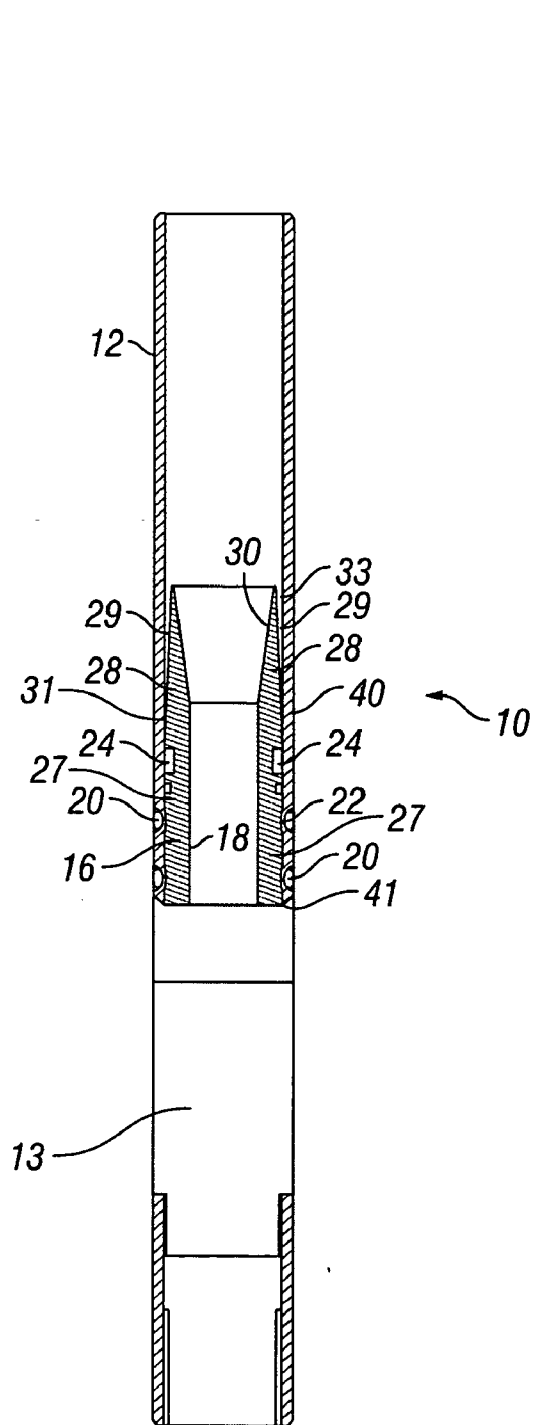


FIG. 4

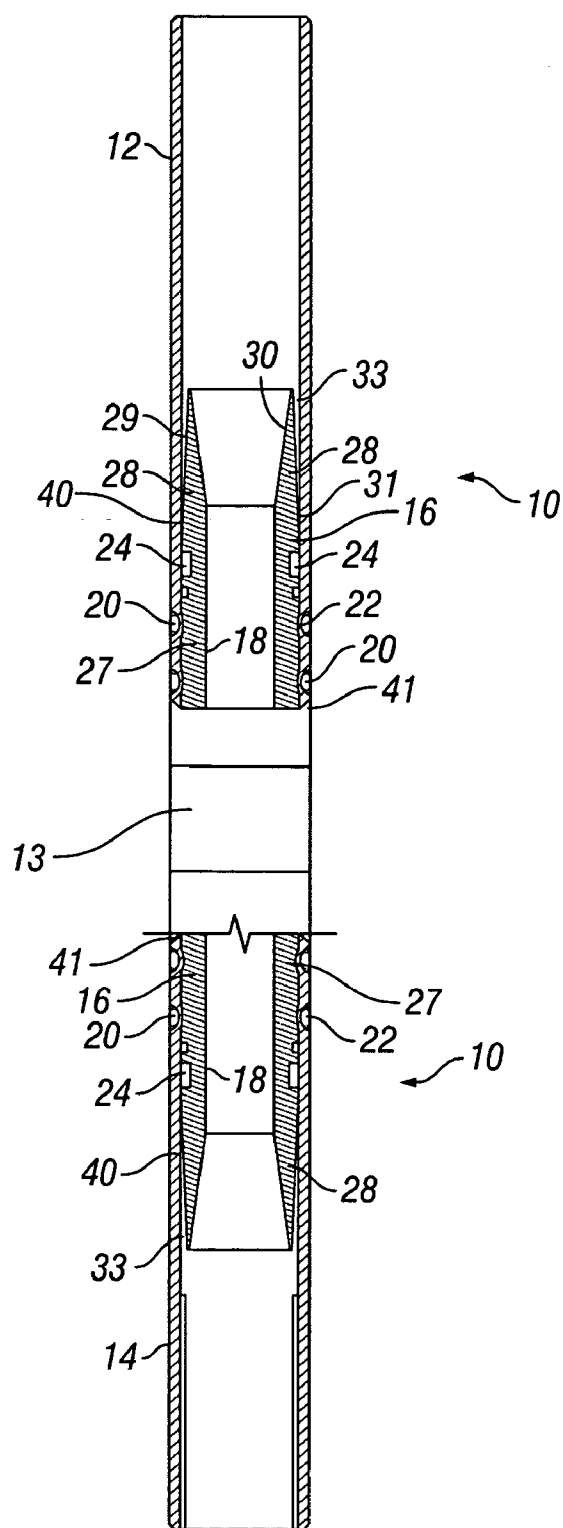


FIG. 5

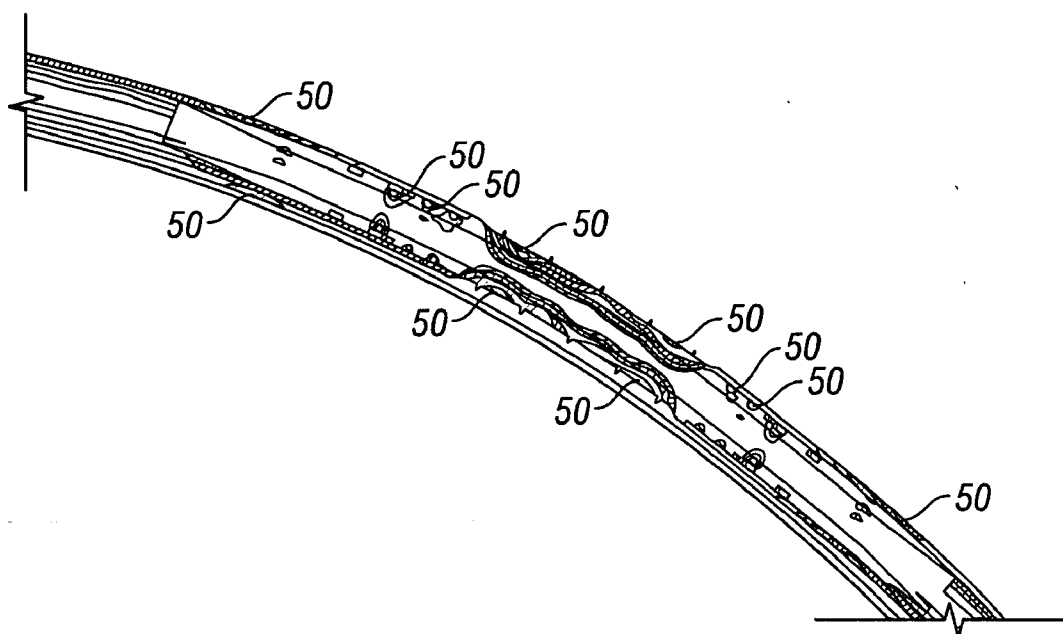


FIG. 6A

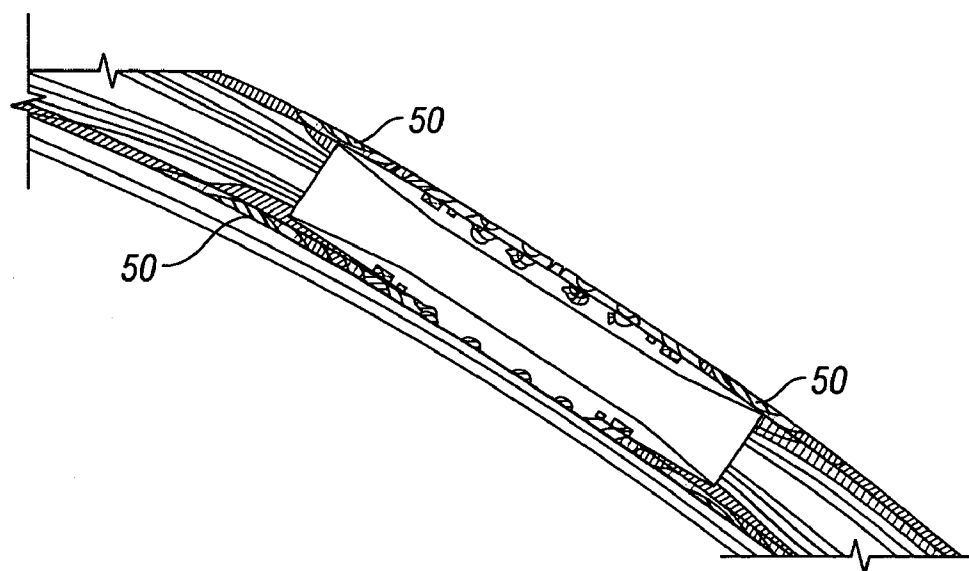


FIG. 6B

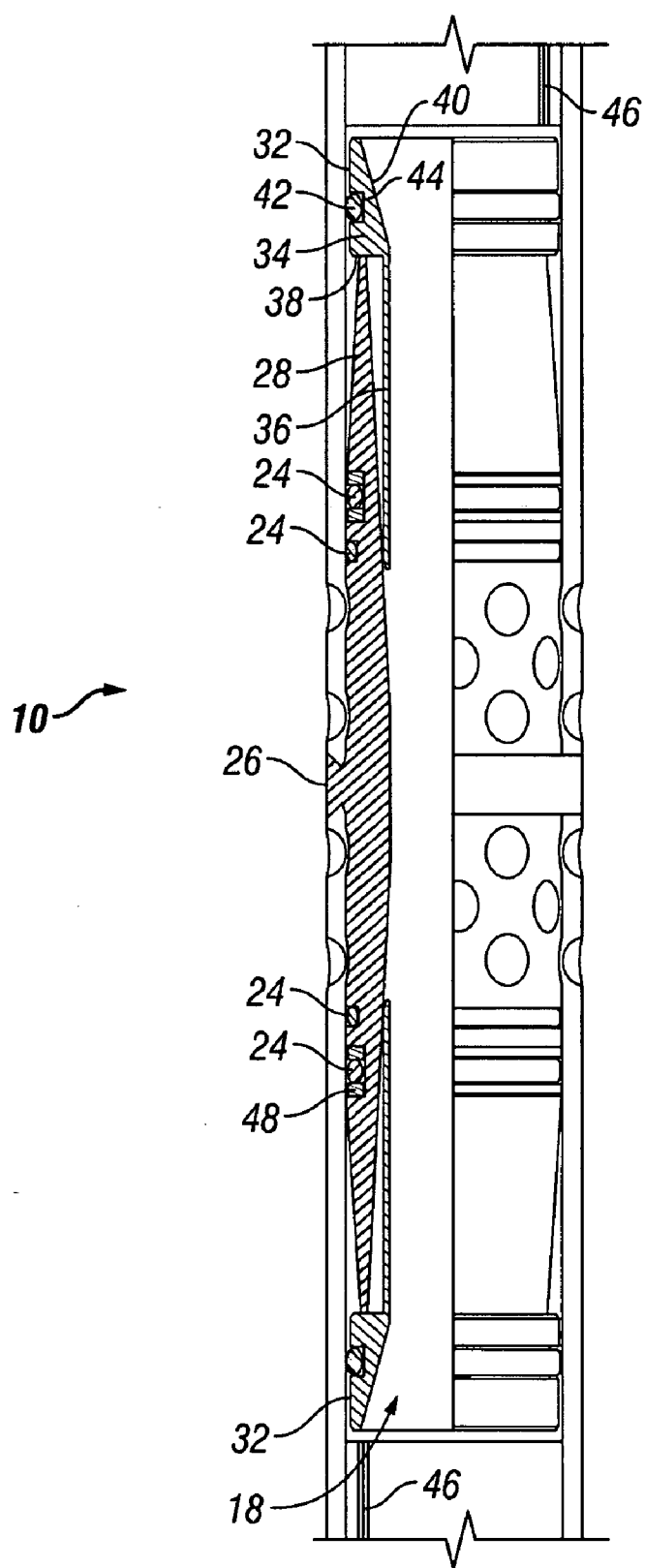


FIG. 7

TUBING CONNECTOR

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention generally pertains to oilfield equipment, and more particularly to a device and method for connecting tubing for downhole use.

[0003] 2. Description of the Related Art

[0004] Coiled tubing is used in a broad array of applications in oilfield operations such as drilling and completing oil and gas wells, conveying equipment, and performing maintenance on completed oil and gas wells. To deploy coiled tubing into a wellbore, the coiled tubing string is unreeled or unspooled from a coiled tubing reel, run over an injector gooseneck and inserted into a wellhead system for injecting the coiled tubing into the wellbore. To retract coiled tubing from a wellbore, the coiled tubing is reeled or spooled back out of the wellbore through the wellhead system over the gooseneck and onto the coiled tubing reel. It is known that bending and straightening the coiled tubing in wellsite operations and spooling the coiled tubing on a reel causes low cycle fatigue in the coiled tubing, which if left unchecked can lead to failure of the coiled tubing. The ability to unroll and roll coiled tubing as a continuous tubing string nevertheless offers attractive operational advantages over jointed pipe that requires connections at each length of pipe.

[0005] There are occasions however when connections are required between coiled tubing strings, for example, in situations when the length of coiled tubing required for an operation exceeds the capacity of the coiled tubing reel; when the capacity of handling equipment limits the permissible weight of the coiled tubing reel, thereby limiting the length of coiled tubing permitted to be spooled thereon; when a repair is required in coiled tubing; or when retrieving a length of coiled tubing from a well.

[0006] The problem of making coiled tubing connections between two coiled tubing strings or between coiled tubing and a tool or completion string has been addressed typically in one of three ways, those being by field welding, by using stiff connectors or by using flexible connectors.

[0007] To connect coiled tubing string in the field, butt-welding is commonly used. Such a weld is made by placing together the ends of two segments of tubing, each segment having an end cut perpendicular to its axis, the ends being placed in line with each other ("butted" together), and a making circumferential weld placed around the juncture of the cut ends. Welding in field conditions is more challenging and less robust than the bias-type welding that is used under controlled conditions in coiled tubing manufacturing. Butt welded sections of coiled tubing usually are weaker and have much shorter low cycle fatigue life than the sections of coiled tubing without welding: typically a butt weld has a low cycle fatigue life in the order of 50% to 60% of the low cycle fatigue life of the coiled tubing. As failure of coiled tubing welds can lead to unsafe working conditions, verification testing using methods such as X-ray, tensile testing, or pressure testing of the butt weld performance is required prior to deployment of the welded coiled tubing in a wellbore. In addition, often connections are required in areas where explosive conditions may be present which lead to the

need to take additional safety precautions in field welding. In sum, field welding is a time-consuming and operationally undesirable method for connecting two segments of coiled tubing together.

[0008] Stiff connectors are used typically for connecting tools and devices to the end of coiled tubing such as for connecting a tool string to the end of unreeled coiled tubing prior to insertion into the wellbore. Stiff connectors may be used during wellbore deployment to connect between one or more unreeled coiled tubing strings. Stiff connectors however are not spooled with the coiled tubing on the coiled tubing reel as they lack the requisite flexibility to bend around the coiled tubing reel and deployment equipment. As a result, stiff connectors present a number of drawbacks. Like field welding, the use of stiff connectors in wellbore deployment requires stopping the unreeling of the coil tubing, installing the stiff connector into the coiled tubing, making the connection, and then restarting the unreeling of the coiled tubing string to deploy the connected coiled tubing string into the wellbore. Furthermore, stiff connectors are often larger in diameter than the coiled tubing and are fitted externally about the coiled tubing. As such, they cause operational difficulties because they do not pass through the wellhead equipment.

[0009] Stiff connectors are known that are designed to be the same diameter as the coiled tubing or to have an end that can be inserted into the interior diameter of the coiled tubing; such connectors are referred to herein as internal connectors. Internal connectors offer operational advantages over externally placed connectors as the internal connectors do not cause an increased outer diameter over the connected portion of the tubing string. Although operational difficulties are reduced by the use of internal connectors, the use of stiff internal connectors in coiled tubing nevertheless poses difficulties. Use of a stiff connector with flexible coiled tubing creates an abrupt transition between the connector and the tubing. As the coiled tubing is bent in routine activities, the end of the coiled tubing adjacent to the end of the stiff connector flexes to an undesirable degree. This area is commonly called the hinge point as the bending can be so severe as to resemble a hinged connection. Such straining of the coiled tubing at a stiff connection can quickly make the coiled tubing unsuitable or unsafe for use. It is common that tubing used with a connector becomes unsuitable for use or fails after only a few bending/straightening cycles.

[0010] In general, stiff connectors lack the flexibility to permit them to be spooled onto the coiled tubing reel. On occasion, in those situations where one end of a stiff connector is connected to the terminal end of the coiled tubing and the connector is relatively short, it may be possible to spool coiled tubing onto a reel with a stiff connector attached, provided that the opposite end of the connector is not connected to anything. One such internal connector for connecting one coiled tubing string to another coiled tubing string or to a completion string (a fixture for permanent installation in a well) to a coiled tubing string is described in U.S. Pat. No. 6,474,701 issued on Nov. 5, 2002 to Bowles et al.

[0011] Flexible connectors are known to provide a spoolable connection for coiled tubing strings. One method for making a spoolable flexible connection for connecting tool strings to a coiled tubing string is described in U.S. Pat. No.

6,561,278 issued on May 13, 2003 issued to Restarick et al. and related U.S. Pat. No. 6,766,858 issued on Jul. 27, 2004 to Restarick et al. The external connectors described therein are particularly applicable for use with coiled tubing made of composite materials and coiled tubing having a line embedded within a sidewall. In these patents, a pair of connectors comprising a first connector disposed about a first end of a severed tubing string and a second connector disposed about a second end of a severed tubing string is used to connect one or more well tool assemblies to the coiled tubing.

[0012] Another type of internal flexible connector for use with coiled tubing is described in SPE 89527, Luft, H. B., et al., entitled *Development of a New Spoolable Mechanical Coiled Tubing Connector*, March 2004. As described therein, this flexible connector uses composite materials, including an elastomeric middle section to provide flexibility, and entails a construction having composite materials and using both super alloy steels and elastomers backfilled into the outer diameter of the connector. The flexible connector described in SPE 89527 has transition sections on either end of the connector where the coiled tubing overlaps the connector. According to Luft et al, testing of this connector indicated that the low cycle fatigue performance of the connector/coiled tubing combination provided a life span for the combination of 39% to 69% of the life span for the coiled tubing alone.

[0013] Testing required for confirming that the materials from which a connector is made are compatible for use in a downhole environment and for oilfield operations also is discussed in SPE 89527. Coiled tubing connectors, like the coiled tubing itself, need to be compatible with the environment in which they will be used. Testing is required to demonstrate that significant degradation to or failure of the coiled tubing connector will not result from exposure to wellbore environments. For example, coiled tubing may be used for delivering acid treatments to subterranean formations, or in environments in which elevated levels of H₂S are present. The acid testing reported in SPE 89527 on various connector materials shows this compatibility can vary. To avoid the cost and time required for compatibility testing, it would be advantageous to construct an internal flexible connector from materials having the same or similar chemical resistance as the coiled tubing. As a general matter, it would be more cost effective to construct an internal coiled tubing connector from readily available commercial materials rather than specialty products such as those used in the connector described in SPE 89537.

[0014] A particular challenge to using a flexible connector and coiled tubing made of conventional materials is the varying range of material properties generally accepted in materials such as commercial grade steel used to make coiled tubing. These materials normally are produced with a 10-20% tolerance for yield strength. For example, 4140 (18-22 Rc) steel is known to have a yield strength between 80,000 psi and 95,000 psi. This variation in yield strength is the foundation for design limitations between the connector and the coiled tubing. For example, if one of the components has a yield strength near the minimum allowed ("low yield component") and the other component has a yield strength near the maximum allowed ("high yield component"), the strain in the components under the same conditions would differ, leading to differing low cycle fatigue lives. In such

situations, when the low yield component reaches the yield point, the low yield component begins to deform plastically but the high yield component remains in its elastic range and does not yield. By the point at which the yield point of the high yield component is reached and the high yield component begins to deform plastically, the low yield component already has deformed significantly. For example, for a conventional material such as 4140 steel having minimum and maximum yield curves as shown in FIG. 1, at a stress of 100 ksi, low yield component would have as much as 4% strain while the high yield component would have a strain of about 0.5%. Since low cycle fatigue life is closely related to the amount of cyclic strain, the low yield component will fail significantly sooner than the high yield component.

[0015] The flexible connectors that are known, such as that disclosed in SPE 89527, have a flexible section in the center of the connector. This middle flexible section is designed to have a bending stiffness similar to that of the coiled tubing. The end sections on either side of the flexible center section are much stiffer than the coiled tubing. The design theory behind such a configuration is to provide a flexible center section of the coiled tubing connector that deforms similarly to the coiled tubing itself under the same amount of strain. The low cycle fatigue performance of these flexible connectors depend both on the stiff end connections providing a gradual transition between the flexible coiled tubing and the flexible center section of the connector and on the flexible centers section having similar stiffness and fatigue life to the coiled tubing. Therefore it is crucial to the performance of these flexible connectors designed with flexible center sections that both flexible center section of the connector and the coiled tubing strain equally. This is not easily achieved given the variation of material properties and the varying stress/strain conditions along the bend distance between the flexible section of the connector and the length of the coiled tubing string beyond the influence of the connector end section. It has been observed that coiled tubing connectors that use a flexible section between two stiff end connections often have inconsistent performance and periodically fail much sooner than expected.

[0016] Therefore, there exists a need for improved methods and apparatus for connecting coiled tubing. In carrying out the principles of the present invention and embodiments thereof, methods and apparatus are provided which solve the problems in the prior art.

SUMMARY OF THE INVENTION

[0017] The present invention provides a method of connecting a first tubing and a second tubing using an internal tubing connector having a bore, the connector having a first end section having a tapered outer surface and stiff section wherein the stiff section of the connector is secured to the first and second tubings. In some embodiments, the internal surface of the connector along the bore is also tapered. In some embodiments, a second end section having a tapered external surface is also provided and disposed within the second tubing. In preferred embodiments, at least one of the first tubing or second tubing is coiled tubing, and in particular embodiments, both of the tubings are coiled tubing. In the methods of the present invention, at least one of the first or second tubings may be spooled on a reel. The connector and method of connecting of the present invention is useful particularly in making repairs in coiled tubing,

wherein a section of coiled tubing is damaged or removed and the apparatus and method of the present invention is used to repair, patch or generally connect the two sections of coiled tubing between which a portion of tubing has been damaged or removed.

[0018] The connector apparatus of the present invention useful for connecting a first and a second section of tubing comprises a body with a longitudinal bore therethrough, a first end section, and a stiff section; the first end section of the connector having a tapered outer surface; and the exterior of the stiff section adapted to be connected to the inner diameter of a first and a second tubing. In some embodiments, the connector may further comprise a second end section, the second end section having a tapered outer surface and the stiff section being disposed between the first and the second end sections. The first or second end section may further comprise a tapered internal surface along the bore. An annular lip may be provided about the body and adapted to be disposed between ends of the first and second sections of tubing. One or more seals may be disposed between the connector body and the first or the second, or both, tubings. The stiff section of the connector of the present invention may be secured within the first and second tubings by engaging the exterior surface of the body with the inner surface of the tubing using a plurality of indentations, grooves, ridges, punch hole, or other connective means. In some embodiments, a debris barrier is provided between at least one end section of the connector and the tubing.

[0019] The present invention in specific embodiments relates to a method of deploying coiled tubing in a wellbore comprising providing a coiled tubing connector having a body with a bore throughout, the body having first and second end sections with tapered external surfaces and a stiff section disposed between the first and the second end sections; placing one end section into a first coiled tubing section, placing the second end section into a second coiled tubing, securing the stiff section to the inner diameter of the first and second coiled tubings to form a connected tubing and lowering the connected tubing into a wellbore. The method may further comprise retrieving the coiled tubing from the wellbore. The first or second coiled tubing may be disposed on a reel. Similarly, the connected coiled tubing may be disposed on a reel. In some embodiments, the connector may comprise an annular lip disposed about the body and adapted to be disposed between ends of the first and second sections of coiled tubing and in some embodiments, the connector may comprise at least one barrier to prevent debris from entering between the end section and the coiled tubing.

[0020] Other features, aspects and advantages of the present invention will become apparent from the following discussion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] **FIG. 1** is a representative stress/strain curve for a grade of steel.

[0022] **FIG. 2** is side view of a specific embodiment of a coiled tubing connector constructed in accordance with the present invention and in use to connect a section of coiled tubing to a tool string.

[0023] **FIG. 3A** is a side view of another specific embodiment of a coiled tubing connector constructed in accordance

with the present invention similar to the one shown in **FIG. 2** but shown not connected to any coiled tubings.

[0024] **FIG. 3B** is a side view of another specific embodiment of a coiled tubing connector constructed in accordance with the present invention.

[0025] **FIG. 3C** is a side view of another specific embodiment of a coiled tubing connector constructed in accordance with the present invention.

[0026] **FIG. 4** is side view of two coiled tubing connectors constructed in accordance with the present invention, and in use to connect coiled tubing to a tool string.

[0027] **FIG. 5** is a side view of a specific embodiment of a coiled tubing connector constructed in accordance with the present invention, and in use to connect two sections of coiled tubing to a tool string.

[0028] **FIG. 6A** is a strain diagram from a finite element model of a prior art internal coiled tubing connector having a flexible center section.

[0029] **FIG. 6B** is a strain diagram from a finite element model of an embodiment of a coiled tubing connector according to the present invention.

[0030] **FIG. 7** is side view of another specific embodiment of a coiled tubing connector constructed in accordance with the present invention, and in use to connect two sections of coiled tubing.

[0031] While the invention will be described in connection with the preferred embodiments, it will be understood that it is not intended to limit the invention to those embodiments. On the contrary, it is intended to cover all alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

[0032] Referring to the drawings in detail, wherein like numerals denote identical elements throughout the several views, there is shown in **FIG. 2 a** coiled tubing connector **10** constructed in accordance with the present invention and in use to connect a first section of coiled tubing **12** and a second section of coiled tubing **14**. The connector **10**, having a body **16** having a longitudinal bore **18** therethrough, comprises a stiff section **27** and at least one end section **28**. Often stiff section **27** is provided between two end sections **28**, as is shown **FIG. 2**. In some embodiments, body **16** of connector **10** may be discontinuous, and in further embodiments, stiff section **27** is separable from one or more end sections **28**. It is preferred for embodiments for connecting two sections of coiled tubing such as that shown in **FIG. 2** that body **16** of connector **10** is a continuous body in which one region of connector body **16** is stiff section **27** and other region or regions of connector body **16** are end section or sections **28**. Such an embodiment is particularly useful to be placed between a first section of coiled tubing **12** and a second section of coiled tubing **14** to form a repair between the two section, for example when an area has been damaged, stressed, or is of inferior quality.

[0033] The stiff section **27** of connector **10** has an outer diameter that it will fit snugly within the inner diameter of

first and second sections of coiled tubing 12 and 14. The exterior diameter of body 16 remains essentially constant throughout stiff section 27, excepting in localized areas where a means, such as a groove or indentation, to effect a connection with coiled tubing 12 and 14 are present.

[0034] In end sections 28 of body 16, external diameter 29 of body 16 gradually decreases from the end 31 of the end section 28 proximate to the stiff section 27 towards the distal end 33 of the body 16, such that the external diameter of end section 28 of body 16 is not engaged snugly within the interior diameter of coiled tubing 12 or 14. When coiled tubing 12 and 14 is straight, end section 28 is not in contact with the inner diameter of the coiled tubing 12 or 14 owing to the decreasing external diameter 29 of end section 28. This decreasing external diameter, referred to herein as tapered, may be constructed in any variety of ways that provides a smaller external diameter at the distal end 33 of end section 28; examples of ways by which a taper may be formed include but are not limited to a single angle, a series of short angle sectors, a constant radius, or a compound radius.

[0035] As coiled tubing 12 is connected to connector 10 in stiff section 27 and coiled tubing 12 bends as is routine in coiled tubing deployment and operation, only a limited area of end section 28 will be in contact with the interior diameter of coiled tubing 12 as it bends owing to the decreasing exterior diameter 29 of end section 28. In this way, there is a limited area of contact between coiled tubing 12/14 as it bends over the length of end section 28 and that limited area of contact translates along the length of end section 28 as coiled tubing 12 bends. As such, the stress point occurring at the point of contact translates along the end section 28 and overlapping coiled tubing 12, thereby avoiding the formation of a specific point of stress concentration or hinge point. This characteristic of the present invention is referred to herein as the restrictive bend feature.

[0036] The restrictive bend feature avoids the formation of a hinge point resulting from stress repeatedly concentrating in areas. It is known that such hinge points create a weak point in coiled tubing connectors. By design, this restrictive bend feature provides a transition between the stiff section 27 of connector 10 and the coiled tubing 12 or 14 and distributes the strain in the coiled tubing over the length of end section 28 rather than in a localized hinge point. By such a strain distribution, the maximum stress imposed on any particular point of coiled tubing 12 or 14 overlapping end section 28 and the duration of time at which any particular point is subjected to that stress is reduced. This serves to improve the low cycle fatigue performance of the overall coiled tubing and connector configuration. Such a configuration is notably different from known flexible internal connectors and is counter to the conventional approach of providing a flexible middle section with stiffer section on either side. Thus the coiled tubing connector of the present invention is useful to provide a connection that is flexible on both ends and stiff in the middle.

[0037] In various embodiments, the diameter of the internal surface of body 16 along longitudinal bore 18 in end section 28 may decrease in a similar manner to external diameter 29, may remain the same throughout end section 28, or may increase to form an internal tapered surface 30. In embodiments in which the diameter of the internal surface

of body 16 along longitudinal bore 18 in end section 28 remains the same or increases, the cross sectional wall thickness of body 16 in end section 28 decreases toward distal end 33 as a result of decreasing external diameter 29. This decreasing wall thickness makes end section 28 more flexible at distal end 33 and increasingly less flexible along the length of end section 28 extending to the end of stiff section 27. In this way, connector 10 is most flexible at the distal end 33 of end section 28 and has diminishing flexibility traversing toward stiff section 27 along the length of end section 28 such that the stiffest area of end section 28 is at end 31 adjacent to stiff section 27.

[0038] Connector 10 may be secured to the coiled tubing 12 and 14 in stiff section 27 by techniques suitable for use with internal connectors such as roll-on connectors, screws, crimping, and dimpling. In FIG. 2, the connection between stiff section 27 and coiled tubing 12 and 14 is shown made by indentations 22 on the outer surface of stiff section 27 receiving protuberances 20 on the coiled tubing 12 and 14. Such indentations may be made a variety of ways such as surrounding the coiled tubing with a mold and pressing the mold to form indentations, using a push or screw to form the indentations, or using a pre-pattern of weaker points in stiff section 27 into which coiled tubing 12 or 14 may be easily pressed. In some embodiments, the exterior surface of stiff section 27 may be patterned in a manner to facilitate this connection with coiled tubing 12 and 14. For example, indentations in the exterior surface of stiff section 27 may spread uniformly about the circumference in a localized area or along the length of stiff section 27. Alternatively, depressions for receiving screws holes may be provided in the exterior surface of stiff section 27; such depressions may similarly be in a localized area or along the length of stiff section 27.

[0039] In addition, the pattern, shape, or depth of such indentations may be varied and in particular, be varied in such a manner that the stress during bending of the connection is distributed across the indentations and not concentrated in a limited localized area. Moreover this variation may be done in such a manner as to vary the relative snugness of the connection between connector 10 and coiled tubing 12 or 14 across stiff section 27 of connector 10 such that the connection between connector 10 and coiled tubing 12 or 14 is relatively snug near the ends of coiled tubing 12 or 14 and the connection is less snug in other areas of stiff section 27 of connector 10. For example, dimple screws closest to the ends of coiled tubing 12 or 14 of the tubing can be tightened to a different depth compared to those screws furthest from the ends of coiled tubing 12 or 14.

[0040] Alternatively or in addition to indentations along the exterior surface of stiff section 27, indentations may be provided on the internal surface of body 16 along longitudinal bore 18. In this manner, a thinner wall section of body 16 is provided in desired locations at which coiled tubing 12 or 14 may be pressed or crimped to secure contact between connector 10 and coiled tubing 12 or 14. In another embodiment, a groove may be provided around the circumference of stiff section 27 or a series of circumferential or partially circumferential grooves may be placed or staggered along the length of stiff section 27. Various combinations of these techniques may also be used and are considered within the scope of the present invention.

[0041] Connector 10 may preferably be provided with one or more seals 24 to prevent fluid leakage between the connector 10 and each of either or both of the coiled tubing 12/14. These seals 24 may be of any known type, including but not limited to O-rings, chevron seals, T-seals, dynamic seals such as PolyPak™, and various other elastomeric devices.

[0042] In specific embodiments, the present connector 10 may include an annular lip 26 disposed about the body 16 in the stiff section 27 and positioned such that it is disposed between the respective ends of the coiled tubings 12 and 14. The diameter of annular lip 26 is the same or essentially equivalent to the outer diameter of coiled tubing 12 and 14. As such, annular lip 26 does not preclude connector 10 from passing through the wellhead equipment. Annular lip 26 provides support for the end of the coiled tubing 12 or 14 or to reduce forces that cause flaring of tubing ends and also to contain and protect the tubing ends. As will be appreciated by those of skill in this art, the annular lip 26 functions to reduce deformation or “egging” of the ends of the coiled tubing 12 or 14 during use.

[0043] In some embodiments, a flow control device, such as a check valve, may be used in conjunction with connector 10. The flow control device permits fluid flow through in one configuration and restricts fluid flow through in another configuration. Methods of switching such flow control devices from one configuration to another configuration are well known and include, for example, exerting an axial external pressure on the connector, dropping a ball, or providing a control signal. Such embodiments are of particular use when the coiled tubing is under pressure, such as well pressure or fluid pressure. The flow control device may be placed within stiff section 27 of connector 10 or within coiled tubing 12 or 14 adjacent to connector 10. A combination of internal and external flow control devices may be also used.

[0044] As shown in FIGS. 3A through 3C, the decreasing exterior diameter 29 of end section 28 can be constructed on the external surface of body 16 in a variety of ways, including but not limited to with a single angle, a series of short angle sectors, a constant radius or a compound radius. In some embodiments, the diameter of the internal surface of body 16 along longitudinal bore 18 may increase in end section 28 to form an internal tapered surface 30. For example, in the specific embodiments shown in FIG. 2, end section 28 is shown having an outer tapered surface 29 and a tapered internal surface 30 in longitudinal bore 18. This internal tapered surface 30 similarly may be constructed in a variety of ways, including but not limited to with a single angle, a series of short angle sectors, a constant radius, or a compound radius. In some embodiments, the manner in which decreasing exterior diameter 29 and internal tapered surface 30 are constructed may be the same and in some embodiments, the manner in which they are formed may be different. In the specific embodiment shown in FIG. 3A, end section 28 includes an internal tapered surface 30 and a tapered outer surface of body 29. In the embodiment shown in FIG. 3B, end section 28 includes a plurality of outer tapered surfaces, or short angle sectors, 29A, 29B and 29C, and internal surface 30 is not tapered. In the embodiment shown in FIG. 3C, end section 28 includes a tapered outer surface 29 formed by a constant radius and internal surface 30 in the longitudinal bore 18 is not tapered.

[0045] There is shown in FIG. 4 a coiled tubing connector 10 constructed in accordance with the present invention and in use to connect a first section of coiled tubing 12 and a tool string 13. Connector 10 has a body 16 having a longitudinal bore 18 therethrough and comprises a stiff section 27 and an end section 28. In some embodiments, connector 10 may be disassembled by separating stiff section 27 from end section 28 and assembled by attaching stiff section 27 to end section 28 by using any number of connection methods known for connecting while maintaining a flush exterior surface such as threading, patterned jointing, or lock and key.

[0046] Stiff section 27 of connector 10 has an outer diameter that fits snugly within the inner diameter of coiled tubing 12. The other end 41 of stiff section 27 connects to tool string 13. Such a connection to tool string 13 may be made by any number of connection methods known for connecting while maintaining a flush exterior surface such as threading, patterned jointing, or lock and key. In end section 28, the external diameter 29 of body 16 gradually decreases from end of the end section 28 proximate to the stiff section 27 towards the distal end 33 of the body 16, such that the external diameter 29 of end section 28 at the distal end 33 of body 16 is not engaged snugly within the interior diameter of coiled tubing 12. When coiled tubing 12 is straight, end section 28 is not in contact with the inner diameter of the coiled tubing owing to its decreasing external diameter 29. In this way, there is a limited area of contact between coiled tubing 12/14 as it bends over the length of end section 28 and that limited area of contact translates along the length of end section 28 as coiled tubing 12 bends. As such, the stress point occurring at the point of contact translates along the end section 28 and overlapping coiled tubing 12, thereby avoiding the formation of a specific point of stress concentration or hinge point. The restrictive bend feature of end section 28 previously described is present in the embodiment shown in FIG. 4.

[0047] A specific embodiment is shown in FIG. 5 in which two coiled tubing connectors 10 constructed in accord with the present invention are shown to connect a first section of coiled tubing 12, a tool string 13, and a second section of coiled tubing 14. Each coiled tubing connector 10 has a body 16 having a longitudinal bore 18 therethrough and comprises a stiff section 27 and an end section 28. Each tubing connector 10 is connected to coiled tubing 12 or 14 at stiff section 27 and to tool string 13 at one end 41. The first tubing connector 10 is connected at stiff section 27 to coiled tubing 12 and the second tubing connector 10 likewise is connected at stiff section 27 to coiled tubing 14. Stiff sections 27 have an outer diameter that fits snugly within the inner diameter of coiled tubing 12. End section 28 of each of the first and the second tubing connector 10 has an external diameter 29 that gradually decreases from the end 40 of the end section 28 proximate to the stiff section 27 towards the distal end 33 of the body 16, such that the external diameter 29 of end section 28 at the distal end 33 of body 16 is not engaged within the interior diameter of coiled tubing 12 or 14 respectively when the coiled tubing is not bent.

[0048] In some embodiments, first or second connector 10, or both, may comprise a body 16 in which one region of the body 16 is stiff section 27 and another region of body 16 is end section 28. In other embodiments, body 16 of the first or second connector 10, or both, may be disassembled by separating

rating stiff section 27 from end section 28 and assembled by attached stiff section 27 to end section 28 using any number of connection methods known for connecting while maintaining a flush exterior surface such as threading, patterned jointing.

[0049] Stiff section 27 of each the first and second connectors 10 have an outer diameter that fits snugly within respectively the inner diameter of coiled tubing 12 or 14. End section 28 of each of the first and the second tubing connector 10 has an external diameter 29 that gradually decreases from the end 31 of the end section 28 proximate to the stiff section 27 towards the distal end 33 of the body 16, such that the external diameter 29 of end section 28 at the distal end 33 of body 16 is not engaged within the interior diameter of coiled tubing 12 or 14 respectively when the coiled tubing is not bent. This restrictive bend feature of end section 28 previously described is included in the embodiment shown in FIG. 5.

[0050] Each of the embodiments described has a reduction in the exterior diameter of end section 28. When bending occurs in routine use, coiled tubing 12/14 bends until it contacts end section 28. As bending continues, the contact point between coiled tubing 12/14 and end section 28 translates along the length of end section 28, thereby avoiding a localized hinge point. In this way, connector 10 of the present invention undergoes lower strain during bending and as a result, suffers lower fatigue and has a longer useful life.

[0051] Advantages of the present invention may be seen by referring to FIGS. 6A and 6B in which output from finite element modeling is shown. FIG. 6A illustrates the output of finite element modeling of a known internal coiled tubing connector having a flexible center section and stiff end sections; numerous areas of high strain concentration 50 are shown including an extended area of high strain concentration 50 in the flexible center section. FIG. 6B illustrates the output of finite element modeling having the same inputs as FIG. 6B, except that the connector is modeled is of the present invention; few areas of high strain concentration 50 are shown for the present invention connector. As high strain concentration leads to diminished usage life or to greater risk of failure, the advantages of the connector of the present invention are apparent from a comparison of FIG. 6B to FIG. 6A from which it can be seen that connector 10 of the present invention undergoes less strain than the coiled tubing connector having a flexible center section.

[0052] As shown in FIG. 7, in another specific embodiment, connector 10 may further be provided with a flow guide/debris barrier 32 disposed at each end of the connector 10. The barrier 32 may include a body 34 with a tubular section 36 extending therefrom and adapted to fit within the bore 18 of the connector 10. The body 34 may include a shoulder 38 designed to engage the tip of end section 28 of connector 10. Body 34 may include an annular recess 44 for receiving an annular seal 42. The body 34 may further include a tapered inner bore 40. The debris barrier 32 functions to keep debris and solids, which could impede controlled bending, out of the restrictive bend area between external diameter 29 of end sections 28 and internal surface 30 of the coiled tubings 12/14. Barrier 32 may be separate from the connector 10, as shown, or it may be integral with the connector 10. In various embodiments, barrier 32 may be rigid or flexible. An example of an integral flexible embodi-

ment is an elastomeric cone molded to the end of connector 10. Any combination of these techniques may be used. If barrier 32 is separate from connector 10 instead of integral with it, it may be held in position by a coiled tubing weld bead 46 on one side and connector 10 on the other side. FIG. 7 further illustrates that connector 10 may include an anti-extrusion ring 48 adjacent seal 24.

[0053] It can be seen in light of the above description of the tubing connector of the present invention and related methods that the present invention represents an improvement over prior coiled tubing connectors and methods. Advantages of the present invention include a tensile strength similar to the tensile strength of the coiled tubing; the capability of bending around a coiled tubing reel and an injector gooseneck during operation; have a low cycle fatigue life similar to the coiled tubing; providing a pressure tight seal both from internal and external sources; and passing through a wellhead assembly.

[0054] Although the embodiments herein have been described with respect to coiled tubing, one skilled in the art would understand that although the present invention is useful in application for connecting any tubing, notwithstanding its particular usefulness in coiled tubing applications.

[0055] Although only a few exemplary embodiments of this invention have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the following claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Thus, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface, in the environment of fastening wooden parts, a nail and a screw may be equivalent structures. It is the express intention of the applicant not to invoke 35 U.S.C. §112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words 'means for' together with an associated function.

1. A method of connecting a first tubing and a second tubing comprising:

providing a tubing connector having a body with a longitudinal bore therethrough, the tubing connector having a first end section and a stiff section, wherein the first end section has a tapered outer surface;

disposing the first end section of the connector within a first tubing; and

securing the stiff section of the connector to the first tubing and a second tubing within the inner diameter of the first and second tubings.

2. The method of claim 1 wherein further comprising an internal tapered surface on the bore.

3. The method of claim 1, wherein the connector further comprises a second end section, the stiff section being disposed between the first and the second end sections, and further comprising:

disposing the second end section of the connector within a second tubing; and

securing the stiff section of the connector to the second tubing;

wherein the second end section has a tapered outer surface.

4. The method of claim 1, wherein the first tubing is coiled tubing.

5. The method of claim 3, wherein each of the first and the second tubing is coiled tubing.

6. The method of claim 5, wherein at least one of the first and the second coiled tubing is spooled on a reel.

7. The method of claim 5, wherein the connector is provided as a repair between the first and second tubing.

8. An apparatus for connecting a first and a second section of tubing comprising:

a body with a longitudinal bore therethrough, a first end section, and a stiff section;

the first end section of the connector having a tapered outer surface; and

the exterior of the stiff section adapted to be connected to the inner diameter of a first and a second tubing.

9. The apparatus of claim 8, wherein the body further comprises a second end section, the second end section having a tapered outer surface and the stiff section being disposed between the first and the second end sections.

10. The apparatus of claim 9, wherein at least one of the first and the second end section further comprises a tapered internal surface.

11. The apparatus of claim 7, further comprising an annular lip disposed about the body and adapted to be disposed between ends of the first and second sections of tubing.

12. The apparatus of claim 7, further comprising a plurality of indentations disposed in the exterior surface of the stiff section of the body adapted for engagement with at least one of the first and second tubings.

13. The apparatus of claim 12, further wherein the indentations are varied.

14. The apparatus of claim 8, further comprising a seal disposed between the body and at least one of the first section and the second section of tubing.

15. The apparatus of claim 8, further comprising at least one barrier to prevent debris from entering between the end section of the body and the tubing.

16. The apparatus of claim 8, further comprising a flow control device disposed therein.

17. A method of deploying coiled tubing in a wellbore comprising:

providing a coiled tubing connector having a body with a longitudinal bore therethrough, the body having a first and a second end sections, each end section having a tapered external surface, and a stiff section disposed between the first and the second end sections;

disposing the first end section within a first coiled tubing;

disposing the second end section within a second coiled tubing;

securing the stiff section to the inner diameter of each of a first and a second coiled tubings, thereby forming a connected tubing; and

lowering the connected tubing into a wellbore.

18. The method of claim 17, wherein the connector further comprises an annular lip disposed about the body and adapted to be disposed between ends of the first and second sections of coiled tubing.

19. The method of claim 17, further comprising at least one barrier disposed adjacent to at least one of the first and the second end section, thereby preventing debris from entering between the end section and the coiled tubing.

20. The method of claim 17, wherein at least one of the first and the second coiled tubing is disposed on a reel.

21. The method of claim 17, wherein the connected coiled tubing is retrieved from the wellbore.

22. The method of claim 21, wherein the connected coiled tubing is spooled onto a reel.

23. The method of claim 17, further comprising providing at flow control device within at least one of the connector, the first coiled tubing, or the second coiled tubing.

24. A method of deploying coiled tubing in a wellbore comprising:

providing a first tubing connector having a body with a longitudinal bore therethrough, the first tubing connector having a first end section and a stiff section, wherein the first end section has a tapered outer surface;

disposing the first end section of the first tubing connector within a first coiled tubing;

securing the stiff section of the first tubing connector to the inner diameter of each the first coiled tubing;

providing a second tubing connector having a body with a longitudinal bore therethrough, the second tubing connector having a first end section and a stiff section, wherein the first end section has a tapered outer surface;

disposing the first end section of the second tubing connector within a second coiled tubing;

securing the stiff section of the second tubing connector within the second coiled tubing;

disposing a tool string between the first tubing connector and the second tubing connector, thereby forming a connected tubing; and

lowering the connected tubing into a wellbore.

25. The method of claim 23, wherein at least one of the first and the second coiled tubing is disposed on a reel.

26. The method of claim 23, further comprising providing at flow control device within at least one of the connector, the first coiled tubing, or the second coiled tubing.

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