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(54) Title: MILLS WITH SWARF DISPOSAL IN WELLBORES

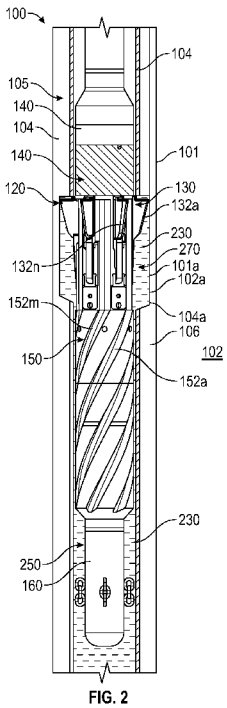


FIG. 2

(57) Abstract: A milling apparatus for cutting a tubular in a wellbore includes a cutting element on a tool body configured to cut the tubular in a wellbore when the cutting element is activated when the tool is moving upward inside the tubular. The cutting element cuts the tubular to form cuttings that fall into an annulus between the tubular and the wellbore. An agitator below the cutting element agitates the cuttings in the annulus to aid the cuttings to move from the annulus into the wellbore below the milling apparatus.

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[Continued on next page]

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

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

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

MILLS WITH SWARF DISPOSAL IN WELLBORES

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Application No. 15/471544, filed on March 28, 2017, which is incorporated herein by reference in its entirety.

BACKGROUND

1. Field of the Disclosure

[0001] The disclosure herein relates generally to mills for milling casings in a wellbore and specifically to mills that include an apparatus that may be used to break-up the cuttings (swarf) created by the mills during upward milling of the casings.

2. Background of the Art

[0002] Wellbores are drilled in subsurface formations to produce hydrocarbons (oil and gas). Modern wells can extend to great well depths, often more than 15,000 ft. A wellbore is typically lined with casing (a string of metal tubulars connected in series) along the length of the wellbore to prevent collapse of the formation (rocks) into the wellbore. A variety of devices are installed in the wellbore to produce the hydrocarbons from the formation surrounding the wellbore from one or more production zones. Sometimes it is necessary to mill a section of the casing to perform a downhole operation, such as forming windows for forming lateral wellbores, abandoning wells, etc. To perform a milling operation, a tool (commonly referred to as a mill), with cutting members (also referred to as knives or blades) is typically conveyed inside the casing by a tubular. In one type of mills, the mill is activated and pulled upward (uphole) to cut the casing into cuttings (also referred to as "swarf"). The cuttings are often in the form of strings and tend to accumulated in the space between the mill and the wellbore.

[0003] The disclosure herein provides mills that include an apparatus attached below the cutters of the mill that breaks-off the cuttings and aids such cuttings to fall into the wellbore below the mill as the mill is pulled uphole.

SUMMARY

[0004] In one aspect, a milling apparatus for cutting a tubular in a wellbore is disclosed that in one non-limiting embodiment includes a cutting element on a tool body configured to cut the tubular in a wellbore when the cutting element is activated when the tool is moving upward inside the tubular. The cutting element cuts the tubular to form

cuttings that that fall into an annulus between the tubular and the wellbore. An agitator below the cutting element agitates the cuttings in the annulus to aid the cuttings to fall from the annulus into the wellbore below the milling apparatus.

[0005] In another aspect, a method of milling a tubular in a wellbore is disclosed that in one non-limiting embodiment includes: positioning a milling device at a start location in the wellbore, wherein the milling device includes: a cutting element on a tool body configured to cut the tubular in the wellbore when the cutting element is activated and moved upward inside the tubular, wherein the cutting element cuts the tubular into cuttings that are disposed in an annular space between the tool body and a wellbore wall; activating the cutting element to contact the tubular; cutting the tubular by moving the cutting element from the start location to an end location; and causing the agitator to aid the cuttings to move from the annular space into the wellbore.

[0006] Examples of the more important features of an apparatus and methods have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features that will be described hereinafter and which will form the subject of the claims.

BRIEF DESCRIPTION OF THE DRAWING

[0007]For a detailed understanding of the apparatus and methods disclosed herein, reference should be made to the accompanying drawing and the detailed description thereof, wherein like elements are generally given same numerals and wherein:

FIG. 1 shows a mill that includes an agitator according to a non-limiting embodiment of the disclosure in a run-in position placed at a staring location inside the casing in a wellbore;

FIG. 2 shows the mill of **FIG. 1** in the milling position while the mill is being pulled uphole, wherein the agitator is not yet active;

FIG. 3 shows the mill of **FIG. 2** when the mill has milled a certain length of the casing and the agitator is active.

DETAILED DESCRIPTION

[0008]FIG. 1 shows a wellbore system **100** that includes a well or wellbore **101** formed in a formation **102**. The well **101** is shown lined with a tubular referred to as casing **104**. The space **105** (also referred to herein as the annulus) between the well **101** and the

casing **104** is shown filled with cement **106**. It is often desired to mill a portion of the casing **104**, for example to provide windows for drilling lateral wellbores from the wellbore **101**. A variety of tools, generally referred to as mills or milling tools are used to mill desired sections of the casings to form windows. A mill or milling tool **120 (**also referred to herein as the cutting apparatus), formed according a non-limiting embodiment of the disclosure, is shown run-in or placed inside the casing **104** at a desired or suitable location **104a** that designates the starting point of the milling operation, for example to form a window. The mill **120** includes a body **122** that carries a cutting device or milling device **130** that includes several cutters (or blades) **132a-132n** disposed around the body **122**. In one embodiment, the cutters **132a-132n** are disposed around the body **122**, wherein each such cutter is radially extendable from the body **122** and retractable to its original position on the body **122**. A power unit **140** in the mill **120** provides power to radially extend the blades **132a-132n** from the body **122**. The power unit **140** may be any suitable device, including, but not limited to, a hydraulic device and an electric device, such as an electric motor. In one aspect, the mill is configured to mill the casing **104** while the mill **120** is being pulled upward or up hole.

[0009]Still referring to **FIG. 1**, the mill **120**, in one embodiment, may further include a channel section or channel device **150** below the cutters **132a-132n** that includes one or more slots or channels **152a-152m** formed on an outer surface **154** of the channel device **150** to facilitate moving of the cuttings or swarf produced by the cutting device **122** to a location below the mill **120**. The channel device **150** rotates as the cutters **132a-132n** rotate. The slots **152a-152m** may be of any shape and size sufficient to move the cuttings therethrough. Such slots may be helical, as shown in **FIG. 1**, or of any other suitable configuration formed axially so that they are in communication with fluid **108** inside the casing **104**. The milling device **120** further includes a nose **160** having a bottom end **160a** and length "**L**" below the channel device **150**. The nose **160** rotates as the cutters **132a-132n** rotate. In one embodiment, the outside dimension or diameter **162** of the nose **160** is less than the outer dimension or diameter **156** of the channel section **150**. In one non-limiting embodiment, the milling device **120** further includes an agitator **180** below the cutting device **130**. In one embodiment, the agitator **180** may be placed around the nose **160**. In one embodiment, the agitator **180** may include a number of extendable elements or members, such as chains **182a-182k**, that rotate as the nose **160** rotates. Although the mill **120** is shown to include both the channel device **150** and the agitator **160**, the mill may be configured without the channel section, with the agitator **160** disposed below the cutters **132a-132n**.

[0010]FIG. 2 shows the milling device **120** of **FIG. 1** that has been activated to initiate milling of the casing **104**. To mill a section of the casing **104**, the milling device **120** is activated to cause the cutters **132a-132n** to rotate and extend radially outward to contact the casing **104**. The power unit **140** may be any suitable device, including but not limited to a hydraulic unit, such as a motor operated by flowing a fluid under pressure therethrough or an electric motor. The milling device **120** is pulled upward toward the surface to mill the casing at a selected or desired rate. The cutters **132a-132n** disintegrate the casing **104** into cuttings or swarf **230**. In **FIG. 2**, the milling device **120** is shown to have milled a portion of the casing **104** starting from the initial location **104a**. The milling device **120** is pulled upward at a selected rate while the cutters **132a-132n** are activated to continuously mill the casing **104**. The size of the cuttings **230** is a function of the cutter design and the rotational speed of the cutters. The cutters produce cuttings **230** of different size that can include strings. As shown in **FIG. 2**, during the initial process of cutting the casing **104**, the cuttings **230** accumulate into an area or annulus **270** between the milling device **120** and inside **101a** of the wellbore **101**. Since the channel device **150** is rotating while the cutters **132a-132n** are cutting the casing **104** and the milling device **120** is moving upward, the cuttings **230** tend to flow downward into the wellbore via the fluid filled channels **152a-152m**. Thus, the channels **152a-152m** aid or facilitate moving of the cuttings **230** from the annulus **270** down to area or annulus **250** between the nose **160** and the casing **104** below the channel device **150**. The cuttings **230** then flow from the annulus **250** into the wellbore inside below the milling device **120**.

[0011]Referring now to **FIG. 3**, once a certain length of the casing **104** has been milled, the bottom end **252** of the channel device comes above the start location **104a** of the casing **104**. As the milling continues and the milling device **120** is pulled upward, the agitator **180** moves above the start location **104a** and the agitator elements **182a-182k** start to rotate as nose **160** is rotating. The agitator elements **182a-182k** agitate the cuttings **230** falling into the area **270** and prevent such cuttings from accumulating in the area **304** at the intersection of the start location **104a** and the enlarged diameter **306** of the area **304** above the casing **104** at location **104a**. The agitator also can break up the strings of the cuttings into smaller pieces, which can facilitate moving such cuttings through the channel device **150**. During the milling process described above, the annulus **270** between the mill **120** and the wellbore inside **101a** remains filled with the wellbore fluid **108**. The agitator elements **182a-182k** continuously agitate or stir the cuttings **230** in the fluid **108**, which causes the cuttings **230** to remain in the fluid and cause such cuttings to fall or flow into the wellbore below the nose

end **160a**, thus preventing accumulation of such cuttings in the annulus **270** above the bottom end **304** of the annulus **270** along the wellbore inside wall **101a**.

[0012]The foregoing disclosure is directed to the certain exemplary non-limiting embodiments. Various modifications will be apparent to those skilled in the art. It is intended that all such modifications within the scope of the appended claims be embraced by the foregoing disclosure. The words "comprising" and "comprises" as used in the claims are to be interpreted to mean "including but not limited to". Also, the abstract is not to be used to limit the scope of the claims.

CLAIMS

1. A milling apparatus for cutting a tubular in a wellbore, comprising:

a cutting element on a tool body configured to cut the tubular in the wellbore when the cutting element is activated and moving upward inside the tubular, wherein the cutting element cuts the tubular to form cuttings;

a power unit for activating the cutting element from a retracted position to an expanded position to cause the cutting element to contact the tubular to cut the tubular into the cuttings, wherein the cuttings fall into an annulus between the tubular and the wellbore and;

an agitator below the cutting element that agitates the cuttings in the annulus to aid cuttings to fall from the annulus into the wellbore below the milling apparatus.

2. The milling apparatus of claim 1, wherein the agitator includes an extension member that rotates to contact the cuttings to guide the cuttings into the wellbore.

3. The apparatus of claim 2, wherein the extension member is selected from a group consisting of: a chain having a length that extends beyond an inside diameter of the tubular; and a flexible mechanical member that extends beyond an inside diameter of the tubular.

4. The milling apparatus of claim 1, wherein the power unit for activating the cutting element is selected from a group consisting of: a hydraulic unit; an electric motor; an electro-mechanical device; and a hydro-mechanical device.

5. The milling apparatus of claim 2, wherein the extension member rotates as the cutting element rotates.

6. The milling apparatus of claim 2, wherein extension element is attached to a reduced diameter section at a bottom end of the body that rotates as the cutting element rotates.

7. The milling apparatus of claim further comprising a channel device below the cutting element that directs the cuttings from the annulus to a location below the channel device.

8. The milling apparatus of claim 7, wherein the channel device includes a channel along a surface thereof that is in communication with cuttings in the annulus and enables the cuttings to flow through the channel to the location below the channel device.

9. The milling device of claim 1, wherein the milling device is configured to be connected to a drill pipe coupled to rotary device at a surface location and wherein rotating the drill pipe at the surface rotates the milling device.

10. A method of milling a tubular in a wellbore, comprising:

positioning a milling device at a start location in the wellbore, wherein the milling device includes: a cutting element on a tool body configured to cut the tubular in the wellbore when the cutting element is activated and moved upward inside the tubular, wherein the cutting element cuts the tubular into cuttings that are disposed in an annular space between the tool body and a wellbore wall;

activating the cutting element to contact the tubular;

cutting the tubular by moving the cutting element from the start location to an end location; and

causing an agitator to aid the cuttings to move from the annular space into the wellbore.

11. The method of claim 10, wherein the agitator includes an extension member that rotates to contact the cuttings in the annular space to guide the cuttings into the wellbore.

12. The method of claim 11, wherein the extension member is selected from a group consisting of: a chain having a length that extends beyond an inside diameter of the tubular; a flexible mechanical member that extends beyond an inside diameter of the tubular.

13. The method of claim 12, wherein activating the cutting element incudes utilizing a power unit to activate the cutting element that is selected from a group consisting of: a hydraulic unit; an electric motor; an electro-mechanical device; and a hydro-mechanical device.

14. The method milling apparatus of claim 13, wherein the extension member rotates as the cutting element rotates.

15. The method of claim 13, wherein the extension element is attached to a reduced diameter section at a bottom end of the body that rotates as the cutting element rotates.

16. A milling apparatus for cutting a tubular in a wellbore, comprising:

a cutting element configured to cut the tubular in the wellbore when the cutting element is activated and moving upward inside the tubular, wherein the cutting element cuts the tubular to form cuttings;

a power unit for activating the cutting element from a retracted position to an expanded position to cause the cutting element to contact the tubular to cut the tubular into the cuttings; and

at least one channel around an outer surface of a body of the milling apparatus below the cutting element to guide the cuttings to fall into the wellbore.

17. The milling apparatus of claim 16, wherein the cuttings are disposed in an annular space between the body of the milling apparatus and a wellbore wall.

18. The milling apparatus of claim 17, wherein the at least one channel causes the cuttings to move from the annular space inside the wellbore below the cutting element.

19. The milling apparatus of claim 16, wherein the at least one channel is selected from a group consisting of: one or more helical channels; and one or more cross-channels.

20. The milling apparatus of claim 16, wherein the power unit for activating the cutting element is selected from a group consisting of: a hydraulic unit; an electric motor; an electro-mechanical device; and a hydro-mechanical device.

21. The milling apparatus of claim 16, wherein the cutting element is disposed on a housing having a nose at a bottom end thereof and wherein the cuttings accumulate in an annular space formed between the housing and the wellbore inside when the bull nose is below the annular space.

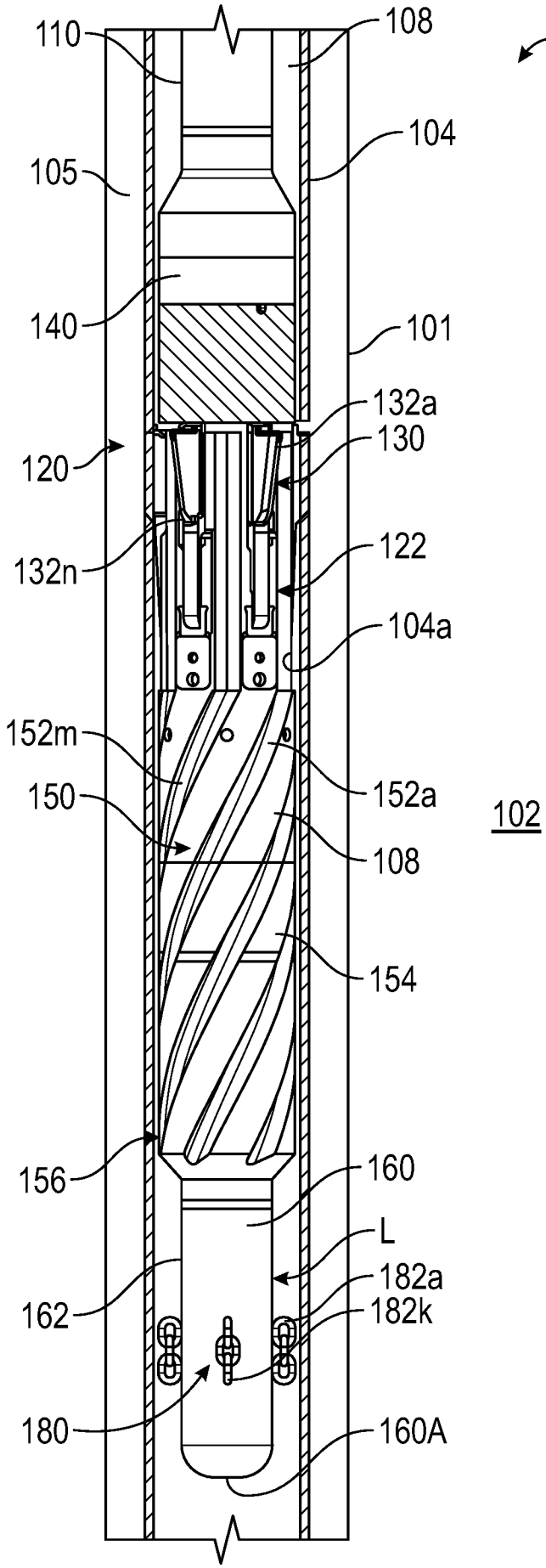

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122
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180
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FIG. 1

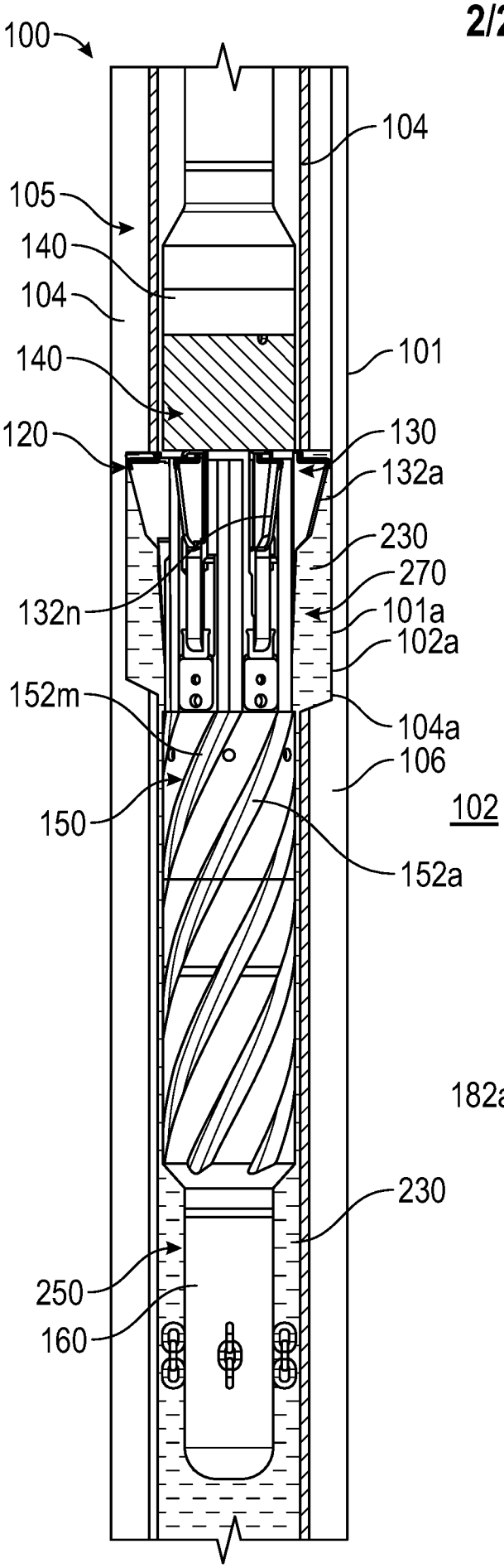

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102a
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104a
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152a
230
250
160

FIG. 2

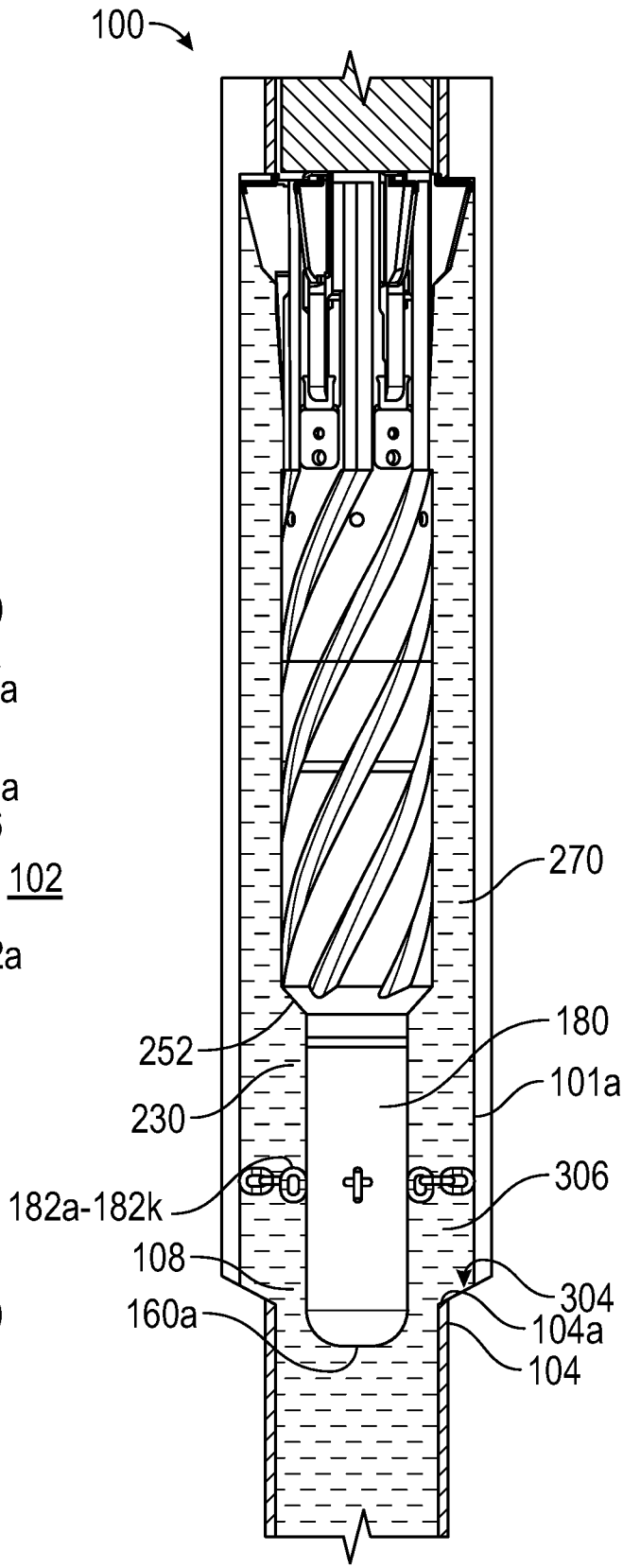

100
270
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101a
230
306
182a-182k
108
304
104a
160a
104

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/019846

A. CLASSIFICATION OF SUBJECT MATTER

E21B 29/00(2006.01)i, E21B 3/00(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 29/00; E21B 7/00; E21D 1/06; E21B 10/00; E21B 21/00; E21B 37/00; E21B 17/22; E21B 3/00

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: milling apparatus, cutting element, power unit, agitator, cuttings, annulus, channel device

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015-0376966 A1 (SMITH INTERNATIONAL, INC.) 31 December 2015 See paragraphs [0033]-[0036] and figures 2-3.	1-21
Y	US 2011-0048803 A1 (ROBSON et al.) 03 March 2011 See paragraphs [0007]-[0009], [0023]-[0027], [0030]-[0034] and figures 1-3.	1-21
A	US 2012-0132469 A1 (ROBSON et al.) 31 May 2012 See paragraphs [0043] and figures 6-7.	1-21
A	US 2007-0215388 A1 (KIRK et al.) 20 September 2007 See paragraph [0072] and figure 1.	1-21
A	US 9493998 B2 (MACHOCKI, KRZYSZTOF) 15 November 2016 See claim 1 and figure 11.	1-21

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"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	Date of mailing of the international search report
25 June 2018 (25.06.2018)	**03 July 2018 (03.07.2018)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2018/019846

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