



- (51) **International Patent Classification:**
E21B 41/00 (2006.01) *E21B 7/00* (2006.01)
E21B 17/02 (2006.01)
- (21) **International Application Number:**
PCT/US2016/012444
- (22) **International Filing Date:**
7 January 2016 (07.01.2016)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
62/101,097 8 January 2015 (08.01.2015) US
- (71) **Applicant (for CA only):** **SCHLUMBERGER CANADA LIMITED** [CA/CA]; 125 - 9 Avenue SE, Calgary, Alberta T2G 0P6 (CA).
- (71) **Applicant (for FR only):** **SERVICES PETROLIERS SCHLUMBERGER** [FR/FR]; 42 rue Saint Dominique, 75007 Paris (FR).
- (71) **Applicant (for all designated States except CA, FR, US):** **SCHLUMBERGER TECHNOLOGY B.V.** [NL/NL]; Parkstraat 83-89m, NL-2514 JG The Hague (NL).
- (71) **Applicant (for US only):** **SCHLUMBERGER TECHNOLOGY CORPORATION** [US/US]; 300 Schlumberger Drive, Sugar Land, Texas 77478 (US).
- (72) **Inventor:** **EKAMBARAM, Raju**; Block 756, Jurong West Street 74, #10-62, Singapore 640756 (SG).
- (74) **Agents:** **STONEBROOK, Michael** et al.; 10001 Richmond Avenue, IP Administration Center of Excellence, Room 4720, Houston, Texas 77042 (US).
- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) **Title:** SHAFT FOR DOWNHOLE EQUIPMENT

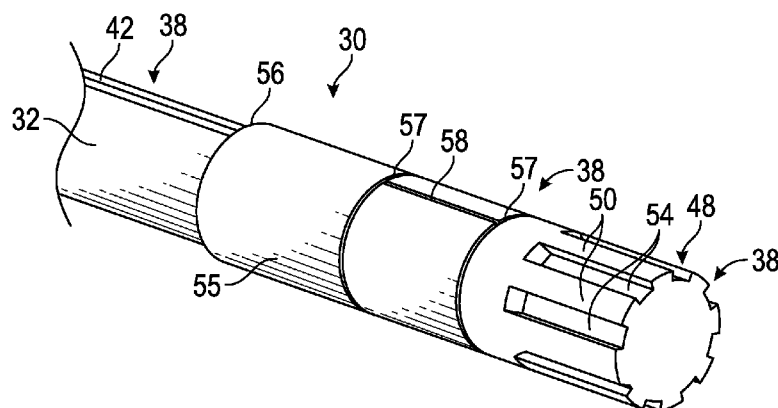


FIG. 5

(57) **Abstract:** A technique facilitates coupling of a shaft, e.g. a shaft used in a well application, with various driven devices without reducing the nominal diameter of the shaft. The technique utilizes a shaft comprising a main body portion having a length and a main body diameter. The main body diameter is the nominal diameter of the shaft. The shaft also comprises an engagement feature extending outwardly of the main body portion. The engagement feature has a diameter greater than the main body diameter and may be used for coupling to a driven device or devices without reducing the nominal diameter of the shaft.



Published:

— *with international search report (Art. 21(3))*

PATENT APPLICATION

SHAFT FOR DOWNHOLE EQUIPMENT

DOCKET NO.: IS14.8526-WO-PCT

INVENTORS: Raju Ekambaram

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present document is based on and claims priority to U.S. Provisional Application Serial No.: 62/101,097, filed January 8, 2015, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Many tools used in downhole applications make use of shafts to transfer power from one section to another for various functionalities. In electric submersible pumping systems, for example, shafts may serve several functions related to torque transfer, downthrust transfer, rotation of devices, and/or other functions. The shaft may be attached to other components, such as impellers, journal bearings, couplings, thrust bearings, and rotor laminations, which are rotated by the shaft. In many applications, these devices are affixed to the shaft, e.g. rotationally affixed to the shaft, to transfer power from the shaft to the device or devices. These types of components or other devices may be affixed to the shaft by arresting one or more degrees of freedom via

techniques involving machining into a nominal diameter of the shaft. For example, keyways, grooves, slots, and other features may be machined into the nominal diameter of the shaft and used with square keys, two-piece rings, or snap rings to secure the device to the shaft. However, the reduction of nominal shaft diameter and/or the removal of material from the nominal diameter of the shaft can detrimentally affect the power handling capacity of the shaft.

SUMMARY

[0003] In general, a technique enables coupling of a shaft, e.g. a shaft used in a well application, with various driven devices without reducing the nominal diameter of the shaft. The technique utilizes a shaft comprising a main body portion having a length and a main body diameter which is the nominal diameter of the shaft. The shaft also comprises an enlarged portion having an engagement feature extending outwardly of the main body portion. The engagement feature has a diameter greater than the main body diameter and may be used for coupling to a driven device or devices without reducing the nominal diameter of the shaft.

[0004] However, many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0006] Figure 1 is a schematic illustration of an example of a well system comprising a shaft coupled with a device to enable rotation of the device within a surrounding housing, according to an embodiment of the disclosure;

[0007] Figure 2 is an illustration of an example of a shaft having an enlarged engagement feature, according to an embodiment of the disclosure;

[0008] Figure 3 is an illustration of another example of a shaft having an enlarged engagement feature, according to an embodiment of the disclosure;

[0009] Figure 4 is an illustration of another example of a shaft having an enlarged engagement feature, according to an embodiment of the disclosure; and

[0010] Figure 5 is an illustration of another example of a shaft having an enlarged engagement feature, according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0011] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0012] The present disclosure generally relates to a system and methodology which facilitate coupling of a shaft, e.g. a shaft used in a well application, with various driven devices without reducing the nominal diameter of the shaft. For example, the technique may be used to couple driven pumping system devices to a shaft in an electric submersible pumping system. By way of specific example, the technique may be used to

couple impellers to a shaft (in a rotational direction) within a submersible pump of an electric submersible pumping system.

[0013] The technique utilizes a shaft comprising a main body portion having a length and a main body diameter which is the nominal diameter of the shaft. The shaft also comprises an enlarged shaft portion having an engagement feature extending outwardly of the main body portion. The engagement feature has a diameter greater than the main body diameter and may be used for coupling to the driven device or devices to the shaft without reducing the nominal diameter of the shaft. In other words, the enlarged engagement feature can be used to eliminate the use of keyways, grooves, or other features milled or otherwise formed into the nominal diameter of the shaft.

[0014] Embodiments described herein also increase the horsepower rating of a shaft by way of integral shaft features used to locate components and/or transmit loads. The integral shaft features, e.g. enlarged engagement features, enable power transmission via the shaft without reducing the nominal diameter of the shaft and without removing material from within the nominal diameter of the shaft. Avoidance of such material removal (and thus avoidance of the corresponding reduction in nominal shaft diameter) effectively removes the tendency to concentrate stresses at the reduced diameter features. The concentration of stresses can lead to detrimental consequences such as reduction in power capacity of the shaft or mechanical failure of the shaft.

[0015] In some embodiments, the integral features may be formed by selective removal of material from a work piece initially having a larger diameter than the desired nominal diameter of the shaft. The selective removal of material effectively leaves portions of material extending outwardly beyond the nominal diameter of the completed shaft for engagement with a device or devices rotated by the shaft. This technique may be used to manufacture shafts which maintain material homogeneity throughout the shaft, including the integral features extending outwardly from the nominal shaft diameter. It should be noted the portions extending radially outwardly from the nominal diameter can

be used for location of components as well as for load bearing/carrying of engaged devices.

[0016] By way of further example, the integral features of the shaft may be formed using various other manufacturing techniques, including additive manufacturing techniques. Additive manufacturing techniques may be applied to add material to an initial shaft portion of nominal diameter by, for example, welding and/or cladding. The material is built-up or affixed to the nominal diameter shaft portion so as to extend radially outwardly to a diameter greater than the nominal shaft diameter. In some embodiments, subsequent operations may be performed to finish the shaft through, for example, polishing and/or heat treating. The integral features, e.g. the enlarged engagement features, may be formed of the same material as the nominal diameter portion of the shaft. However, the integral features also may be formed from or may comprise a different material than the material used to construct the nominal diameter portion of the shaft.

[0017] Referring generally to Figure 1, an example of a system 20 is illustrated as being used in a well. By way of example, the system 20 may comprise a well tool 22 sized for deployment in a wellbore 24. The well tool 22 may comprise a variety of well tools, including electric submersible pumping system components such as submersible motors, submersible pumps, and/or other components. In the specific example illustrated, the well tool 22 comprises a housing 26, e.g. a submersible pump housing, and at least one device 28 rotatable within the housing 26. In the submersible pump example, the at least one device 28 may comprise a plurality of impellers rotated within the pump housing 26. As illustrated, a shaft 30 is coupled with the at least one device 28 to rotate the at least one device 28 within the housing 26. The shaft 30 may comprise a variety of integral features, e.g. thicker or enlarged shaft portions, for engaging the at least one device 28 without reducing the nominal diameter of the shaft as described in greater detail below with reference to Figures 2-5.

[0018] Referring generally to Figure 2, an embodiment of shaft 30 is illustrated. In this example, the shaft 30 comprises a main body portion 32 having a given length 34 and a main body diameter 36. The main body diameter 36 is the nominal diameter of the shaft 30 and establishes the minimum diameter along the shaft 30. The shaft 30 further comprises a thicker or enlarged shaft portion 38 which creates a shaft diameter 40 greater than the main body diameter 36. The thicker/enlarged shaft portion 38 is used to engage the device or devices 28 and thus to mount the device(s) 28 to shaft 30. For example, the enlarged shaft portion 38 may be used to rotationally affix the device or devices 28 with respect to shaft 30.

[0019] In the embodiment illustrated in Figure 2, the enlarged shaft portion 38 is established by a key 42 which may be in the form of an integral key feature extending outwardly, e.g. radially outwardly, from main body portion 32 of shaft 30. The key 42 has a height or radial dimension as well as an axial length dimension and a circumferential dimension. The axial length dimension may be generally parallel with a longitudinal axis 44 of shaft 30 and the circumferential dimension extends circumferentially along the exterior of main body portion 32. In the example illustrated, key 42 has a substantially greater axial dimension compared to the circumferential dimension. The height, axial, and circumferential dimensions of key 42 may be selected according to the parameters of a given application for engagement with corresponding features of device(s) 28.

[0020] In some applications, the key 42 may extend along the entire length of shaft 30 and may run generally parallel with the longitudinal axis 44. However, the key 42 also may be constructed to be present along a portion of shaft 30, e.g. extending along a half or a quarter of the length of shaft 30. The key 42 also may be an intermittent or discontinuous feature or may comprise a plurality of key features arranged in a desired pattern along the main body portion 32. For example, the key 42 may be arranged as a plurality of key features angularly offset from each other such that they are not co-linear. The key or keys 42 are engagement features which can be very useful for mounting a variety of devices 28, e.g. impellers, along shaft 30.

[0021] Referring generally to Figure 3, another embodiment of shaft 30 is illustrated. In this example, the enlarged shaft portion 38 has a greater circumferential dimension than the axial dimension and, in some applications, may extend around the entire circumference of main body portion 32. By way of example, the enlarged shaft portion 38 may be in the form of a step feature 46 which may be affixed to or integrally formed with main body portion 32. The step feature 46 is disposed along an exterior of the main body portion 32 and extends, e.g. projects, outwardly from the main body portion 32 with a height dimension, axial dimension, and circumferential dimension selected according to the parameters of a given application.

[0022] In some embodiments, the step feature 46 is in the form of a ring or band disposed about the main body portion 32 of shaft 30 to establish the greater diameter 40 relative to the nominal, main body diameter 36. The step feature 46 may be continuous or discontinuous about the circumference of main body portion 32. The step feature 46 also may be a singular step feature or a plurality of step features arranged at different axial positions along shaft 30. As with engagement feature 42, the step feature or features 46 provide engagement features which can be very useful for mounting a variety of devices 28, e.g. a thrust bearing, along shaft 30.

[0023] Referring generally to Figure 4, another embodiment of shaft 30 is illustrated. In this example, the enlarged shaft portion 38 is in the form of a splined section 48 having at least one spline 50 extending radially outwardly from the main body portion 32. As illustrated, the splined section 48 may comprise a plurality of splines 50 oriented, for example, in a generally axial direction. The splined section 48 establishes the diameter 40 which is greater than the nominal, main body diameter 36. However, the splined section 48 also establishes a root diameter 52 which is the diameter measured across shaft 30 between recessed portions 54 established between splines 50. The root diameter 52 is less than diameter 40 but often equal to or greater than the nominal, main body diameter 36. In some applications, however, the root diameter 52 may be smaller

than the nominal diameter 36 and still achieve an improved torque rating with respect to shaft 30.

[0024] In the example illustrated, the splined section 48 is located on a thicker portion 55 which has a transition 56. In some embodiments, the transition 56 provides a smoothly continuous linear slope between the exterior of main body portion 32 and the radially outer surface of splined section 48. However, the transition 56 also may be in the form of a continuous surface perpendicular to the longitudinal axis 44 of shaft 30. It should be noted that other types of enlarged shaft portions 38, e.g. key 42 or step feature 46, also may have sloped or perpendicular surfaces extending between the exterior of main body portion 32 and the outer surface of the enlarged shaft portion 38. The splined section 48 provides an engagement feature which can be very useful for mounting a variety of devices 28 and/or for coupling with other shaft sections.

[0025] Referring generally to Figure 5, another embodiment of shaft 30 is illustrated. In this example, the shaft 30 utilizes a plurality of engagement features on the at least one enlarged shaft portion 38. As illustrated, the shaft 30 may establish at least one enlarged shaft portion 38 via thicker portion 55 having the desired transition 56 extending to the main body portion 32. The thicker portion 55 may comprise a plurality of engagement features, e.g. splined section 48 and a groove or grooves 57, e.g. circumferential grooves 57. The plurality of engagement features on thicker portion 55 also may comprise at least one groove/keyway 58, such as the illustrated keyway 58 extending between grooves 57. The grooves 57, 58 may be machined or otherwise formed in the thicker portion 55 to facilitate mounting and securing of components to the shaft 30 while still maintaining the nominal shaft diameter torque rating. In the example illustrated, the shaft 30 also includes additional engagement features, such as key 42 extending longitudinally along the main body portion 32.

[0026] As described above, the various engagement features establish the desired greater diameter or diameters 40 relative to the nominal, main body diameter 36. Additionally, the engagement features 42, 46, 48, 57, 58 may each have a desired height

dimension, axial dimension, and circumferential dimension independently selected according to the parameters of a given application. As described above, the engagement features may be formed as single features or as a plurality of features disposed in desired patterns along the shaft 30.

[0027] Additionally, the splines 50 may be arranged in desired patterns, e.g. the splines 50 may be arranged generally parallel with longitudinal axis 44. Depending on the application, the spline or splines 50 also may be involute, crowned, serrated, helical, and/or formed in other patterns or with other features. Additionally, the diameter across shaft 30 between splines 50 may be equal to or different than, e.g. less than, the diameter of thicker portion 55. The thicker portion 55 also may utilize the groove or grooves 57, 58 to secure a desired device(s) 28, e.g. retaining rings and a corresponding sleeve, to shaft 30.

[0028] Depending on the application, the shaft 30 may have a variety of shapes and/or features. For example, the shaft 30 may comprise at least one enlarged shaft portion 38 with an individual engagement feature. Or, the enlarged shaft portions 38 each may comprise a plurality of cooperating engagement features. The length, diameter, horsepower rating, and/or other characteristics of main body portion 32 may be selected according to the parameters of a given application.

[0029] Similarly, the engagement features 42, 46, 48, 57 and/or 58 may be constructed for engagement with corresponding features of a variety of devices 28, e.g. impellers, journal bearings, couplings, thrust bearings, rotor laminations, and/or other devices which cooperate, e.g. are rotated, with the shaft 30. Some engagement features, e.g. engagement features 42, 46, and/or 48, may be integrally formed with the main body portion 32 or may be attached to the main body portion 32 by a suitable additive technique, e.g. welding. The engagement features also may be formed of the same material or a different material relative to the material used to form main body portion 32. The shaft 30 may be used in well tools or in a variety of other tools in which the shaft 30 is engaged with cooperating, e.g. driven, devices.

[0030] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

CLAIMS

What is claimed is:

- 1 1. A system for use in a well, comprising:
2
3 a well tool sized for deployment in a wellbore, the well tool having:
4 a housing;
5 a device rotatable within the housing; and
6 a shaft coupled to the device to rotate the device within the
7 housing, the shaft having: a main body portion with a given length and a
8 main body diameter; and an enlarged shaft portion having a diameter
9 greater than the main body diameter, the enlarged shaft portion engaging
10 the device to secure the device to the shaft during rotation of the device.

- 1 2. The system as recited in claim 1, wherein the enlarged shaft portion comprises a
2 key extending outwardly from the main body portion and along at least a portion
3 of the length of the main body portion, the key having a height dimension and a
4 circumferential dimension.

- 1 3. The system as recited in claim 2, wherein the key extends the entire length of the
2 main body portion.

- 1 4. The system as recited in claim 2, wherein the key is discontinuous.

- 1 5. The system as recited in claim 2, where the key extends parallel to a longitudinal
2 axis of the main body portion.

- 1 6. The system as recited in claim 1, wherein the enlarged shaft portion extends
2 circumferentially at least partially about the main body portion.

- 1 7. The system as recited in claim 6, wherein the enlarged shaft portion extends
2 circumferentially around the entire main body portion.
1
- 1 8. The system as recited in claim 1, wherein the enlarged shaft portion comprises at
2 least one surface perpendicular to a longitudinal axis of the main body portion.
1
- 1 9. The system as recited in claim 1, wherein the enlarged shaft portion comprises a
2 spline section.
1
- 1 10. A system, comprising:
2
3 a shaft comprising:
4 a main body portion having a length and a main body diameter
5 which is a minimum diameter of the shaft; and
6 an engagement feature extending outwardly from the main body
7 portion, the engagement feature having a diameter greater than the main
8 body diameter.
- 1 11. The system as recited in claim 10, further comprising a device rotated by the
2 shaft, the device being coupled with the engagement feature.
- 1 12. The system as recited in claim 10, wherein the engagement feature comprises a
2 step.
- 1 13. The system as recited in claim 10, wherein the engagement feature has a
2 circumferential dimension greater than an axial dimension.
- 1 14. The system as recited in claim 10, wherein the engagement feature has an axial
2 dimension greater than a circumferential dimension.
1

- 1 15. The system as recited in claim 10, wherein the engagement feature has at least
2 one surface perpendicular to a longitudinal axis of the main body portion.
- 1 16. The system as recited in claim 10, wherein the engagement feature comprises a
2 plurality of splines oriented generally axially with respect to the main body
3 portion.
- 1 17. The system as recited in claim 10, wherein the engagement feature and the main
2 body portion comprise different materials.
- 1 18. A device, comprising:
2
3 a shaft having:
4 a main body portion defined with a length and a main body
5 diameter; and
6 a thicker portion having an outer diameter greater than the main
7 body diameter, the thicker portion comprising a spline feature having
8 splines extending radially between a root diameter and the outer diameter.
- 1 19. The device as recited in claim 18, wherein the shaft further comprises a transition
2 between the main body portion and the thicker portion, wherein the transition
3 comprises at least one surface perpendicular to a longitudinal axis of the main
4 body portion.
- 1 20. The device as recited in claim 18, wherein the shaft comprises a key extending
2 outwardly from the main body portion.

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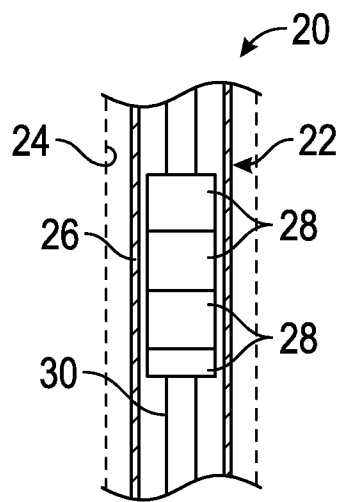


FIG. 1

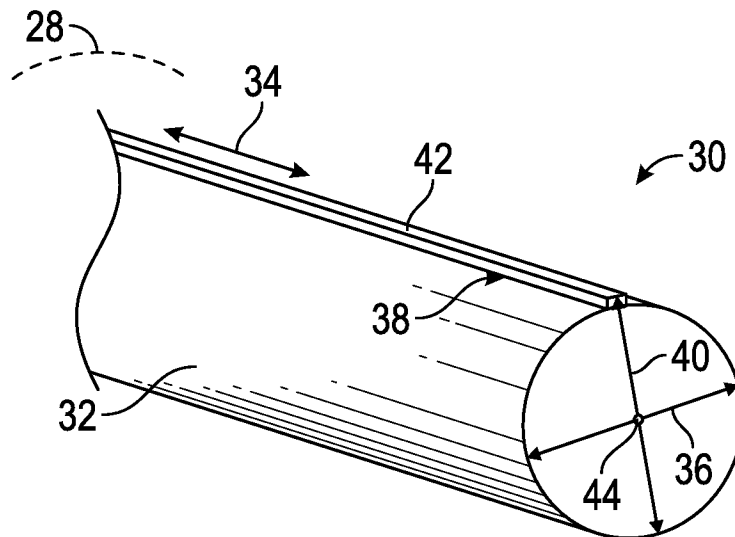


FIG. 2

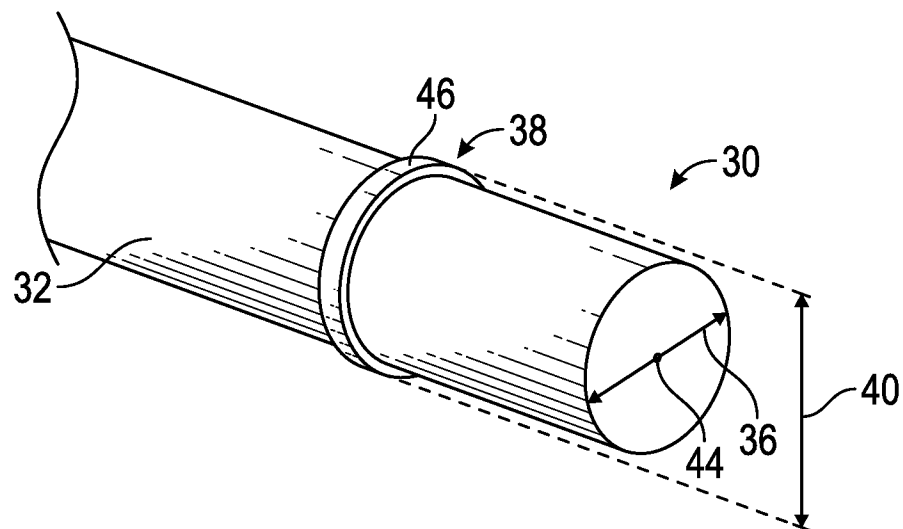


FIG. 3

2/2

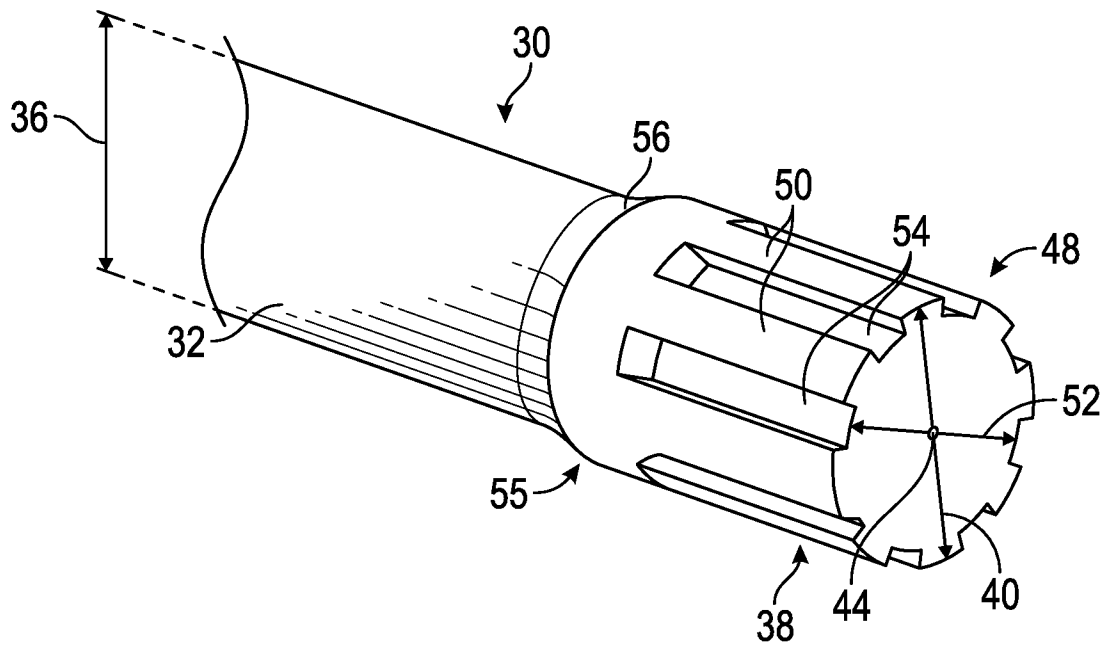


FIG. 4

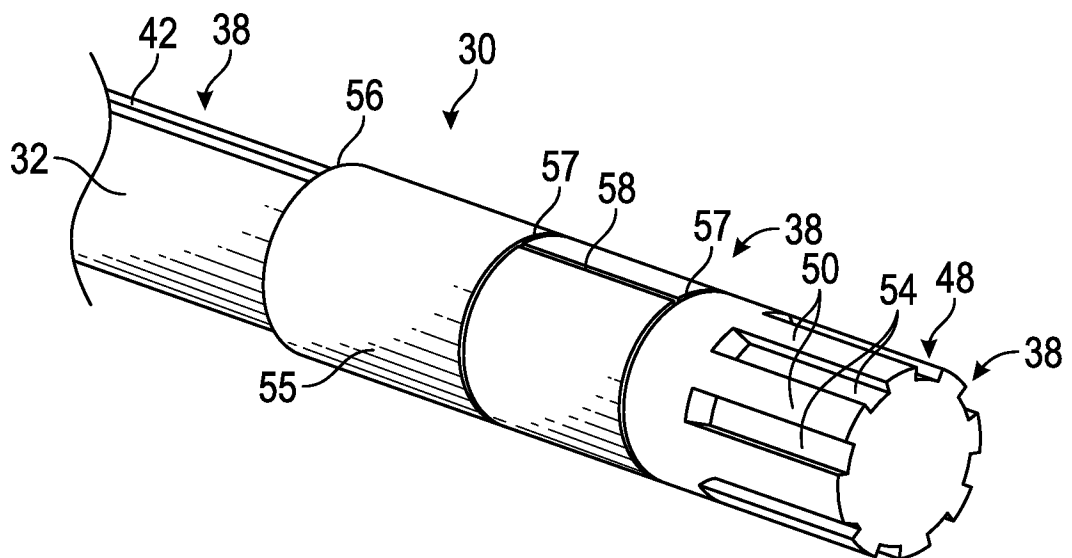


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/012444**A. CLASSIFICATION OF SUBJECT MATTER****E21B 41/00(2006.01)i, E21B 17/02(2006.01)i, E21B 7/00(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 41/00; E21B 7/00; E21B 4/02; F01C 3/00; E21B 19/16; F04B 53/00; F04B 17/03; E21B 17/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: shaft, housing, device, diameter, engagement feature, enlarge, wellbore, body, main, system, rotate, portion and length

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005-0279513 A1 (EPPINK, JAY MILTON) 22 December 2005 See paragraphs [0019]-[0023] and figures 2-4.	10, 13-17
Y		1-9, 11-12, 18-20
Y	US 2014-0079574 A1 (BRUNNER et al.) 20 March 2014 See paragraphs [0004]-[0023] and figures 2-4.	1-9, 11-12, 18-20
A	US 7004730 B1 (WILLIAMS, KEVIN R.) 28 February 2006 See column 4, line 58-column 6, line 57 and figures 1-10.	1-20
A	US 2004-0112642 A1 (KRUEGER et al.) 17 June 2004 See paragraphs [0033]-[0096] and figures 1A-11.	1-20
A	US 2014-0332275 A1 (SMITH INTERNATIONAL, INC.) 13 November 2014 See paragraphs [0024]-[0069] and figures 1-16.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

06 April 2016 (06.04.2016)

Date of mailing of the international search report

08 April 2016 (08.04.2016)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

LEE, Hun Gil

Telephone No. +82-42-481-8525



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/012444

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/012444

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