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DOWNHOLE FLUID MOTOR COMPOSITE TORQUE SHAFT.

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Description

This invention relates to downhole fluid motors of the type used at the end of a drill string for rotating a drill bit, and more particularly to the shafts for connecting fluid motors to drill bits.

In well drilling operations, it is conventional to use a downhole fluid motor to rotate the drill bit when conducting special drilling operations such as, for example, directional drilling of boreholes. However, while downhole fluid motors of the progressive cavity type, also known as Moineau or positive displacement motors, have proven to be effective for generating rotational motion at the end of a drill string, there are inherent drawbacks related to the design of such motors. One particular drawback relates to the connection between the motor and the drill bit.

To fully understand the problem, one must understand the basic design of such fluid motors. In particular, fluid motors of the above type comprise a helical rotor positioned within the cavity of a helical stator. Drilling fluid, which is pumped down through the drill string to cool the drill bit and to carry drill cuttings to the surface, is directed down through the annulus between the rotor and stator to cause rotation of the rotor. However, the rotor does not simply rotate about a fixed vertical axis. The rotor rotates while gyrating, or translating along an orbital path. More particularly, the orbital path is not a simple circular orbit but rather an eccentrically orbital path typified by lateral excursions toward and away from the axis of the downhole fluid motor. Such complex gyrational and rotational motion of the rotor tends to be very demanding on the connecting shaft which connects the rotor to the drill bit and converts the gyrational and rotational motion to pure rotation.

Several arrangements have been developed for the design of the connecting shaft which have not been entirely satisfactory. A first arrangement for connecting the fluid motor to the drill bit and transforming the translating and rotating motion of the rotor to the pure rotation of the drill bit comprises a specially manufactured torque shaft. The special torque shaft is made of high strength, high quality steel and is machined to a near mirror surface finish. The high quality finish is necessary because the cyclical bending and flexing of the shaft would quickly cause fatigue cracking of the steel resulting in failure of the shaft. However, the metallurgical and production costs of such torque shafts are substantial and their reliability has been less than satisfactory. Moreover, such shafts have intrinsic design limitations which are particularly unsatisfactory. For example, in a large diameter drill string, the rotor follows a path having more exaggerated lateral excursions which result in increased bending stresses for the torque shaft.

A second arrangement is an articulated or double knuckle connector shaft which includes universal

joints at opposite ends thereof. The universal joints obviate any bending stresses such as incurred by the above arrangement and are preferred in the larger diameter drill strings. However, the universal joints include seals which are subject to excessive wear and failure downhole. Also, in drill strings of less than 6 1/2 inches in diameter, the universal joints must be of such a small size that the load bearing elements in the joints are subject to high shear stress. Therefore, the shaft has less than acceptable maximum allowable loading characteristics. This is a particular drawback for hard rock drilling where impact loading would exceed design limitations of the joints. Accordingly, the double knuckled connector has been less than fully satisfactory.

US-A- 4,679,638 issued July 14, 1987 to Eppink discloses a torque shaft which comprises a flexible rod and a coaxial overload sub surrounding the flexible rod. The flexible rod is similar to the torque shaft in the first arrangement discussed above, however, its maximum torque strength need not be as great since the overload sub will carry a portion of the load. The overload sub includes splines which intermesh but do not normally engage with splines at the outer surface of the rod. When the rod twists beyond a predetermined deflection, the splines engage and the overload sub carries a portion of the load. However, this type of arrangement occupies more space than the above arrangements and the additional space may be critically important for achieving drilling fluid flow rates for drilling in particular types of formations. Moreover, the rod is still subjected to the same fatigue stresses as the torque shaft in the first arrangement above as well as the additional twisting deflections prior to the spline engagement. Thus, the rod may be prone to fatigue cracking.

Accordingly, it is an object of the present invention to provide a connector for a downhole fluid motor which overcomes the above noted disadvantages and drawbacks of the prior art.

It is a more particular object of the present invention to provide a connector for a downhole fluid motor which has high torque strength and stiffness characteristics while accommodating bending flexibility with minimal bending fatigue and failure.

The above and other objects are achieved by the present invention by a downhole fluid motor composite torque shaft comprising an elongate matrix body including a plurality of fibers fixed therein and which are oriented to provide the elongate matrix body with high torsional strength and stiffness while allowing bending flexibility. The torque shaft further includes a first coupling member at one end of the elongate matrix body for connecting to the rotor of the downhole fluid motor and a second coupling member at the other end of said elongate matrix body for connecting to the drill bit.

Some of the objects of the invention have been

stated and others will appear as the description proceeds when taken in conjunction with the accompanying drawings in which --

Figure 1 is a top partially fragmentary perspective view of a downhole fluid motor assembly in accordance with a preferred embodiment of the present invention;

Figure 2 is a cross sectional view of the downhole motor assembly taken along the line 2-2 of Figure 1;

Figure 3 is a front elevational view of a first embodiment of a torque shaft for the fluid motor assembly with parts broken away for clarity;

Figure 4 is a front elevational view similar to Figure 3 of a second embodiment of a torque shaft for the fluid motor assembly;

Figure 5 is a front elevational view similar to Figure 3 of a third embodiment of a torque shaft for the fluid motor assembly; and

Figure 6 is a graph generally illustrating the axial and shear moduli for a composite tube having fibers in a crisscross pattern in a range of angles with respect to the axis of the tube.

With reference to Figure 1, a downhole fluid motor assembly is generally indicated by the numeral 10. The downhole fluid motor assembly 10 is connected to the end of a pipe string (not shown) for drilling a bore hole such as for an oil or gas well. The assembly 10 comprises a housing 12 which has a diameter generally corresponding with the diameter of the drill pipe in the drill string and includes suitable means (not shown) for connecting to the distal end of the pipe string.

The housing 12 is an elongate hollow cylindrical tube having an axis 14 which in conventional drilling operations is vertical and coincides with the axis of the remainder of the drill string. The housing 12 includes an articulation joint 13 dividing the housing 12 into an upper portion 12a and a lower portion 12b. The articulation joint allows the lower portion 12b of the housing 12 to deviate from the axis 14 for altering the path of the drilling operation such as for directional drilling. A progressive cavity downhole fluid motor 20, sometimes referred to as a Moineau motor or a positive displacement motor, is secured inside the upper portion 12a of the housing 12. The motor 20, as best illustrated in Figure 2, includes a stator 21 fixed to the inner surface of the housing 12 and a rotor 22 positioned within the stator 21 so as to rotate and gyrate under the force of drilling fluid being pumped down through the pipe string. Referring again to Figure 1, a drill bit 30 projects from the end of the housing 12 for cutting through the earth during the drilling of the bore hole. The drill bit 30 is connected to a bearing set 31 which is secured within the housing 12 adjacent the lower end thereof. The bearing set 31 is a conventional device which includes bearing races and other means so as to allow free rotation about the

axis 14 as indicated by the arrow 32 while preventing movement in other directions. The fluid motor 20 and the bearing set 31 are spaced apart in the housing 12 so as to define a torque shaft chamber 40. A torque shaft 41 is positioned within the torque shaft chamber 40 and is connected by its opposite ends to the rotor 22 and the bearing set 31. The torque shaft 41 thus provides the mechanical link between the downhole fluid motor 20 and the drill bit 30.

However, as discussed in the Background of the Invention above, the rotor 22 of the downhole fluid motor 20 does not simply rotate about the axis 14, but rather gyrates and rotates in a complex motion. Therefore, the conversion of the rotational and gyrational motion of the rotor 22 to the pure rotation of the drill bit 30 requires that the torque shaft have significant strength, stiffness, and durability. Figures 1 and 2 provide a general illustration of the problems posed by the downhole fluid motor 20 for the torque shaft 41. In particular, Figure 1 illustrates the gyration of the rotor 22 as indicated by the arrows 23 as well as the resultant bending in the torque shaft 41 as should be apparent from the lateral displacement of the upper end of the torque shaft 41 from the axis 14. The movement of the rotor 22 within the stator 21 is also generally indicated in Figure 2 wherein the rotor 22 has a central axis C which is spaced apart from the axis 14. During the operation of the motor 20, the axis C gyrates or orbits about the axis 14. However, the radial distance between the axes 14 and C is not constant, thus, the orbital path of the axis C about the axis 14 is thus not circular. The path indicated by arrow 24 is an eccentric orbital path having lobes of eccentricity corresponding to the number of lobes in the stator. The eccentric lobes may be characterized as lateral excursions of the rotor 22 toward and away from the axis 14 which further bends the torque shaft 41. The bending of the torque shaft 41 is further compounded by the rotation about axis C being opposite to the direction which the axis C orbits about axis 14 as indicated by the arrows 23 and 24 being opposite to the arrow 32.

Accordingly, the torque shaft 41 of the present invention is particularly constructed to possess high torsional strength and stiffness while having bending flexibility or in other words substantial bending fatigue strength to withstand the continuous cyclic bending inherent in the downhole fluid motor assembly 10. Referring to Figure 3, the torque shaft 41 is more clearly illustrated with portions of the shaft 41 broken away to better show its structure and construction. The torque shaft 41 is a composite material formed of a matrix body having oriented fibers fixed therein. The fibers each have significant axial strength and, thus, the orientation and number of the fibers determine strength and bending characteristics of the composite torque shaft 41.

The construction of the composite torque shaft

41 is based on procedures known in the composite materials field. Briefly, the process comprises the steps of laying up resin coated fibers in predetermined orientations and treating the resin so as to coalesce and harden to form the resin matrix body. Suitable fibers for use in the composite torque shaft **41** include carbon fibers, E-glass fibers, S-glass fibers, aramid fibers as well as others. Moreover, it may be preferable to use combinations of different fibers to achieve desirable characteristics for the shaft **41**. Each of the fibers have different strength and stretch characteristics as well as cost considerations so that one may be more appropriate for some circumstances while another may be better for another situation. Any suitable resin may be used to form the resin matrix body such as a thermoset epoxy resin or a thermoplastic resin. Two representative materials which may be used are Fiberite 977-3 epoxy and bismaleimide.

As an alternative to resin matrix composites, the composite torque shaft **41** may be made of a metal matrix composite wherein the body is formed of metal such as titanium, aluminum or other suitable metal and the oriented fibers are made of silicon carbide, boron carbide or other suitable material. Such composite materials are able to operate in higher temperature environments and are more resistant to corrosion and abrasion.

The composite torque shaft **41** includes suitably shaped connector ends **42** for connecting the shaft **41** to the rotor **22** and the bearing set **31**. The connector ends **42** may also include metal inserts or other strength and reinforcing members to provide a satisfactory connection.

In the preferred embodiment, the composite torque shaft **41** comprises layers of oriented fibers overlaid one upon the other. The illustrated embodiment includes three layers **51**, **52** and **53**, however, this is for clarity and explanation purposes. The preferred embodiment comprises substantially more layers, such as twenty or more wherein each layer has a thickness of between 0.003 and 0.04 inches.

Referring to Figure 3, the composite torque shaft **41** includes a first fiber layer **51** comprising fibers oriented in a crisscross pattern. The crisscross pattern, as will be further explained hereafter, provides substantial torsional strength for the composite torque shaft **41** without introducing significant resistance to bending. For clarity, the fiber orientation is specified in terms of an angle θ formed between the fiber and the axis **45** of the composite torque shaft **41**. The fibers are crisscrossed at an angle θ in the range of between 30 and 60 degrees with respect to the axis **45** and expressed as "+/-" such as +/- 45 degrees. The second fiber layer **52** comprises fibers oriented approximately 90 degrees with respect to the axis **45** of the composite torque shaft **41**. The 90 degree orientation provides integral strength or structural integrity for the composite torque shaft **41** without impairing the

bending flexibility thereof. A third fiber layer **53** is generally similar to the first layer **51** in that the fibers are again arranged in a crisscross pattern. However, the fiber orientation of the third fiber layer **53** may be selected to be a different θ angle while still being in the range of 30 to 60 degrees with respect to the axis **45**. As shown below, the angle +/- 45 degrees provides the maximum torsional stiffness, thus, the preferred angle is approximately +/- 45 degrees.

As noted above, the composite torque shaft **41** comprises a significant number of fibers oriented in a crisscross pattern so as to provide torsional strength and stiffness without introducing significant resistance to bending. Referring to Figure 6, the graph indicates a general relationship of the fiber orientation angle θ and a crisscross fiber layer to the axial modulus (which effects the resistance to bending) and the shear modulus (which relates to the torsional strength and stiffness characteristics) of the composite torque shaft **41**. This graph is based upon a composite tube formed of E-glass fibers with an epoxy resin matrix. While other combinations may have markedly different values for each modulus, the general relationships between the crisscross angles and moduli will be quite similar. For example, as noted from the graph, the axial modulus is substantially reduced when the angle between the axis **45** is increased from zero degrees (parallel to the axis **45**) to approximately 45 degrees. The higher the axial modulus, the stiffer the composite shaft will be in bending. At the same time, the shear modulus is maximized at approximately 45 degrees, which translates to the maximum torsional stiffness for the composite torque shaft **41**. Thus, a crisscross pattern of generally between 30 and 60 degrees will provide the desired characteristics of the composite torque shaft **41**. As noted from the graph in Figure 6, the fiber orientation angle of approximately +/- 45 degrees would be preferred so as to provide maximum torsional strength and stiffness combined with low bending resistance. However, other factors may be considered in the preferred angle. For example, if the shaft **41** is hollow and carries internal fluids under pressure, an angle of less than +/- 45 degrees would be preferred to accommodate the added stresses due to such internal pressure. On the other hand, if the shaft is to carry compression loads, it would be desirable to have the angle be greater than +/- 45 degrees.

Referring again to Figure 3, the preferred embodiment of the torque shaft **41** is a hollow tube as noted by the hollow internal passageway **56**. As such, the composite shaft **41** will be of minimal weight and the material will be concentrated in the circumference of the tube to provide high torsional strength and stiffness. The hollow tube embodiment may also provide an alternative path **56** for drilling fluid to pass through the torque shaft chamber **40** to the drill bit **30**. As illustrated in Figure 1, the shaft has a large diameter

compared to the space available in the torque shaft chamber **40** so as to provide the necessary torque load capacity. The path for the drilling fluid through the interior of the shaft **41** allows a sufficient volume of drilling fluid to drive the downhole fluid motor **20** and lubricate the bit **30**. Moreover, the hollow internal flow path **56** does not sacrifice the strength and stiffness characteristics of the composite torque shaft **41** while obtaining the desired flow rate.

The drilling fluid may be allowed to enter and exit the torque shaft **41** by any suitable means. In Figure 1, there is indicated passages **27** in the lower end of the rotor **22** which connects to the shaft **41**. The passages allow drilling fluid to be directed into the internal passageway **56**. The bearing set **31** includes a connector at the upper portion thereof for connecting to the composite torque shaft **41**. In the connector there are passages **33** allowing the drilling fluid to exit from the internal passageway **56** back to the torque shaft chamber **40** below the composite torque shaft. A part or all the fluid passing through the internal passageway **56** may alternatively be directed through the center of the bearing set **31** to the bit **30**. Another suitable arrangement (not shown) for directing the drilling fluid through the internal passageway includes engineering slots into the composite torque shaft **41** leading to the internal passageway.

In a preferred aspect of the present invention, the torque shaft **41** further includes an outer protective layer **55** to protect the outer surface of the matrix body from abrasion, wear or corrosion in the hostile downhole environment. Also, the composite torque shaft **41** may further comprise, as an optional feature, a protective liner **54** to line the hollow inner surface of the matrix body to protect the same from abrasion, wear and corrosion. The liner **54** may further serve as a mandrel or form for manufacturing the composite torque shaft **41**. The outer protective layer **55** and liner **54** may be made from any suitable material, such as for example an elastomer such as a polyurethane, or fluoroelastomer with or without fiber reinforcement such as aramid pulp, or a metal such as aluminum, titanium, or steel etc.

A second embodiment of the composite torque shaft is generally indicated by the numeral **141** in Figure 4 and is very similar to the first embodiment. Therefore, similar features are indicated by the same numbers with a prefix of "1". For example, the composite torque shaft of the first embodiment is indicated by the number **41** and the composite torque shaft of the second embodiment is indicated by the number **141**. The primary difference between the second embodiment of the composite torque shaft **141** and the first embodiment is that the second embodiment is a solid shaft. More particularly, the composite torque shaft **141** includes a solid rod **154** with the matrix body overlying the rod **154**. The rod **154** may be formed of any suitable material such as a resin or an

elastomer and serves as an excellent mandrel for laying up the fibers. In one preferred arrangement the rod **154** is formed of a metal such as aluminum or steel. Oriented fiber layers **151**, **152**, and **153** overlie the rod and are fixed in a matrix body similar to the first embodiment in Figure 3. The composite torque shaft **141** further includes connector ends **142** and may be provided with a protective outer layer **155** similar to the protective outer layer **55** in the first embodiment.

A third embodiment of the composite torque shaft is generally indicated by the numeral **241** in Figure 5 and is very similar to the first embodiment. Therefore, similar features are indicated by the same numbers with a prefix of "2". For example, the composite torque shaft of the first embodiment is indicated by the number **41** and the composite torque shaft of the second embodiment is indicated by the number **241**. The primary difference between the third embodiment of the composite torque shaft **241** and the first embodiment is that the second embodiment includes a plurality of composite rods **258** within the hollow shaft. The composite rods **258** are preferably small diameter, parallel composite rods made with axially oriented fiber such as graphite, carbon, aramid, boron or other high modulus fiber, formed in a resin matrix such vinyl ester, epoxy, nylon, etc. so as to provide substantial axial strength for the torque shaft **241**. At times during downhole operations, the compression load on the composite torque shaft **41** can become quite substantial. Since the composite torque shaft **41** is bent and offset while installed in the housing **12**, axial compression loading can cause buckling and failure thereof. Due to their small diameter, the composite rods **258** individually have low bending stiffness. Moreover, they are positioned near the axis of the composite torque shaft and are preferably able to move relative to one another. As such they do not significantly impair the bending stiffness of the composite torque shaft while providing substantial axial strength.

The third embodiment further differs from the first embodiment by not including the protective liner **54**. Since there is no material flowing through the interior thereof to protect the composite torque shaft from. Another composite layer **257** is shown in Figure 5 but, as noted above, the drawing Figures 3 through 5 have been simplified for explanation purposes and any preferred embodiment would contain a number of layers of oriented fibers and the third embodiment would not necessarily include more or less layers than the first or second embodiments.

In the drawings and specification, there has been set forth embodiments of the invention, and although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation.

Claims

1. A downhole fluid motor torque shaft (41;141;241) for connecting a downhole fluid motor (20) to a drill bit (30) at the distal end of a drill string, wherein the fluid motor (20) is of the type positioned adjacent to the end of a drill string and includes a rotor (22) which rotates and gyrates about a common axis of the drill string and the torque shaft (41;141;241) converts the rotating and gyrating motion to pure rotation for the drill bit (30), the torque shaft (41;141;241) comprising an elongate body (41;141;241), a first coupling member (42) at one end of said elongate body for connecting to the rotor (22) of the downhole fluid motor, and a second coupling member (42) at the other end of said elongate body for connecting to the drill bit (30), characterised in that the elongate body is an elongate matrix body (41;141;241) including a plurality of overlying layers (51,52, 53;151,152,153;251,252,253) of oriented fibers fixed therein and wherein the fibers are oriented within the elongate matrix body to provide said body (41;141;241) with high torsional strength and stiffness while allowing bending flexibility and further wherein at least one of said layers (51,52,53;151,152, 153;251,252,253) includes fibers oriented in a criss-cross pattern.
2. A downhole fluid motor torque shaft (41;141;241) as claimed in claim 1, wherein at least some of said fiber layers (51,52,53;151,152,153;251, 252,253) have a predetermined orientation of between 30 and 60 degrees with respect to a longitudinal axis (45;145;245) of said elongate body (41;141;241) and at least a substantial portion of the immediately aforementioned layers (51,52, 53;151,152,153;251,252,253) include additional fibers which are oriented at a reciprocal angle ($-\theta$) of the predetermined angle (θ) with respect to said longitudinal axis (45;145;245) so that such fiber layers (51,52,53;151,152,153;251,252,253) have cross-plying fibers.
3. A downhole fluid motor torque shaft (41;141;241) as claimed in claim 1 or 2, wherein at least one of said layers (51,52,53;151,152,153;251,252,253) includes fibers oriented at approximately 90 degrees with respect to a longitudinal axis (45;145;245) of said elongate body (41;141;241).
4. A downhole fluid motor torque shaft (41;141;241) as claimed in any preceding claim, wherein said fibers in at least one said layer (51,52,53; 151,152,153;251,252, 253) are fixed in a matrix binder comprising a thermoset or thermoplastic resin.
5. A downhole fluid motor torque shaft (41;141;241) as claimed in any preceding claim, wherein said fibers in at least one said layer (51,52,53; 151,152,153;251,252, 253) are fixed in a matrix binder comprising a metal.
6. A downhole fluid motor torque shaft (41;141;241) as claimed in any preceding claim, wherein said fibers are made of silicon carbide or boron.
7. A downhole fluid motor torque shaft (41;141;241) as claimed in any preceding claim, wherein said elongate body (41;141;241) overlies an elongate metallic liner (54,154).
8. A downhole fluid motor torque shaft (41;141;241) as claimed in any preceding claim, wherein said elongate body (41;141;241) comprises an elongate hollow cylindrical tube.
9. A downhole fluid motor torque shaft (41;141;241) as claimed in any preceding claim, further comprising a plurality of generally parallel elongate composite rods (258) extending generally longitudinally through said elongate body (41;141; 241).
10. A downhole fluid motor torque shaft (41;141;241) as claimed in any preceding claim, further comprising an outer layer (55;155;255) overlying and bonded to the outer surface of said elongate body (41;141;241) to protect said body (41;141;241) from wear and abrasion.

Patentansprüche

1. Bohrlochfluidmotor-Drehmomentwelle (41; 141; 241) zum Verbinden eines Bohrlochfluidmotors (20) mit einem Bohrer (30) an dem distalen Ende eines Bohrstrangs, wobei der Fluidmotor (20) von dem in der Nähe des Endes eines Bohrstrangs angeordneten Typ ist und einen um eine gemeinsame Achse des Bohrstrangs sich drehenden und kreisenden Rotor (22) umfaßt und die Drehmomentwelle (41; 141; 241) die Dreh- und Kreisbewegung in eine reine Drehung des Bohrers (30) umwandelt, wobei die Drehmomentwelle (41; 141; 241) einen langgestreckten Körper (41; 141; 241), ein erstes Kopplungselement (42) an einem Ende des langgestreckten Körpers zur Verbindung mit dem Rotor (22) des Bohrlochfluidmotors und ein zweites Kopplungselement (42) an dem anderen Ende des langgestreckten Körpers zur Verbindung mit dem Bohrer (30) umfaßt, dadurch gekennzeichnet, daß der langgestreckte Körper ein langgestreckter Matrixkörper (41; 141; 241) mit einer Mehrzahl

- übereinander liegender Schichten (51, 52, 53; 151, 152, 153; 251, 252, 253) von darin festgelegten orientierten Fasern umfaßt, wobei die Fasern in dem langgestreckten Matrixkörper so orientiert sind, um dem Körper (41; 141; 241) hohe Torsionsfestigkeit und Steifheit zu geben, während eine Biegeflexibilität möglich ist, wobei ferner wenigstens eine der Schichten (51, 52, 53; 151, 152, 153; 251, 252, 253) in einem Kreuzmuster orientierte Fasern umfaßt.
2. Bohrlochfluidmotor-Drehmomentwelle (41; 141; 241) nach Anspruch 1, bei welcher wenigstens einige der Faserschichten (51, 52, 53; 151, 152, 153; 251, 252, 253) eine vorbestimmte Orientierung zwischen 30 und 60° relativ zu einer Längsachse (45; 145; 245) des langgestreckten Körpers (41; 141; 241) aufweisen und wenigstens ein wesentlicher Anteil der unmittelbar zuvor erwähnten Schichten (51, 52, 53; 151, 152, 153; 251, 252, 253) zusätzliche Fasern umfaßt, welche in einem zu dem vorbestimmten Winkel (θ) umgekehrten Winkel ($-\theta$) relativ zur Längsachse (45; 145; 245) orientiert sind, so daß derartige Faserschichten (51, 52, 53; 151, 152, 153; 251, 252, 253) diagonale Fasern aufweisen.
3. Bohrlochfluidmotor-Drehmomentwelle (41; 141; 241) nach Anspruch 1 oder 2, bei welcher wenigstens eine der Schichten (51, 52, 53; 151, 152, 153; 251, 252, 253) Fasern umfaßt, welche mit ungefähr 90° relativ zu einer Längsachse (45; 145; 245) des langgestreckten Körpers (41; 141; 241) orientiert sind.
4. Bohrlochfluidmotor-Drehmomentwelle (41; 141; 241) nach einem der vorhergehenden Ansprüche, bei welcher die Fasern in wenigstens einer der Schichten (51, 52, 53; 151, 152, 153; 251, 252, 253) in einem ein warmausgehärtetes oder thermoplastisches Harz umfassenden Matrixbindemittel festgelegt sind.
5. Bohrlochfluidmotor-Drehmomentwelle (41; 141; 241) nach einem der vorhergehenden Ansprüche, bei welcher die Fasern in wenigstens einer der Schichten (51, 52, 53; 151, 152, 153; 251, 252, 253) in einem ein Metall umfassenden Matrixbindemittel festgelegt sind.
6. Bohrlochfluidmotor-Drehmomentwelle (41; 141; 241) nach einem der vorhergehenden Ansprüche, bei welcher die Fasern aus Siliciumcarbid oder Bor erzeugt sind.
7. Bohrlochfluidmotor-Drehmomentwelle (41; 141; 241) nach einem der vorhergehenden Ansprüche, bei welcher der langgestreckte Körper (41;

141; 241) über einer langgestreckten Metallausfütterung (54, 154) liegend angeordnet ist.

8. Bohrlochfluidmotor-Drehmomentwelle (41; 141; 241) nach einem der vorhergehenden Ansprüche, bei welcher der langgestreckte Körper (41; 141; 241) ein langgestrecktes, hohles Zylinderrohr umfaßt.
9. Bohrlochfluidmotor-Drehmomentwelle (41; 141; 241) nach einem der vorhergehenden Ansprüche, ferner umfassend eine Mehrzahl im allgemeinen paralleler, langgestreckter Verbundmaterialstangen (258), welche sich im allgemeinen in Längsrichtung durch den langgestreckten Körper (41; 141; 241) erstrecken.
10. Bohrlochfluidmotor-Drehmomentwelle (41; 141; 241) nach einem der vorhergehenden Ansprüche, ferner umfassend eine über der Außenfläche des langgestreckten Körpers (41; 141; 241) liegende und mit dieser verbundene äußere Schicht (55; 155; 255) zum Schutz des Körpers (41; 141; 241) vor Abnutzung und Abrieb.

Revendications

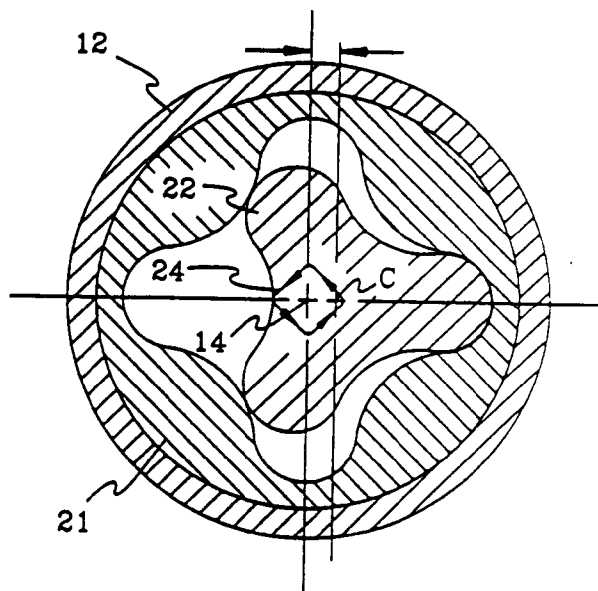
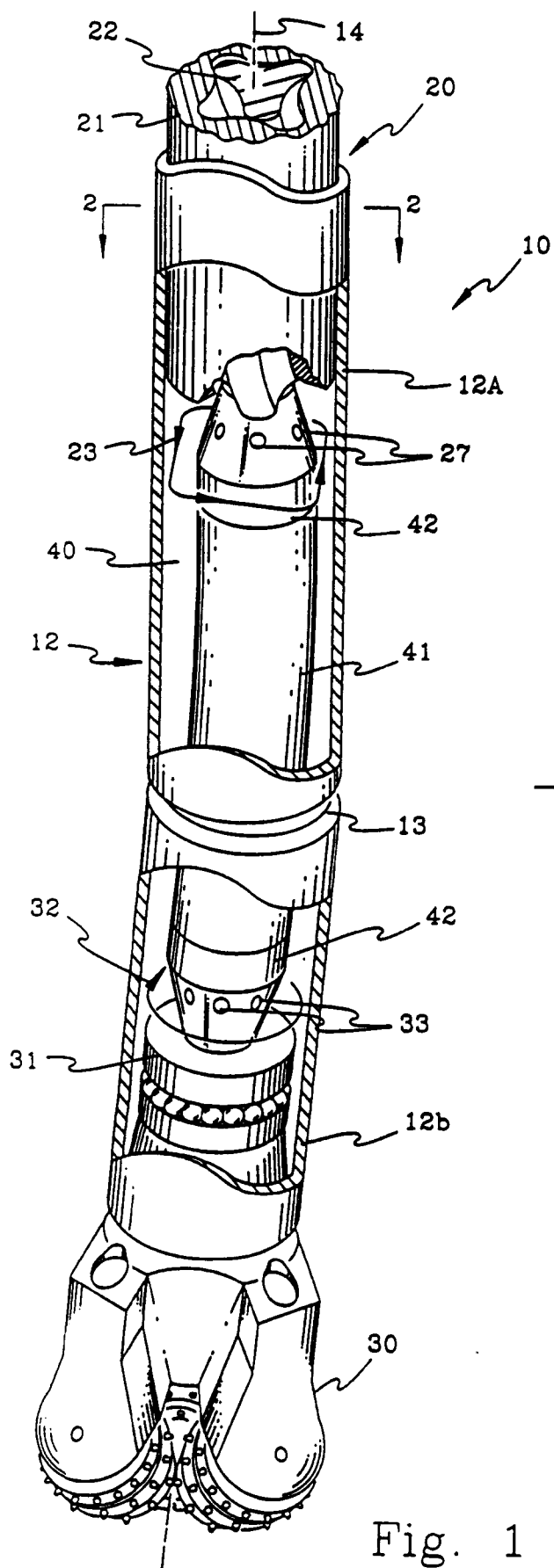
1. Arbre de torsion pour moteur hydraulique de fond de trou (41 ; 141 ; 241) pour raccorder un moteur hydraulique de fond de trou (20) à un trépan (30) à l'extrémité distale d'un train de tiges de forage, dans lequel le moteur hydraulique (20) est du type positionné adjacent à l'extrémité d'un train de tiges de forage et comprend un rotor (22) qui effectue un mouvement rotatoire et giratoire autour d'un axe commun du train de tiges de forage, et dans lequel l'arbre de torsion (41 ; 141 ; 241) transforme le mouvement rotatoire et giratoire en pure rotation pour le trépan (30), l'arbre de torsion (41 ; 141 ; 241) comprenant un corps allongé (41 ; 141 ; 241), un premier organe de couplage (42) à l'une des extrémités de ce corps allongé pour raccordement au rotor (22) du moteur hydraulique de fond de trou, et un second organe de couplage (42) à l'autre extrémité du corps allongé pour raccordement au trépan (30), caractérisé en ce que le corps allongé est un corps de matrice allongé (41 ; 141 ; 241) comprenant une pluralité de couches superposées (51, 52, 53 ; 151, 152, 153 ; 251, 252, 253) de fibres orientées fixées à l'intérieur, et dans lesquelles les fibres sont orientées à l'intérieur du corps de matrice allongé pour doter ce corps (41 ; 141 ; 241) d'une grande résistance à la torsion et d'une grande rigidité en torsion tout en autorisant une souplesse de flexion, et dans lesquelles en outre au moins l'une de ces couches (51, 52, 53 ; 151, 152, 153 ;

251, 252, 253) comprend des fibres orientées en une structure entrecroisée.

2. Arbre de torsion pour moteur hydraulique de fond de trou (41 ; 141 ; 241) selon la revendication 1, dans lequel au moins quelques-unes de ces couches de fibres (51, 52, 53 ; 151, 152, 153 ; 251, 252, 253) ont une orientation prédéterminée comprise entre 30 et 60 degrés par rapport à un axe longitudinal (45 ; 145 ; 245) du corps allongé (41 ; 141 ; 241) et au moins une portion importante des couches mentionnées juste ci-dessus (51, 52, 53 ; 151, 152, 153 ; 251, 252, 253) comprend des fibres supplémentaires qui sont orientées à un angle commun ($-\theta$) de l'angle prédéterminé (θ) par rapport à l'axe longitudinal (45 ; 145 ; 245) de telle sorte que ces couches de fibres (51, 52, 53 ; 151, 152, 153 ; 251, 252, 253) ont des fibres disposées en diagonale. 5
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15
20
3. Arbre de torsion pour moteur hydraulique de fond de trou (41 ; 141 ; 241) selon les revendications 1 ou 2, dans lequel au moins l'une des couches (51, 52, 53 ; 151, 152, 153 ; 251, 252, 253) comprend des fibres orientées à environ 90 degrés par rapport à un axe longitudinal (45 ; 145 ; 245) du corps allongé (41 ; 141 ; 241). 25
4. Arbre de torsion pour moteur hydraulique de fond de trou (41 ; 141 ; 241) selon l'une quelconque des revendications précédentes, dans lequel les fibres dans au moins l'une des couches (51, 52, 53 ; 151, 152, 153 ; 251, 252, 253) sont fixées dans un liant de matrice comprenant une résine thermodurcie ou thermoplastique. 30
35
5. Arbre de torsion pour moteur hydraulique de fond de trou (41 ; 141 ; 241) selon l'une quelconque des revendications précédentes, dans lequel les fibres dans au moins l'une des couches (51, 52, 53 ; 151, 152, 153 ; 251, 252, 253) sont fixées dans un liant de matrice comprenant un métal. 40
6. Arbre de torsion pour moteur hydraulique de fond de trou (41 ; 141 ; 241) selon l'une quelconque des revendications précédentes, dans lequel les fibres sont réalisées en carbure de silicium ou en bore. 45
7. Arbre de torsion pour moteur hydraulique de fond de trou (41 ; 141 ; 241) selon l'une quelconque des revendications précédentes, dans lequel le corps allongé (41 ; 141 ; 241) recouvre une enveloppe métallique allongée (54, 154). 50
55
8. Arbre de torsion pour moteur hydraulique de fond de trou (41 ; 141 ; 241) selon l'une quelconque des revendications précédentes, dans lequel le

corps allongé (41 ; 141 ; 241) comprend un tube cylindrique creux allongé.

9. Arbre de torsion pour moteur hydraulique de fond de trou (41 ; 141 ; 241) selon l'une quelconque des revendications précédentes, comprenant en outre une pluralité de tiges composites allongées généralement parallèles (258) s'étendant généralement longitudinalement à travers le corps allongé (41 ; 141 ; 241).
10. Arbre de torsion pour moteur hydraulique de fond de trou (41 ; 141 ; 241) selon l'une quelconque des revendications précédentes, comprenant en outre une couche extérieure (55 ; 155 ; 255) superposée et liée à la face extérieure du corps allongé (41 ; 141 ; 241) pour protéger le corps (41 ; 141 ; 241) contre l'usure et l'abrasion.



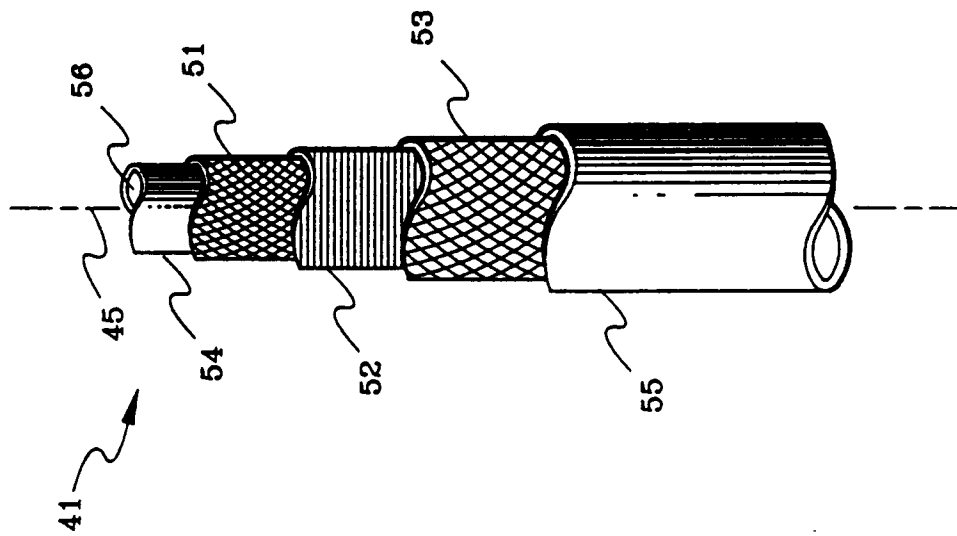


Fig. 3

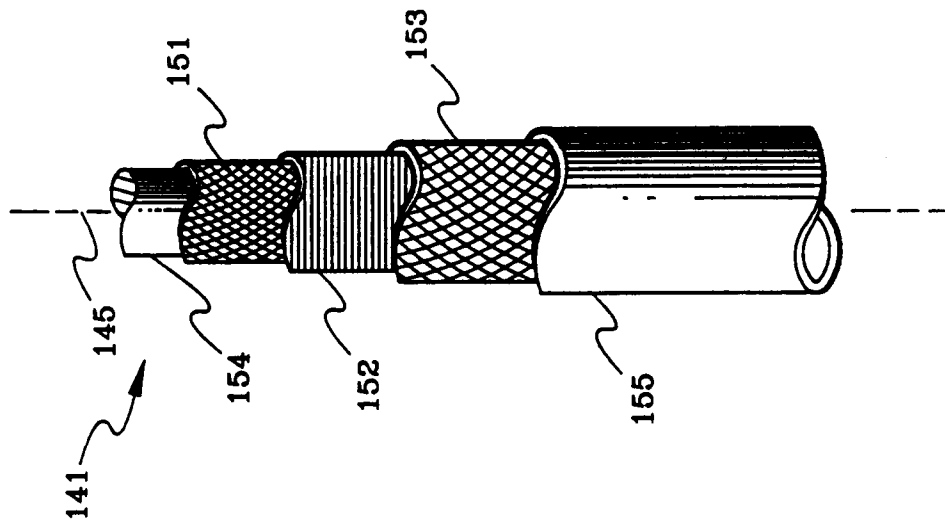


Fig. 4

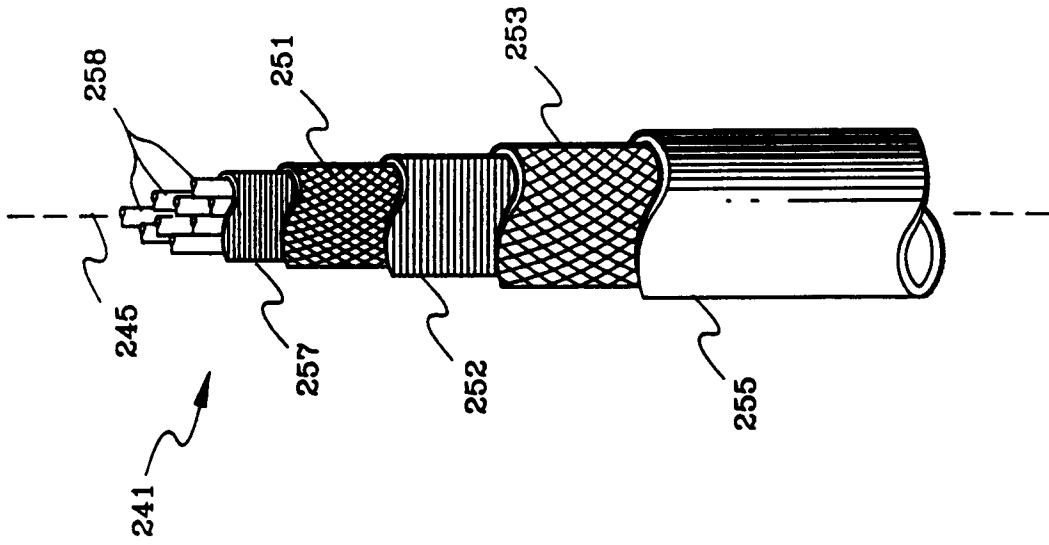


Fig. 5

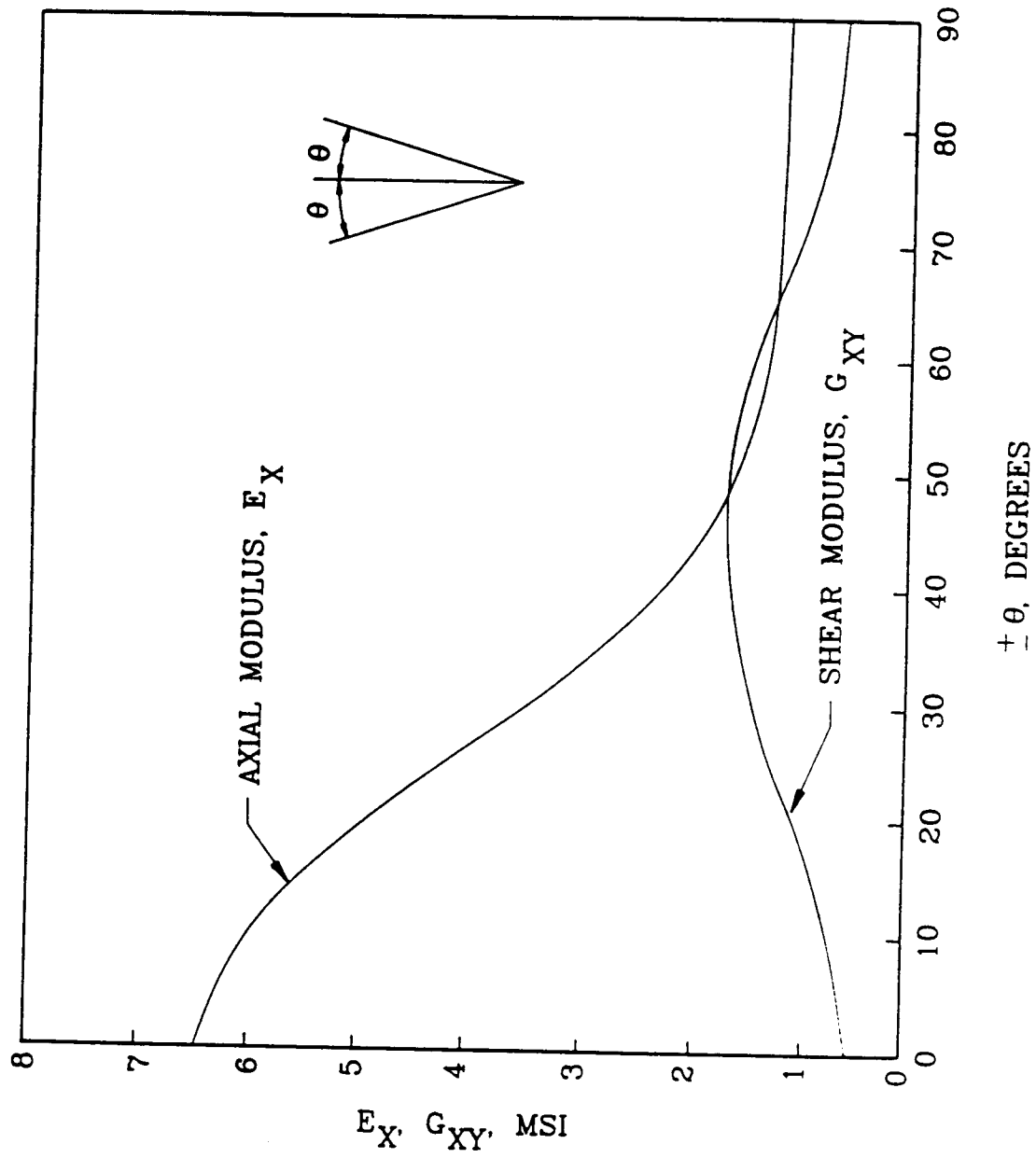


Fig. 6