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(54) Title: DOWNHOLE MUD MOTOR AND METHOD OF IMPROVING DURABILITY THEREOF

(57) Abstract: Disclosed herein is a downhole mud motor. The mud motor includes, a stator, a rotor in operable communication with the stator, a polymer in operable communication with the stator and the rotor, and a plurality of carbon nanorubes embedded in the polymer.

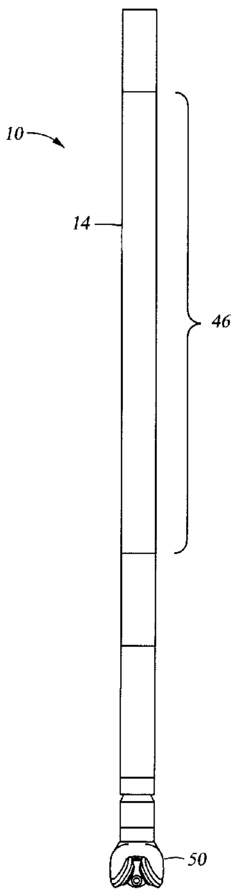

Fig. 1

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

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DOWNHOLE MUD MOTOR AND METHOD OF IMPROVING DURABILITY THEREOF

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BACKGROUND

[0001] Downhole tools used in the hydrocarbon recovery industry often experience extreme conditions, such as, high temperatures and high pressures, for example. These high temperatures can be elevated further by heat generated in by the tools themselves. Mud motors, for example, can generate additional heat during operation thereof. Materials used to fabricate the various components that make up the downhole tools are therefore carefully chosen for their ability to operate, often for long periods of time, in these extreme conditions.

[0002] Many polymeric materials have maximum operating temperature ranges, that when exceeded, result in early failure of components made therefrom. Advancements in the field that allow tools to operate below these temperature ranges are well received in the art.

BRIEF DESCRIPTION

[0003] Disclosed herein is a downhole mud motor. The mud motor includes, a stator, a rotor in operable communication with the stator, a polymer in operable communication with the stator and the rotor, and a plurality of carbon nanotubes embedded in the polymer.

[0004] Further disclosed herein is a method of improving durability of a mud motor elastomer. The method includes, dissipating heat through the mud motor elastomer with carbon nanotubes embedded therein, and maintaining temperature of the mud motor elastomer below a threshold temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

FIG. 1 depicts a side view of a mud motor disclosed herein;

FIG. 2 depicts a cross sectional view of the mud motor of **FIG. 1**; and

FIG. 3 depicts a cross sectional view of the mud motor of **FIG. 2** taken along arrows **3-3**.

DETAILED DESCRIPTION

[0006] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0007] Referring to **Figures 1-3,** an embodiment of a downhole mud motor **10** disclosed herein is illustrated. The mud motor **10**, among other things, includes, a stator **14**, a rotor **18** and a polymer **22**, also referred to herein as an elastomer, positioned between the stator **14** and the rotor **18**. Mud **26**, pumped through the mud motor **10** flows through cavities **30** defined by clearances between lobes **34** of the stator **14** and the elastomer **22** and lobes **38** of the rotor **18**. The mud **26**, being pumped through the cavities **30**, causes the rotor **18** to rotate relative to the stator **14** and the elastomer **22**. The elastomer **22** is sealingly engaged with both the stator **14** and the rotor **18** to minimize leakage therebetween that could have a detrimental effect on the performance and efficiency of the mud motor **10**. The elastomer **22**, of embodiments disclosed herein, has carbon nanotubes **42** (CNT) embedded therein to increase heat transfer through the elastomer **22** and into the stator **14**, the rotor **18** and the mud **26**. The increased heat transfer, provided by the carbon nanotubes **42**, permits temperatures of the elastomer **22** to more quickly adjust toward temperatures of matter contacting the elastomer **22** than would occur if the carbon nanotubes **42** were not present.

[0008] The operating temperature of the elastomer **22** can affect the durability of the elastomer **22**. Typically, the relationship is such that the durability of the elastomer **22** reduces as the temperature increases. Additionally, temperature thresholds exist, for specific materials, that when exceeded will significantly reduce the life of the elastomer **22**.

[0009] The elevated operating temperatures of the mud motor **10** are due, in part, to the high temperatures of the downhole environment in which the mud motor **10** operates. Additional temperature elevation, beyond that of the environment, is due to such things as, frictional engagement of the elastomer with one or more of the stator **14**, the rotor **18** and the mud **26**, and to hysteresis energy, in the form of heat, developed in the elastomer **22** during operation of the mud motor **10**, for example. This hysteresis energy comes from the difference in energy required to deform the elastomer **22** and the energy recovered from the elastomer **22** as the deformation is released. The hysteresis energy generates heat in the elastomer **22**, called heat build-up. It is these additional sources of heat generation within the elastomer **22** that the addition of the nanotubes **42** to the elastomer **22**, as disclosed herein, is added to mitigate.

[0010] Several parameters effect the additional heat generation, such as, the amount of dimensional deformation that the elastomer **22** undergoes during operation, the frictional engagement between the elastomer **22** and the rotor **18** and an overall length **46** of the mud motor **10**, for example. Additional heat generation may be reduced with specific settings of these parameters, and the temperature of the elastomer **22** may be maintainable below specific threshold temperatures. Such settings of the parameters, however, may adversely affect the performance and efficiency of the mud motor **10**, for example, by allowing more leakage therethrough, as well as increase operational and material costs associated therewith. Embodiments disclosed herein allow an increase in power density of a mud motor **10** by, for example, having a smaller overall mud motor **10** that produces the same amount of output energy to a bit **50**, attached thereto, without resulting in increased temperature of the elastomer **22**. Additionally, the mud motor **10**, using embodiments disclosed herein, may be able to operate at higher pressures, without leakage between the elastomer **22** and the rotor **18**, thereby leading to higher overall motor efficiencies, for example.

[0011] The carbon nanotubes **42,** disclosed in embodiments herein, are embedded in the elastomer **22**, such that, the carbon nanotubes **42** interface with a surface **54** of the elastomer **22**. Having the carbon nanotubes **42** interface with the surface **54** allows a decrease frictional engagement to exist between the elastomer **22** and matter that comes into contact with the surface **54**, such as, the rotor **18** and the mud **26**, for example. Such a decrease in friction can result in a corresponding decrease in heat generation. Additionally, in embodiments of the invention, the presence of the carbon nanotubes **42**, embedded within the elastomer **22**, decrease the hysteresis energy and heat generation resulting therefrom.

[0012] While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise ~~stated used in a generic and descriptive sense only and not for purposes of limitation, the~~ scope of the invention therefore not being so limited. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another. Furthermore, the use of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item.

CLAIMS

What is claimed is:

1. A downhole mud motor, comprising
   (a) a stator;
   (b) a rotor in operable communication with the stator;
   (c) a polymer in operable communication with the stator and the rotor; and
   (d) a plurality of carbon nanotubes embedded in the polymer.

2. The downhole mud motor of claim 1, wherein the polymer is an elastomer.

~~3. The downhole mud motor of claim 1, wherein the polymer is positioned between the~~ stator and the rotor.

4. The downhole mud motor of claim 1, wherein the plurality of carbon nanotubes are configured to increase heat transfer through the polymer.

5. The downhole mud motor of claim 1, wherein the plurality of carbon nanotubes are configured to increase heat transfer from the polymer to matter that comes into contact therewith.

6. The downhole mud motor of claim 1, wherein the plurality of carbon nanotubes interface with a surface of the polymer to reduce friction between the polymer and matter engagable therewith.

7. The downhole mud motor of claim 1, wherein the plurality of carbon nanotubes decreases heat generated related to deformation of the polymer.

8. The downhole mud motor of claim 1, wherein the plurality of carbon nanotubes allows the downhole mud motor to have a greater power density.

9. A method of improving durability of a mud motor elastomer, comprising:
   (a) dissipating heat through the mud motor elastomer with carbon nanotubes embedded therein; and
   (b) maintaining temperature of the mud motor elastomer below a threshold temperature.

10. The method of improving durability of a mud motor elastomer of claim 9, further comprising:

    (a) interfacing a surface of the mud motor elastomer with the carbon nanotubes; and

    (b) and decreasing friction between the surface and matter in contact therewith.

11. The method of improving durability of a mud motor elastomer of claim 9, further comprising decreasing heat generated in relation to deformation of the mud motor elastomer with the carbon nanotubes embedded therein.

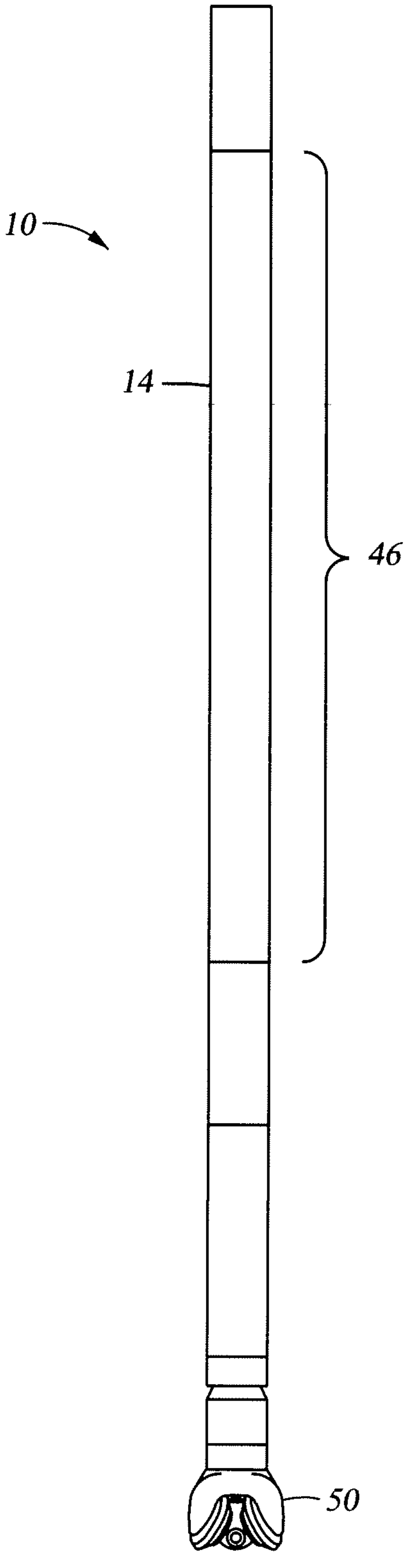

Fig. 1

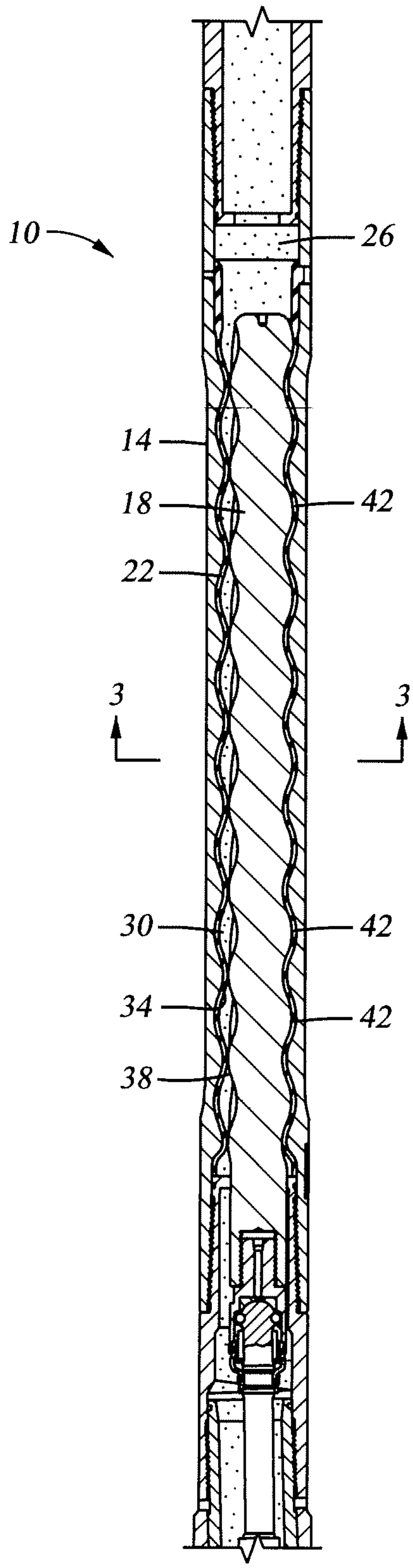

Fig. 2

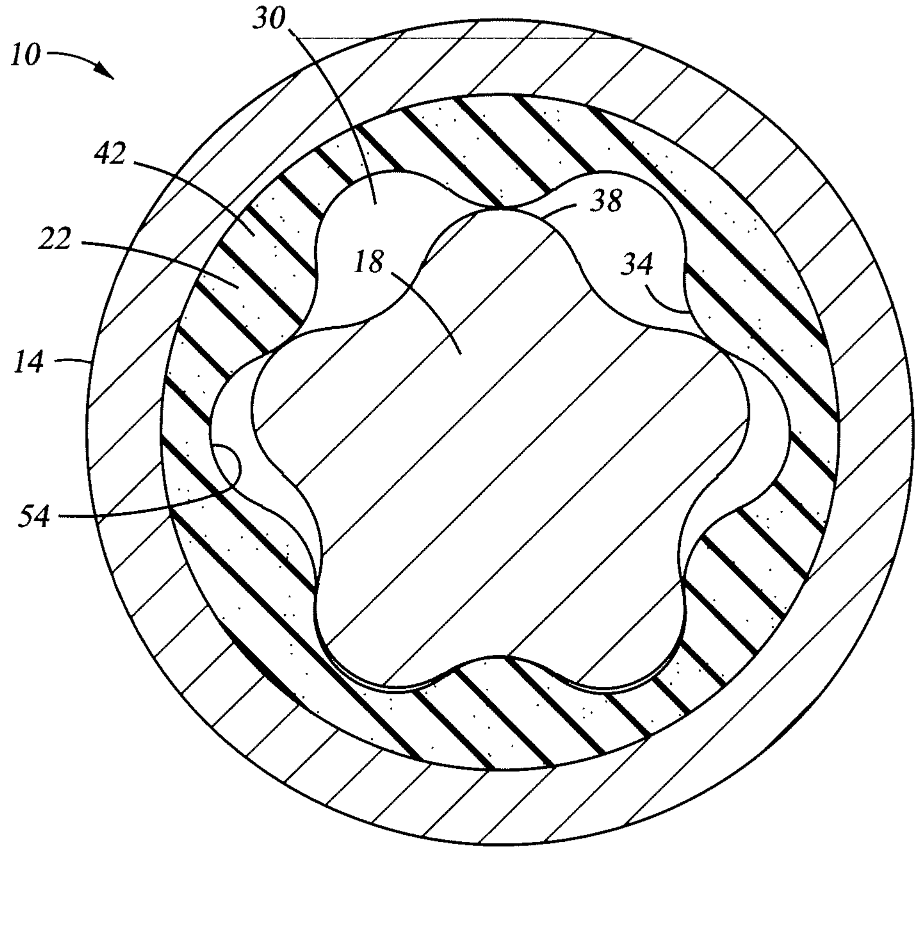

Fig. 3