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Pipe cutting tool

Abstract

A pipe-cutting tool, which can be independently pumped down to cut a wellbore pipe or casing, is disclosed. When the tool is lowered into the wellbore, a pump down ring, included in the tool, remains flush with the inner surface of the pipe. To power the tool's descent, high-pressure fluid is pumped into the wellbore. On reaching the target location, a swellable sleeve included in the tool, on being exposed to fluid in the wellbore, expands to push against the inner surface of the pipe, lodges the tool at the location, and seals any fluid flow path bypassing the tool. Thereafter, high-pressure abrasive fluid is pumped through the tool to eject in the form of high-pressure abrasive fluid jets, which cut through the wellbore pipe at the target location.

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Background/Summary

BACKGROUND

(1) In the oil and gas industry, there is often a need to cut a wellbore pipe or a coiled tubing

downhole. For instance, when a drill pipe, coiled tubing or any downhole equipment deployed in the wellbore (or deployed with the coiled tubing) gets stuck, to recover the pipe upper portion, it is often necessary to sever the pipe. Sometimes, downhole tubing also needs to be cut for repairs or to remove it from an abandoned well. Several cutting devices have been used for these purposes, but most of them require a separate conveyance method, like slickline, wireline, or coil tubing. When cutting coiled tubing at any point below the surface, there is a lack of tools or equipment that can be deployed inside the coil tubing, without the need for cutting the coil tubing at the surface in order to gain access to the coil tubing inner diameter.

(2) Hence, there is a need for an improved downhole cutting device that would be capable of being independently pumped down into a wellbore (or into a coiled tubing, as the case may be) and which would then hold its position at the target location downhole. Still further, compared with current options, the device should be easier to place, and be easier to operate by eliminating the need for additional conveyance equipment to place it downhole.

SUMMARY

(3) The invention is a generally cylindrically shaped pipe-cutting tool, operated using abrasive fluid, which can be independently pumped down and stationed in a wellbore pipe, coiled tubing (or casing). The tool is operated to initiate and cease cutting downhole by regulating the flow of pressurized abrasive fluid through it.

(4) The tool includes a pump down ring and a swellable sleeve, both on the outer surface of the tool. Preferably, the pump down ring is made of a flexible material (such as rubber) and is located below the swellable sleeve. While the pump down ring, under fluid pressure, assists the descent of the tool within a wellbore pipe (or coiled tubing), the swellable sleeve, when exposed to fluids (such as drilling mud, water, oil-based fluid systems, or any other suitable fluid) for a sufficient period, absorbs fluid and expands to increase its outer diameter. The swellable sleeve is preferably made of swellable material supplied by RUBBERATKINS LIMITED, Aberdeen, Scotland.

(5) To perform a cut at a target location of a wellbore pipe or a coiled tubing, firstly, the tool is lowered in or positioned at a point inside the pumping lines that would allow it to enter the coiled tubing once fluid is pumped. The pump down ring is preferably flush with the inner surface of the wellbore pipe (or of the coiled tubing) and catches the fluid pressure on its upper surface to force the tool down to its target location.

(6) If the target location is at a downhole restriction of some type (for example, a connector of a coiled tubing or a nipple connector of a threaded pipe, as the case may be), the tool's descent stops at the restriction. However, if the target location lies in a restriction-free path, the tool's level is controlled by the quantity of fluid pumped into the wellbore pipe (or into the coiled tubing). Based on the internal diameter of the wellbore pipe or the coiled tubing, and the quantity of fluid pumped in, the depth of the tool can be calculated. Once the tool descends to the depth of the target location, pumping is halted to stop further descent of the tool.

(7) At this stage, the swellable sleeve remains fully submerged in the fluid. Exposure to the oil or water-based fluid for a sufficient time causes the sleeve to absorb fluid and expand. As a result, its outer diameter increases to the extent that the outer surface of the sleeve pushes against the internal surface of the wellbore pipe or of coiled tubing, and lodges the tool at the target location. The expanded sleeve also seals any fluid flow path bypassing around the tool.

(8) Once the tool is lodged in place, high-pressure abrasive fluid, usually a mixture of water, gel and sand or another solid in suspension is pumped in, and it enters and flows through the tool. Inflowing abrasive fluid gets ejected from fluid ejection nozzles of the tool in the form of high-pressure jets which cut the pipe or coiled tubing. Preferably, the direction of the high-pressure jets could be set at different angles depending on a particular application and need not necessarily lie transverse to the axis of the tool.

(9) In addition to facilitating firm positioning of the tool and sealing off fluid flow around the tool, the swollen sleeve also acts as a damper and absorber of vibrations produced during cutting

operations. This enhanced stability during tool operation aids quick and effective pipe severance.
(10) Embodiments of the present invention will be discussed in greater detail with reference to the accompanying figures in the detailed description that follows.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** illustrates a cross-section of a first embodiment of an abrasive fluid operated pipe cutting tool in accordance with the present invention.
(2) FIG. **2** illustrates a cross-section of the tool of FIG. **1** in a wellbore.
(3) FIG. **3** illustrates a cross section of the tool of FIG. **2** lodged in the wellbore with its swellable sleeve expanded.
(4) FIG. **4** illustrates the tool of FIG. **3** with inflow of high-pressure abrasive fluid, and ejecting high pressure jets of abrasive fluid, for cutting the wellbore pipe. Note that only the wellbore pipe is shown in cross-section.
(5) It should be understood that the drawings and the associated descriptions below are intended to illustrate one or more embodiments of the present invention and not to limit the scope or the number of different possible embodiments of the invention.
(6) It should be noted that the drawings are not necessarily drawn to scale.
DETAILED DESCRIPTION
(7) In the description of the invention which follows, unless specified otherwise, terms ‘upper’, ‘upward’ and ‘upwards’ are used to denote a direction towards the top of the wellbore or towards the source of fluid flowing through the tool. Similarly, terms ‘lower’, ‘below,’ ‘downward,’ and ‘downwards’ are used to denote the direction of fluid flowing through the tool, which is top to bottom in all figures.
(8) Similarly, in the entire description provided herein, the term ‘wellbore pipe’ has been used synonymously to denote ‘wellbore casing’ or ‘wellbore wall’ or ‘wellbore pipe’ or ‘wellbore piping’ or ‘coil tubing’ or ‘drill string’ or ‘casing drill pipe’ or ‘drill string wall’.
(9) Some components and/or portions of the embodiments of the invention illustrated in the figures may not be fully discussed in the description which follows, because they are not needed to provide a full and complete description of the embodiments of the invention, which is adequate for comprehension by anyone with relevant experience in the field.
(10) Reference will now be made in detail to a first embodiment of an abrasive fluid operated pipe cutting tool of the invention with reference to the accompanying figures. FIG. **1** illustrates a cross section of a first embodiment of generally cylindrically shaped abrasive fluid operated pipe cutting tool **100**. Tool **100** includes an upper retainer tube **102**, a swellable sleeve **104**, a connector tube **106**, a pump down ring **108**, a connector flow tube **110**, and an ejector tube **112**. Other parts in FIG. **1** are discussed below.
(11) As illustrated in FIG. **1**, the connector tube **106** includes an upper narrow tube **114**, a lower wider tube **116** and a central bore **118** extending through both the upper narrow tube **114** and the lower wider tube **116**. Central bore **118** is narrower within the upper narrow tube **114** and is wider within lower wider tube **116**. Similarly, the upper retainer tube **102**, and the connector flow tube **110** also include a bore extending through them, illustrated as bore **120** and bore **122** respectively. As shown, bore **122** is narrower towards the upper end of the connector flow tube **110**, and flares towards its lower end.
(12) The ejector tube **112** further includes bore **124** which has an upper end that does not extend through the tool. Still further, multiple fluid ejection nozzles **130** are screwed, welded or held in position by interference symmetrically around the ejector tube **112**. Each fluid ejection nozzle **130** includes a fluid ejection channel **132**, which connects with bore **124**.

(13) The lower portion of the ejector tube **112** includes a lower bore **138** which extends from lower end **128** but does not extend through the tool, and is not connected with upper bore **124**. Multiple fluid flow channels **134** are distributed symmetrically around the lower bore **138**. The flow channels **134** connect the lower bore **138** with the exterior of ejector tube **112** (and that of tool **100**). In this embodiment, as illustrated, fluid flow channels **134** are directed at an angle towards the upper end **126** of ejector tube **112**.
(14) The swellable sleeve **104** is a tubular structure preferably made of material such as the swellable product supplied by RUBBERATKINS LIMITED, Aberdeen, Scotland. When exposed to fluids (preferably wellbore fluids, including drilling mud, water, oil-based fluid systems, or any other suitable fluid), the sleeve absorbs fluid and swells to increase its outer diameter.
(15) The pump down ring **108** includes an annular fin **140**. The annular fin **140**, surrounds the tubular portion of the pump down ring **108**, and is flared upwardly in this embodiment. In a dry state tool **100**, the outermost periphery of the annular fin **140** has a larger outer diameter than any other component of tool **100**. Preferably, annular fin **140** is flush with the inner surface of the wellbore pipe or coiled tubing, in which tool **100** is intended to be used.
(16) For assembling tool **100**, firstly, a sleeve **104** (before fluid causes its swelling) is slipped over the upper narrow tube **114** and is placed adjacent to the upper end of the lower wider tube **116**. Once sleeve **104** is in place, an externally threaded upper end of upper narrow tube **114** protrudes from the upper end of sleeve **104**. In the next step, the internally threaded lower end of upper retainer tube **102** is screwed over the protruding externally threaded upper end of upper narrow tube **114**. Sleeve **104** is now confined between the lower end of the upper retainer tube **102** and the upper end of the lower wider tube **116**.
(17) In the next step, the externally threaded upper end of the connector flow tube **110** is screwed into the internally threaded lower end of lower wider tube **116**. Thus, the upper end of the connector flow tube **110** gets screwed into the lower end of bore **118**. Thereafter, the pump down ring **108** is slipped over the unthreaded middle portion of the connector flow tube **110** such that the annular fin **140** is tilted upwards (i.e. towards the upper end of tool **100**). Finally, the externally threaded lower end of the connector flow tube **110** is screwed into the internally threaded upper end **126** of the ejector tube **112**. Once the ejector tube **112** is screwed into the connector flow tube **110**, the pump down ring **108** is confined between the lower end of the upper end of the lower wider tube **116** and the upper end of the ejector tube **112**.
(18) In the assembled tool **100**, bores **118**, **120**, **122**, and **124** extend collinearly and provide a common fluid flow path for pressurized fluid to flow through the tool **100**. In an operational tool **100**, while the upper end of the bore **120** provides an entrance for pressurized fluid to flow through the tool **100**, and fluid ejection nozzles **130** provide exits for the pressurized fluid, which is ejected as high-pressure abrasive fluid jets (shown as jets **204** in FIG. **4**).
(19) Operation of the assembled dry abrasive fluid-operated pipe cutting tool **100**, when deployed in a wellbore for cutting wellbore pipe at a target location will now be explained with the help of FIGS. **2**, **3** and **4**.
(20) Firstly, the assembled tool **100** is lowered into wellbore **200** defined by a wellbore pipe **202**. Thereafter, high-pressure fluid (such as drilling mud) is pumped into the wellbore pipe **202** to power the descent of the tool **100** towards a target location downhole.
(21) If the target location is at a downhole restriction of some type (for example, a connector of a coiled tubing, or a nipple connector of a threaded pipe, as the case may be) which restricts descent of the tool **100**, the descending tool **100** stops at the restriction. However, if the target location lies in a restriction-free path, the descent of the tool **100** is controlled by controlling the quantity of high-pressure fluid pumped into the wellbore pipe **202**.
(22) Based on the internal diameter of the wellbore pipe **202** and the quantity of fluid being pumped into the well pipe **202**, the instantaneous depth of tool **100** can be calculated according to the formula:

$D=Q/(\pi\times r^2)$ Where: 'D'=depth of the tool (in meters) 'Q'=is volume of fluid being pumped into the wellbore pipe (in liters) 'r'=is radius of the wellbore pipe (in meters) 'π'=3.14 (a numeric constant).

(23) As soon as the tool **100** descends to the depth of the target location, further pumping of fluid into the wellbore pipe **202** is halted to stop further downward descent of the tool **100**.

(24) At this stage, with tool **100** stationed the target location, sleeve **104** remains fully submerged in the fluid. Exposure to the fluid for a sufficient time allows the sleeve **104** to swell (by absorbing fluid) and expand. As a result, its outer diameter increases to lodge tool **100** at the target location. The expanded sleeve **104** also seals any fluid flow path around the tool (see FIG. **3**).

(25) Once the tool **100** is lodged in place, high pressure abrasive fluid (usually a mixture of water, gel, and a solid particulate, such as sand, in suspension) is pumped into the wellbore pipe **202**, and it enters and flows through tool **100** (since bypass paths around the tool **100** for fluid are sealed by expanded sleeve **104**). Inflowing abrasive fluid gets ejected from fluid ejection nozzles **130** in the form of high-pressure jets **204** which cut the wellbore pipe **202** (see FIG. **4**; cut not illustrated). Preferably, the direction of the high-pressure jets **204** could be set at different angles depending on a particular application and need not necessarily lie transverse to the axis of the tool **100**.

(26) It is to be noted that apart from facilitating firmly stationing the tool **100** and sealing off fluid flow exterior to the tool, the swollen sleeve **104** also acts as damper and absorber of vibrations produced during cutting operations.

(27) It is to be noted that, though the explanation above describes the operation of tool **100** in a wellbore pipe, embodiments of the tool of the present invention can also be operated in a coiled tubing of a wellbore. When intended to be operated in a coiled tubing, dimensions of the tool are selected based on the dimensions of the internal diameter of the coiled tubing.

(28) It is to be understood that the foregoing description and embodiments are intended to merely illustrate and not limit the scope of the invention. Other embodiments, modifications, variations and equivalents of the invention are apparent to those skilled in the art and are also within the scope of the invention, which is only described and limited in the claims which follow, and not elsewhere.

Claims

1. A generally cylindrical shaped abrasive fluid operated pipe cutting tool having a first upper end and a lower end comprising: a pump down ring, wherein an outermost diameter of said ring is larger than that of any other component of said tool when the tool is in dry state; a swellable sleeve, upstream from said pump down ring, surrounding at least a portion of an outer surface of said tool, said sleeve being capable of expanding when exposed to a first oil or water-based fluid; and one or more flow channels connecting a portion of the outer surface of the tool downstream the pump-down ring with the lower end of the tool; and a fluid flow path having, at the first upper end of the tool, an entrance for pressurized abrasive fluid to flow into the tool, and multiple fluid ejection nozzles downstream of said swellable sleeve, and said multiple fluid ejection nozzles for ejection of inflowing pressurized abrasive fluid from the tool in the form of pressurized abrasive fluid jets, the swellable sleeve and abrasive fluid jets configured such that: exposing said sleeve to said first oil or water-based fluid causes the sleeve to expand, wherein expansion of said sleeve seals fluid flow paths around the tool and stops fluid flow to the pump-down ring; and pumping pressurized fluid into entrance of said fluid flow path causes ejection of pressurized abrasive fluid jets from said nozzles.
2. The tool of claim 1, wherein said swellable sleeve is made of swellable rubber.
3. The tool of claim 1, wherein said first oil or water-based fluid includes aqueous solutions, drilling mud or oil-based fluids.
4. The tool of claim 1, wherein said abrasive fluid is a mixture of water, gel, and sand or another solid in suspension.

5. The tool of claim 1, wherein the fluid ejection nozzles are angled upstream.
6. The tool of claim 1, wherein the pump down ring includes an annular fin.
7. The tool of claim 6, wherein the annular fin is configured to lie flush with the inner surface of the pipe when in position.
8. A method of cutting a pipe comprising: i) lowering a generally cylindrical-shaped abrasive fluid-operated pipe-cutting tool having a first upper end and a lower end to a target location within the pipe; said tool comprising: a pump down ring, wherein an outermost diameter of said ring is larger than that of any other component of said tool when the tool is in dry state; a swellable sleeve, upstream from said pump down ring, surrounding at least a portion of an outer surface of said tool, said sleeve being capable of expanding when exposed to a first oil or water-based fluid; and a fluid flow path having, at the first upper end of the tool, an entrance for pressurized abrasive fluid to flow into the tool, and multiple fluid ejection nozzles downstream of said swellable sleeve, and said multiple fluid ejection nozzles for ejection of inflowing pressurized abrasive fluid from the fluid flow path in the form of pressurized abrasive fluid jets; one or more flow channels connecting a portion of the outer surface of the tool downstream the pump-down ring with the lower end of the tool; ii) exposing said sleeve to said first oil or water-based fluid for a period sufficient to cause said sleeve to expand and seal any fluid flow bypassing the tool and thereby stopping any fluid flow to the pump-down ring from the first end; iii) pumping pressurized abrasive fluid into the entrance of said fluid flow path and causing ejection of pressurized abrasive fluid jets from said nozzles; and iv) cutting said pipe at the target location through the ejected pressurized abrasive fluid jets.
9. The method of claim 8, wherein said swellable sleeve is made of swellable rubber.
10. The method of claim 8, wherein said first oil or water-based fluid includes aqueous solutions, drilling mud or oil-based fluids.
11. The method of claim 8, wherein said abrasive fluid is a mixture of water, gel, and sand or another solid in suspension.
12. The method of claim 8, wherein said lowering is achieved by pushing said tool downhole by pumping said first oil or water-based fluid into the pipe.
13. The method of claim 8, wherein the fluid ejection nozzles are angled upstream.
14. The method of claim 8, wherein the pump down ring includes an annular fin.
15. The method of claim 14, wherein the annular fin is configured to lie flush with the inner surface of the pipe when in position.