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(71) Applicant: **Sandvik Intellectual Property AB**
811 81 Sandviken (SE)

(72) Inventor: **Jansson, Tomas**
80253 Gävle (SE)

(54) **Drill string rod with strengthened spigot coupling**

(57) A drill string rod (100) to form a part of a drill string having a threaded spigot end portion (108). The male spigot portion (108) is configured specifically to provide a robust coupling to withstand both bending moments and tensile loads and to minimise stress concentrations.

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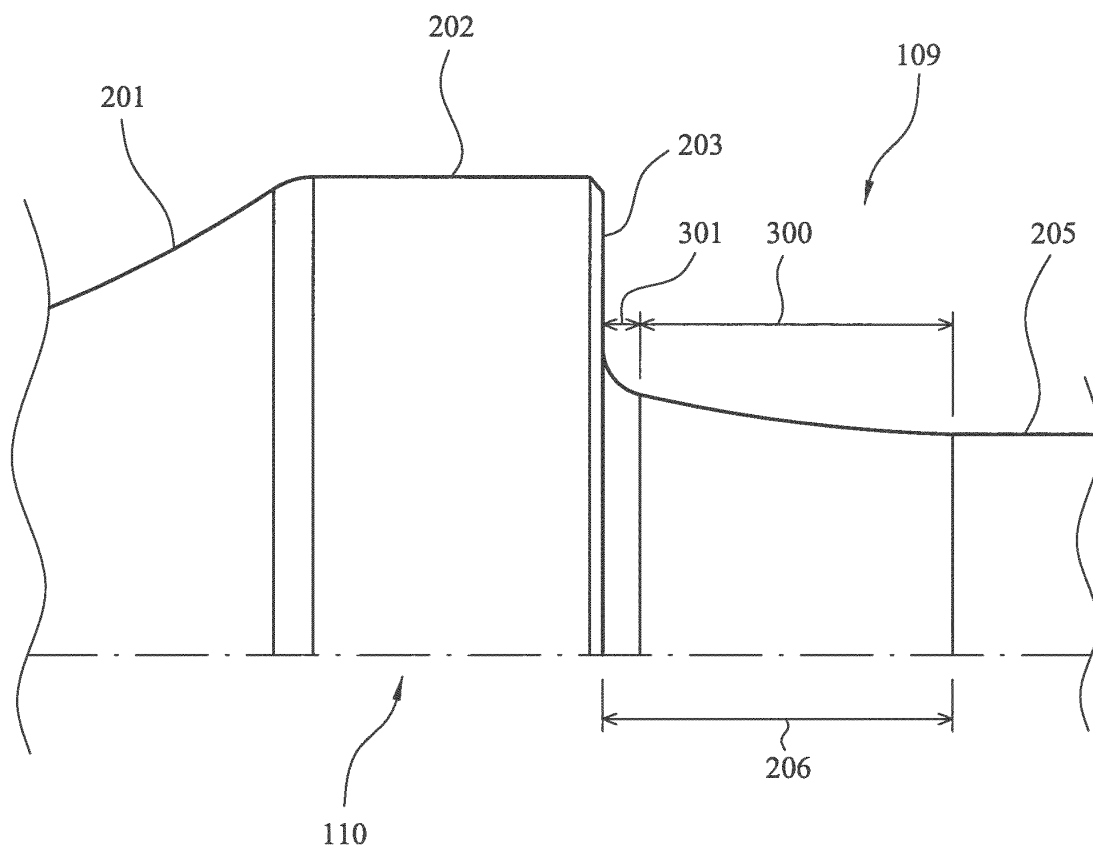


FIG. 3

Description

Field of invention

[0001] The present invention relates to a drill string rod to form part of a drill string having a male spigot portion provided at one end of the rod and in particular, although not exclusively, to a spigot portion having a threaded section and a non-threaded shank configured to minimise stress concentrations.

Background art

[0002] Percussion drilling is used to create a long borehole via a plurality of elongate drill string rods coupled together end-to-end by interconnected male and female threaded ends. The well-established technique breaks rock by hammering impacts transferred from the rock drill bit, mounted at one end of the drill string, to the rock at the bottom of the borehole. Typically, the energy required to break the rock is generated by a hydraulically driven piston that contacts the end of the drill string (via a shank adaptor) to create a stress (or shock) wave that propagates through the drill string and ultimately to the base rock level.

[0003] Conventional male and female threaded couplings are described in US 4,332,502; US 4,398,756; US 1,926,925; US 5,169,183; EP 1705415; GB 2321073 and US 4,687,368.

[0004] When the male and female threaded ends of neighbouring drill rods are coupled to create the drill string, the joint is typically subjected to bending force during drilling. These bending moments fatigue the coupling and may lead to breakage within the threaded portion of the joint. Typically, it is the threaded male spigot that is damaged and determines the operational lifetime of the coupling. US 6,767,156 discloses a threaded joint between two percussive drill rods having conical guiding surfaces provided at the leading axial ends of the male and female portions in an attempt to achieve a secure couple and avoid damage to the threads.

[0005] In particular, the transition between the different diameters of the threaded male spigot and the main length of the drill rod (or an annular shoulder at the rod end required for 'shoulder contact' couplings) provides a region for potentially high stress concentrations due to bending moments and tensile loads. Conventionally, the outside diameter of the rod at the transition axially between the threaded male spigot and the main length or shoulder is flared radially outward with a curved shape profile having a single radius curvature that is as large as can be accommodated between the two regions. However, for a typical threaded coupling stressed by 200 MPa in tension, the transition region reaches a stress level of approximately 300 MPa. Fatigue and possible breakage are therefore very likely and the multiple threaded couplings represents significantly weaker region of the drill string. Drill rods are typically replaced periodically ac-

cording to their predetermined lifetime to try and avoid fracture of the male spigot during use which would cause significant disruption to a drilling operation. There is therefore a need for a drill rod that addresses these problems.

Summary of the Invention

[0006] It is an objective of the present invention to provide a drill string rod having a male threaded coupling part that is optimised to minimise the likelihood of stress concentrations at the transition region between the end of the main length section of the rod and the spigot to extend the operational lifetime of the rod and minimise fatigue and the risk of breakage in use. It is a further specific objective to provide a drill rod that is compatible with existing drilling apparatus and methods that comprises an enhanced capacity to withstand large bending moments and tensile loads.

[0007] The objectives are achieved by specifically configuring a transition region positioned axially at the interface with the end of the main length section, or an annular shoulder at the end of the main length section, and the male spigot that comprises a gradually increasing cross sectional area or diameter in a direction from the spigot threaded end towards the main length section or shoulder. The present invention provides a drill rod coupling that exhibits no or minimal stress concentrations at the junction of the male spigot with the main length section resultant from incident bending moments or tensile loads. According to a first aspect of the present invention there is provided a drill string rod to form a part of a drill string, the rod comprising: an elongate hollow main length section extending axially between a first end and a second end; a male spigot portion provided at the second end having an externally threaded section and a non-threaded shank positioned axially intermediate the main length section and the threaded section; the shank having a transition region positioned adjacent the main length section or a radially projecting shoulder at the second end, the transition region having an outside diameter that increases in a direction from the spigot section to the main length section or the shoulder; wherein a cross sectional profile of an outer surface of the rod at the transition region in a plane extending in a longitudinal axis of the rod is curved; **characterised in that:** a curvature of the transition region axially closest to the main length section or the shoulder comprises a first radius of curvature that is less than a second radius of curvature of the outer surface at the transition region axially closest to the threaded section.

[0008] Within the specification, reference to 'curvature' encompasses a smooth or gradual change in surface profile and a plurality of sequential linear increases (or decreases) in diameter that collectively may be regarded as a 'curved' shape profile. For example, the term 'curvature' encompasses relatively small linear step changes such that an edge or middle region of each step may be

considered to collectively define a curve.

[0009] Preferably, the rod comprises a shoulder projecting radially from the main length section wherein an outside diameter of the shoulder is greater than an outside diameter of the main length section and the transition region of the shank. Such a configuration allows for the conventional '*shoulder contact*' coupling between the male spigot and the female sleeve that is preferred over the alternative '*bottom contact*' due to the larger diameter and surface area contact between the rod ends at the region of the male and female parts.

[0010] Preferably, a side surface of the shoulder that is in contact with the transition region comprises an annular radially outer region that is aligned substantially perpendicular to the longitudinal axis. The curved transition region therefore does not continue over the full radial length of the annular side surface to provide a flat annular surface for contact by the annular end face of the female sleeve.

[0011] Optionally, a cross sectional shape profile of the outer surface of the transition region in the plane of the longitudinal axis comprises a segment of an ellipse. Optionally, the segment is substantially one quarter of a perimeter of the ellipse. The utilisation of an elliptical segment profile (in the axial direction from the threaded section) provides a gradual cross sectional area increase (over the initial region of the transition closest to the threaded section) and a more rapidly increasing diameter or cross sectional area within a second region of the transition coaxially closest to the main length section or shoulder.

[0012] Optionally, a cross sectional shape profile of the outer surface of the transition region in the plane of the longitudinal axis comprises a polynomial. Optionally, the profile corresponds to a second degree parabola. The present transition configuration also provides that the transition region begins at an axial position close to the threaded section such that at least half or a majority of the axial length of the non-threaded shank comprises a diameter or cross sectional area that increases in a direction towards the main length section or shoulder. Optionally, an axial length of the transition region is substantially equal to an axial length of the shank at a region axially between the transition region and the threaded section. Optionally, an axial length of the outer surface of the transition region having the first radius of curvature is greater than an axial length of the outer surface of the transition region having the second radius of curvature. Optionally, an outside diameter of the shank axially between the threaded section and the transition region is substantially equal to an outside diameter of the main length section. Optionally, an outside diameter of the shank is at least equal to an outside diameter of the main length section along a full axial length of the shank axially between the threaded section and the main length section or the shoulder.

[0013] Optionally, the threaded section comprises at least one axially extending helical ridge and groove,

wherein an outside diameter of the shank axially between the threaded section and the transition region is substantially equal to an outside diameter of the threaded section at an axial and a radial position corresponding to the ridge of the threaded section. Optionally, the threaded section comprises a plurality of threads formed as a double or triple helix etc. Such configurations can be selected to achieve a desired threaded profile having desired mechanical and physical properties.

[0014] Optionally, a cross sectional area of the shank is at least equal to a cross sectional area of the main length section in a plane perpendicular to the longitudinal axis over a full axial length of the shank between the threaded section and the main length section or the shoulder. Accordingly, the shank is configured to be robust during bending moments and tensile loads and to avoid creation of stress concentrations resultant from changes in diameter along the length of the rod.

[0015] Preferably, the first end comprises a female hollow portion having an internal threaded section to engage with the threaded section of the male spigot portion of a neighbouring rod of the drill string. Preferably, an internal diameter of the threaded section of the female portion is substantially equal to an outside diameter of the main length section. The present coupling therefore provides a region that is enlarged in diameter and cross sectional area (perpendicular to the longitudinal axis of the rod) relative to the elongate hollow main length section.

[0016] According to a second aspect of the present invention there is provided a drill string comprising a drill string rod as claimed herein.

Brief description of drawings

[0017] A specific implementation of the present invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

Figure 1 is an external view of a drill string formed from a plurality of elongate drill rods connected end-to-end by cooperating male and female threaded couplings according to a specific implementation of the present invention;

Figure 2 is an external side view of the drill rod end of figure 1 at the region of the male coupling according to a specific implementation of the present invention;

Figure 3 is a magnified view of a shank part of the male coupling of figure 2;

Figure 4 is an external perspective view of the shank region of figure 3.

Detailed description of preferred embodiment of the invention

[0018] Referring to figure 1, a drill string comprises a plurality of interconnected drill string rods 100. Each rod 100 comprises a main length section 101 having a first end 105 and a second end 106. An outside diameter of the main length section 101 increases at each end 105, 106 to form a radially flared end coupling region 103, 104 respectively. A part of each coupling region 103, 104 comprises a threaded portion to allow the regions 103, 104 to engage one another and form a secure threaded coupling 102 to interconnect a plurality of rods 100 to form the drill string. In particular, male end 103 comprises an annular shoulder 110 from which projects axially a male spigot 108. Spigot 108 is divided axially into an endmost threaded section 107 and a non-threaded shank 109 positioned axially intermediate threaded section 107 and shoulder 110. An internal bore 113 extends axially through main length section 101 and spigot 108 of uniform internal diameter. Female end 104 comprises a hollow sleeve 111 having cooperating threads 112 formed at the internal surface of the sleeve 111 so as to cooperate with the threaded turns of the male threaded section 107. When the male and female ends 103, 104 are coupled, an axially endmost annular surface 115 of the female sleeve 111 abuts against shoulder 110 such that an annular end face 114 of male spigot 108 is housed fully within sleeve 111.

[0019] Referring to figure 2, the tubular main length section 101 comprises a cylindrical external surface 200 that is flared radially outward at shoulder 110 to provide a annular concave region 201 that terminates at a cylindrical surface 202 located at shoulder 110. A diameter and cross sectional area of surface 202 in a plane perpendicular to axis 204 is accordingly greater than a corresponding diameter or cross sectional area (in a parallel plane) of main length surface 200. Shoulder 110 in particular cylindrical surface 202 is terminated at the spigot side by an annular side surface 203 aligned perpendicular to axis 204. Spigot 108 projects axially from a radially inward region of surface 203 and is aligned coaxial with main length section 101 and the annular shoulder 110. As illustrated in figure 1, spigot 108 comprises a generally tubular configuration such that an internal diameter of the bore within the spigot 108 is equal to the internal diameter of the bore 113 extending through main length section 101.

[0020] Threaded section 107, according to the specific implementation, comprises a pair of helical turns 209 that extend axially from shank 109 to spigot end 114. In particular, a pair of helical ridges 207 and troughs 208 extend axially over section 107. The non-threaded shank 109 may be divided axially into a first length part 205, positioned axially closest to threaded section 107, and a second length part 206, positioned axially closest to side surface 203. A combined axial length of the parts 205, 206 is greater than an axial length of shoulder surface

202 but less than an axial length of threaded section 107. An external surface of length part 205 is substantially parallel to axis 204 whilst the external surface of length part 206 tapers radially outward in a direction from threaded section 107 to contact against annular side surface 203. Accordingly, a diameter or cross sectional area of part 205 is less than a diameter or cross sectional area of part 206. Additionally, a diameter or cross sectional area of part 205 is approximately equal to a diameter or cross sectional area of the threaded section 107 at an axial and radial position corresponding to the radially outermost part of peak 207.

[0021] Referring to figures 2 to 4, length part 206 may be considered a transition region between spigot 108 and the annular shoulder 110. As illustrated in figure 3, the transition region 206 is further divided axially into a first transition 300, axially closest to threaded section 107, and a second transition 301 axially closest to side surface 203. A diameter and cross sectional area of the first transition 300 increases from length part 205 such that the external surface profile of first transition 300 in a plane along axis 204 is curved according to a gradual curvature having a relatively large radius. In contrast, the second transition 301 comprises a corresponding cross sectional shape profile in the same plane that is curved relatively steeply and with a relatively smaller radius of curvature. Accordingly, the rate of change of the diameter and cross sectional area increases significantly when passing from the first transition 300 and extending along the second transition 301. According to the specific implementation, the surface profile of the transition region 206 between length part 205 and shoulder 110 corresponds to a quarter segment of a perimeter of an ellipse. According to further specific implementations, a curvature over transition region 206 may correspond to a polynomial and in particular a double parabola.

[0022] As illustrated in figure 3, an axial length of second transition 301 is less than that of first transition 300. The configuration of transition region 206 provides that the diameter of shank 109 starts to increase at a greater axial distance from shoulder 110 with respect to conventional threaded spigot embodiments. The increased axial length of the transition region 206 together with the plurality of sub-transition regions 300, 301 (having different or non-uniform curvature in the axial direction) provides a male coupling end exhibiting enhanced stiffness and that is more resilient to bending moments and tensile forces with respect to conventional couplings. Additionally, transition region 206 is configured to eliminate or at least minimise stress concentrations at the region where spigot 108 projects axially from shoulder 110.

[0023] According to further specific implementations, transition region 206 may comprise a frusto conical configuration or a combination of frusto conical sections and curved sections with respect to the outside surface shape profile in the plane parallel to axis 204.

Claims

1. A drill string rod to form a part of a drill string, the rod (100) comprising:

an elongate hollow main length section (101) extending axially between a first end (105) and a second end (106);
 a male spigot portion (108) provided at the second end (106) having an externally threaded section (107) and a non-threaded shank (109) positioned axially intermediate the main length section (101) and the threaded section (107);
 the shank (109) having a transition region (206) positioned adjacent the main length section (101) or a radially projecting shoulder (110) at the second end (106), the transition region (206) having an outside diameter that increases in a direction from the spigot portion (108) to the main length section (101) or the shoulder (110);
 wherein a cross sectional profile of an outer surface of the rod (100) at the transition region (206) in a plane extending in a longitudinal axis of the rod (100) is curved;

characterised in that:

a curvature of the transition region (206) axially closest to the main length section (101) or the shoulder (110) comprises a first radius of curvature that is less than a second radius of curvature of the outer surface at the transition region (206) axially closest to the threaded section (107).

2. The rod as claimed in claim 1 comprising a shoulder (110) projecting radially from the main length section (101) wherein an outside diameter of the shoulder (110) is greater than an outside diameter of the main length section (101) and the transition region (206) of the shank (109).
3. The rod as claimed in claim 2 wherein a side surface (203) of the shoulder (110) that is in contact with the transition region (206) comprises an annular radially outer region that is aligned substantially perpendicular to the longitudinal axis (204).
4. The rod as claimed in any preceding claim wherein a cross sectional shape profile of the outer surface of the transition region (206) in the plane of the longitudinal axis (204) comprises a segment of an ellipse.
5. The rod as claimed in claim 4 wherein the segment is substantially one quarter of a perimeter of the ellipse.
6. The rod as claimed in any one of claims 1 to 3 wherein

a cross sectional shape profile of the outer surface of the transition region (206) in the plane of the longitudinal axis (204) comprises a polynomial.

7. The rod as claimed in any preceding claim wherein an axial length of the transition region (206) is substantially equal to an axial length of the shank (109) at a region axially between the transition region (206) and the threaded section (107).
8. The rod as claimed in any preceding claim wherein an axial length of the outer surface of the transition region (206) having the first radius of curvature is greater than an axial length of the outer surface of the transition region (206) having the second radius of curvature.
9. The rod as claimed in any preceding claim wherein an outside diameter of the shank (109) axially between the threaded section (107) and the transition region (206) is substantially equal to an outside diameter of the main length section (101).
10. The rod as claimed in any preceding claim wherein an outside diameter of the shank (109) is at least equal to an outside diameter of the main length section (101) along a full axial length of the shank (109) axially between the threaded section (107) and the main length section (101) or the shoulder (110).
11. The rod as claimed in any preceding claim wherein the threaded section (107) comprises at least one axially extending helical ridge (207) and trough (208), wherein an outside diameter of the shank (109) axially between the threaded section (107) and the transition region (206) is substantially equal to an outside diameter of the threaded section (107) at an axial and a radial position corresponding to the ridge (207) of the threaded section (107).
12. The rod as claimed in any preceding claim wherein a cross sectional area of the shank (109) is at least equal to a cross sectional area of the main length section (101) in a plane perpendicular to the longitudinal axis over a full axial length of the shank (109) between the threaded section (107) and the main length section (101) or the shoulder (110).
13. The rod as claimed in any preceding claim wherein the first end (105) comprises a female hollow portion having an internal threaded section (107) to engage with the threaded section (107) of the male spigot (108) portion of a neighbouring rod (100) of the drill string.
14. The rod as claimed in claim 13 wherein an internal diameter of the threaded section (107) of the female portion is substantially equal to an outside diameter

of the main length section (101).

15. A drill string comprising a drill string rod (100) according to any preceding claim.

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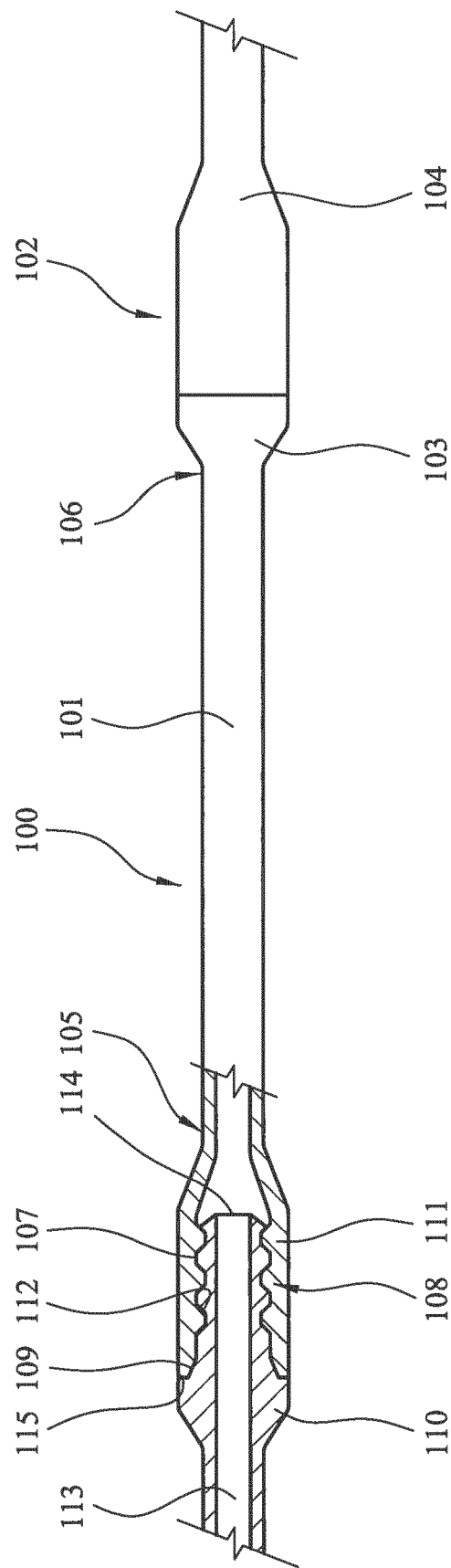


FIG. 1

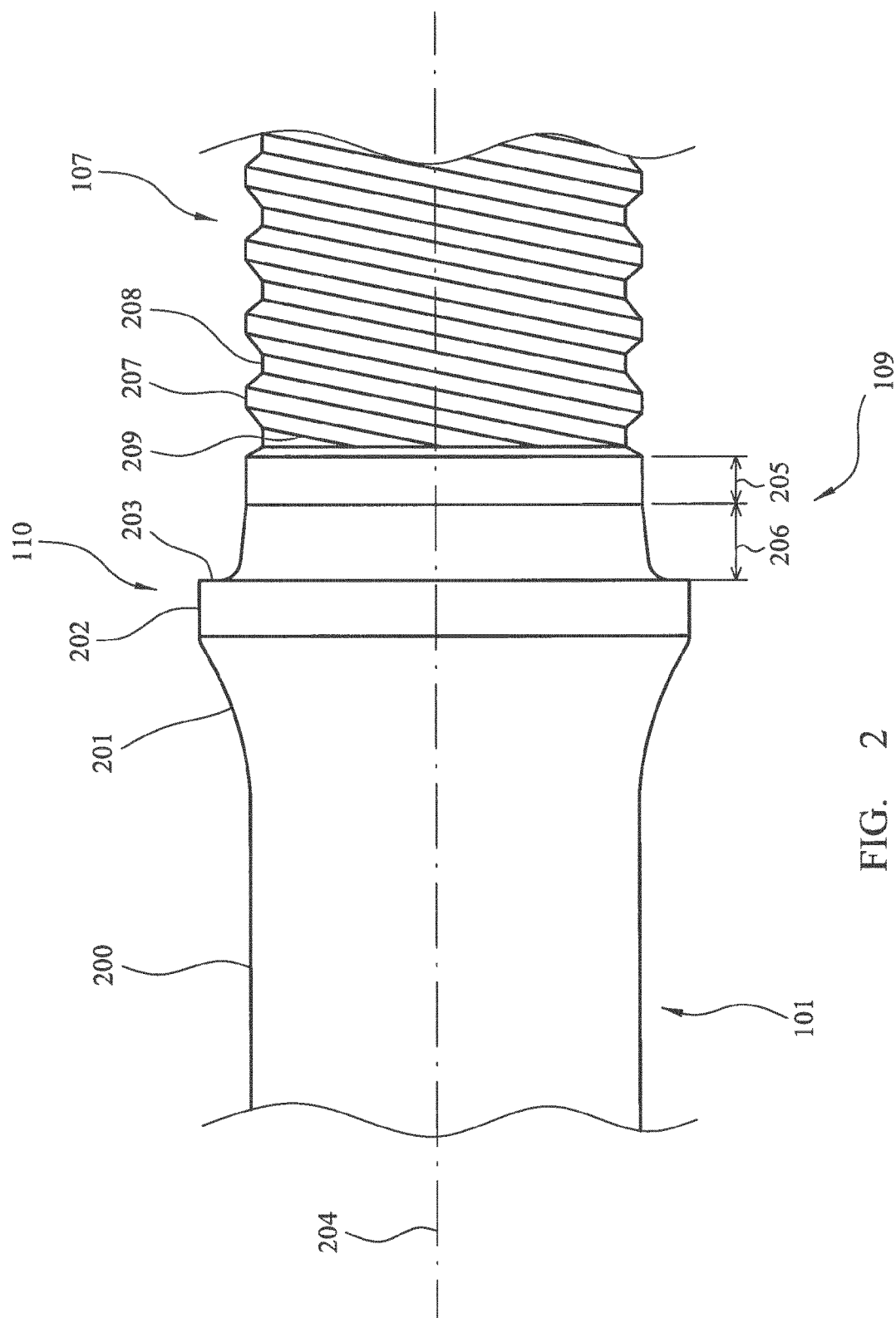


FIG. 2

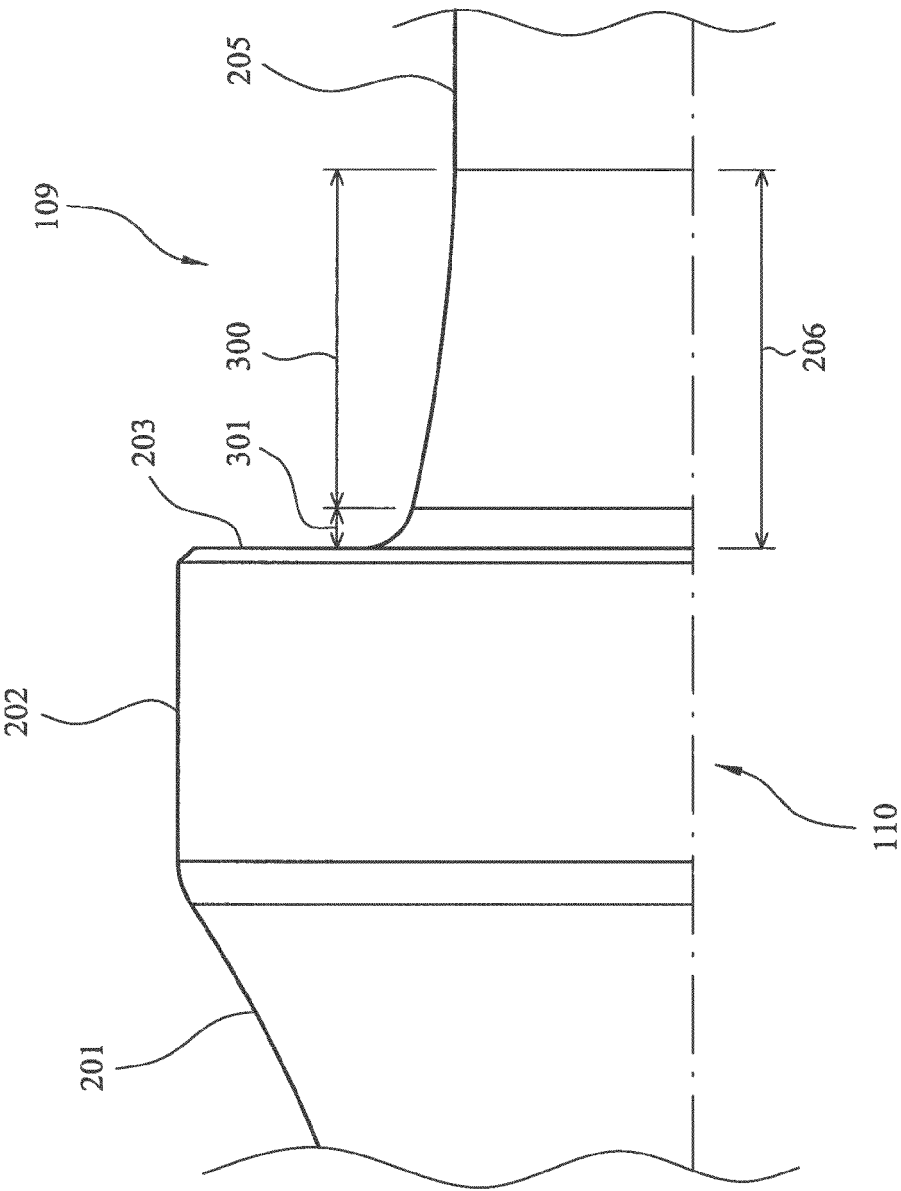


FIG. 3

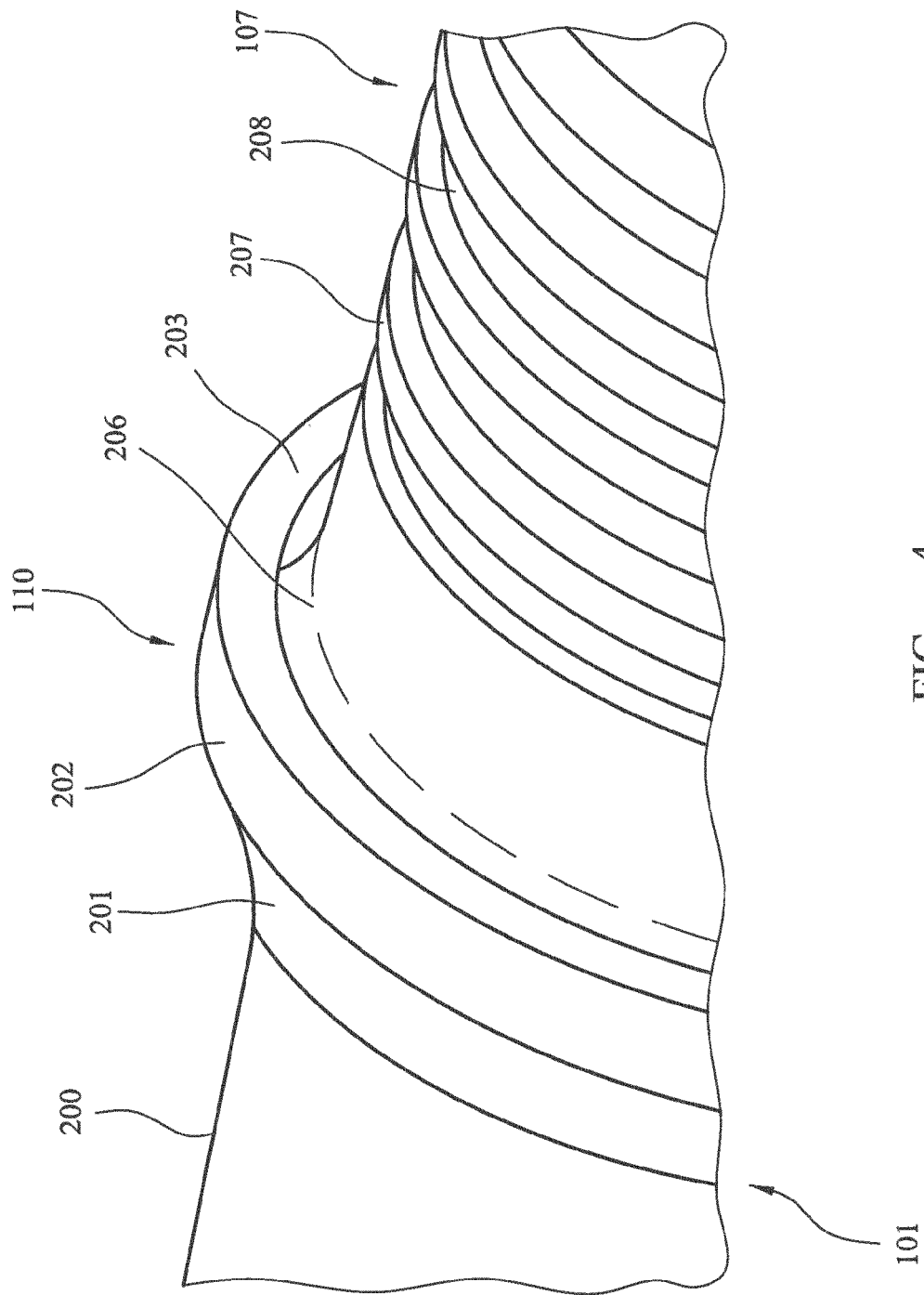


FIG. 4



EUROPEAN SEARCH REPORT

Application Number
EP 13 18 3491

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 23 January 2014	Examiner Thomas, Judith
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 13 18 3491

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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