Title: DOWNHOLE TRACTOR WITH TURBINE-POWERED MOTOR

Abstract: A wellbore tractor comprises an elongated body having an internal fluid chamber, at least one gripper assembly, a drilling mud driven turbine (150), and a power transmission assembly. The output shaft of the turbine is connected to a generator (152) which drives an electric motor (154) which in turn drives a hydraulic pump (156). The pump operates the closed loop hydraulic system for actuating the gripper assembly and the tractor drive.
DOWNHOLE TRACTOR WITH TURBINE-POWERED MOTOR

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to tools for conducting operations within passages, and specifically to tools for borehole intervention and/or drilling.

Description of the Related Art

U.S. Patent No. 6,003,606, entitled "Puller-Thruster Downhole Tool," discloses an innovative self-propelled tool or tractor for drilling, completion, stimulation, and intervention that pulls a drill string and simultaneously thrusts itself and its payload downhole and/or into a casing or borehole formation. The '606 patent discloses a tractor that includes one or more gripper assemblies (e.g., bladders or packerfeet) that grip onto an inner surface of a borehole or casing, and one or more propulsion assemblies that propel the tractor body forward when at least one of the gripper assemblies is gripping the borehole. A valve system directs a fluid (e.g., drilling mud, intervention fluid, hydraulic fluid) to and from the gripper assemblies and propulsion assemblies to power movement of the tractor.

The '606 patent discloses two basic types of tractor configurations — open loop and closed loop. The open loop system uses an externally provided fluid as a medium of hydraulic communication within the tractor. The open loop consists of a ground surface pump, tubing extending from the pump into a borehole, a tractor within the borehole and connected to the tubing, and an annulus between the exterior of the tractor and an inner surface of the borehole. The fluid is pumped down through the tubing to the tractor, used by the tractor to move and conduct other downhole operations, and then forced back up the borehole through the annulus. The tractor is powered by differential pressure — the difference of the pressure at the point of intake of fluid to the tractor and the pressure of fluid ejected from the tractor into the annulus. In the open loop system, a portion of the fluid is used to power the tractor's movement and another portion of the fluid flows through the tractor for various downhole purposes, such as hole cleaning, sand washing, acidizing, and
lubricating of a drill bit (in drilling operations). Both portions of the fluid return to the ground surface through the annulus.

The '606 patent also discloses a closed loop configuration in which a hydraulic fluid is circulated through the gripper assemblies and propulsion assemblies to power the tractor's movement within the borehole. In particular, Fig. 19 of the '606 patent discloses a downhole motor that powers the recirculation of the hydraulic fluid.

U.S. Patent Nos. 6,347,674; 6,241,031; and 6,679,341, as well as U.S. Patent Application Publication No. 2004/0168828, disclose alternative valve systems and methods for directing fluid to and from a downhole tractor's gripper assemblies and propulsion assemblies for moving the tractor.

SUMMARY

In one aspect, a tool for moving within a passage is provided. The tool comprises an elongated body having an internal fluid chamber, at least one gripper assembly engaged with the body, a turbine, and a power transmission assembly. The body is configured to be secured to a fluid conduit so that a first fluid flowing through the conduit flows into the internal fluid chamber of the body. The gripper assembly has an actuated position in which the gripper assembly grips onto an inner surface of the passage to substantially limit relative movement between the gripper assembly and the inner surface. The gripper assembly also has a retracted position in which the gripper assembly permits substantially free relative movement between the gripper assembly and the inner surface of the passage. The turbine is configured to receive the first fluid flow through the internal fluid chamber, the turbine having an output shaft configured to rotate as the first fluid flows through the turbine. The power transmission assembly is configured to convert rotation of the output shaft into power for moving the gripper assembly to its actuated position.

In another aspect, a method of moving a tool within a passage is provided. In accordance with the method, an elongated body having an internal fluid chamber is provided. The body is secured to a fluid conduit so that a first fluid flowing through the conduit flows into the internal fluid chamber of the body. At least one gripper assembly is provided and engaged with the body. The gripper assembly has an actuated position in which the gripper...
assembly grips onto an inner surface of the passage to substantially limit relative movement between the gripper assembly and the inner surface. The gripper assembly also has a retracted position in which the gripper assembly permits substantially free relative movement between the gripper assembly and the inner surface of the passage. A turbine is provided, the turbine configured to receive the first fluid flow through the internal fluid chamber. The turbine has an output shaft configured to rotate as the first fluid flows through the turbine. A power transmission assembly is provided, the power transmission assembly being configured to convert rotation of the output shaft into power for moving the gripper assembly to its actuated position. Finally, the first fluid is pumped through the conduit into the internal fluid chamber of the body and through the turbine.

For purposes of summarizing the invention and the advantages achieved over the prior art, certain objects and advantages of the invention have been described herein above. Of course, it is to be understood that not necessarily all such objects or advantages may be achieved in accordance with any particular embodiment of the invention. Thus, for example, those skilled in the art will recognize that the invention may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other objects or advantages as may be taught or suggested herein.

All of these embodiments are intended to be within the scope of the invention herein disclosed. These and other embodiments of the present invention will become readily apparent to those skilled in the art from the following detailed description of the preferred embodiments having reference to the attached figures, the invention not being limited to any particular preferred embodiment(s) disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of a conventional coiled tubing tractor system.

Figure 2 is a schematic diagram of a closed loop system for powering a downhole tractor, according to one embodiment of the invention.

Figure 3 is a more detailed schematic diagram of the closed loop system of Figure 2.
DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 illustrates a conventional coiled tubing tractor or tool for conducting downhole operations such as intervention and drilling. The illustrated system is an open loop configuration. The coiled tubing system 100 typically includes a power supply 102 for powering ground-level equipment, a tubing reel 104, a tubing guide 106, and a tubing injector 110, which are well known in the art. The illustrated system includes a bottom hole drilling assembly 120 for drilling a borehole 132 with a drill bit 130. However, other types of bottom hole assemblies 120 can alternatively be provided, such as those for intervention operations like hole cleaning, sand washing, acidizing, and the like. As known, coiled tubing 114 is inserted into the borehole 132, and a fluid (e.g., drilling mud, intervention fluid) is typically pumped through the inner flow channel of the coiled tubing 114 towards the drill bit 130 located at the end of the drill string. Positioned between the drill bit 130 and the coiled tubing 114 is a tool or tractor 112. The illustrated bottom hole assembly (BHA) 120 includes a number of elements known to those skilled in the art, such as a downhole motor 122 and a Measurement While Drilling (MWD) system 124. The tractor 112 is preferably connected to the coiled tubing 114 and the bottom hole assembly 120 by connectors 116 and 126, respectively, as known in the art. In this system, the fluid is pumped through the inner flow channel of the coiled tubing 114 and through the tractor 112 to the drill bit 130. The fluid and drilling debris return to the surface in the annulus defined between the exterior surface of the tractor 112 and the inner surface of the borehole 132, and also defined between the exterior surface of coiled tubing 114 and the inner surface of the borehole 132.

When operated, the tractor 112 is configured to move within the borehole 132. This movement allows, for example, the tractor 112 to maintain a pre-selected force on the bottom hole assembly 120 such that the rate of movement or drilling can be controlled. The tractor 112 can be used to move various types of equipment through the borehole 132. For example, it will be understood that the tractor 112 can be connected with or include, without limitation, a downhole motor (for rotating a drill bit), steering system, instrumentation sub (an instrumented package that controls various aspects of downhole operation, including shock vibration, weight on bit, torque at bit, rate of penetration, downhole motor rpm, and differential pressure across motor), Measurement While Drilling apparatus (an apparatus for
measuring gyroscopic data such as azimuth, inclination, and measured depth), drill bit, mechanical and hydraulic disconnect for intervention, jetting tools, production logging tools (including apparatus for measuring and recording, without limitation, temperature, annulus pressure, and various flow rates), drilling logging tools (for measuring and recording, without limitation, resistivity measurements, magnetic resonance (MRI), sonic neutron density, density, fluid identification, and gamma ray measurements), perforation guns, casing collar locators, and torque limiting tools (for drilling).

A closed loop configuration has relevant differences from an open loop system that operates on differential pressure (the difference in pressure between the bore of the tractor and the exterior of the tractor). With an open system, a restriction in the system is required to produce a pressure difference (decrease) between the interior and exterior of the tractor. Typically, the restriction is an orifice such as a fixed diameter nozzle, and is not capable of being adjusted from the surface. For typical coiled tubing rig operations, the effective means of control is to control the surface pump output flow rate. However, the differential pressure available at the tractor is a quadratic (non-linear) function of the surface pump output flow rate. Thus, doubling the surface pump output flow rate will increase the differential pressure through an in-series fixed orifice by a factor of four. This makes power control of the tractor more difficult as normal operational changes can have non-linear impact on tractor power, requiring additional features to be incorporated into the open loop powered tractor to restrict the amount of pressure delivered to the gripper assemblies, for example. Further, this has a disadvantage in that the normal operating range of the surface pump output flow rate required for various operations may have to be restricted, thus reducing cleaning efficiency during the operation.

Figure 2 is a schematic illustration of a turbine-powered motor for circulating hydraulic fluid in a closed loop for powering a downhole tool or tractor, according to one embodiment of the present invention. In this configuration, a first fluid (typically drilling/intervention fluid) that is externally pumped into the coiled tubing usually at the ground surface flows through the tractor and passes through a turbine 150 on its way to the remaining bottom hole assembly (typically secured to the distal end of the tractor). The turbine 150 drives a generator 152 that produces electricity, as known in the art of turbine
power generation. The electricity produced by the generator 152 powers an electric motor
154 that in turn powers a pump 156. The pump 156 circulates a second fluid (typically
hydraulic fluid) in a closed system loop 155. Box 158 represents a valve system, gripper
assemblies, and propulsion assemblies as known in the art. For example, the valve system,
gripper assemblies, and propulsion assemblies can be substantially as shown and described in
U.S. Patent Nos. 6,003,606; 6,347,674; 6,241,031; and 6,679,341, as well as U.S. Patent
Application Publication No. 2004/0168828. Also, the gripper assemblies can be substantially
as shown and described in U.S. Patent Nos. 6,464,003 and 6,715,559; U.S. Patent
Application Publication No. 2005/0247488; and U.S. Provisional App. No. 60/781,885. The
second fluid provides hydraulic force for operation of the gripper assemblies and propulsion
assemblies, and in some cases the valves.

Commercially available turbine-generators are sold by Spring Electronics of
Worcestershire, United Kingdom. One turbine-generator sold by Spring Electronics
comprises a three-phase alternator, rectifier, and switch mode power supply producing about
70 Watts at 50 volts. Larger versions of turbine-generators are commercially available.

Figure 3 is a more detailed schematic illustration of the closed loop system of Figure
2 adapted for use with a variation of the Puller-Thruster Downhole Tool (also referred to as
the "Puller-Thruster Assembly" or "PTA") described in U.S. Patent No. 6,003,606. As the
first fluid is pumped through the turbine 150, the turbine powers the motor 154 and in turn
the pump 156 that circulates the second fluid through the illustrated valve assembly. The
second fluid flows from a supply line 228 through a start/stop valve 160 (also known as an
"idler valve") into the valve system. A six-way control valve 162 shuttles back and forth to
direct the fluid to and from an aft gripper assembly 180 (illustrated as a deflated packerfoot)
and a forward gripper assembly 182 (illustrated as an inflated packerfoot), and also to and
from an aft propulsion assembly 184 and a forward propulsion assembly 186 (each
propulsion assembly comprising barrels and internal pistons, as taught in the '606 patent).
Valves 164 and 166 (also known as "directional control valves") control the shuttling and
position of the six-way control valve 162. Packerfeet valves 168 and 170 regulate the flow of
fluid into the packerfeet 180 and 182. A reverser valve 172 controls the direction of tractor
movement (i.e., uphole or downhole). The operation of these valves is understood from the
teachings of the aforementioned patents incorporated by reference. A sump 157 is preferably provided to store a reservoir of the second fluid. The circulating second fluid returns to the sump 157 via a return line 230.

Figure 3 shows an embodiment of a tool 200 (illustrated as a Puller-Thruster Assembly) positioned within a drilled hole 205 inside a rock formation 212. The tool 200 includes an elongated body formed of central coaxial cylinders 207. The aft gripper assembly 180, aft propulsion assembly 184, forward gripper assembly 182, and forward propulsion assembly 186 are engaged on the central coaxial cylinders 207. The aft propulsion assembly 184 includes annular pistons 218 secured to the cylinders 207. Similarly, the forward propulsion assembly 186 includes annular pistons 220 secured to the cylinders 207. The number of pistons can vary (e.g., up to 20 pistons) and depends on the desired thrust and pull loads.

The tool body defines an internal mud flow passage 224 inside the cylinders 207. The aft end of the tool body has an inlet 201 connected to coiled tubing 114 via a coiled tubing connector 206 (connection can be threaded or snapped together). While Figure 3 shows coiled tubing 114, the tool 200 can also be used with rotary drill rigs instead. The forward end of the tool body is connected to a bottom hole assembly (BHA) 204. The illustrated tool includes a female coiled tubing connector 208 and stabilizers 210. The valve control pack 214 is positioned between the forward and aft gripper assemblies and also between the forward and aft propulsion assemblies. Splines 216 can optionally be incorporated between the central coaxial cylinders 207 and the gripper assemblies to prevent the transmission of torque from the BHA 204 to the coiled tubing 114.

In use, drilling/intervention fluid flows from the coiled tubing 114 into the inlet 201 of the tool body, and downhole (toward the bottom of the hole) through the mud flow passage 224. The fluid flows through the turbine 150, turning the motor 154. The fluid continues through the passage 224 into the BHA 204, exiting the BHA 204 through an outlet 203. The inlet 201 and outlet 203 are also shown in relation to the turbine 150 on the bottom right hand side of Figure 3. The drilling/intervention fluid that exits via the outlet 203 then flows uphole to the ground surface through an annulus defined between the tool 200 and the drilled hole 205.
The upper right hand side of Figure 3 includes a cross-sectional view of the inflated packerfoot 182, taken along line A-A. The illustrated packerfoot 182 includes three inflated sections. Three mud flow return paths 222 are defined between the three inflated sections of the packerfoot. These return paths 222 allow drilling fluid that exits via the outlet 203 to flow back uphole past the inflated packerfoot. It will be understood that the aft packerfoot 180 can be substantially identical to the forward packerfoot 182. The illustrated packerfoot cross section shows the packerfoot inflated radially beyond the outside diameter 226 of the tool 200.

An advantage of the system using a turbine-powered motor as illustrated is that the system is flow-based, meaning that the downhole tractor can be more easily controlled by the surface pump that pumps fluid down into the coiled tubing toward the turbine. With a flow-based system, any change in the surface pump output volume flow rate linearly changes the power available to the tractor. Since the surface pump output flow rate can be relatively easily adjusted dynamically during tractor operation, the resulting adjustment of the power to the tractor provides enhanced control over the tractor's speed and pulling force. This enhanced control is available over a substantial operating range of surface pump output flow rates. This is convenient for some types of operations. For example, during sand washing it is desirable to provide a maximum amount of fluid into the borehole while the tractor continues its forward movement, usually at near-maximum pulling capacity.

Although this invention has been disclosed in the context of certain preferred embodiments and examples, it will be understood by those skilled in the art that the present invention extends beyond the specifically disclosed embodiments to other alternative embodiments and/or uses of the invention and obvious modifications thereof. Thus, it is intended that the scope of the present invention herein disclosed should not be limited by the particular disclosed embodiments described above.
WHAT IS CLAIMED IS:

1. A tool for moving within a passage, comprising:
   an elongated body having an internal fluid chamber, the body configured to be secured to a fluid conduit so that a first fluid flowing through the conduit flows into the internal fluid chamber of the body;
   at least one gripper assembly engaged with the body, the gripper assembly having an actuated position in which the gripper assembly grips onto an inner surface of the passage to substantially limit relative movement between the gripper assembly and the inner surface, the gripper assembly having a retracted position in which the gripper assembly permits substantially free relative movement between the gripper assembly and the inner surface of the passage;
   a turbine configured to receive the first fluid flow through the internal fluid chamber, the turbine having an output shaft configured to rotate as the first fluid flows through the turbine; and
   a power transmission assembly configured to convert rotation of the output shaft into power for moving the gripper assembly to its actuated position.

2. The tool of Claim 1, wherein the power transmission assembly comprises:
   a generator operatively connected to the output shaft of the turbine so that rotation of the output shaft causes the generator to produce electricity; and
   a motor configured to be powered by electricity generated by the generator, the motor configured to cause the gripper assembly to move to its actuated position.

3. The tool of Claim 2, wherein the tool includes a closed system for converting a circulating flow of a second fluid into movement of the tool within the passage, the closed system comprising:
   the at least one gripper assembly, the gripper assembly configured to utilize fluid pressure to move to its actuated position;
   at least one propulsion assembly on the body, the propulsion assembly configured to utilize fluid pressure to propel the body within the passage when the gripper assembly is in its actuated position;
a valve assembly configured to direct fluid to and from the gripper assembly and the propulsion assembly to produce movement of the body within the passage;

and

a pump configured to circulate the second fluid through the closed system; wherein the motor is operatively connected to power the pump.

4. The tool of Claim 1, wherein the conduit comprises coiled tubing.

5. The tool of Claim 3, wherein the power transmission assembly is adapted to substantially linearly convert changes in flow rate of the first fluid through the fluid conduit into changes in velocity of the body or propulsion thrust provided by the propulsion assembly to the body.

6. A method of moving a tool within a passage, comprising:

providing an elongated body having an internal fluid chamber;

securing the body to a fluid conduit so that a first fluid flowing through the conduit flows into the internal fluid chamber of the body;

providing at least one gripper assembly engaged with the body, the gripper assembly having an actuated position in which the gripper assembly grips onto an inner surface of the passage to substantially limit relative movement between the gripper assembly and the inner surface, the gripper assembly having a retracted position in which the gripper assembly permits substantially free relative movement between the gripper assembly and the inner surface of the passage;

providing a turbine configured to receive the first fluid flow through the internal fluid chamber, the turbine having an output shaft configured to rotate as the first fluid flows through the turbine;

providing a power transmission assembly configured to convert rotation of the output shaft into power for moving the gripper assembly to its actuated position; and

pumping the first fluid through the conduit into the internal fluid chamber of the body and through the turbine.

7. The method of Claim 6, wherein providing a power transmission assembly comprises:
providing a generator operatively connected to the output shaft of the turbine so that rotation of the output shaft causes the generator to produce electricity; and
providing a motor configured to be powered by electricity generated by the generator, the motor configured to cause the gripper assembly to move to its actuated position.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. E21B23/04

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B F16L

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

Electronic database consulted during the international search (name of database and, where practical, search terms used)

EPO-I external

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X Further documents are listed in the continuation of Box C

X See patent family annex

* Special categories of cited documents

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"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

"A" document member of the same patent family

Date of the actual completion of the international search 18 January 2008

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Authorized officer Rampelmann, Klaus

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**C(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT**

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