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(54) **DOWNHOLE TOOL STRING**

(57) The present invention relates to a downhole tool string for performing an operation downhole, the tool string having a tool axis, said downhole tool string comprising an operating tool configured to fish an object in a well downhole, an actuating tool configured to actuate the operating tool, wherein the operating tool comprises a shroud having a shroud outer diameter, a grabbing tool part comprising at least two arms, the shroud and the grabbing tool part being movable in relation to each other along the tool axis by means of the actuating tool, the grabbing tool part having a projected position and a retracted position in relation to the shroud, and in the projected position the arms are in a relaxed condition and the grabbing tool part has a first outer diameter which is larger than in the retracted position.

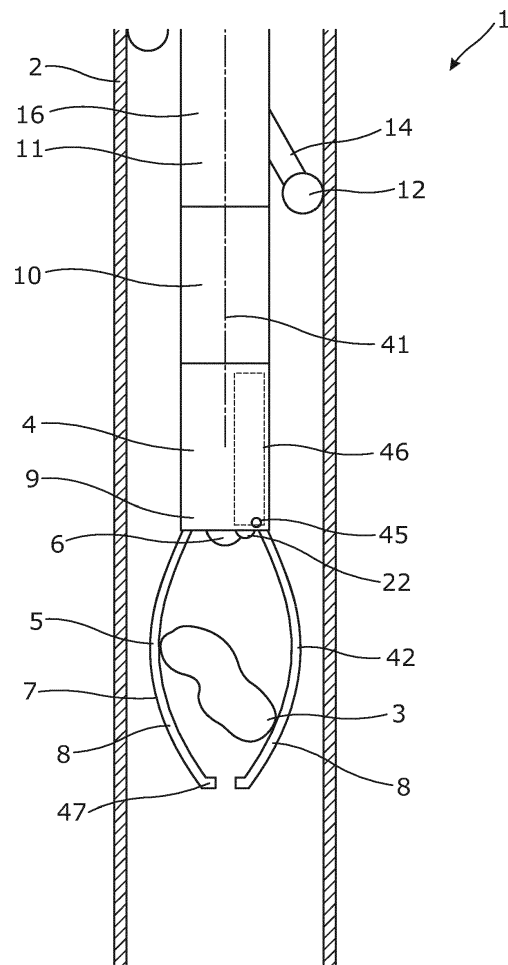


Fig. 2

DescriptionField of the invention

[0001] The present invention relates to a downhole tool string for performing an operation downhole.

Background art

[0002] When operating several kilometres down a well, operations become much more complex than when operating at surface, and some circumstances which at surface do not seem to be a problem can be difficult to handle in a well. Unintentional dropping of objects down a well is one problem which is very difficult to solve, and such dropped object may prohibit an operator from performing another operation or even to produce from the well again.

[0003] Another challenge when operating downhole is the lack of visibility, and therefore detecting a leak or a lost object and the position thereof may be very difficult if not impossible. Another challenge is to verify that an operation has been performed as intended and thus to prove that a specific operation is not the cause of another problem occurring.

Summary of the invention

[0004] It is an object of the present invention to wholly or partly overcome the above disadvantages and drawbacks of the prior art. More specifically, it is an object to provide an improved tool string capable of fishing any dropped objects from a well and bringing them to surface.

[0005] It is a further object to provide an improved tool string capable of verifying the operation performed.

[0006] The above objects, together with numerous other objects, advantages and features, which will become evident from the below description, are accomplished by a solution in accordance with the present invention by a downhole tool string for performing an operation downhole, the tool string having a tool axis, said downhole tool string comprising:

- an operating tool configured to fish an object in a well downhole, and
- an actuating tool configured to actuate the operating tool,

wherein the operating tool comprises:

- a shroud having a shroud outer diameter, and
- a grabbing tool part comprising at least two arms, the shroud and the grabbing tool part being movable in relation to each other along the tool axis by means of the actuating tool, the grabbing tool part having a projected position and a retracted position in relation to the shroud, and in the projected position the arms are in a relaxed condition and the grabbing tool part has a first outer diameter which is larger than in the

retracted position.

[0007] The arms may be more flexible than the shroud.

[0008] Moreover, the arms may be made of metal.

[0009] Also, the shroud may be made of metal.

[0010] Further, the arms may each have a curved part.

[0011] In addition, the grabbing tool part may have more than two arms.

[0012] Moreover, the shroud may be movable in relation to the grabbing tool part, and/or the grabbing tool part may be movable in relation to the shroud.

[0013] The shroud may comprise an end part having an internal space configured to receive the grabbing tool part.

[0014] Said end part may comprise a camera configured to watch the operating tool.

[0015] Also, the end part may comprise a plurality of cameras arranged between the arms.

[0016] Furthermore, the end part may comprise at least one source configured to illuminate visible light or infrared light in front of the operating tool and the camera.

[0017] Moreover, the end part may have at least one opening configured to eject a transparent fluid in front of the camera.

[0018] Additionally, the tool string may comprise a fluid chamber for the transparent fluid.

[0019] Further, the camera may be connected with a monitor above surface, enabling an operator to follow the operation downhole in real-time.

[0020] The camera may be connected with a storage unit configured to store images provided by the camera.

[0021] In addition, the arms may circumvent the camera.

[0022] Also, the actuating tool may be an axial stroking tool having a housing, a chamber, a first tool part comprising a pump unit providing pressurised fluid to the chamber, a shaft penetrating the chamber and a piston dividing the chamber into a first chamber section and a second chamber section.

[0023] Furthermore, the actuating tool may comprise a threaded spindle and a motor.

[0024] The downhole tool string according to the present invention may further comprise a driving tool for propelling the tool string forward in a well.

[0025] Said driving tool may be a downhole tractor.

[0026] Moreover, the downhole tool string may be a wireline downhole tool string.

[0027] Also, the downhole tool string may further comprise an anchoring tool section.

[0028] The present invention also relates to a downhole tool string for performing an operation downhole, the downhole tool string comprising:

- a wireline,
- an operating tool,
- a driving section receiving power from the wireline for driving the operating tool, and
- a camera section having a camera facing radially

from the tool string,

wherein the camera section is arranged between the wireline and the operating tool, and the camera section has a first end part and a second end part and at least an electric conductor and/or a hydraulic channel extending from the first end part to the second end part for providing electricity and/or hydraulics to the operating tool.

[0029] The driving section may comprise a pump and a motor.

[0030] Further, the driving section may be a driving tool with wheels for propelling the tool string forward in a well.

[0031] Moreover, the driving tool may be a downhole tractor.

[0032] In addition, the camera section may comprise at least one source configured to illuminate an area in front of the camera.

[0033] The source may be a light source configured to radiate any kind of electromagnetic radiation, such visible light or infrared light.

[0034] The camera section may comprise a sensor unit configured to measure a condition of the well and, on the basis of the measurement, activate the camera.

[0035] Furthermore, the sensor unit may comprise a sensor configured to measure a temperature, a pressure and/or a flow content of a fluid.

[0036] Also, the sensor unit may comprise an ultrasonic sensor configured to measure a thickness of a metal casing arranged in the well.

[0037] Said sensor unit may comprise a first magnet for generating a magnetic field, a first sensor for measuring the magnitude and/or direction of the magnetic field, said first sensor being arranged in a first plane and at a first distance from the first magnet, for detecting changes in the magnetic field, and a second sensor for measuring the magnitude and/or direction of the magnetic field, said second sensor being arranged in the same first plane and at a second distance from the first sensor along the axis, also for detecting changes in the magnetic field and for locating casing collars and/or sliding sleeves in the metal casing.

[0038] Further, the camera section may comprise a storage unit configured to store images provided by the camera and/or data from measurements provided by the sensor unit.

[0039] Moreover, the camera may be arranged in a circumference of the camera section.

[0040] Additionally, the camera section may comprise a transparent cover for protecting the camera.

[0041] Also, the camera section may comprise a plurality of cameras.

[0042] Furthermore, the camera section may comprise at least one opening configured to eject a transparent fluid in front of the camera.

[0043] The tool string may comprise a fluid chamber for the transparent fluid.

[0044] In addition, the tool string may comprise a driving unit configured to rotate the camera in relation to the

driving section.

[0045] Also, the tool string may comprise a positioning unit connected with the camera section, so that a downhole position of an image provided by the camera is stored with said image.

[0046] Moreover, the operating tool may be a grabbing tool part, a casing cutter, a sleeve operating tool, a logging tool, a drilling tool or a milling tool.

[0047] The downhole tool string may further comprise a second camera in front of the tool string.

Brief description of the drawings

[0048] The invention and its many advantages will be described in more detail below with reference to the accompanying schematic drawings, which for the purpose of illustration show some non-limiting embodiments and in which

Fig. 1 shows a partly cross-sectional view of a downhole tool string,

Fig. 2 shows a partly cross-sectional view of a downhole tool string,

Fig. 3 shows a partial view of the downhole tool string having a grabbing tool part, and

Fig. 4 shows a partly cross-sectional view of a downhole tool string.

[0049] All the figures are highly schematic and not necessarily to scale, and they show only those parts which are necessary in order to elucidate the invention, other parts being omitted or merely suggested.

Detailed description of the invention

[0050] Fig. 1 shows a downhole tool string 1 for fishing an object 3 in a well 2 downhole where the tool string has a tool axis 41 extending along the extension of the casing. The downhole tool string 1 comprises an operating tool 5 configured to fish the object 3 and an actuating tool 10 configured to actuate the operating tool 5. The operating tool comprises a shroud 4 having a shroud outer diameter OD_S which is approximately the same as the outer diameter of the downhole tool string 1. The operating tool 5 further comprises a grabbing tool part 7 comprising at least two arms 8. The shroud 4 and the grabbing tool part 7 are movable in relation to each other along the tool axis 41 by means of the actuating tool 10. The grabbing tool part 7 has a projected position and a retracted position in relation to the shroud. The projected position is shown in Fig. 1 and the partly retracted position is shown in Fig. 2. In the projected position, the arms are in a relaxed condition and the grabbing tool part has a first outer diameter OD_{1G} which is larger than in the retracted position. The arms are more flexible than the shroud and are

able to flex radially inwards and are in their retracted position limited in flexing back into their relaxed position by means of the shroud. Each arm has a curved part 42 and an inwardly projecting part 47.

[0051] By having a shroud 4 and a grabbing tool part 7 movable in relation to each other and having arms of the grabbing tool part which are able to assume a retracted position, a very simple fishing tool is provided. The arms having a relaxed extended position are arranged to enclose the identified object, and by a simple axial movement, the arms flex inwards to grab around the object and the shroud prevents the arms from assuming their relaxed position and thus provides the arms with a pre-tension, bringing them to squeeze around the object. When fishing an object downhole, the size of the object is not often known. If the object is smaller than predicted, the arms are thus retracted further into the shroud and the arms are then diminishing the outer diameter of the grabbing tool part and are able to provide a sufficient squeezing force around the object to be able to retrieve the object.

[0052] The shroud comprises an end part 9 comprising a camera 6 configured to watch the operating tool during the fishing operation and even identify the object 3 and the position thereof if required. The camera 6 is arranged between the arms so that the arms do not significantly limit the camera's visual range towards the object. The arms circumvent the camera and due to the curved shape of the arms, the camera has a full view of the operation and the object. The end part 9 comprises at least one light source 22 configured to illuminate in front of the operating tool 5 and the camera 6.

[0053] The end part of Fig. 1 has an opening 45 for ejecting a transparent fluid in front of the camera and thus displacing the well fluid to create a better environment in front of the camera so that better images can be obtained. The tool string comprises a fluid chamber 46 containing the transparent fluid. The end part further comprises a plurality of cameras arranged between the arms.

[0054] As can be seen in Fig. 3, the shroud comprises an end part 9 having an internal space 43 which is configured to receive the grabbing tool part 7. As shown, the grabbing tool part 7 has more than two arms, e.g. three arms, to provide a better grip around the object to be fished in the well. In Fig. 3, the grabbing tool part 7 is divided into three arms in that the arms are cut out of one rod and then bent into the shape shown. The grabbing tool part 7 is retracted into the shroud 4 by the actuating tool.

[0055] In Fig. 1, the shroud is moved downwards pressing the arms inwards to have them squeeze around the object. The movement is performed by the actuating tool 10 which moves the shroud away from the actuating tool 10.

[0056] The actuating tool may be an axial stroking tool having a housing, a chamber, a first tool part comprising a pump unit providing pressurised fluid to the chamber,

a shaft penetrating the chamber and a piston dividing the chamber into a first chamber section and a second chamber section. When said actuating tool is influenced by the pressurised fluid, an axial movement is provided along the tool axis 41 to retract the arms into the shroud or project the shroud over the arms, limiting the free movement of the arms.

[0057] The actuating tool may be a non-hydraulic tool comprising a threaded spindle and a motor providing a linear actuator retracting the arms into the shroud or projecting the shroud over the arms, limiting the free movement of the arms.

[0058] Each arm may be arranged in a space in between the cameras and the light sources.

[0059] The arms are made of metal, e.g. in a spring metal. The shroud is also made of metal but may be made of other rigid materials suitable for use in a well.

[0060] Fig. 4 shows a downhole tool string 1 for performing an operation downhole, comprising a wireline 34, an operating tool 5 and a driving section 11 receiving power from the wireline for driving the operating tool 5. The downhole tool string 1 further comprises a camera section 23 having a camera 6 facing radially from the tool string. The camera section is arranged between the wireline and the operating tool, and the camera section has a first end part 35 and a second end part 36 and at least an electric conductor 37 and a hydraulic channel 38 extending from the first end part to the second end part for providing electricity and/or hydraulics to the operating tool.

[0061] By having a camera section with at least an electric conductor or a hydraulic channel extending from the first end part to the second end part, the camera section can be arranged at any position along the tool string wherever suited in relation to other tool sections and performance of the tool sections. The operating tool 5 may be a cutter tool 31 driven by both hydraulic fluid for pressing the cutter arms 32 and thus the cutting edge 33 in engagement with the casing and by electricity for driving a motor 39 rotating the cutter tool 31. After the cutting operation is completed, the camera section is run past the cut part of the casing, and the camera 6 is thus able to detect the cut and verify that the casing is in fact completely cut through. Sometimes even though the casing is cut perfectly, the upper part of the casing can, for other reasons, be difficult to pull out of the well, and then the cutting operator may be accused of not having performed the cutting operation in a satisfactory manner.

[0062] As shown in Fig. 4, the camera section 23 has a plurality of light sources 22 arranged around the circumference of the camera section 23 and around the camera 6 to illuminate the object or the wall of the casing and thus determine if a leak 15 is present or determine the position and the size of an object. As shown in Fig. 4, the camera 6 is arranged in a groove 40 in the camera section 23 so that the camera does not extend from the camera section 23, thus preventing the camera from potential damage. The camera section 23 may further com-

prise a transparent cover covering the camera 6 and thus protecting the camera and the light sources. The tool string 1 further comprises a driving unit 21 for rotating the camera 6 in relation to the driving unit 21 so that only one camera is required for capturing images of the casing along also the entire circumference of the casing.

[0063] The camera section may further have an opening 45 configured to eject a transparent fluid in front of the camera. The tool string may thus comprise a fluid chamber containing the transparent fluid.

[0064] The driving section may comprise a pump 17 driven by a motor 39 for providing fluid to an operating tool such as a sleeve operating tool for sliding a sleeve in order to open or close the sleeve.

[0065] In Fig. 4, the camera section comprises a sensor unit 51 configured to measure a condition of the well and, on the basis of the measurement, activate the camera when a condition of the well has changed. For instance the temperature dropping is an indication of water coming into the casing. The sensor unit 51 thus comprises a sensor 52 configured to measure a temperature, a pressure and/or a flow content of a fluid. The sensor unit may also comprise an ultra-sonic sensor configured to measure a thickness of the metal casing arranged in the well in order to detect a leak 15, as shown in Fig. 4.

[0066] In Fig. 4, the tool string comprises a positioning unit 53 connected with the camera section 23, so that a downhole position of an image provided by the camera is stored with said image. In this way, the camera section may be connected as part of a tool string performing an operation downhole which does not need the camera for performing the operation, but due to the fact that the camera section follows the tool string all the way down the well, the camera section is able to obtain images along the way if the sensor unit detects an unexpected condition, such as dropping temperature.

[0067] In another aspect, the sensor unit comprises a first magnet for generating a magnetic field, a first sensor for measuring the magnitude and/or direction of the magnetic field, the first sensor being arranged in a first plane and at a first distance from the first magnet, for detecting changes in the magnetic field. The sensor unit further comprises a second sensor for measuring the magnitude and/or direction of the magnetic field, the second sensor being arranged in the same first plane and at a second distance from the first sensor along the axis, also for detecting changes in the magnetic field, for locating casing collars and/or sliding sleeves in the metal casing. The camera section may comprise a storage unit configured to store images provided by the camera and/or data from measurements provided by the sensor unit.

[0068] The tool string 1 may further comprise an anchoring tool section 24 having projectable anchors 27 for engaging the wall of the casing and thus maintaining the tool string in a predetermined position along the tool axis 41 while performing an operation.

[0069] As shown in Fig. 4, the driving section 11 may be a driving tool for propelling the tool string forward in

a well, such as a downhole tractor having wheels 12 on arms 14. The downhole tool string is connected with a wireline and is thus a wireline downhole tool string.

[0070] Even though not shown, the camera may be connected with a monitor above surface, enabling an operator to follow the operation downhole in real-time. The camera may further be connected with a storage unit configured to store images provided by the camera.

[0071] The operating tool may be a grabbing tool part, a casing cutter, a sleeve operating tool, a logging tool, a drilling tool or a milling tool.

[0072] By fluid or well fluid is meant any kind of fluid that may be present in oil or gas wells downhole, such as natural gas, oil, oil mud, crude oil, water, etc. By gas is meant any kind of gas composition present in a well, completion, or open hole, and by oil is meant any kind of oil composition, such as crude oil, an oil-containing fluid, etc. Gas, oil, and water fluids may thus all comprise other elements or substances than gas, oil, and/or water, respectively.

[0073] By an annular barrier is meant an annular barrier comprising a tubular metal part mounted as part of the well tubular metal structure and an expandable metal sleeve surrounding and connected to the tubular part defining an annular barrier space.

[0074] By a casing is meant any kind of pipe, tubing, tubular, liner, string etc. used downhole in relation to oil or natural gas production.

[0075] In the event that the tool string is not submersible all the way into the casing, a downhole tractor can be used to push the tool all the way into position in the well. The downhole tractor may have projectable arms having wheels, wherein the wheels contact the inner surface of the casing for propelling the tractor and the tool forward in the casing. A downhole tractor is any kind of driving tool capable of pushing or pulling tools in a well downhole, such as a Well Tractor®.

[0076] Although the invention has been described in the above in connection with preferred embodiments of the invention, it will be evident for a person skilled in the art that several modifications are conceivable without departing from the invention as defined by the following claims.

Claims

1. A downhole tool string (1) for performing an operation downhole, the tool string having a tool axis (41), said downhole tool string comprising:

- an operating tool (5) configured to fish an object (3) in a well (2) downhole, and
- an actuating tool (10) configured to actuate the operating tool,

wherein the operating tool comprises:

- a shroud (4) having a shroud outer diameter (OD_S), and
 - a grabbing tool part (7) comprising at least two arms (8), the shroud and the grabbing tool part being movable in relation to each other along the tool axis by means of the actuating tool, the grabbing tool part having a projected position and a retracted position in relation to the shroud, and in the projected position the arms are in a relaxed condition and the grabbing tool part has a first outer diameter (OD_{1G}) which is larger than in the retracted position.
2. A downhole tool string according to claim 1, wherein the arms are more flexible than the shroud.
 3. A downhole tool string according to claim 1 and/or 2, wherein the arms each have a curved part (42).
 4. A downhole tool string according to any of the preceding claims, wherein the shroud is movable in relation to the grabbing tool part, and/or wherein the grabbing tool part is movable in relation to the shroud.
 5. A downhole tool string according to any of the preceding claims, wherein the shroud comprises an end part (9) having an internal space (43) configured to receive the grabbing tool part.
 6. A downhole tool string according to claim 5, wherein the end part comprises a camera (6) configured to watch the operating tool.
 7. A downhole tool string according to claim 6, wherein the end part comprises at least one light source (22) configured to illuminate in front of the operating tool and the camera.
 8. A downhole tool string according to any of the preceding claims, wherein the arms circumvent the camera.
 9. A downhole tool string according to any of the preceding claims, further comprising a driving tool (16) for propelling the tool string forward in a well.
 10. A downhole tool string for performing an operation downhole, the downhole tool string comprising:
 - a wireline (34),
 - an operating tool (5),
 - a driving section (11) receiving power from the wireline for driving the operating tool, and
 - a camera section (23) having a camera (6) facing radially from the tool string, wherein the camera section is arranged between the wireline and the operating tool, and the camera section has
- a first end part (35) and a second end part (36) and at least an electric conductor (37) and/or a hydraulic channel (38) extending from the first end part to the second end part for providing electricity and/or hydraulics to the operating tool.
 11. A downhole tool string according to claim 10, wherein the driving section comprises a pump (17) and a motor (39).
 12. A downhole tool string according to claim 10 and/or 11, wherein the camera section comprises a sensor unit (51) configured to measure a condition of the well and, on the basis of the measurement, activate the camera.
 13. A downhole tool string according to claim 12, wherein the sensor unit comprises a sensor (52) configured to measure a temperature, a pressure and/or a flow content of a fluid.
 14. A downhole tool string according to any of claims 10 to 13, wherein the tool string comprises a driving unit configured to rotate the camera in relation to the driving section.
 15. A downhole tool string according to any of claims 10 to 14, wherein the tool string comprises a positioning unit (53) connected with the camera section, so that a downhole position of an image provided by the camera is stored with said image.

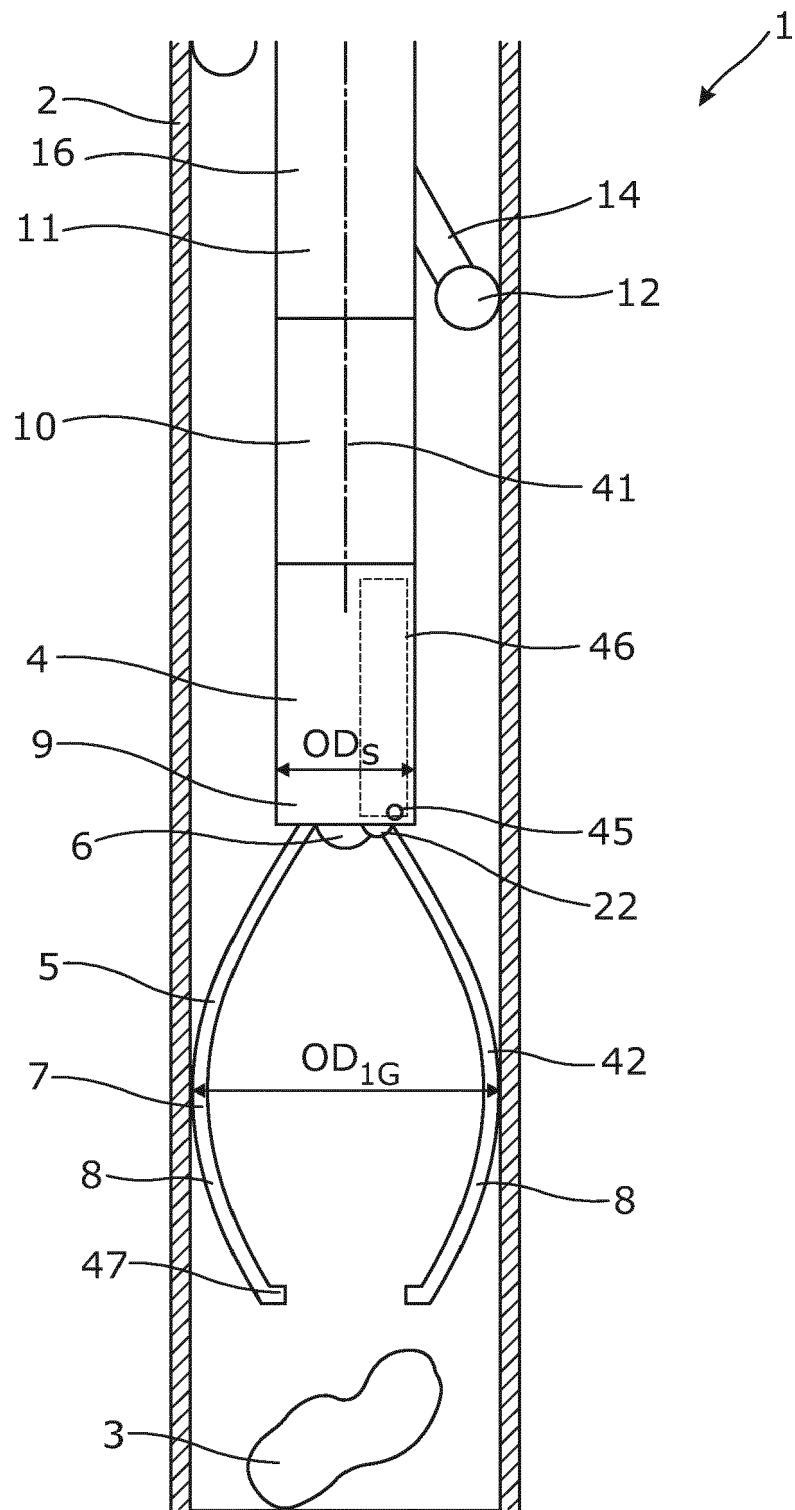


Fig. 1

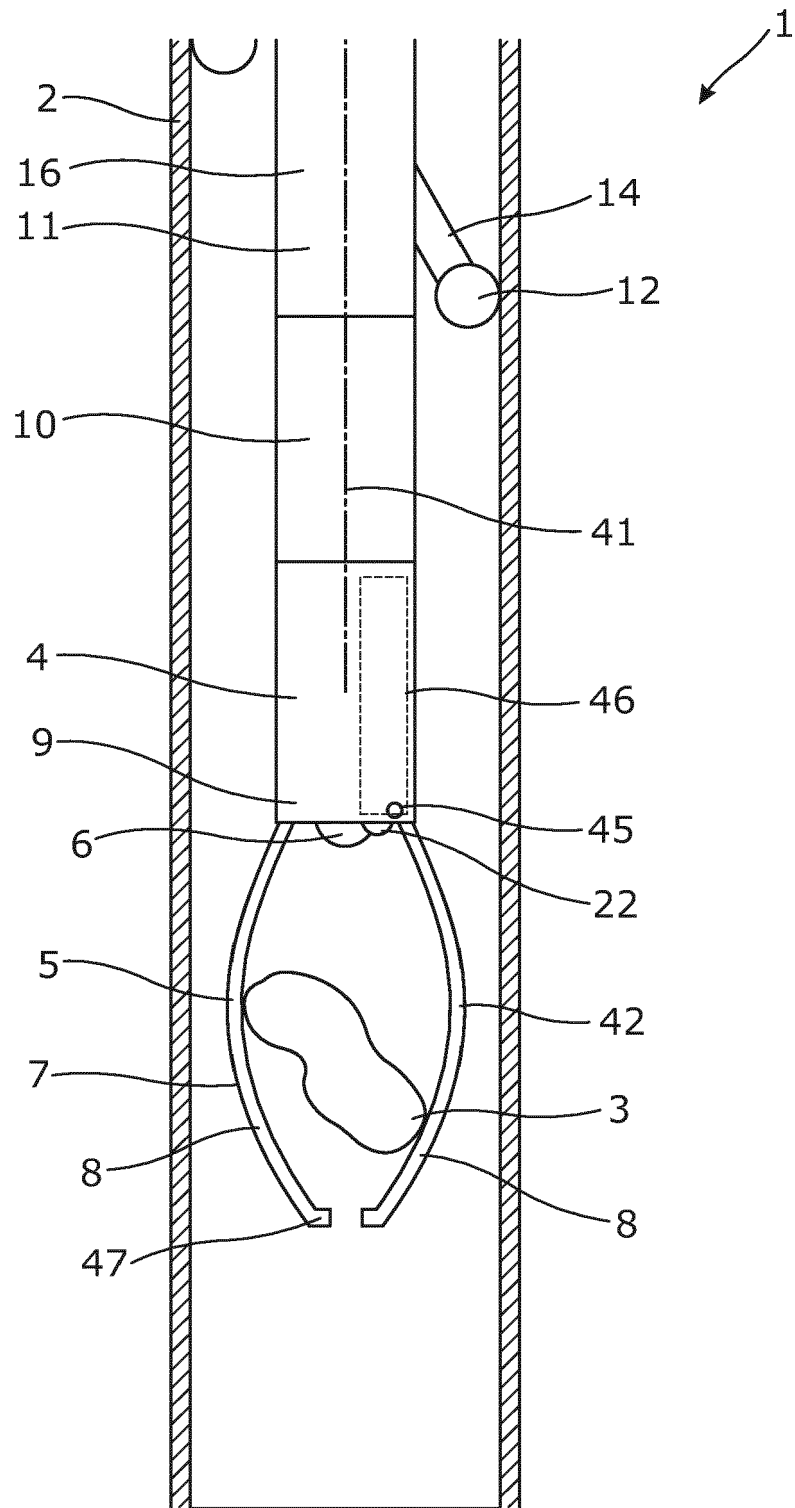
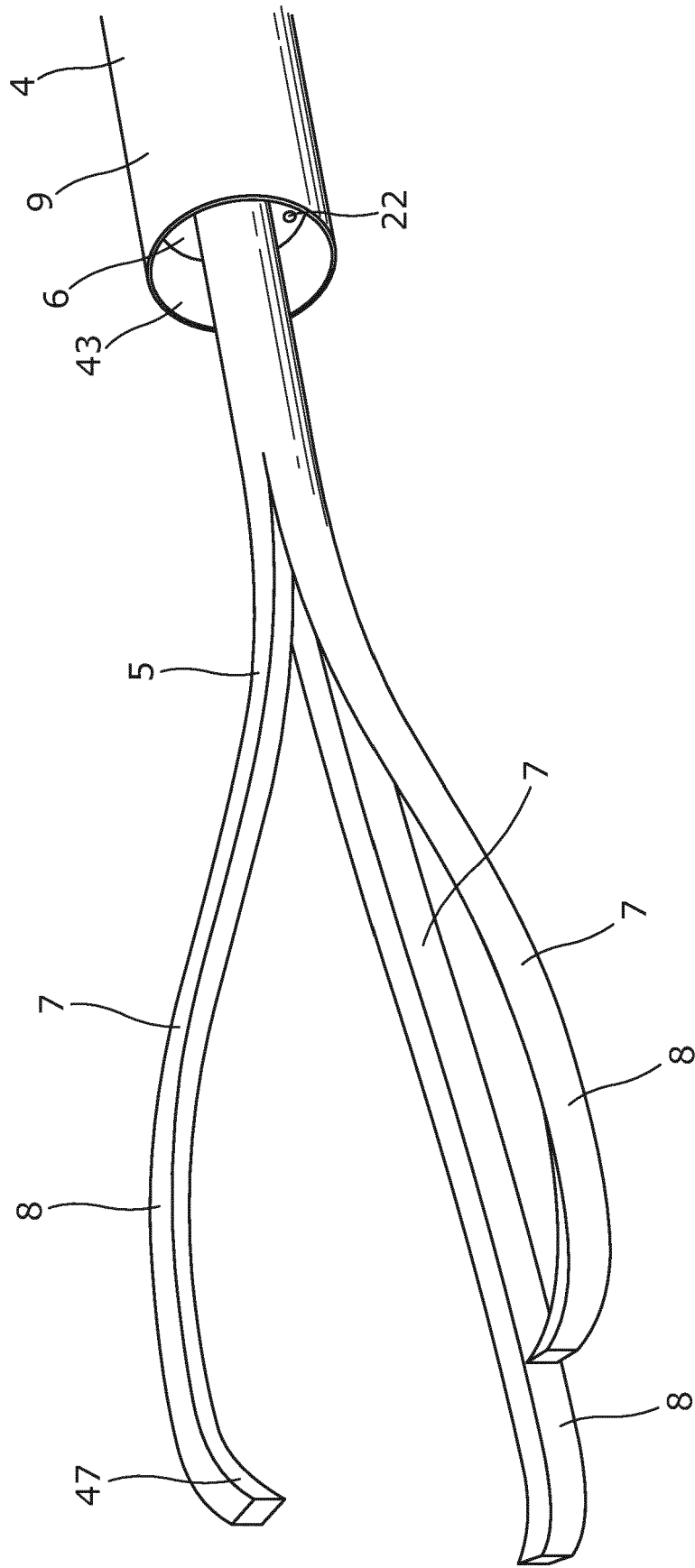


Fig. 2



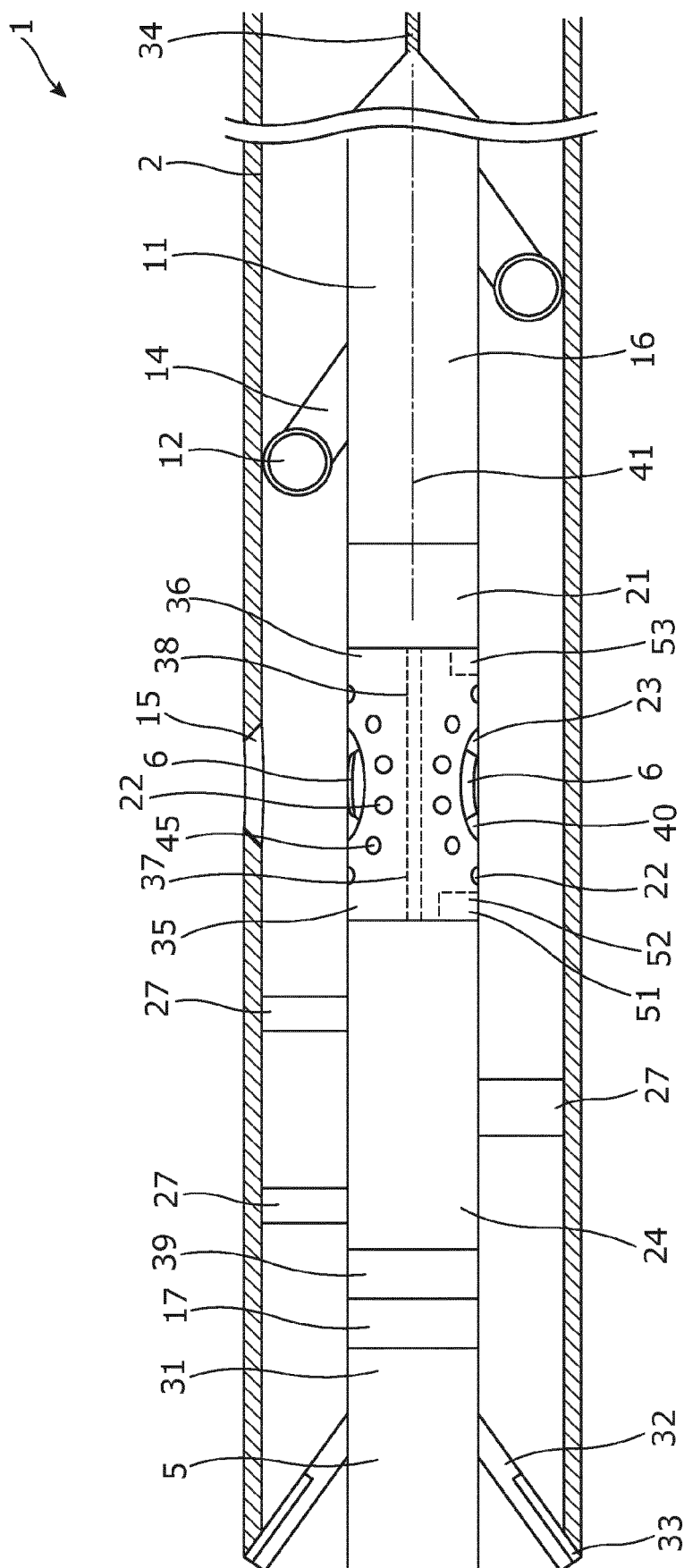


Fig. 4

**PARTIAL EUROPEAN SEARCH REPORT**

Application Number

under Rule 62a and/or 63 of the European Patent Convention.
This report shall be considered, for the purposes of
subsequent proceedings, as the European search report

EP 17 16 0609

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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Y	* page 1, column 1, line 22 - line 25 * * page 1, column 2, line 25 - line 45 * * page 2, column 1, line 3 - line 30 * * figures 1-2 *	6-8	
X	US 4 061 389 A (KELLER V J ET AL) 6 December 1977 (1977-12-06) * figures 2-3 *	1,5	
X	US 1 553 991 A (DAVISON WILLIAM E ET AL) 15 September 1925 (1925-09-15) * the whole document *	1	
X	US 1 456 943 A (SMITH ROBERT E) 29 May 1923 (1923-05-29) * the whole document *	1	
X	US 2012/048552 A1 (MACDOUGALL TOM [US] ET AL) 1 March 2012 (2012-03-01) * paragraphs [0018], [0021] *	6	TECHNICAL FIELDS SEARCHED (IPC) E21B
	-/--		

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

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EPO FORM 1503 03.82 (P04E07)

Place of search	Date of completion of the search	Examiner
Munich	6 September 2017	Ing, James
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		

**INCOMPLETE SEARCH
SHEET C**

Application Number

EP 17 16 0609

5

Claim(s) completely searchable:
1-9

10

Claim(s) not searched:
10-15

Reason for the limitation of the search:

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In response to the invitation sent under Rule 62a (1) EPC, no reply was received in the allocated time. The search is therefore to be restricted to claims 1 to 9. Claim 10 is formulated as an additional independent apparatus claim; this claim along with claims 11-15, which are dependent on claim 10, were not searched.

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

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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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06-09-2017

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82