(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 June 2016 (16.06.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/091967 A1

(51) International Patent Classification:
E21B 43/10 (2006.01)

(21) International Application Number:
PCT/EP2015/079155

(22) International Filing Date:
9 December 2015 (09.12.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
14197684.5 12 December 2014 (12.12.2014) EP

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(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).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

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

(54) Title: METHOD AND SYSTEM FOR INSTALLING A TUBULAR ELEMENT IN A BOREHOLE

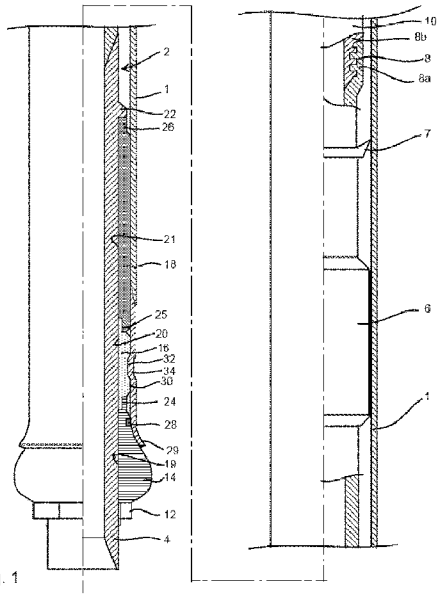


Fig. 1

(57) Abstract: A radially expandable tubular element (1) is installed in an underground borehole by: - lowering the tubular element (1) into the borehole from a work string (2) and an anchor tool (16) to which the tubular element (1) is connected via a dimple connection (32) to increase the weight carrying capacity of the anchor tool (16); - connecting an expander (14) to the work string (2) at a position below the anchor tool (16); and - radially expanding the tubular element (1) by pulling the expander (14) on the work string (2) through the tubular element (1).

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METHOD AND SYSTEM FOR INSTALLING A TUBULAR ELEMENT IN A BOREHOLE

The present invention relates to a system and a method for installing a tubular element in a borehole extending into an earth formation

Wellbores for the production of hydrocarbon fluid generally are provided with steel casings and/or liners to provide stability to the wellbore wall and to prevent undesired flow of fluid between the wellbore and the surrounding earth formation. A casing generally extends from surface into the wellbore, whereas a liner may extend only a lower portion of the wellbore. However in the present description the terms “casing” and “liner” are used interchangeably and without such intended difference.

In a conventional wellbore, the wellbore is drilled in sections whereby each section is drilled using a drill string that has to be lowered into the wellbore through a previously installed casing. In view thereof the wellbore and the subsequent casing sections decrease in diameter with depth. The production zone of the wellbore therefore has a relatively small diameter in comparison to the upper portion of the wellbore. In view thereof it has been proposed to drill a “mono diameter” wellbore whereby the casing or liner to be installed is radially expanded in the wellbore after lowering to the required depth. Subsequent wellbore sections may therefore be drilled at a diameter larger than in the conventional wellbore. If each casing section is expanded to the same diameter as the previous section, the wellbore diameter may remain substantially constant with depth.

US-2006/0065403-A1 discloses an assembly for expanding a tubular element in a wellbore, whereby the tubular element is suspended during running-in into the wellbore on a work string having an expander at its lower end, and whereby the tubular element passes through an existing casing in the wellbore. There is a risk that the lower end of the tubular element is prematurely expanded by the expander, for example if the weight of the tubular element causes the tubular element to slip downward relative to the work string. Such unintended expansion may hamper, or prevent, lowering of the tubular element through the existing casing.

Other prior art anchoring systems are known from US patent applications 2007/000669; 2008/041596 and 2006/196654 and International patent application WO/196654, which have the risk that the tubular element unintentially slips down and is prematurely released from the work string.

It is an object of the invention to provide an improved method and system for installing a tubular element in a borehole extending into an earth formation, which overcome or alleviate drawbacks of the prior art.

The invention provides a method of installing a radially expandable tubular element in an underground borehole comprising the steps of:

(a) positioning in the tubular element an anchor tool having a cylindrical outer surface provided with at least one dimple;

(b) operating a pressing device to press a respective wall portion of the tubular element into the at least one dimple to create a dimple connection between the tubular element and the anchor tool;

(c) providing a work string connected to the anchor tool;

(d) operating a drive device to lower the tubular element into the borehole on the work string when the tubular element is connected to the anchor tool via the dimple connection;

(e) connecting an expander to the work string at a position below the anchor tool; and

(f) radially expanding the tubular element by pulling the expander on the work string through the tubular element.

The invention also provides a system for installing a radially expandable tubular element in an underground borehole, the system comprising:

(a) an anchor tool adapted to be positioned in the tubular element and having a cylindrical outer surface provided with at least one dimple;

(b) a pressing device for pressing a respective wall portion of the tubular element opposite the at least one dimple into the dimple, to create a dimple connection between the tubular element and the anchor tool;

(c) a work string connected to the anchor tool;

(d) a drive device for lowering the tubular element into the borehole on the work string when the tubular element is connected to the anchor tool via the dimple connection;

(e) means for connecting an expander to the work string at a position below the anchor tool; and

(f) means for radially expanding the tubular element by pulling the expander on the work string through the tubular element.

According to the method and system of the invention, the weight carrying capacity of the work string is increased by virtue of the dimple connection between the tubular element and the anchor tool. The dimple connection carries at least a portion of the weight of the tubular

element during installation in the borehole. Furthermore, the dimple connection may be released easily by pulling up the work string, or pushing down the work string, through the tubular element after installation in the borehole whereby each wall portion is deformed back to substantially the original shape.

Suitably, each dimple has first and second surfaces arranged opposite each other and extending in circumferential direction of the anchor tool, said surfaces having mutually different inclination angles relative to the cylindrical outer surface. It is thereby achieved that the dimple connection has a high load carrying capacity in one axial direction and may be released easily in the other axial direction. For example, the first surface may extend at an inclination angle $\alpha 1$ and the second surface at an inclination angle $\alpha 2$ relative to the cylindrical outer surface, the first surface facing upwardly in the borehole, and wherein $\alpha 1 > \alpha 2$. Furthermore, the dimple connection may be released more easily if a rounded transition surface extends between the second surface and the cylindrical outer surface.

Suitably the dimple has a bottom surface located between said first and second surfaces, the bottom surface extending substantially parallel to a longitudinal axis of the anchor tool. To increase the torque transmission capacity of the dimple connection the bottom surface may have a truncated V-shape.

The cylindrical outer surface of the anchor tool is advantageously provided with a plurality of said dimples spaced in circumferential direction of the anchor tool.

Suitably the pressing device includes a die member having an end portion with a shape similar to the shape of the dimple. To accurately position the die member relative to the anchor tool, the pressing device may comprise

positioning means connectable to the anchor tool and adapted to move the anchor tool relative to the die member so that the dimple is located opposite the die member.

In an embodiment, the tubular element is a radially expandable tubular element and the system further comprises an expander for radially expanding the tubular element by axially moving the expander through the tubular element, the expander being connected to the work string at a position below the anchor tool.

The anchor tool may be released from the tubular element by inducing the drive device to move the work string in axial and/or rotational direction relative to the tubular element so as to deform each said wall portion to a shape substantially similar to the shape of the wall portion prior to step (2) of the method.

The invention will be described hereinafter in more detail and by way of example with reference to the accompanying schematic drawings in which:

Fig. 1 shows an exemplary embodiment of the system of the invention, partially in longitudinal section;

Fig. 2 shows a lower portion of an expansion string of the exemplary embodiment, partially in longitudinal section;

Fig. 3 shows an anchor tool of the exemplary embodiment;

Fig. 4 shows cross-section 4-4 of Fig. 3;

Fig. 5 shows a pressing device used with the exemplary embodiment;

Fig. 6 shows a perspective view of a die member of the pressing device;

Fig. 7 shows the die member after pressing a wall portion of the tubular element into a dimple of the anchor tool; and

Fig. 8 shows an alternative die member.

In the detailed description and the figures, like reference numerals relate to like components.

Figs. 1 and 2 show an assembly including a tubular element 1 adapted to be radially expanded in a wellbore (not shown) and a work string in the form of expansion string 2 for radially expanding the tubular element in the wellbore. The expansion string 2 includes from bottom to top: a mandrel 4, a far-cone centralizer 6, a debris catcher 7 and an on-off sub 8 having lower and upper parts 8a, 8b. The on-off sub 8 connects the expansion string to the lower end of a drill pipe 10 and is adapted to be disconnected by rotation of the drill pipe 10 relative to the mandrel 4.

The mandrel 4 is provided with, from bottom to top: a lock nut 12, an expander in the form of expansion cone 14, an anchor tool 16 and a near-cone centralizer 18. The expansion cone 14, the anchor tool 16 and the near-cone centralizer 18 have respective central passages 19, 20, 21 through which the mandrel 4 extends. The mandrel can slide through the passages 19 to 21.

The lock nut 12 is screwed to the mandrel 4 so as to lock the assembly of expansion cone 14, anchor tool 16 and near-cone centralizer 18 in place whereby the near-cone centralizer abuts against a shoulder 22 of the mandrel 4. Furthermore, the expansion cone 14 is rotationally locked to the anchor tool 16 by a castellated connection 24, the anchor tool 16 is rotationally locked to the near-cone centralizer 18 by a castellated connection 25, and the near-cone centralizer 18 is rotationally locked to the shoulder 22 of mandrel 4 by a castellated connection 26.

Alternatively the anchor tool 16 may be directly rotationally locked to the mandrel 4 by means of key slots formed in the anchor tool 16 and mandrel 4, with keys

fitting in such key slots. This way the castellated connections 24, 25 may be eliminated.

The expansion cone 14 has a nose portion of diameter substantially equal to the inner diameter of the unexpanded tubular element 1. The diameter of the expansion cone 14 gradually increases from the nose portion in downward direction to a diameter corresponding to a desired expansion ratio of the tubular element 1. The nose portion is provided with an annular seal 28 of resilient material. Furthermore the tubular element 1 has an outwardly flaring end section 29 adapted to receive the expansion cone 14 , with the largest outer diameter of the end section 29 being less than, or equal to, the largest outer diameter of the expansion cone 14.

The anchor tool 16 has a cylindrical outer surface 30 of diametrical size allowing the anchor tool 16 to snugly fit into the tubular element 1. A plurality of dimples 32 are formed in the cylindrical outer surface 30, the dimples being regularly spaced along the circumference of the anchor tool. At each dimple 32, a corresponding wall portion 34 of the tubular element 1 extends into the dimple 32 so as to axially and rotationally lock the anchor tool to the tubular element.

Figs. 3, 4 show the anchor tool 16 in more detail. Each dimple 32 has first and second surfaces 35a, 35b oppositely arranged and extending in circumferential direction of the anchor tool. The surfaces 35a, 35b are inclined relative to the cylindrical outer surface 33 at respective inclination angles $\alpha 1$, $\alpha 2$. A bottom surface 36 is located between the first and second surfaces 35a, 35b, which bottom surface extends substantially parallel to a longitudinal axis 37 of the anchor tool. Rounded surface portions 38a, 38b extend at the transition between the cylindrical outer surface 33

and the respective first and second surfaces 35a, 35b. The surface portions 38a, 38b have rounding radius R.

Figs. 5 to 7 show a pressing device 40 for pressing, at each dimple 32, the respective wall portion 34 of the tubular element 1 into the dimple 32 so as to create a dimple connection between the tubular element 1 and the anchor tool 16. The pressing device 40 comprises a housing 44 having a longitudinal bore 46 into which a lower section 47 of the tubular element 1 snugly fits. The pressing device 40 further comprises a die member 48 positioned in a radial bore 49 of the housing 44 in slidable manner. The die member 48 has an end portion 50 facing the tubular element 1, with inclined surfaces 52a, 52b and bottom surface 52c so as to have a shape similar to the shape of the dimple 32. The anchor tool 16 is arranged inside the tubular element 1 whereby the dimple 32 is positioned opposite the end portion 50 of die member 48. The pressing device 40 optionally further comprises a positioning assembly including a plate 53 and a cylinder 54 to be arranged inside the anchor tool 16. The cylinder 54 may be axially and rotationally locked to the anchor tool 16 by a flange abutting one end of the anchor tool and bolts 56 interconnecting the cylinder 54 and the plate 53.

Fig. 8 shows a die member 60 that is largely similar to the die member 48, except that inclined surfaces 52a, 52b do not extend parallel to each other so that bottom surface 52c has a truncated V-shape.

During normal operation the anchor tool 16 is inserted into the lower tubular section 47, and the assembly is then arranged in the longitudinal bore 46 of the pressing device 40 whereby it is ensured that the bottom surface 36 of the dimple is parallel to, and in line with, the bottom surface 52c of the die member 48. Optionally the cylinder 54, plate 53 and bolts 56 may be used to accurately position the

anchor tool 16 so that the dimple 32 is exactly opposite the die member 48.

The pressing device 40 is then operated to induce die member 48 to press the wall portion 34 of the tubular element into the dimple 32 until the inside of the wall portion 34 contacts the bottom surface 36 of the dimple. This procedure is repeated for all dimples 32 whereby each time the tubular element 1 with the anchor tool 16 inside is rotated relative to the pressing device so as to position the next dimple 32 opposite the die member 48. In this manner a dimple connection is obtained between the lower tubular section 47 and the anchor tool 16. Any suitable power source may be used to operate the pressing device, for example hydraulic power, electrical power or mechanical power. In a next step the lower tubular section 47 is removed from the pressing device 40 and the positing assembly, if used, is removed from the anchor tool 16.

The near-cone centralizer 18 is then fitted to the mandrel 4 so that the near-cone centralizer 18 abuts against shoulder 22 and is rotationally locked to the mandrel 4 by castellated connection 26. Then the anchor tool 16, with the lower tubular section 47 connected thereto, is fitted to the mandrel 4 until the anchor tool abuts the near-cone centralizer. Subsequently the expansion cone 14 is fitted to the mandrel 4 until the nose portion of the expansion cone 14 abuts the anchor tool 16. Then the lock nut 12 is screwed to the mandrel 4 so as to axially lock the expansion cone 14, the anchor tool 16 and the near-cone centralizer 18 to the mandrel 4. The mandrel 4 is then connected to the far-cone centralizer 6, the debris catcher 7 and to the lower end of drill pipe 10 via on-off sub 8 as shown in Fig. 1.

Subsequently the assembly is run into the wellbore whereby drill pipes are added to form the expansion string

2, and tubular joints are added to form the tubular element 1 in correspondence with the depth of lowering.

During running-in the assembly into the wellbore the weight of the tubular element 1 is transferred to the expansion string 2 via the dimple connection between the anchor tool 16 and the lower tubular section 47, and via the contact between the outwardly flaring end section 29 of tubular element 1 and the expansion cone 14. Rotary torque required for making-up the on-off sub 8, or for reaming the wellbore while running-in is transferred from the mandrel 4 via the castellated connection 26 to the near-cone centralizer 18, then via the castellated connection 25 to the anchor tool 16, and then via the dimple connection to the tubular element 1.

If the tubular element needs to be pushed in downward direction to overcome friction between the tubular element 1 and the wellbore wall, for example in an inclined borehole section, the required downward force is also transmitted to the tubular element via the dimple connection.

After the tubular element 1 has reached the target depth in the wellbore, the dimple connection between anchor tool 16 and tubular element 1 is released. This may be done by moving the expansion string 2 upward or downward while the tubular element 1 is kept stationary in the wellbore. In this manner each wall portion 34 of the tubular element is moved out of the respective dimple 32 whereby the wall portion is subjected to plastic and/or elastic deformation. Such deformation is facilitated by the inclined surfaces 35a, 35b and the rounded surface portions 38a, 38b. Generally, the dimple connection is released more easily for smaller inclination angles $\alpha 1$ and $\alpha 2$ and/or for larger values of R. Instead of, or in addition to, releasing the dimple connection by axial movement of the expansion string

2 relative the tubular element 1, the dimple connection may be released by rotating the expansion string 2 relative the tubular element 1.

In the present example the inclination angles α1 and α2 are equal. However the surfaces 35, 35b may have different inclination angles. For example, since surface 35a must carry a relatively large portion of the weight of the tubular element 1 during lowering into the wellbore, angle α1 may be selected larger than angle α2 in order to increase the load carrying capacity of surface 35a. In such application the inclination angle α2 is relatively small, therefore the dimple connection may be released relatively easy by moving the expansion string 2 downward while the tubular element 1 is kept stationary.

Once the dimple connection is released, radial expansion of the tubular element 1 is started by pulling the expansion string 2 upwardly through the tubular element.

If the expansion cone 14 gets stuck in the tubular element 1 during the expansion process, for example with the expansion cone in a section of overlap of the tubular element 1 with another tubular element, the drill pipe has to be disconnected from the expansion string 2 by breaking out the on-off sub 8. The required break-out torque is transmitted from the drill pipe 10 via the on-off sub 8 to the mandrel 4, then via the castellated connections 26, 25, 24 to the expansion cone 14, and finally via the face of the expansion cone 14 to the tubular element 1.

The load carrying capacity of the dimple connection is selected such that the force required to release the dimple connection by upward movement of the anchor tool relative to the tubular element exceeds the buoyant weight of the tubular element in a vertical borehole. In this manner

premature plastic deformation of the tubular element is prevented.

Instead of the tubular shaped anchor tool 16 described above, the anchor tool may be formed as a massive cylinder that is integrally formed with the mandrel 4 or connected to the mandrel in any suitable manner.

Design parameters for the anchor tool may be based on the dimple length L, depth D, angle α1 and/or α2 and round-off radius R (Fig. 4). For example, axial load capacity may be increased by providing more dimples, increasing α1 and/or α2, or increasing depth D. Torsional load capacity may be increased by providing more dimples, increasing length L, increasing depth D or using a dimple with a V-shaped bottom surface (Fig. 8). Release forces required to release the dimple connection may be reduced by less dimples, improved lubrication, decreased α1 and/or α2 or lower depth D. Galling between the anchor tool and the tubular element may be mitigated by increasing the round-off radius R. Furthermore, a relatively sharp angle α1 may increase the weight carrying capacity and a relatively low angle α2 may reduce the release force of the dimple connection.

The present invention is not limited to the embodiments as described above, wherein various modifications are conceivable within the scope of the appended claims. Features of different embodiments may for instance be combined.

C L A I M S

1. A method of installing a radially expandable tubular element in an underground borehole comprises the steps of:

(a) positioning in the tubular element an anchor tool having a cylindrical outer surface provided with at least one dimple;

(b) operating a pressing device to press a respective wall portion of the tubular element into the at least one dimple to create a dimple connection between the tubular element and the anchor tool;

(c) providing a work string connected to the anchor tool;

(d) operating a drive device to lower the tubular element into the borehole on the work string when the tubular element is connected to the anchor tool via the dimple connection;

(e) connecting an expander to the work string at a position below the anchor tool; and

(f) radially expanding the tubular element by pulling the expander on the work string through the tubular element.

2. The method of claim 1, wherein the step of operating the pressing device comprises pressing a die member against said wall portion of the tubular element, the die member having an end portion with a shape similar to the shape of the dimple.

3. The method of claim 1 or 2, further comprising releasing the anchor tool from the tubular element by inducing the drive device to move the work string in axial and/or rotational direction relative to the tubular element to deform each said wall portion to a shape substantially similar to the shape of the wall portion prior to the step of operating the pressing device.

4. A system for installing a radially expandable tubular element in an underground borehole, the system comprising:

(a) an anchor tool adapted to be positioned in the tubular element and having a cylindrical outer surface provided with at least one dimple;

(b) a pressing device for pressing a respective wall portion of the tubular element opposite the at least one dimple into the dimple, to create a dimple connection between the tubular element and the anchor tool;

(c) a work string connected to the anchor tool;

(d) a drive device for lowering the tubular element into the borehole on the work string when the tubular element is connected to the anchor tool via the dimple connection;

(e) means for connecting an expander to the work string at a position below the anchor tool; and

(f) means for radially expanding the tubular element by pulling the expander on the work string through the tubular element.

5. The system of claim 4, wherein the at least one dimple has a first surface and a second surface arranged opposite each other and extending in circumferential direction of the anchor tool, said first and second surfaces having mutually different inclination angles relative to the cylindrical outer surface.

6. The system of claim 5, wherein the first surface extends at an inclination angle $\alpha 1$ and the second surface at an inclination angle $\alpha 2$ relative to the cylindrical outer surface, the first surface facing upwardly in the borehole.

7. The system of claim 6, wherein $\alpha 1 > \alpha 2$.

8. The system of claim 6, wherein a rounded transition surface extends between the second surface and the cylindrical outer surface.

9. The system of any one of claims 5 to 8, wherein the dimple has a bottom surface located between the first surface and the second surface, the bottom surface extending substantially parallel to a longitudinal axis of the anchor tool.

10. The system of claim 9, wherein the bottom surface has a truncated V-shape.

11. The system of any one of claims 4 to 10, wherein the cylindrical outer surface of the anchor tool is provided with a plurality of said dimples spaced in circumferential direction of the anchor tool.

12. The system of any one of claims 4 to 10, wherein the pressing device includes a die member having an end portion with a shape similar to the shape of the dimple.

13. The system of claim 12, wherein the pressing device comprises positioning means connectable to the anchor tool and adapted to move the anchor tool relative to the die member so that the dimple is located opposite the die member.

14. The system of any one of claims 4 to 13, wherein the tubular element is a radially expandable tubular element, and wherein the system further comprises an expander for radially expanding the tubular element by axially moving the expander through the tubular element, the expander being connected to the work string at a position below the anchor tool.

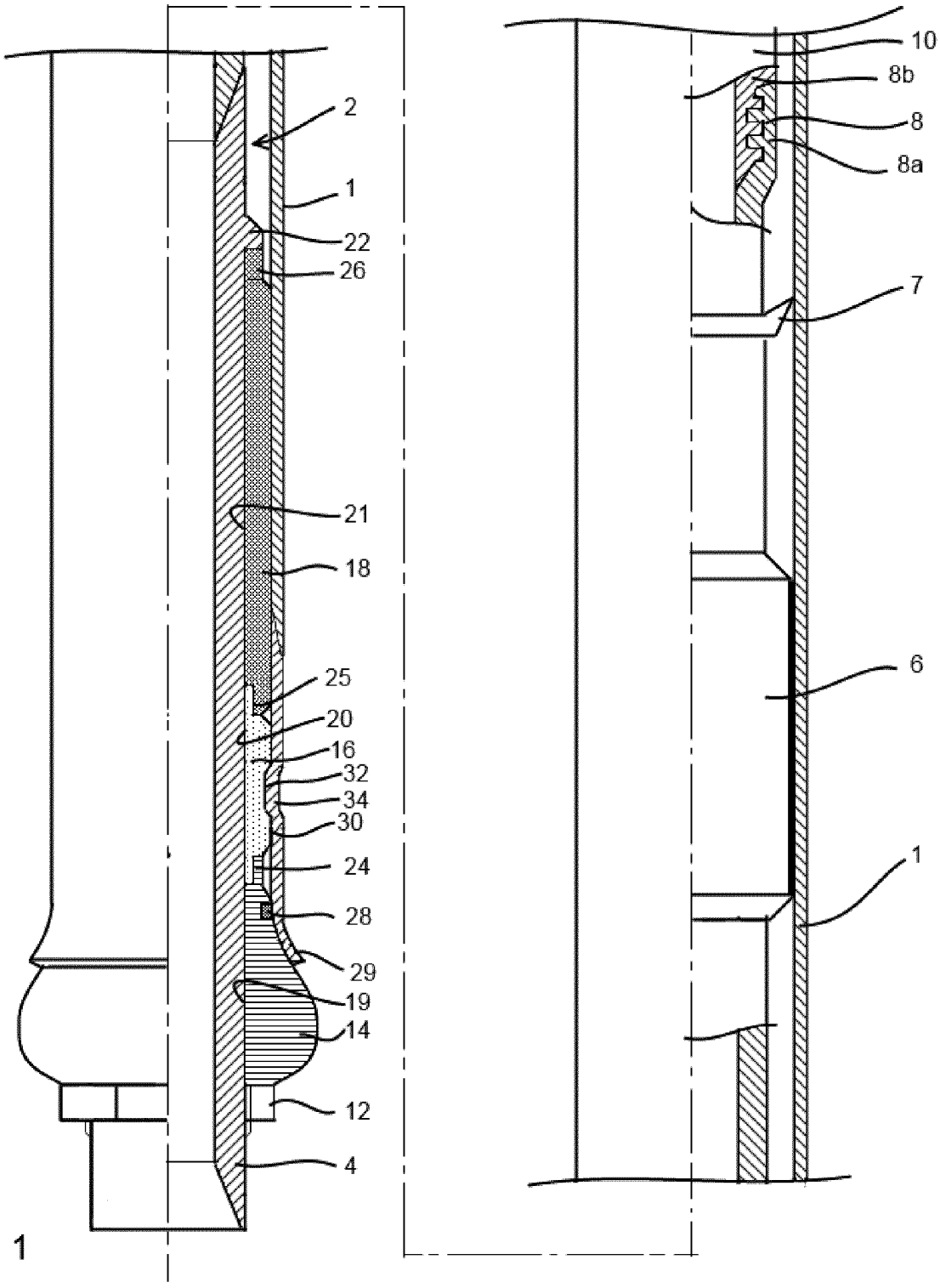


Fig. 1

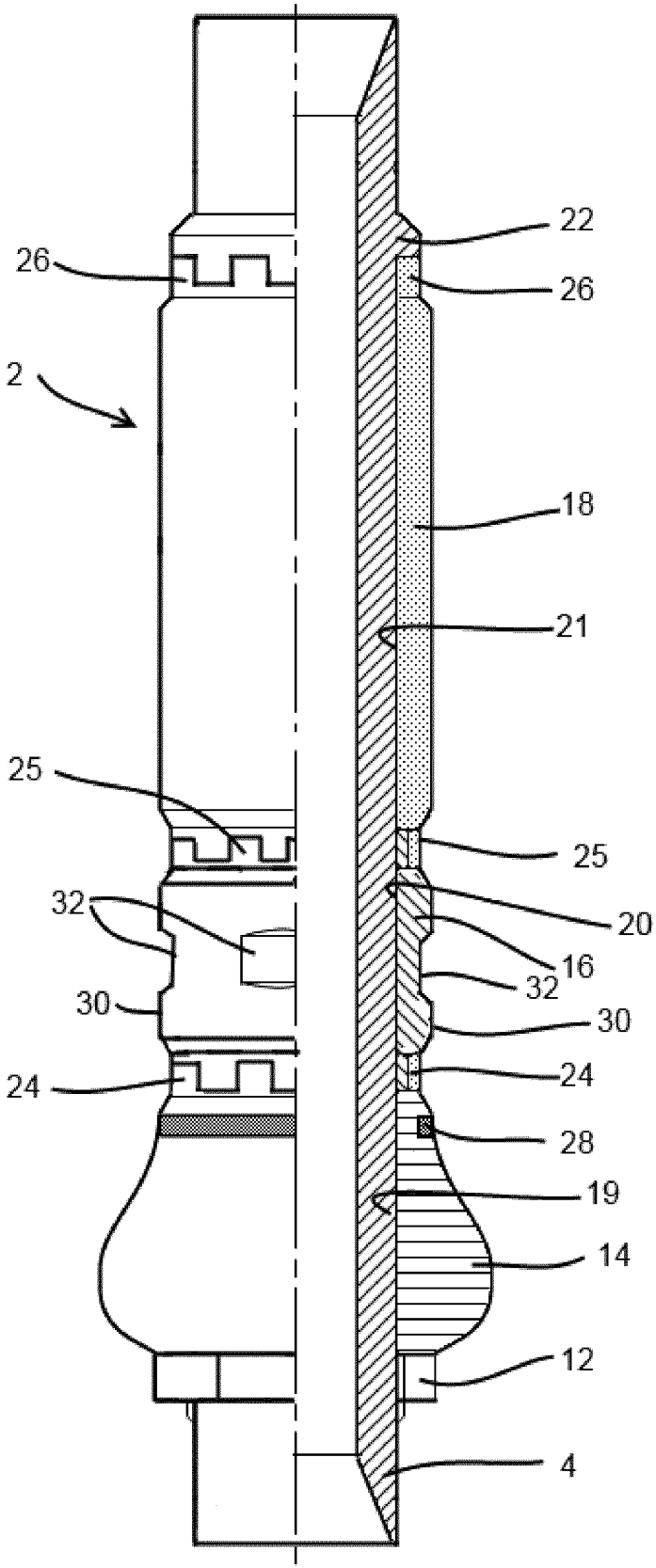


Fig. 2

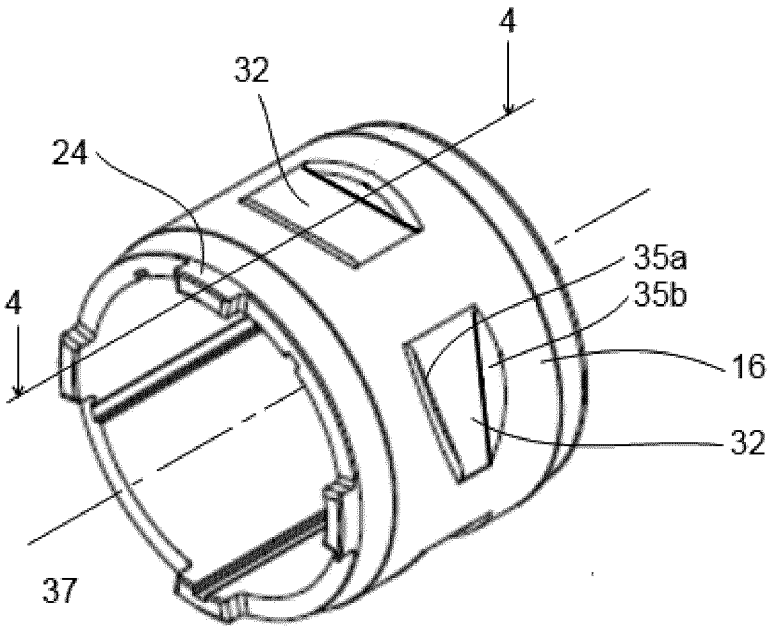


Fig. 3

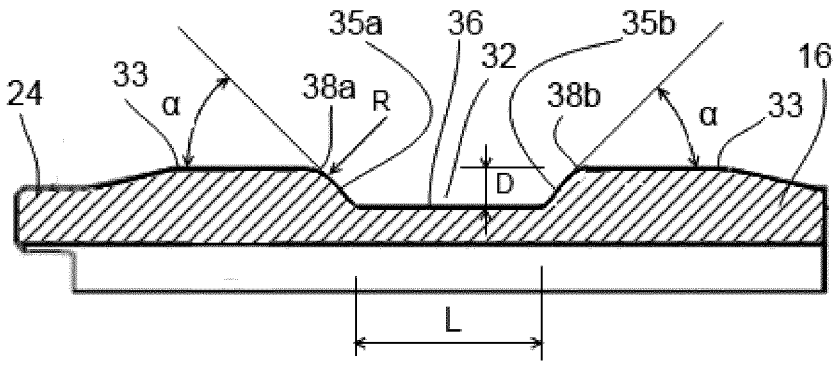


Fig. 4

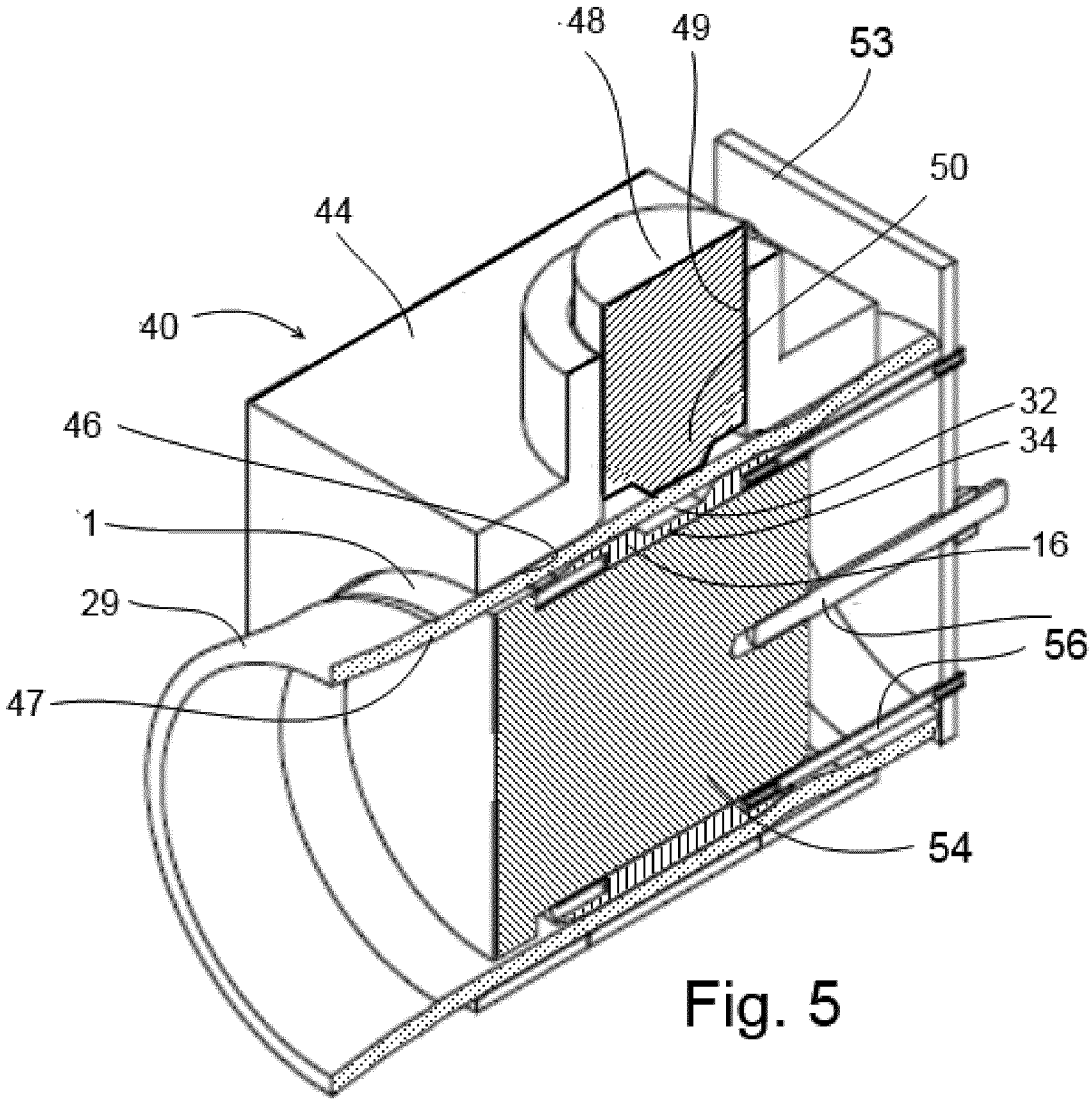


Fig. 5

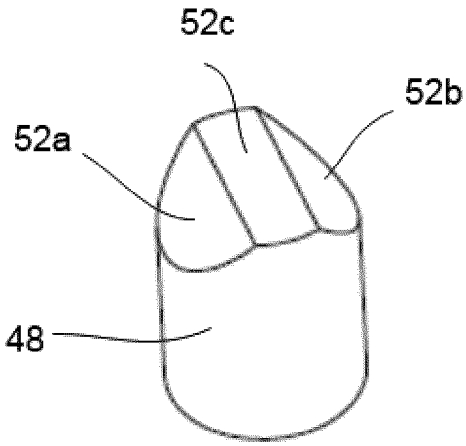


Fig. 6

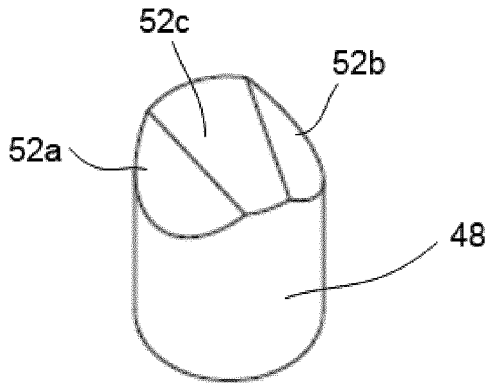


Fig. 8

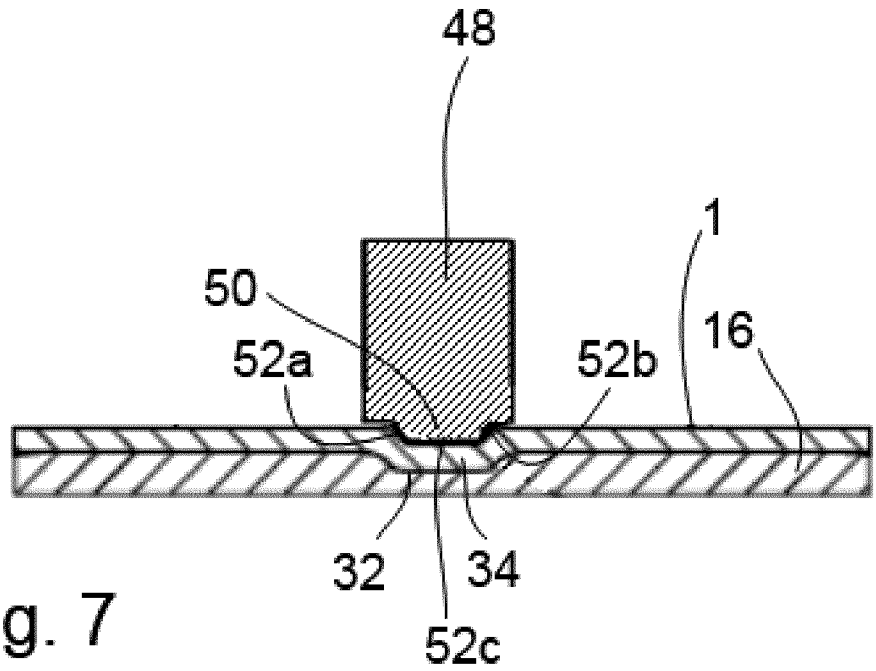


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/079155

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B43/10
ADD.

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

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007/000669 A1 (MCKEE L M [US] ET AL MCKEE L MICHAEL [US] ET AL) 4 January 2007 (2007-01-04) figures 4,8	1-14
A	US 2008/041596 A1 (BLOUNT CURTIS G [US] ET AL) 21 February 2008 (2008-02-21) paragraph [0028] figures 1,2	1-14
A	WO 97/41377 A1 (B D KENDLE ENGINEERING LTD [GB]; BOWLES RODNEY GORDON [GB]; KENDLE BAR) 6 November 1997 (1997-11-06) the whole document	1-14

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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8 February 2016	15/02/2016

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