



(12)

Oversættelse af
europæisk patentsskriftPatent- og
Varemærkestyrelsen

(51) Int.Cl.: **E 21 B 17/042 (2006.01)** **F 16 L 15/06 (2006.01)**

(45) Oversættelsen bekendtgjort den: **2019-01-07**

(80) Dato for Den Europæiske Patentmyndigheds
bekendtgørelse om meddelelse af patentet: **2018-09-12**

(86) Europæisk ansøgning nr.: **12193698.3**

(86) Europæisk indleveringsdag: **2012-11-21**

(87) Den europæiske ansøgnings publiceringsdag: **2013-06-12**

(30) Prioritet: **2011-12-09 US 201113315354**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

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(54) Benævnelse: **Gevindforbindelse med forbedret rødgevindprofil**

(56) Fremdragne publikationer:
EP-A2- 1 705 415
US-A- 4 549 754
US-A- 5 163 523
US-A1- 2003 038 476

DK/EP 2602423 T3

DESCRIPTION

FIELD OF INVENTION

[0001] This invention relates in general to pipe connections, and in particular to a threaded connection having an improved root thread profile design that improves fatigue resistance.

BACKGROUND

[0002] Searching for oil or more generally hydrocarbons is becoming more demanding in terms of hardware and devices in recent years because oil and gas fields (reservoirs) are located deeper in the earth or in places difficult to reach.

[0003] Numerous onshore drilling and production activities require tubular connections having high levels of fatigue resistance; for example, drilling applications and thermal applications.

[0004] Additionally, exploring and producing hydrocarbon fields in deep water environments (offshore applications) has increased and necessitates tubular connections which are more resistant to environmental challenges such as fatigue and corrosion.

[0005] Off-shore platforms have production facilities located above the sea surface. These facilities are frequently used for exploitation of hydrocarbon fields lying below the sea floor. These platforms are anchored to the sea bottom and tubular strings are used to deliver the hydrocarbons from wells drilled into reservoirs below the sea bed. The tubular strings are sometimes referred to in the art as "risers."

[0006] These riser strings are immersed in the sea and are subject to movements caused by sea currents and surface wave movements. Because of continuous and periodical movements of the sea, the tubular strings do not remain immobile, but are subject to lateral movements of small magnitude which can produce deformations in certain parts of the tubular connections. These riser strings must withstand loads which induce fatigue stresses in the tubes and the tubular connections, in particular with respect to the zone of the threaded connection. These stresses tend to cause ruptures in the tube and/or connection in the vicinity of the thread and there is a need to improve the fatigue resistance of the threaded connections.

[0007] Some prior art patents, for example US 7,780,202 and US 6,609,735 disclose flank-to-flank ("FtF") engagement type connections which are subject to fatigue, including riser connectors. Prior art document US 5 163 523 A, considered the closest prior art, discloses a thread root comprising elliptic sections connected to each other by a flat section. Prior art document, US2003038476 A1 relates to a threaded connector having a separate rigid external seal/support ring affixed to the connector pin for engaging the box.

[0008] Other prior art conventional interference fit threaded connections (including API buttress-style thread forms), have profiles in which the threads engage along only one thread flank upon make up. This type of connection must completely unload the contacting flank, undergo relative movement between the pin and the coupling until the opposite flanks contact, and then transfer load to the newly contacting flank. Repeated, cyclical side loading and load transfers make these connection types especially susceptible to fatigue failures.

[0009] In flank-to-flank (FtF) threads, upon make up, contact is made between both stabbing and load flanks. Clearance exists between crests and roots. The thread is designed with the thread teeth of one member being wider than the mating teeth of the other member (e.g., flank to flank interference). Due to the inclination of the flanks, contact forces (normal to the surface of the flank) have the main component placed in an axial direction, pressing the material that forms the thread teeth. To achieve the flank to flank interference, contact forces work mainly on the elasticity of the teeth. The elasticity of the teeth is very low so high contact pressures are reached during make up. This explains why FtF threads have high galling tendency during make up.

[0010] Additional drawbacks of FtF threads are present for very sloping angles of the lead-in flank of the thread, measured compared to a perpendicular surface to the pipe's axis. The compression action of the connection is unsatisfactory because this type of solution aids the onset of the phenomenon defined as "jump-in," when the compression forces exceed certain limits. Jump-in occurs when the male pipe segment slides into the female segment, exceeding the resistance given by the threading of the two pieces. This phenomenon occurs more frequently the more inclined the angle of thread lead-in.

[0011] Other drawbacks of the FtF type of thread is that it is subject to high risk of seizure of the joint with the consequent risk of not ensuring the airtight seal of the fluids inside the tube. Due to the seizure effect, torque varies greatly as the screwing operation (make up) of the joint proceeds. This type of joint typically has more turns. This introduces difficulties in making the joint and creates the possibility of imprecision in applying the correct make up torque.

[0012] In Crest-to-Root (CtR) Threads (which are used in the threaded connection of the present disclosure), upon make up, contact is made between a pair of mating flanks (load flanks for tension or stabbing flank for compression) and also contact between crest and roots. The CtR thread is designed with interference between crest and roots. In this case the main component of the contact forces (normal to the surface of the crest/root) are placed in a radial direction, and so the interference is achieved taking advantage of the elasticity of a tubular body by deforming geometrically the pipe. Only a minor part of the interference is achieved by the elasticity of the thread teeth, so contact pressures achieved on the teeth are lower than in the case of FtF threads, and so the galling tendency during make up is diminished.

[0013] The CtR design of the present disclosure has an optimum fatigue performance and also a very low galling tendency during make up. Therefore, the presence of micro cracks (due to

such galling) is minimized.

[0014] The present disclosure can be used in integral connections, threaded and coupled connections and in big outside diameter ("OD") threaded connectors, for offshore and onshore applications. There are two major types of big OD threaded connectors used for production risers. The first type is referred to in the art as a "welded" type; the pin and box are machined separately from heavy-wall material and then welded to the pipe. In the second type, referred to in the art as "threaded-and-coupled" type, the pin is typically machined directly onto the pipe ends. The box is machined into each end of a coupling that is used to join the pipe ends together.

[0015] Moreover, the design of the present disclosure can be combined with internal and/or external/and or intermediate metal to metal seal configurations, internal and external elastomeric seals, intermediate metal to metal seals and two step threads. For big diameter connectors, stabbing guides and anti-rotation devices can also be used together with the thread profile of this disclosure.

SUMMARY

[0016] A threaded connection design having a double ellipse in the thread root for reducing fatigue stress is disclosed herein. In the design of the present disclosure the radius of the stress concentrator (located in the joint between the root and the load flank) is increased using a double ellipse configuration (curved surface having variable radius, not an arc of a circle which has a constant radius). This configuration allows maximizing the radius of the stress concentrator but also minimizes the loss of contact between load flanks, and also minimizes the section of the connection in which the "critical section" is diminished. Another benefit of this profile is that the stress concentrator is put away from the contact points between pin and box so the tensional state on the stress concentrator is more beneficial to the fatigue behavior of the joint. In the new design disclosed herein, maximized contact between load flanks and crest and roots is assured so the relative movement between parts of the connection is minimized. In general, the profile of the root surface in the present disclosure is composed by a linear portion and a curved portion having a double elliptical profile.

[0017] In particular, a design for a male or female threading, which is disposed on an end of a tubular element, is disclosed. The male or female threading includes: a tapered root surface having a first angle of taper (β) measured from a longitudinal axis (aa) of the threading, said tapered root surface being joined tangentially at a first end by a concave curved surface of a constant radius of curvature to a stabbing flank, said tapered root surface being joined at a second end by a convex curved surface of constant radius of curvature to a root groove. The root groove extends from the tapered root surface to a load flank.

[0018] The root groove includes: a first portion comprising a first elliptical surface having a variable radius of curvature, said first elliptical surface being part of an ellipse, and said root

groove further including a second portion comprising a second elliptical surface having a variable radius of curvature, said second elliptical surface being part of a second ellipse, said second elliptical surface being joined tangentially at a first end to the first elliptical surface at a junction point that defines the bottom of the root groove; and said second elliptical surface being joined tangentially at a second end to the load flank. The bottom of the root groove is disposed in the sidewall of the tubular element below the level of the tapered root surface

[0019] The tapered root surface (101) includes a first angle of taper (β) measured between the tapered root surface 101 and a longitudinal axis (aa) of the threading. In some implementations the first angle of taper (β) is 0 degrees, such that the tapered root surface (101, 301) is parallel to the axis of threading (aa). In other implementations the first angle of taper (β) greater than 0 but less than the measured value of an angle measured between a stabbing flank 220 of the male threading and the axis of threading (aa).

[0020] In some implementations an angle theta measured between the axis of threading (aa) and the longitudinal axis (dd) of the sidewall of the tubular element (11) is between 1.5 degrees and 12 degrees.

[0021] In the present disclosure, a major axis (cc) of the second ellipse is disposed perpendicular to the load flank; and the major axis (bb) of the first ellipse is perpendicular to the major axis (cc) of the second ellipse. The major axis (bb) of the first ellipse is concurrent with a minor axis of the second ellipse.

[0022] In some implementations the first ellipse and the second ellipse are the same size. For example, the first ellipse has a first predetermined diameter (D1) along a major axis (bb), and a second predetermined diameter (D2) along a minor axis; and wherein the second ellipse has a predetermined diameter (D3) along the major axis (cc) that is equal to the diameter (D1) along the major axis (bb) of the first ellipse, and the second ellipse has a second diameter (D4) along a minor axis that is equal to the diameter (D2) along the minor axis of the first ellipse.

[0023] In other implementations the ellipses may have differing shapes. For example, the first ellipse has a first predetermined diameter (D1) along a major axis (bb), and a second predetermined diameter (D2) along a minor axis; and wherein the second ellipse has a predetermined diameter (D3) along a major axis (cc) that is equal to the diameter (D1) along the major axis (bb) of the first ellipse, and the second ellipse has a second diameter (D4) along a minor axis that is greater than the diameter (D2) along the minor axis of the first ellipse. In other implementations, the second diameter (D4) along a minor axis of the second ellipse is greater than the diameter (D2) along the minor axis of the first ellipse, but the diameter of D1 may not necessarily be equal to the diameter of D3. In other implementations the second diameter (D4) along a minor axis is less than the diameter (D2) along the minor axis of the first ellipse. In other implementations the diameter (D3) along the major axis (cc) of the second ellipse is less than the diameter D1 along the major axis (bb) of the first ellipse. In other implementations, the diameter (D3) along the major axis (cc) of the second ellipse may be greater than the diameter (D1) along the major axis (bb) of the first ellipse. It will be

understood and is expressly disclosed that any combination of one or more of the above ellipse diameter configurations may be combined in the implementation of this disclosure.

[0024] In some implementations, the load flank slopes away from the root groove and an angle measured between the load flank and a line perpendicular to an axis of the threading (aa) is in the range of 0 to 5 degrees. This is referred to in the art as a trapezoidal thread. In other implementations, the load flank slopes toward the root groove and an angle measured between the load flank and a line perpendicular to an axis of the threading (aa) is in the range of 0 to -9 degrees. This is referred to in the art as a hook thread.

[0025] The various implementations of the double ellipse root profile of the present disclosure may be used in a thread connection having a male tubular element including a tapered male threading having an axis of taper (aa), and a female tubular element including a tapered female threading having an axis of taper (aa), said female threading cooperates with the male threading when the threaded connection is made up. The root surface in at least one of the male threading and female threadings includes a tapered root surface having a first angle of taper (β) measured between the tapered root surface 101 and a longitudinal axis (aa) of the threading, said tapered root surface being joined tangentially at a first end by a concave curved surface of a constant radius of curvature to a stabbing flank, said tapered root surface being joined at a second end by a convex curved surface of constant radius of curvature to a root groove. The root groove extends from the tapered root surface to a load flank. The root groove includes: a first portion comprising a first elliptical surface having a variable radius of curvature, said first elliptical surface being part of an ellipse, and said root groove further including a second portion comprising a second elliptical surface having a variable radius of curvature, said second elliptical surface being part of a second ellipse, said second elliptical surface being joined tangentially at a first end to the first elliptical surface at a junction point that defines the bottom of the root groove; and said second elliptical surface being joined tangentially at a second end to the load flank. The bottom of the root groove is disposed in the sidewall of the tubular element below the level of the tapered root surface.

[0026] A method is disclosed for cutting a tapered male or female threading of the double ellipse root profile of the present disclosure. The method includes: providing a tubular element; cutting a tapered male or female threading on an end of said tubular element wherein said tapered male or female threading includes a tapered root surface having a first angle of taper (β) measured between the tapered root surface 101 and a longitudinal axis (aa) of the threading, said tapered root surface being joined tangentially at a first end by a concave curved surface of a constant radius of curvature to a stabbing flank, said tapered root surface being joined at a second end by a convex curved surface of constant radius of curvature to a root groove. The root groove extends from the tapered root surface to a load flank. The root groove includes: a first portion comprising a first elliptical surface having a variable radius of curvature, said first elliptical surface being part of an ellipse, and said root groove further including a second portion comprising a second elliptical surface having a variable radius of curvature, said second elliptical surface being part of a second ellipse, said second elliptical surface being joined tangentially at a first end to the first elliptical surface at a junction point

that defines the bottom of the root groove; and said second elliptical surface being joined tangentially at a second end to the load flank. The bottom of the root groove is disposed in the sidewall of the tubular element below the level of the tapered root surface.

[0027] The details of one or more implementations of the disclosure are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the disclosure will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0028]

FIG. 1 is a partial cross-section of a first implementation of a threaded connection design having a double ellipse in the thread root for reducing fatigue stress;

FIG. 1A is an enlarged portion of the cross-section of FIG. 1, wherein the angle of thread taper is further enlarged for illustrative purposes; FIG. 1A is very schematic, showing mainly the orientations of the axis bb and cc, reference 103 is very schematic and does not reflect the real elliptical form shown on figure 1;

FIG. 2 is a partial cross-section of a second implementation of a threaded connection design having a double ellipse in the thread root for reducing fatigue stress;

FIG. 2A is an enlarged portion of the cross-section of FIG. 2, wherein the angle of thread taper is further enlarged for illustrative purposes; FIG. 2A is very schematic, showing mainly the orientations of the axis bb and cc, reference 203 is very schematic and does not reflect the real elliptical form shown on figure 2;

FIG. 3 is a partial cross-section of a third implementation of a threaded connection design having a double ellipse in the thread root for reducing fatigue stress;

FIG. 3A is an enlarged portion of the cross-section of FIG. 3, wherein the angle of thread taper is further enlarged for illustrative purposes; FIG. 3A is very schematic, showing mainly the orientations of the axis bb and cc, reference 303 is very schematic and does not reflect the real elliptical form shown on figure 3;

FIGS. 4A to 4D are partial cross-sections illustrating different root profiles of a Crest-to-Root ("CtR") thread; FIG. 4A to 4D are schematic, showing mainly the location of the contact points, the form of the root groove is schematic and may correspond to the precise form of the root grooves of figures 1 to 3;

FIG. 5 is a partial cross-section of a tubular connection with a threading profile of FIG. 1; of course the threading profile comprises several identical turns of the threading profile with the specific form of the root groove represented in the middle of the figure, the threading profile being periodic ; the figure 5 is schematic in the sense that the specific threading profile has not

been reproduced on the left and on the right of the figure, whereas this specific threading profile in the center of the figure is present on several turns of the threading;

FIG. 6 is a partial cross-section of a tubular connection with a threading profile of FIG. 2; of course the threading profile comprises several identical turns of the threading profile with the specific form of the root groove represented in the middle of the figure, the threading profile being periodic ; the figure 6 is schematic in the sense that the specific threading profile has not been reproduced on the left and on the right of the figure, whereas this specific threading profile in the center of the figure is present on several turns of the threading;

FIG. 7 is a partial cross-section of a tubular connection with a threading profile of FIG. 3; of course the threading profile comprises several identical turns of the threading profile with the specific form of the root groove represented in the middle of the figure, the threading profile being periodic ; the figure 7 is schematic in the sense that the specific threading profile has not been reproduced on the left and on the right of the figure, whereas this specific threading profile in the center of the figure is present on several turns of the threading;

FIG. 8A is a graphical illustration of finite element analysis generated data showing estimated cycles to fatigue failure for a standard prior art CtR thread; to correspond to the orientation of the threading profile represented on figures 1 to 3, the figure 8A should be rotated by a quarter of a turn counter-clockwise;

FIG. 8B is a graphical illustration of finite element analysis generated data showing estimated cycles to fatigue failure for a double elliptical thread of the present disclosure; to correspond to the orientation of the threading profile represented on figures 1 to 3, the figure 8B should be rotated by a quarter of a turn counter-clockwise;

FIG. 9A is a graphical illustration of finite element analysis generated data showing stress distribution for a standard prior art CtR thread; to correspond to the orientation of the threading profile represented on figures 1 to 3, the figure 9A should be rotated by a quarter of a turn counter-clockwise; and

FIG. 9B is a graphical illustration of finite element analysis generated data showing stress distribution for a double elliptical thread of the present disclosure; to correspond to the orientation of the threading profile represented on figures 1 to 3, the figure 9B should be rotated by a quarter of a turn counter-clockwise;

[0029] Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0030] In all what precedes and in all what follows, the longitudinal axis of the tube dd can also be called axis of the pipe, longitudinal axis of the sidewall of the tubular member, longitudinal

axis of the wall of the tube, longitudinal axis of the tube. In all what precedes and in all what follows, the longitudinal axis of the threading aa can also be called axis of the threading, axis of threading, axis of taper, axis of taper of the threading, pipe axis of the threading. The convex / concave orientation of the threading profile has been given with respect to the material of the tube, that is why tapered root surface and stabbing flank are joined by a concave curved surface and that tapered root surface and root groove are joined by a convex curved surface. Referring to Fig. 1 where therein is illustrated a first implementation of a threaded connection design having a double ellipse in the thread root for reducing fatigue stress. A tubular element has a male threading 100 disposed on a pin end 12 of the tubular element 11. The male threading 100 includes a tapered root surface 101. In the first implementation illustrated in Fig. 1, the tapered root surface 101 is parallel to the axis of threading (aa). The axis of threading (aa) forms an angle θ of approximately 2.4 degrees with a longitudinal axis (dd) of the wall of the tube 11. The range for theta in this implementation may range from about 1.5 degrees to 12 degrees, and more preferably from 1.5 to 4.5 degrees. It will be understood that in this embodiment, since the tapered root surface 101 is parallel to the axis aa of the threading an angle β between the root tapered root surface 101 and the axis of threading (aa) will be equal to 0 degrees. However, in a modification of this embodiment, the angle β may have other values (e.g., see Fig. 2).

[0031] The tapered root surface 101 is joined tangentially at a first end by a concave curved surface 102 of a constant radius of curvature to a stabbing flank 120 and the tapered root surface 101 is joined at a second end by a convex curved surface 104 of constant radius of curvature to a root groove 103. The root groove 103 extends from the tapered root surface 101 to a load flank 150.

[0032] The root groove 103 includes a first portion comprising a first elliptical surface 106 having a variable radius of curvature. The first elliptical surface 106 is part of an ellipse 107. The root groove 103 further includes a second portion having a second elliptical surface 108 with variable radius of curvature. The second elliptical surface is part of a second ellipse 110. The second elliptical surface 108 is joined tangentially at a first end to the first elliptical surface 106 at a junction point 109 that defines the bottom of the root groove 103. The second elliptical surface is joined tangentially at a second end to the load flank 150.

[0033] The bottom of the groove 103 is placed below the level of the tapered root surface 101.

[0034] The major axis (bb) of the first ellipse 107 is disposed perpendicular to the major axis (cc) of the second ellipse 110, and the major axis (bb) of the first ellipse 107 is concurrent with (aligned with and overlaying) a minor axis of the second ellipse 110. This configuration ensures that ellipses 107 and 110 join tangentially at the junction point 109.

[0035] In the first implementation illustrated in Fig. 1, the major axis (cc) of the second ellipse 110 is disposed perpendicular to the load flank 150. This configuration ensures that the second ellipse 110 is joined tangentially to the load flank 150.

[0036] In the first implementation illustrated in Fig. 1, the first ellipse 107 has a first predetermined diameter (D1) along the major axis (bb), and a second predetermined diameter (D2) along a minor axis; and wherein the second ellipse 110 has a predetermined diameter (D3) along the major axis (cc) that is equal to the diameter (D1) along the major axis (bb) of the first ellipse 107, and the second ellipse 110 has a second diameter (D4) along a minor axis that is equal to the diameter (D2) along the minor axis of the first ellipse 107. In this configuration the first ellipse 107 and the second ellipse 110 are identically shaped. Alternatively, it will be understood that in the design of threading 100, the first ellipse 107 and the second ellipse 110 may have different relative diameters. For example, the first ellipse 107 may be longer and narrower than the implementation illustrated in Fig. 1 (e.g., the ellipse may be shaped similar to the ellipse 207 illustrated in Fig. 2).

[0037] It will be understood that a female box connection may have the same elements and profile as the male threading 100 illustrated and discussed above.

[0038] Referring now to Fig. 5 wherein is illustrated a tubular connection 10 having a first tube 11 with a male pin end 12 with the tapered male threading 100 (as illustrated in Fig. 1) made up to a female box end 14 of a second tube 13. The female box end 14 is illustrated with the same threading profile 100 as the male threading 100. As discussed hereinafter it will be understood that the male threading and the female threading do not have to be identical and either the male threading or the female threading may have modifications as discussed hereinafter.

[0039] In the first implementation illustrated in Figs. 1, 1A and 5, the load flank 150 is sloped positively away from the root groove 103. (You will note that Fig. 1A has the angle of the load flank 150 exaggerated for illustrative purposes.) Such a thread configuration is referred to in the art as a trapezoidal thread. The angle of the load flank measured with a line perpendicular to the axis (aa) of the threading is generally in the range of 0 to 5 degrees and more preferably from 1.5 to 5 degrees and preferably about 3 degrees. Moreover, angles from 0° (that is to say load flank perpendicular to the axis (aa) of the threading can also be used. In addition, negative flank angles from -9° to 0 (e.g. see Fig. 3a) may also be used for variations of this embodiment. That is to say, the range angle of the load flank may range from -9° to 5° and a preferred range for this embodiment is 1.5° to 5° and the preferred value is 3°.

[0040] Referring to Fig. 2 where therein is illustrated a second implementation of a threaded connection design having a double ellipse in the thread root for reducing fatigue stress. An axis of threading (aa) forms a preferred angle theta of approximately 2.4 degrees with a longitudinal axis (dd) of the wall of the tube 21. The range for theta in this implementation may range from about 1.5 degrees to 12 degrees, and more preferably from 1.5 to 4.5 degrees.

[0041] In the second implementation, a tapered threading 200 includes a tapered root surface 201 disposed at an angle of taper (β) measured between the root surface 201 and the axis of taper (aa) of the threading. The angle of taper (β) measured from the axis of taper (aa) of the threading is less than a measured angle between the stabbing flank (220) and the axis aa of

the threading. The tapered root surface 201 is joined tangentially at a first end by a concave curved surface 202 of a constant radius of curvature to a stabbing flank 220 and the tapered root surface 201 is joined at a second end by a convex curved surface 204 of constant radius of curvature to a root groove 203. The root groove 203 extends from the tapered root surface 201 to a load flank 250.

[0042] The root groove 203 includes a first portion having a first elliptical surface 206 with a variable radius of curvature. The first elliptical surface 206 is part of an ellipse 207. The root groove 203 further includes a second portion having a second elliptical surface 208 with a variable radius of curvature. The second elliptical surface 208 is part of a second ellipse 210. The second elliptical surface 208 is joined tangentially at a first end to the first elliptical surface 206 at a junction point 209 that defines the bottom of the root groove 203. The second elliptical surface 208 is joined tangentially at a second end to the load flank 250. The bottom of the groove 203 is placed below the level of the tapered root surface 201.

[0043] The major axis (bb) of the first ellipse 207 is disposed perpendicular to the major axis (cc) of the second ellipse 210, and the major axis (bb) of the first ellipse 207 is concurrent with (aligned with and overlaying) a minor axis of the second ellipse 210. This configuration ensures that ellipses 207 and 210 join tangentially at the junction point 209.

[0044] In the second implementation illustrated in Fig. 2, the major axis (cc) of the second ellipse 210 is disposed perpendicular to the load flank 250. This configuration ensures that the second ellipse 210 is joined tangentially to the load flank 250.

[0045] In the second implementation, the first ellipse 207 has a first predetermined diameter (D1) along a major axis (bb), and a second predetermined diameter (D2) along a minor axis; and wherein the second ellipse 210 has a predetermined diameter (D3) along a major axis (cc) that is equal to the diameter (D1) along the major axis (bb) of the first ellipse 207, and the second ellipse 210 has a second diameter (D4) along a minor axis that is greater than the diameter (D2) along the minor axis of the first ellipse 207. Alternatively, it will be understood that in the design of threading 200, the first ellipse 207 and the second ellipse 210 may have different relative diameters. For example, the second ellipse 210 may have a first diameter (D3) along a major axis that may be greater than the diameter (D1) along the major axis of the first ellipse.

[0046] It will be understood that a female box connection may have the same elements and profile as the male threading 200 illustrated and discussed above.

[0047] Referring now to Fig. 6 wherein is illustrated a tubular connection 20 having a first tube 21 with a male pin end 22 with the tapered male threading 200 (as illustrated in Fig. 2) made up to a female box end 24 of a second tube 23. The female box end 24 is illustrated with a modified threading profile 100 (as illustrated in Fig 1). It will be understood that the male threading and the female threading do not have to be identical as illustrated in Fig. 6, as long as the surfaces are designed to mate properly. It will also be understood that the male

threading and female threading may be identical as previously discussed herein with regard to Figs. 1 and 5.

[0048] In the second implementation (see Figs. 2, 2A and 6), the load flank 250 is sloped positively away from the root groove 203. (You will note that Fig. 2A has the angle of the load flank 150 exaggerated for illustrative purposes). Such a thread configuration is referred to in the art as a trapezoidal thread. The angle of the load flank 250 measured between a line perpendicular to the pipe axis (aa) of the threading is generally in the range of 0 to 5 degrees and more preferably from 1.5 to 5 degrees and preferably about 3 degrees. In variations of this embodiment and angle of 0° (that is to say load flank perpendicular to the axis (aa) can also be used. In addition, negative flank angles from - 9° to 0 (e.g. see Fig. 3) may also be used for this embodiment. That is to say, the angle of the load flank may range from -9° to 5° with a preferred range for this embodiment of 1.5° to 5° and the preferred value being 3°.

[0049] Referring to Fig. 3 where therein is illustrated a third implementation of a threaded connection design 300 having a double ellipse in the thread root for reducing fatigue stress. The tapered male threading 300 includes a tapered root surface 301. The axis of the threading (aa) forms a preferred angle theta with the longitudinal axis of the tube (dd) of approximately 8 degrees. The range for theta in this implementation may range from about 1.5° to 12 degrees and more preferably from 4.5 degrees to 12 degrees.

[0050] In the third implementation illustrated in Fig. 3, the tapered root surface 301 is parallel to the axis of threading (aa) as in the implementation of Fig. 1. It will be understood that in this embodiment, since the tapered root surface 301 is parallel to the axis aa of the threading an angle β between the root tapered root surface 301 and the axis of threading (aa) will be equal to 0 degrees. However, in a modification of this embodiment, the angle β may have other values (e.g. see Fig. 2).

[0051] The tapered root surface 301 is joined tangentially at a first end by a concave curved surface 302 of a constant radius of curvature to a stabbing flank 320 and the tapered root surface 301 is joined at a second end by a convex curved surface 304 of constant radius of curvature to a root groove 303. The root groove 303 extends from the tapered root surface 301 to a load flank 350.

[0052] The root groove 303 includes a first portion having a first elliptical surface 306 with a variable radius of curvature. The first elliptical surface 306 being part of an ellipse 307. The second elliptical surface is part of a second ellipse 310. The root groove 303 further includes a second portion having a second elliptical surface 308 with a variable radius of curvature. The second elliptical surface 308 is joined tangentially at a first end to the first elliptical surface 306 at a junction point 309 that defines the bottom of the root groove 303. The second elliptical surface is joined tangentially at a second end to the load flank 350. The bottom of the groove 303 is placed below the level of the tapered root surface 301.

[0053] In the third implementation illustrated in Fig. 3, the first ellipse 307 has a first

predetermined diameter (D1) along the major axis (bb), and a second predetermined diameter (D2) along a minor axis; and wherein the second ellipse 310 has a predetermined diameter (D3) along the major axis (cc) that is equal to the diameter (D1) along the major axis (bb) of the first ellipse 307, and the second ellipse 310 has a second diameter (D4) along a minor axis that is equal to the diameter (D2) along the minor axis of the first ellipse 307. Alternatively, it will be understood that in the design of threading 300, the first ellipse 307 and the second ellipse 110 may have different relative diameters. For example, the first ellipse 307 may be longer and narrower than the implementation illustrated in Fig. 3 (e.g., the ellipse may be shaped similar to the ellipse 207 illustrated in Fig. 2).

[0054] The major axis (bb) of the first ellipse 307 is disposed perpendicular to the major axis (cc) of the second ellipse 310, and the major axis (bb) of the first ellipse 307 is concurrent with (aligned with and overlaying) a minor axis of the second ellipse 310. This configuration ensures that ellipses 307 and 310 join tangentially at the junction point 309.

[0055] In the third implementation illustrated in Fig. 3, the major axis (cc) of the second ellipse 310 is disposed perpendicular to the load flank 350. This configuration ensures that the second ellipse 310 is joined tangentially to the load flank 350. All orientations of other axis are defined with respect to axis cc of the second ellipse 310.

[0056] It will be understood that a female box connection may have the same elements and profile as the male threading 300 illustrated and discussed above.

[0057] Referring now to Fig. 7 wherein is illustrated a tubular connection 30 having a first tube 31 with a male pin end 32 with the tapered male threading 300 (as illustrated in Fig. 3) made up to a female box end 34 of a second tube 33. The female box end 34 is illustrated with the same threading profile 300 as the male threading 300. As discussed previously herein with regard to Figs. 2 and 6, it will be understood that the male threading and the female threading do not have to be identical and either the male threading or the female threading may have modifications as long as the profiles mate together.

[0058] In the third implementation illustrated in Figs. 3, 3A and 7, the load flank 350 is sloped toward the root groove 303. (You will note that Fig. 3A has the angle of the load flank 350 exaggerated for illustrative purposes.) Such a thread configuration is referred to in the art as a hook thread. The angle of the load flank measured with a line perpendicular to the axis (aa) of the threading is generally in the range of -9 to 0 degrees and more preferably from -9 to -1.5 degrees and preferably about -3 degrees. Moreover, angles from 0° (that is to say load flank perpendicular to the axis (aa) can also be used. In addition, positive flank angles from 0° to 5 degrees (e.g. see Fig. 1a) may also be used for variations of this embodiment. That is to say, the range angle of the load flank may range from -9° to 5, a more preferably the angle may range between -9 to -1.5 and a preferred value for this embodiment is -3°.

[0059] The present disclosure also includes a method of cutting a male or female threading 100, 200, 300 on an end of a tubular element. The method includes: providing a tubular

element 11, 21, 31, 13, 23, 33; cutting a tapered male or female threading on a respective pin end 12, 22, 32 or box end 14, 24, 34 of the tubular element wherein the tapered threading includes a root surface 101, 201, 301. The tapered root surface 101, 201, 301 is joined tangentially at a first end by a concave curved surface 102, 202, 302 of a constant radius of curvature to a stabbing flank 120, 220, 320. The tapered root surface 101, 201, 301 is joined at a second end by a convex curved surface 104 of constant radius of curvature to a root groove 103. The root groove 103, 203, 303 extends from the tapered root surface 101, 201, 301 to a load flank 150, 250, 350. The root groove 103, 203, 303 includes: a first portion comprising a first elliptical surface 106, 206, 306 having a variable radius of curvature, said first elliptical surface 106, 206, 306 being part of an ellipse 107, 207, 307, and the root groove 103, 203, 303 further including a second portion comprising a second elliptical surface 108, 208, 308 having variable radius of curvature, said second elliptical surface being a part of the second ellipse 110, 210, 310. The second elliptical surface 108, 208, 308 is joined tangentially at a first end to the first elliptical surface 106, 206, 306 at a junction point that defines the bottom of the groove 109, 209, 309. The second elliptical surface is joined tangentially at a second end to the load flank 105, 205, 305. The second elliptical surface has its major axis (cc) perpendicular to the load flank 150, 250, 350. The major axis bb is perpendicular to the major axis cc. Orientation of axis is defined having in mind that cc should be perpendicular to the load flank and that bb and cc should be one perpendicular to the other.

ADVANTAGES OF PRESENT DISCLOSURE

[0060] The root profile design of the present disclosure improves fatigue resistance of the threaded connection by a combined action of several features which manifest themselves at the end of the make up operation of the connection:

1. a) provision of large radial loads ("hoop loads"), as a function of root-to-crest interference. The large hoop loads improve fatigue resistance;
2. b) provision of large shoulder loads that improve fatigue resistance; and
3. c) provision of an lengthened radius Rb (of the arc of the curve the connects the root to the flank) lowers stress concentration in the thread roots.

[0061] The present design configuration of two ellipses allows maximization of the radius of the stress concentrator in the joint between the load flank 150, 250, 350 and the root surface 101, 201, 301, so the effect of the stress concentrator on the fatigue performance of the joint is minimized. Moreover, the effective contact between mating load flanks of the male and female element 12 and 14 of the connection 10 is also maximized and hence efficiency of the connection is also maximized.

[0062] Figs. 4A, 4B, 4C and 4D illustrate problems and benefits of incremental change in design configuration from the prior art standard CtR design of Fig. 4A to an exemplary root

design of the present disclosure as illustrated in Fig. 4D. In Figs. 4A to 4D, R_b is the radius of the arc connecting the root of the male thread to the load flank of the male thread. R_i is the radius of the arc connecting the thread crest and the load flank of the female thread. See Fig. 4A wherein the R_b and the R_i are equal.

[0063] Referring to Fig. 4A, wherein is illustrated a full load flank contact. Problem: contact pressures over the stress concentrator and low stress concentrator radius (R_b). Benefit: High tension efficiency due to maximized load flank contact L1.

[0064] Referring to Fig. 4B wherein is illustrated a modified CtR profile (similar to prior art design of US 20110042946 A1). Benefit: The radius R_i is enlarged to avoid contact points over the stress concentrator. Problem: The stress state near the stress concentrator is highly affected by contact stresses and remote stresses. Another problem of this configuration is the low stress concentrator radius (R_b). This configuration has the same R_b as in Figure 4A.

[0065] Referring to Fig. 4C to maximize the stress concentrator radius R_b , there is the limit of (R_b), because it is important to avoid full load flank contact. Moreover, when increasing R_b the effect of contact stresses in the stress state around the stress concentrator becomes bigger because points A and C are closer to B.

[0066] Referring to Fig. 4D wherein the stress concentrator radius (R_i) of the male thread has been enlarged to maximize load flank contact and crest to root contact. Moreover, the stress state in the stress concentrator is less influenced by contact stresses and is only a function of remote stresses, due to the fact that contact points A and C are spaced farther away from the stress concentrator. With this geometry, contact surface L1 is restored but without contact in the stress concentrator.

[0067] Referring to Fig. 4B (a prior art design similar to US 2011 0042946 A1) and Fig. 4D (an implementation of the present root design), another benefit of using the double elliptical groove as illustrated in Figs. 1, 2 and 3 of the present disclosure is that the stress state around the stress concentrator (KT) is less affected by the components of stresses due to contact points ($\sigma_A + \sigma_C$), and so values of stresses are lower than the ones obtained for a joint without a groove and only affected by remote stresses (σ_B).

[0068] In some prior art CtR threads (see Fig. 4B), the stress state around the stress concentrator KT is a function of contact stresses ($\sigma_A + \sigma_C$) and remotes stresses (σ_B):

$$\sigma_{KT} = \sigma_A + \sigma_B + \sigma_C$$

[0069] However, in the joint of the present disclosure (see Fig. 4D), contact points A and C are far away from the stress concentrator, so the stress state around the stress concentrator KT is a function only of the remotes stresses (σ_B):

$$\sigma_{KT} = \sigma_B$$

[0070] It is important to note that the choice of ellipses to form the groove is based on the fact that the ellipses are functions that allow joining two perpendicular surfaces with a curved surface that has a radius that varies from point to point. Therefore, the radii can be maximized and minimized. For example, an arc of circle having the same radius as the radius of the ellipse in the KT will remove all possibility of contact between load flanks (see Figs. 1 to 3).

[0071] The use of a second ellipse to go from the load flank to the KT is used to maximize the radius of the KT, then the design switches to the first ellipse to quickly restore crest to root contact. This design provides a minimal removal of crest to root contact surface. Therefore, contact pressures are maintained low (see Figs. 1 to 3).

[0072] To enhance the effect of the first ellipse, it can be narrowed as illustrated in the second implementation of the present disclosure (see Fig. 2).

[0073] Additionally increasing the taper of the tapered portion of the root surface as illustrated in the second implementation (Fig. 2), the contact surface between crest and root is enlarged and so contact pressures are minimized and galling is minimized. The contact length at crest/root is approximately double in the second implementation as compared to the design illustrated in the first implementation. This design minimizes galling. Additionally, positive (major than 0) angle of taper (β) measured from the axis of taper (aa) of the threading helps to maintain the thread locked. (β)angle is also useful in enlarging the crest/root contact surface and at the same time provides for additional room for the groove for stress reduction at the pin root (see Fig. 2).

[0074] Referring now to Figs. 8A, 8B, 9A and 9B, wherein finite element analysis has been used to generate data comparing parameters for a standard Crest to Root (CtR) thread (as illustrated in Fig. 4A) to the exemplary double elliptical design of the present disclosure (as illustrated in Fig. 4D). In Fig. 8A the cycles to fatigue failure is illustrated for the standard CtR thread design. In Fig. 8B the cycles to fatigue failure are illustrated for the double elliptical design of the present disclosure. It can be seen in Figs. 8A and 8B how the double elliptical design of the present disclosure directly impacts on the number of cycles to failure in the zone where the stress concentrator is placed. The first layer of material (in the area of the stress concentrator, that is to say the joint between load flank and root surface) in the standard CtR design is the one having less number of cycles 1.120×10^3 to fatigue failure (Fig 8A), while dotted area (area near the stress concentrator) in the double elliptic profile (Fig. 8B) is the one having less number of cycles 1.0×10^4 . It can be seen that the fatigue life of the component is increased with the double elliptical design of the present disclosure.

[0075] Referring to Figs. 9A and 9B, the stress distribution and representative von Mises values for the standard CtR thread is illustrated in Fig. 9A and the double elliptical thread profile of the present disclosure is illustrated in Fig. 9B. It can be seen that in Fig. 9A (prior art CtR design), high values of von Mises stress exist around the stress concentrator and near

the contact points between the male and female thread near the stress concentrator. However, Fig. 9B, (the double elliptical thread profile of the present disclosure) demonstrates a lower level of stress values and a more uniform distribution of stress near the stress concentrator. The contact points between the male and female members are desirably spaced apart from the stress concentrator and therefore not contributing to the stress state of the area near the stress concentrator.

[0076] A number of embodiments of the disclosure have been described. Nevertheless, it will be understood that various modifications may be made without departing from the scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- [US7780202B \[0007\]](#)
- [US6609735B \[0007\]](#)
- [US5163523A \[0007\]](#)
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- [US20110042946A1 \[0064\] \[0067\]](#)

P a t e n t k r a v

1. Rørformet element (11), som har et udvendigt eller indvendigt gevind (100), der er anbragt på en ende (12) af det rørformede element, hvor det rørformede element er **kendetegnet ved, at** det udvendige eller indvendige gevind omfatter:

5 en tilspidset rodflade (101), som har en første tilspidset vinkel (β) målt mellem den tilspidsede rodflade og en længdegevindakse (aa), hvor den tilspidsede rodflade ved en første ende er tangentialt forbundet med en stikflanke (120) via en konkav buet overflade (102) med en konstant krumningsradius, hvor den tilspidsede rodflade ved en anden ende er forbundet med en rodrille (103) via en konveks buet overflade (104) med en konstant krumningsradius; hvilken rodrille strækker sig fra den tilspidsede rodflade til en belastningsflanke (150), hvilken rodrille indeholder:

10 15 en første del omfattende en første ellipseformet overflade (106), som har en variabel krumningsradius, hvor den første ellipseformede overflade er del af en ellipse (107), og

15 20 hvilken rodrille endvidere indeholder en anden del omfattende en anden ellipseformet overflade (108), som har en variabel krumningsradius, hvor den anden ellipseformede overflade er del af en anden ellipse (110), hvor den anden ellipseformede overflade er tangentialt forbundet med den første ellipseformede overflade ved en første ende, og den anden ellipseformede overflade er tangentialt forbundet med belastningsflanken ved en anden ende.

25 2. Rørformet element ifølge krav 1, hvor den første tilspidsede vinkel (β) er 0 grader, således at den tilspidsede rodflade er parallel med gevindaksen (aa).

30 3. Rørformet element ifølge krav 1, hvor den første tilspidsede vinkel (β) er mindre end den målte værdi af en vinkel målt mellem en stikflanke (220) af det udvendige eller indvendige gevind og gevindaksen (aa).

35 4. Rørformet element ifølge krav 1, hvor en vinkel theta målt mellem gevindaksen (aa) og længdeakse (dd) af sidevæggen af det rørformede element er mellem 1,5 grader og 12 grader.

5. Rørformet element ifølge krav 1, hvor en hovedakse (cc) af den anden ellipse er anbragt vinkelret på belastningsflanken.

5 6. Rørformet element ifølge krav 1, hvor en hovedakse (bb) af den første ellipse er vinkelret på hovedaksen (cc) af den anden ellipse.

10 7. Rørformet element ifølge krav 1, hvor en hovedakse (bb) af den første ellipse er på linje med og overlapper en mindre akse af den anden ellipse.

15 8. Rørformet element ifølge krav 1, hvor den første ellipse har en første forudbestemt diameter (D1) langs en hovedakse (bb) og en anden forudbestemt diameter (D2) langs en mindre akse; og hvor den anden ellipse har en forudbestemt diameter (D3) langs hovedaksen (cc), som er lig med diameteren (D1) langs hovedaksen (bb) af den første ellipse, og den anden ellipse har en anden diameter (D4) langs en mindre akse, som er lig med diameteren (D2) langs den mindre akse af den første ellipse.

20 9. Rørformet element ifølge krav 1, hvor den første ellipse har en første forudbestemt diameter (D1) langs en hovedakse (bb) og en anden forudbestemt diameter (D2) langs en mindre akse; og hvor den anden ellipse har en forudbestemt diameter (D3) langs en hovedakse (cc), som er lig med diameteren (D1) langs hovedaksen (bb) af den første ellipse, og den anden ellipse har en anden diameter (D4) langs en mindre akse, som er større end diameteren (D2) langs den mindre akse af den første ellipse.

25 10. Rørformet element ifølge krav 1, hvor den første ellipse har en første forudbestemt diameter (D1) langs en hovedakse (bb) og en anden forudbestemt diameter (D2) langs en mindre akse; og hvor den anden ellipse har en forudbestemt diameter (D3) langs en hovedakse (cc) og har en anden diameter (D4) langs en mindre akse, som er større end diameteren (D2) langs den mindre akse af den første ellipse.

30 11. Rørformet element ifølge krav 1, hvor den første ellipse har en første forudbestemt diameter (D1) langs en hovedakse (bb) og en anden forudbestemt diameter (D2) langs en mindre akse; og hvor den anden ellipse har en forudbestemt diameter (D3) langs en hovedakse (cc) og har en anden diameter (D4)

langs en mindre akse, som er mindre end diameteren (D2) langs den mindre akse af den første ellipse.

5 **12.** Rørformet element ifølge krav 1, hvor den første ellipse har en første forudbestemt diameter (D1) langs en hovedakse (bb) og en anden forudbestemt diameter (D2) langs en mindre akse; og hvor den anden ellipse har en forudbestemt diameter (D3) langs en hovedakse (cc) og har en anden diameter (D4) langs en mindre akse; og hvor diameteren (D3) langs hovedaksen (cc) af den anden ellipse er mindre end diameteren D1 langs hovedaksen (bb) af den første ellipse.

10 **13.** Rørformet element ifølge krav 1, hvor den første ellipse har en første forudbestemt diameter (D1) langs en hovedakse (bb) og en anden forudbestemt diameter (D2) langs en mindre akse; og hvor den anden ellipse har en forudbestemt diameter (D3) langs en hovedakse (cc) og har en anden diameter (D4) langs en mindre akse; og hvor diameteren (D3) langs hovedaksen (cc) af den anden ellipse er større end diameteren (D1) langs hovedaksen (bb) af den første ellipse.

20 **14.** Rørformet element ifølge krav 1, hvor belastningsflanken er anbragt i forhold til en vinkel målt mellem belastningsflanken og en linje vinkelret på en gevindakse (aa), hvor vinklen er i området fra -9 til 5 grader.

25 **15.** Rørformet element ifølge krav 1, hvor den anden ellipseformede overflade ved en første ende er tangentialt forbundet med den første ellipseformede overflade ved et forbindelsespunkt, som definerer bunden af rodritten.

30 **16.** Rørformet element ifølge krav 15, hvor bunden af rillen er anbragt i sidevæggen af det rørformede element under niveauet af den tilspidsede rodflade.

35 **17.** Rørformet gevindforbindelse, **kendetegnet ved, at** den omfatter:
- et udvendigt rørformet element, der indeholder et tilspidset første gevind med en tilspidset akse (aa),
- et indvendigt rørformet element, der indeholder et tilspidset andet gevind med en tilspidset akse (aa), hvor det andet gevind samvirker med det første gevind, når gevindforbindelsen er fremstillet;

hvor det første tilspidsede gevind af det udvendige rørformede element svarer til det udvendige gevind ifølge et af kravene 1 til 16, og/eller det andet tilspidsede gevind af det indvendige rørformede element svarer til det indvendige gevind ifølge et af kravene 1 til 16.

5

18. Fremgangsmåde til skæring af et tilspidset udvendigt gevind på en ende af et rørformet element, hvilken fremgangsmåde er **kendetegnet ved, at den omfatter:**

tilvejebringelse af et rørformet element (11);

10

skæring af et tilspidset udvendigt gevind på en ende (12) af det rørformede element, hvor det tilspidsede udvendige gevind omfatter: en tilspidset rodflade (101), som har en første tilspidset vinkel (β) målt mellem den tilspidsede rodflade og en længdegevindakse (aa), hvor den tilspidsede rodflade ved en første ende er tangentialt forbundet med en stikflanke (120) via en konkav buet overflade (102) med en konstant krumningsradius, hvor den tilspidsede rodflade ved en anden ende er forbundet med en rodrille (103) via en konveks buet overflade (104) med en konstant krumningsradius;

15

hvilken rodrille strækker sig fra den tilspidsede rodflade til en belastningsflanke (150), hvilken rodrille indeholder:

20

en første del omfattende en første ellipseformet overflade (106), som har en variabel krumningsradius, hvor den første ellipseformede overflade er del af en ellipse (107), og

hvilken rodrille endvidere indeholder en anden del omfattende en anden ellipseformet overflade (108), som har en variabel krumningsradius, hvor den anden

25

ellipseformede overflade er del af en anden ellipse (110), hvor den anden ellipseformede overflade er tangentialt forbundet med den første ellipseformede overflade ved en første ende, og den anden ellipseformede overflade er tangentialt forbundet med belastningsflanken ved en anden ende.

30

19. Fremgangsmåde til skæring af et tilspidset indvendigt gevind på en ende af et rørformet element, hvilken fremgangsmåde er **kendetegnet ved, at den omfatter:**

tilvejebringelse af et rørformet element (11);

35

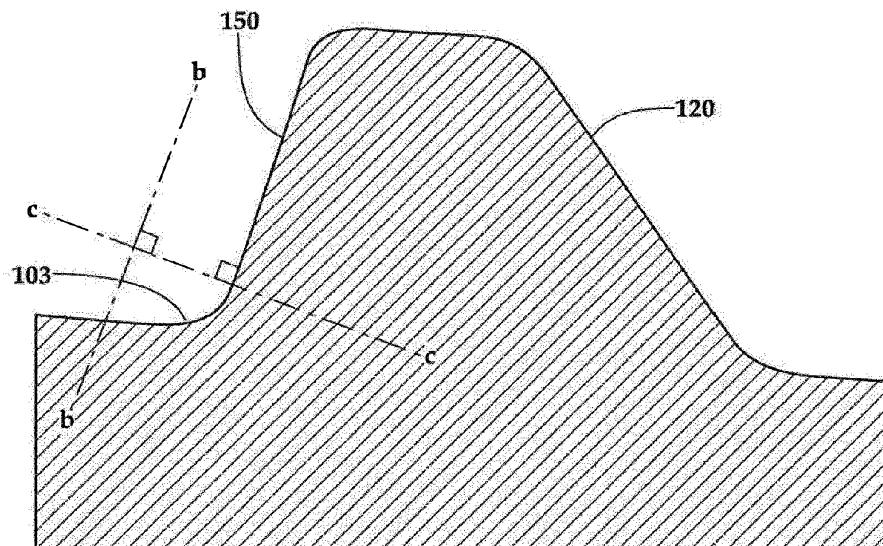
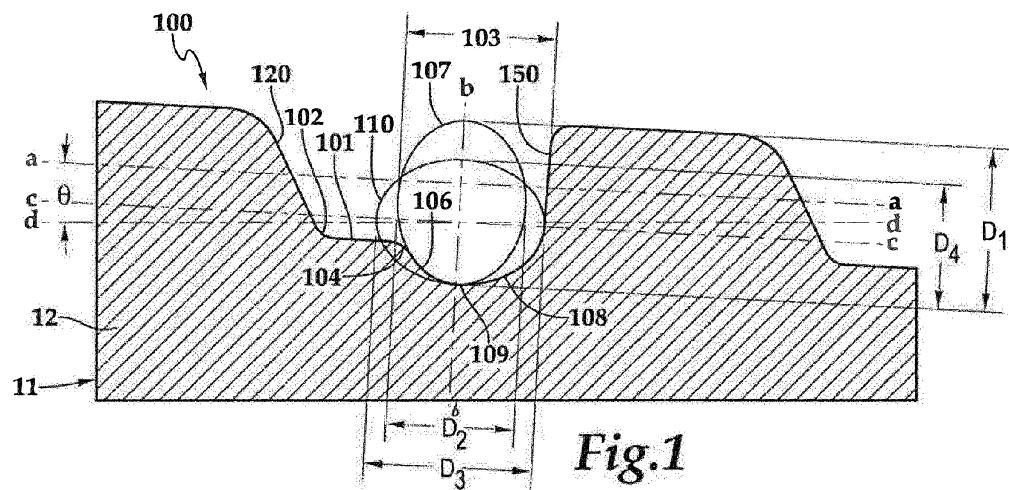
skæring af et tilspidset indvendigt gevind på en ende (12) af det rørformede element, hvor det tilspidsede indvendige gevind omfatter:

en tilspidset rodflade (101), som har en første tilspidset vinkel (β) målt mellem den tilspidsede rodflade og en længdegevindakse (aa), hvor den tilspidsede rodflade ved en første ende er tangentialt forbundet med en stikflanke (120) via en konkav buet overflade (102) med en konstant krumningsradius, hvor den tilspidsede rodflade ved en anden ende er forbundet med en rodrille (103) via en konveks buet overflade (104) med en konstant krumningsradius; hvilken rodrille strækker sig fra den tilspidsede rodflade til en belastningsflanke (150), hvilken rodrille indeholder:

en første del (106) omfattende en første ellipseformet overflade, som har en variabel krumningsradius, hvor den første ellipseformede overflade er del af en ellipse (107), og

hvilken rodrille endvidere indeholder en anden del omfattende en anden ellipseformet overflade (108), som har en variabel krumningsradius, hvor den anden ellipseformede overflade er del af en anden ellipse (110), hvor den anden ellipseformede overflade er tangentialt forbundet med den første ellipseformede overflade ved en første ende, og den anden ellipseformede overflade er tangentialt forbundet med belastningsflanken ved en anden ende.

DRAWINGS



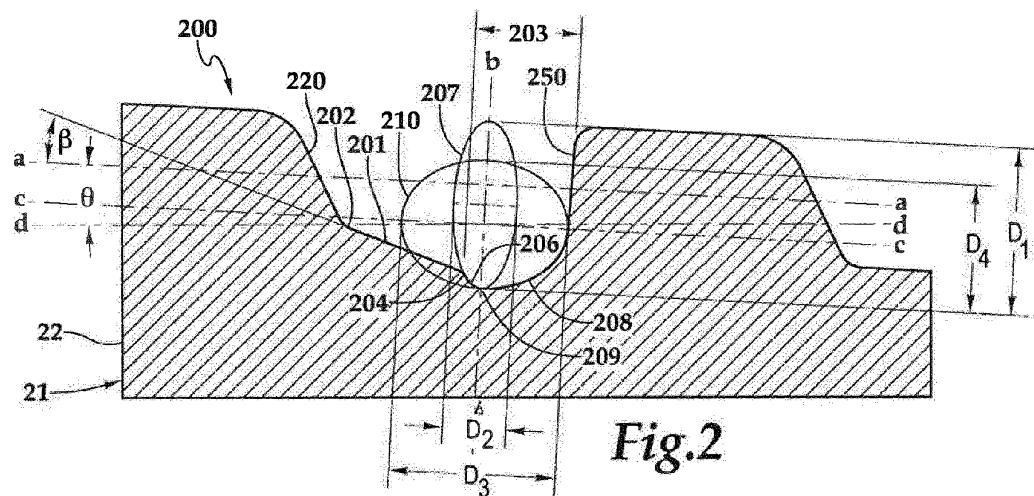


Fig.2

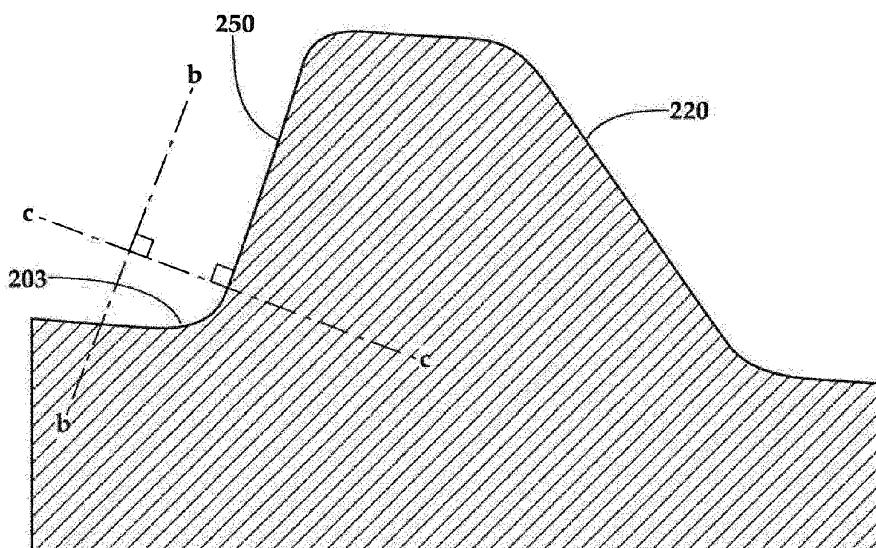
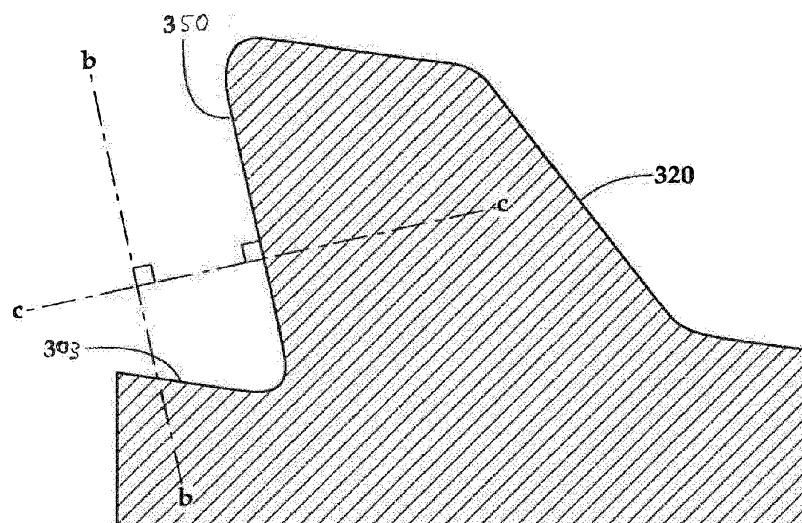
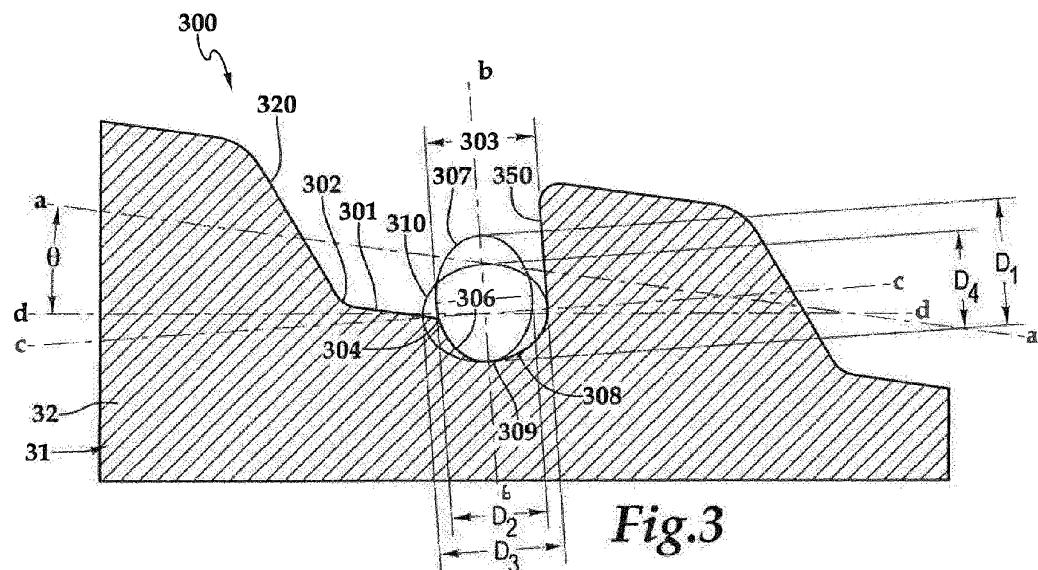
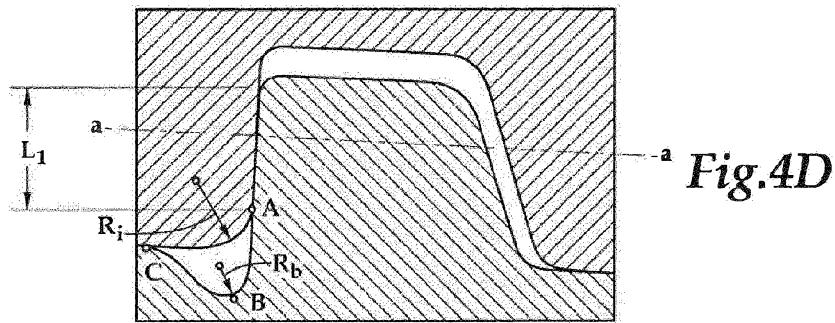
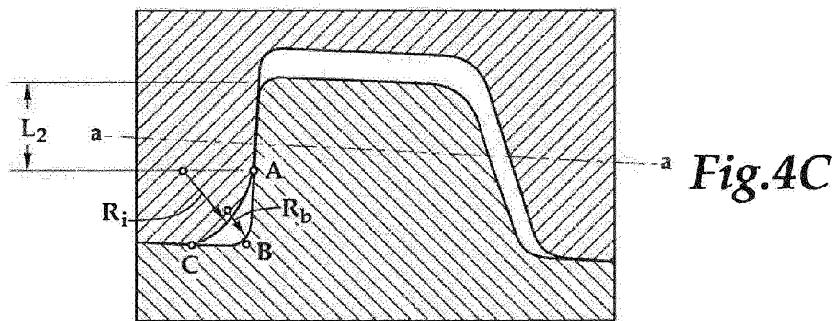
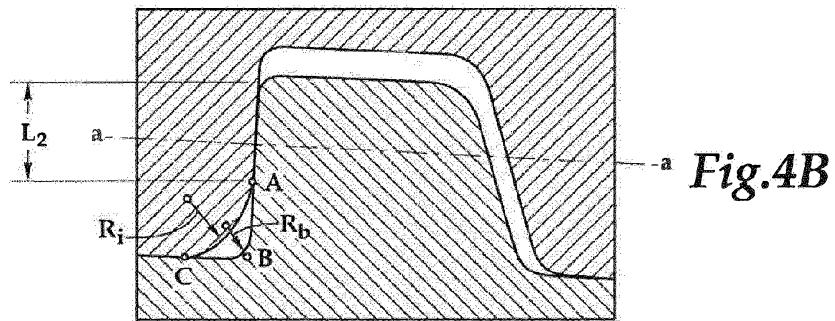
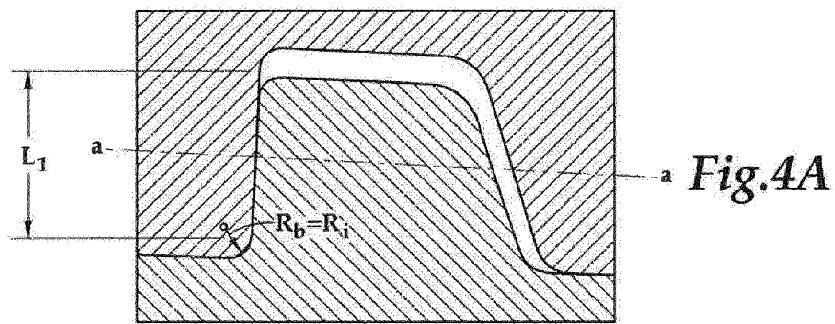
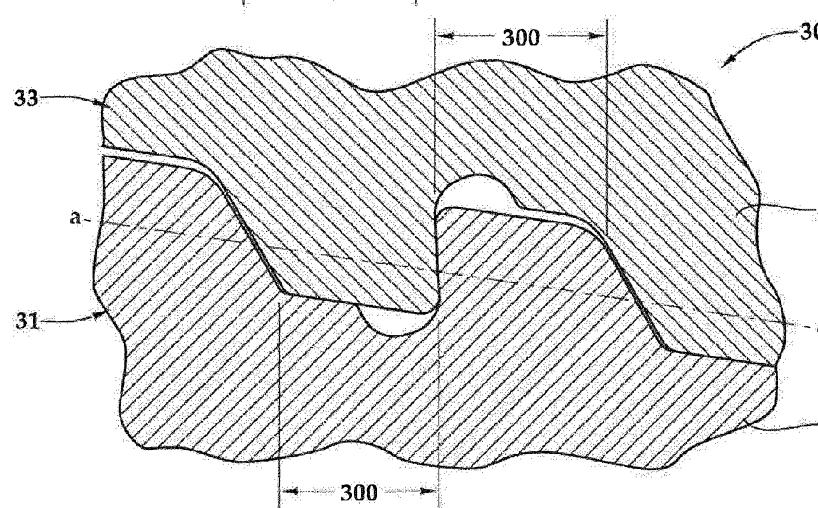
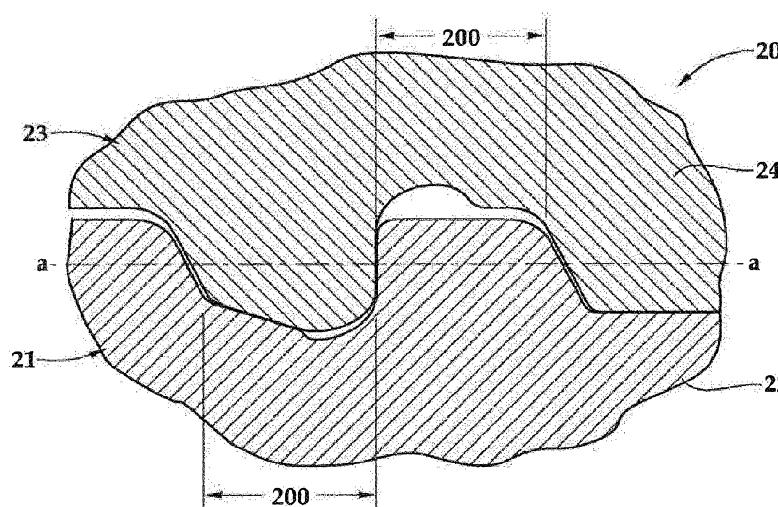
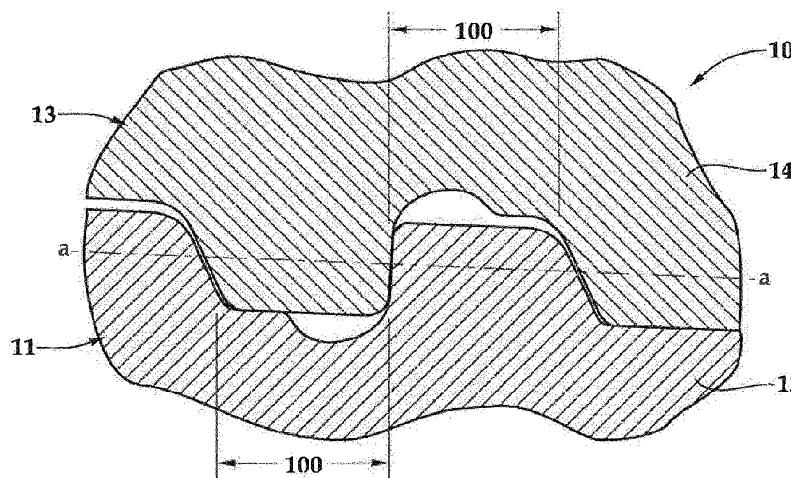
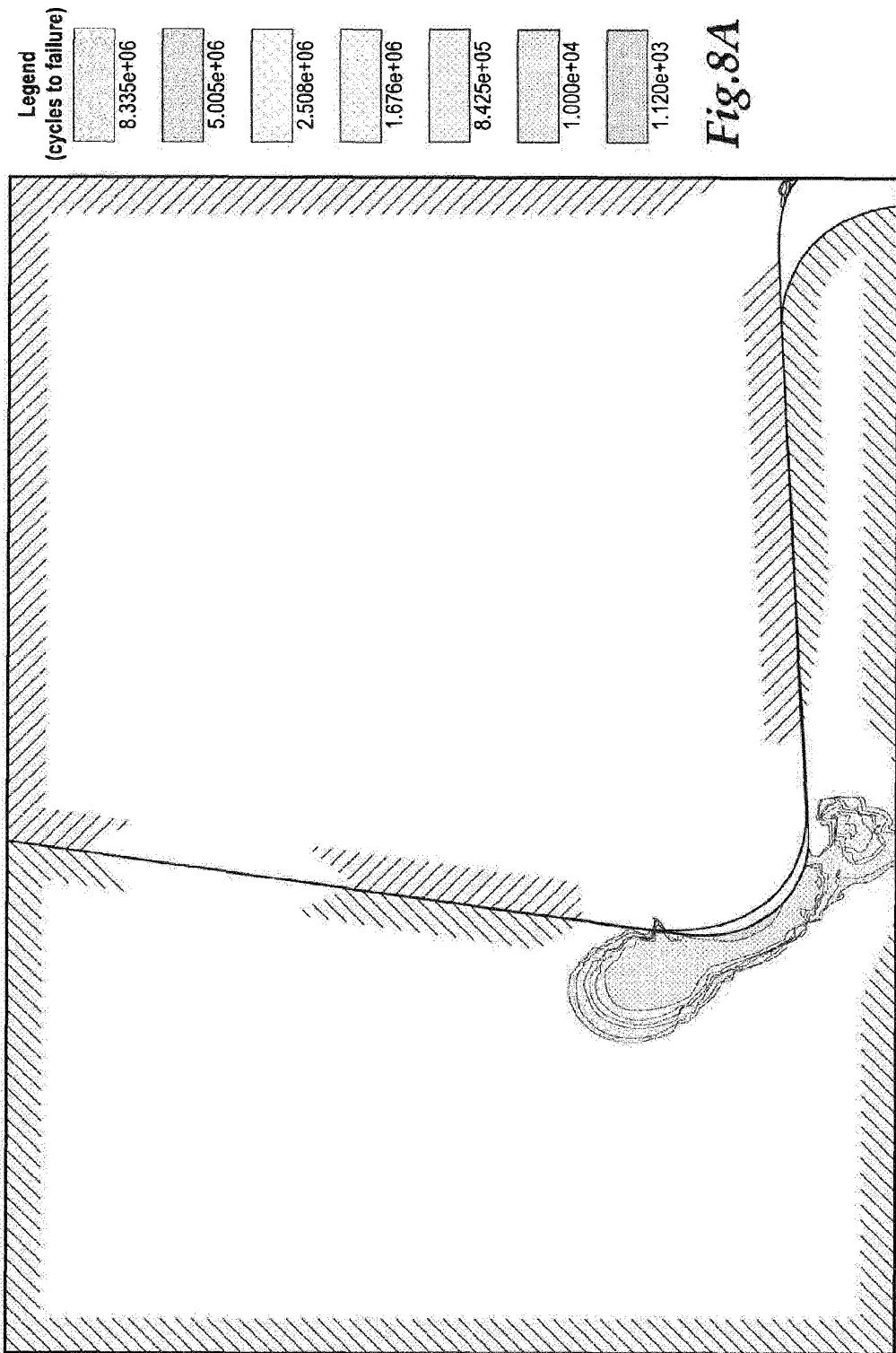


Fig.2A









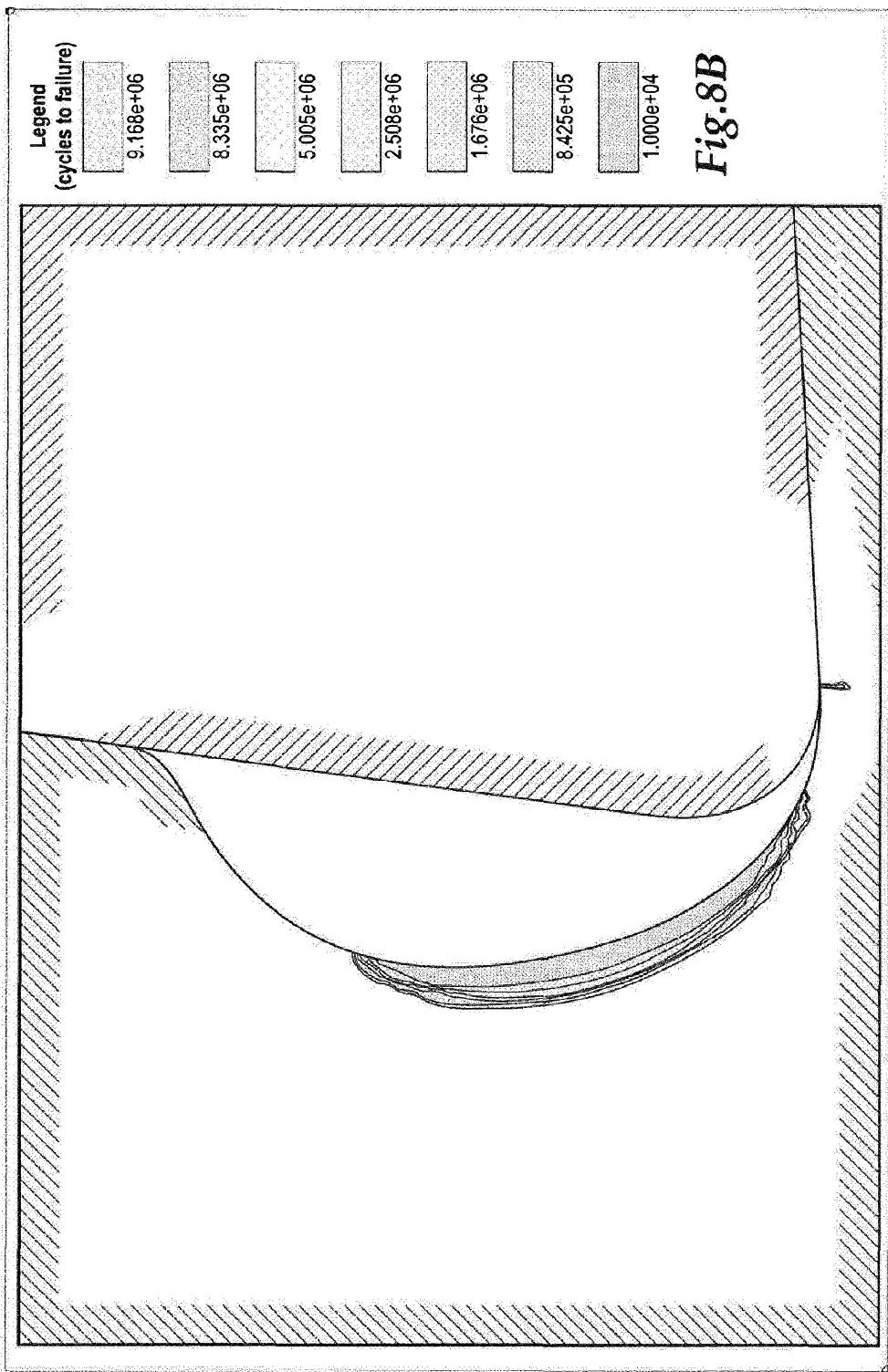


Fig.8B

