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(54) **HYDRAULIC THRUSTER FOR USE IN A DRILL STRING**

HYDRAULISCHE SCHUBVORRICHTUNG ZUR VERWENDUNG IN EINER BOHRSTANGE

PROPULSEUR HYDRAULIQUE POUR TRAIN DE SONDE

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Description

[0001] The present invention relates to a hydraulic thruster for generating a thrust force to a drill bit located at the lower end of a drill string. Hydraulic thrusters are generally applied in order to generate the desired weight on bit (WOB) which is the force exerted by the drill bit to the bottom of the borehole, or to isolate axial vibrations of the drill string from the bottom hole assembly. Especially in deviated wellbores or horizontal wellbores a considerable amount of axial force of the drill string is dissipated by friction between the drill string and the borehole wall, necessitating the application of a thruster to generate the desired WOB. A common thruster consists of two telescoping members of which the fixed member is connected to an upper part of the drill string, and the travelling member is connected to the downhole assembly, whereby an axial spline/groove arrangement enables torque to be transmitted between the two members. The thruster allows the downhole assembly to move axially relative to the upper part of the drill string. The delivered thrust force is thus independent of the axial position of the drill string, and furthermore the thrust force is independent of the inclination of the drill string which may vary between a vertical orientation and a horizontal orientation. Furthermore, the WOB can be accurately controlled as it depends on the effective cross-sectional area of the thruster and on the difference between the internal fluid pressure of the thruster and the external pressure thereof. Also the thruster improves the dynamic behaviour of the assembly by the axial decoupling of the drill bit from the drill string.

[0002] US patent No. 4,901,806 discloses a device for use in a drill string to control the force applied to the drill bit (i.e. the WOB), and to decouple the axial vibrations acting on the drill string, which device therefore in effect forms a thruster. The known thruster comprises a first member connectable to an upper part of the drill string and a second member connectable to a lower part of the drill string, said members being telescopically arranged relative to each other and being capable of transmitting torsional forces between the upper member and the lower member during drilling, and a fluid passage passing through said members for drilling fluid flowing through the drill string towards the drill bit.

[0003] A problem associated with the known thruster is the occurrence of WOB variations due to variations of the drilling fluid pressure. Such pressure variations may occur, for example, due to pressure pulses generated during measurement while drilling. The fluid pressure variations tend to induce an outward telescoping movement of the device thereby causing variations in WOB. The problem is even more pronounced in case a downhole drilling motor is applied to drive the drill bit, which motor is located between the thruster and the drill bit. When the torque of the downhole motor increases, for example because of increasing frictional forces at the drill bit, the fluid pressure at the fluid inlet of the motor

increases and thereby also the fluid pressure in the thruster. This leads to a further outwardly telescoping tendency of the thruster and consequently to an increasing WOB and corresponding torque at the motor. The increased motor torque requires again an increased fluid pressure at the motor inlet and hence also at the thruster, leading to a further outwardly telescoping tendency of the thruster, etc. This process leads to uncontrolled behaviour of the thruster/motor/bit combination and as a result the system may stall out. The drilling process is thus severely hampered and damage to one or more of the components may result.

[0004] US-A-1,688,994 discloses a hydraulic thruster for generating a thrust force to a drill bit located at the lower end of a drill string, comprising a first member connectable to an upper part of the drill string and a second member connectable to a lower part of the drill string, said members being telescopically arranged relative to each other and being capable of transmitting drill string torque during drilling, a fluid passage passing through said members for drilling fluid flowing through the drill string towards the drill bit, and means for generating an inward telescoping reaction of said members upon transmission of drill string torque during drilling, said means comprising at least one helical spline provided at least one of said members and arranged in a corresponding helical groove provided at the other of said members, the spline and groove co-operating so as to transmit torque between the upper and lower part of the drill string during drilling. The WOB of this known thruster depends on the bit/rock friction coefficient which shows large variations.

[0005] It is an object of the invention to provide an improved thruster which provides a controlled WOB and which overcomes the problems of the known thruster.

[0006] In accordance with the invention there is provided a hydraulic thruster for generating a thrust force to a drill bit located at the lower end of a drill string, comprising a first member connectable to an upper part of the drill string and a second member connectable to a lower part of the drill string, said members being telescopically arranged relative to each other and being capable of transmitting drill string torque during drilling, a fluid passage passing through said members for drilling fluid flowing through the drill string towards the drill bit, and means for generating an inward telescoping reaction of said members upon transmission of drill string torque during drilling, characterized in that each spline (11) is arranged at a helix angle β relative to the longitudinal axis of the thruster, of between

$$0.8 \arctan (r \cdot A_i / k_m) < \beta < 1.2 \arctan (r \cdot A_i / k_m);$$

wherein

r = average outer radius of the thruster;

A_i = effective cross-sectional thrust area of the

thruster;

k_m = the motor constant defined as the motor torque per unit pressure drop across the motor.

[0007] The inward telescoping reaction upon transmission of torque counter-acts the tendency of the thruster to telescope outwardly by the fluid pressure fluctuations, so that thereby the uncontrolled sequence of increasing fluid pressure, WOB and torque of the prior art thruster is avoided.

[0008] Suitably a plurality of said splines and grooves are distributed regularly along the interface between the inner and outer member.

[0009] The thruster can be advantageously applied in a drill string including a downhole motor driving the drill bit, the downhole motor being arranged between the thruster and the drill bit.

[0010] The invention will be described hereinafter in more detail, with reference to the accompanying drawings in which:

Fig. 1 schematically shows a longitudinal cross-section of an embodiment of the hydraulic thruster according to the invention;

Fig. 2 schematically shows a perspective view of the thruster of Fig. 1;

Fig. 3 schematically shows an alternative embodiment of the thruster according to the invention;

Fig. 4 schematically shows a partial cross-section of yet another embodiment of the thruster according to the invention; and

Fig. 5 shows a view along the line V-V of Fig. 4.

[0011] Referring to Fig. 1 there is shown a thruster 1 including a cylindrical outer member 3 and a cylindrical inner member 5 telescoping within the outer member 3, the inner member 5 having an annular piston 7 sealed by a suitable seal from the inner surface of the outer member 3. The members 3, 5 have a common fluid passage 9 for drilling fluid to flow through the thruster 1. The outer member 3 is connected at its upper end to the upper part of a drill string (not shown), and the inner member 5 is connected at its lower end to a lower part of the drill string including a hydraulic downhole motor (not shown). The inner member 5 is provided at its outer surface with helical splines 11 extending from the piston 7 along a substantial portion of the length of the inner member 5. The outer member 3 has a lower part 13 provided with helical grooves 15 which correspond to, and co-operate with, the splines 11 of the inner member 5. As shown in Fig. 2, in which for reason of clarity only the lower part 13 of outer member 3 is indicated, the splines 11 and grooves 15 are oriented at a helix angle β relative to the longitudinal axis 14 of the thruster 1. The helix orientation is such that during right hand rotation of the thruster 1 during drilling, when torque is transmitted from the outer member 3 to the inner member 5, the splines 11 and grooves 15 induce an inwardly telescoping reac-

tion to the members 3, 5. Furthermore, in Fig. 1, A_i indicates the effective thruster area and r indicates the average radius of the splines/grooves.

[0012] During normal operation of the thruster 1, drilling fluid is pumped through the drill string and the thruster to the fluid inlet of the downhole motor which drives a drill bit. With P_o being the fluid pressure outside the thruster and P_i being the fluid pressure inside the thruster, the thrust force induced by the fluid pressure is:

$$F_t = (P_i - P_o) \cdot A_i \quad (1)$$

and the WOB is:

$$WOB = F_t + F_g - T \tan(\beta) / r \quad (2)$$

[0013] in which F_g is the gravity force of the lower part of the drill string (i.e. the travelling part);

T is the motor torque.

The motor torque T depends on the fluid pressure at the motor inlet P_i and the fluid pressure at the motor outlet P_{mo} :

$$T = k_m (P_i - P_{mo}) \quad (3)$$

in which k_m is the motor constant defined as unit torque delivered per unit pressure drop across the motor. The bit torque T is substantially linearly dependent on WOB:

$$T = A_b \cdot WOB \quad (4)$$

where A_b is the bit/rock friction coefficient.

The fluid pressure drop across the bit nozzles can be written as:

$$\Delta P = 0.5 \rho v^2 \quad (5)$$

where ρ is the drilling fluid density and v the average fluid velocity in the nozzles.

With

$$\Delta P = P_{mo} - P_o \quad (6)$$

$$v = Q / A_n \quad (7)$$

where Q is the fluid flow rate and A_n is the effective cross-sectional area of the nozzles it follows from equations (1) - (7) that

$$WOB = \alpha^{-1} (\rho Q^2 A_i / 2A_n^2 + F_g) \quad (8)$$

where

$$\alpha = 1 - (A_i A_b / k_m) + (A_b \tan(\beta) / r)$$

The parameters A_i and k_m are design parameters which can be accurately selected. However the bit/rock friction coefficient A_b depends on the bit and rock formation properties and shows large variations. This problem is overcome by selecting

$$\tan(\beta) / r = A_i / k_m \quad (9)$$

so that

$$WOB = (\rho Q^2 A_i / 2A_n^2 + F_g) \quad (10)$$

thereby eliminating the dependency of WOB on the bit/rock friction coefficient. In this manner it is achieved that the effect of varying friction between the bit and the rock is eliminated without determining the magnitude of such varying friction.

[0014] For example, with a thruster of outer diameter of 0.1651 m (6.5"), $A_i = 0.013 \text{ m}^2$, $r = 0.065 \text{ m}$, and with a motor having a motor constant $k_m = 0.0009 \text{ m}^3$, it follows from equation (9) that

$$\beta = 43 \text{ degrees.}$$

[0015] In the above description it has been assumed that equations (1) - (10) are exact. However in practice slight variations in some of the parameters may occur, and it has been found that adequate reduction of the dependency of WOB on the bit/rock friction is achieved if the helix angle β is selected between

$$0.8 \arctan (r.A_i/k_m) < \beta < 1.2 \arctan (r.A_i/k_m)$$

11)

More preferably the helix angle is between

$$0.95 \arctan (r.A_i/k_m) < \beta < 1.05 \arctan (r.A_i/k_m)$$

12)

[0016] An implication of equations (9), (11) and (12) is that the helix angle β depends on the motor constant k_m , so that the thruster would have to be selected in dependence of the motor type. Referring to Fig. 3, an alternative embodiment of the thruster can be applied with reduced dependency on the motor type. The alternative

thruster 20 has an inner member 22 provided with a set of helical splines of varying helix angle, and an outer member 26 provided with a set of corresponding grooves 28.

[0017] Normal use of the alternative thruster 20 is similar to normal use of the thruster described with reference to Figs. 1 and 2, however with the additional feature of optionally varying the effective helix angle by raising or lowering the drill string in accordance with the motor type applied.

[0018] Referring to Fig. 4, instead of applying fixed grooves 28 as in the embodiment of Fig. 3, in another embodiment of the thruster a plurality of guides 30 are positioned in corresponding recesses 32 of the thruster outer member 34, each guide 30 being provided with a groove 36 in which a spline 38 of the thruster inner member 40 is positioned. Each guide 30 is rotatable around a radial shaft 42 fixedly connected to the outer member 34. In this manner it is achieved that the helix angle of the grooves 36 of the outer member 34 conforms to the varying helix angles of the splines 38. It is to be understood that instead of the guides 30 being connected to the outer member 34, the guides can alternatively be connected to the inner member, in which case the splines are provided at the outer member.

[0019] Instead of the downhole motor being arranged between the hydraulic thruster according to the invention and the drill bit, the hydraulic thruster can alternatively be arranged between the downhole motor and the drill bit.

Claims

1. A hydraulic thruster (1) for generating a thrust force to a drill bit located at the lower end of a drill string, comprising a first member (3) connectable to an upper part of the drill string and a second member (5) connectable to a lower part of the drill string, said members being telescopically arranged relative to each other and being capable of transmitting drill string torque during drilling, a fluid passage (9) passing through said members for drilling fluid flowing through the drill string towards the drill bit, and means for generating an inward telescoping reaction of said members upon transmission of drill string torque during drilling, said means comprising at least one helical spline (11) provided at at least one of said members and arranged in a corresponding helical groove (15) provided at the other of said members, the spline and groove co-operating so as to transmit torque between the upper and lower part of the drill string during drilling and a downhole motor driving the drill bit, characterized in that each spline (11) is arranged at a helix angle β relative to the longitudinal axis of the thruster, of between

$$0.8 \arctan (r.A_i/k_m) < \beta < 1.2 \arctan (r.A_i/k_m);$$

wherein r = average outer radius of the thruster;

A_i = effective cross-sectional thrust area of the thruster;

k_m = the motor constant defined as the motor torque per unit pressure drop across the motor.

2. The thruster of claim 1, wherein said first member forms an outer member (3) and said second member forms an inner member (5).

3. The thruster of claim 2, comprising a plurality of said splines (11) and grooves (15) distributed regularly along the interface between the inner and outer member (3,5).

4. The thruster of claim 3, wherein each spline (11) is arranged at a helix angle β relative to the longitudinal axis of the thruster, of between

$$0.95 \arctan (r.A_i/k_m) < \beta < 1.05 \arctan (r.A_i/k_m).$$

5. The thruster of any of claims 1-4, wherein the helix angle of each spline (11) and groove (15) varies along the length of the thruster.

6. The thruster of claim 5, wherein at least one of each spline (30) and each groove (36) is rotatable around a radial axis (42) so as to conform the helix angle thereof to the helix angle of the other one of each spline (30) and groove (36).

7. The thruster of any of claims 1-6, wherein each spline (11) is provided at the inner member (5), and each groove (15) is provided at the outer member (3).

8. The thruster of any of claims 1-7, wherein the drill string includes a downhole motor driving the drill bit, the downhole motor being arranged between the thruster and the drill bit.

Patentansprüche

1. Hydraulischer Schubzeuger (1) zum Erzeugen einer Schubkraft auf eine Bohrkronen, die am unteren Ende eines Bohrstranges angeordnet ist, mit einem ersten Teil (3), das an einen oberen Abschnitt des Bohrstranges anschließbar ist, und einem zweiten Teil (5), das an einen unteren Abschnitt des Bohrstranges anschließbar ist, wobei die Teile teleskopierend zueinander angeordnet und in der Lage sind,

ein Bohrstrangdrehmoment während des Bohrens zu übertragen, einem Fluiddurchlaß (9), welcher durch die Teile hindurchgeht, damit Bohrfluid durch den Bohrstrang zur Bohrkronen strömt, Mitteln zum Erzeugen einer einwärts-teleskopierenden Reaktion der beiden Teile bei der Übertragung eines Bohrstrangdrehmomentes während des Bohrens, welche Mittel zumindest eine wendelförmige Rippe (11) umfassen, die auf zumindest einem der genannten Teile vorgesehen und in einer korrespondierenden wendelförmigen Nut (15) liegt, welche auf dem anderen der genannten Teile vorgesehen ist, wobei die Rippe und die Nut zusammenwirken, um Drehmoment zwischen dem oberen Abschnitt und dem unteren Abschnitt des Bohrstranges während des Bohrens zu übertragen, und einem unten im Bohrloch arbeitenden Motor zum Antreiben der Bohrkronen, dadurch gekennzeichnet, daß jede Rippe (11) unter einem Helixwinkel β bezüglich der Längsachse des Schubzeugers angeordnet ist, der im Bereich von

$$0,8 \arctan(r.A_i/k_m) < \beta < 1,2 \arctan(r.A_i/k_m)$$

liegt, mit

r = mittlerer Außenradius des Schubzeugers;

A_i = effektive Querschnitts-Schubfläche des Schubzeugers;

k_m = Motorkonstante, definiert als Motordrehmoment pro Einheit Druckabfall über den Motor.

2. Schubzeuger nach Anspruch 1, bei welchem das erste Teil ein Außenteil (3) und das zweite Teil ein Innenteil (5) bildet.
3. Schubzeuger nach Anspruch 2, mit mehreren Rippen (11) und Nuten (15), die regelmäßig über die Schnittstelle zwischen Innen- und Außenteil (3, 5) verteilt sind.
4. Schubzeuger nach Anspruch 3, bei welchem jede Rippe (11) unter einem Helixwinkel β bezüglich der Längsachse des Schubzeugers angeordnet ist, der im Bereich von

$$0,95 \arctan(r.A_i/k_m) < \beta < 1,05 \arctan(r.A_i/k_m)$$

liegt.

5. Schubzeuger nach einem der Ansprüche 1 bis 4, bei welchem der Helixwinkel jeder Rippe (11) und Nut (15) über die Länge des Schubzeugers vari-

iert.

6. Schuberzeuger nach Anspruch 5, bei welchem zumindest ein Element jeder Paarung "Rippe (30) und Nut (36)" um eine radiale Achse (42) drehbar ist, um seinen Helixwinkel an den Helixwinkel des anderen Elementes der genannten Paarung "Rippe (30) und Nut (36)" anzupassen.
7. Schuberzeuger nach einem der Ansprüche 1 bis 6, bei welchem jede Rippe (11) am Innenteil (5) und jede Nut (15) am Außenteil (3) angeordnet ist.
8. Schuberzeuger nach einem der Ansprüche 1 bis 7, bei welchem der Bohrstrang einen unten im Bohrloch arbeitenden Motor aufweist, welcher die Bohrkronen antreibt, wobei der Motor zwischen dem Schuberzeuger und der Bohrkronen angeordnet ist.

Revendications

1. Poussoir hydraulique (1) destiné à générer une force de poussée sur un trépan de forage situé à l'extrémité inférieure d'un train de forage, comportant un premier élément (3) qui peut être relié à une partie supérieure du train de forage et un deuxième élément (5) qui peut être relié à une partie inférieure du train de forage, lesdits éléments étant agencés de manière télescopique l'un par rapport à l'autre et étant aptes à transmettre le couple du train de forage pendant le forage, un passage (9) pour fluide traversant lesdits éléments pour permettre au fluide de forage de s'écouler dans le train de forage en direction du trépan de forage, et des moyens pour générer une réaction télescopique desdits éléments vers l'intérieur lors de la transmission d'un couple du train de forage pendant le forage, lesdits moyens comportant au moins une cannelure hélicoïdale (11) prévue sur au moins l'un desdits éléments et agencée dans une rainure hélicoïdale (15) correspondante prévue sur l'autre desdits éléments, la cannelure et la rainure coopérant de manière à transmettre un couple entre la partie supérieure et la partie inférieure du train de forage pendant le forage et un moteur de fond de trou entraînant le trépan de forage, caractérisé en ce que chaque cannelure (11) est agencée à un angle d'hélice β par rapport à l'axe longitudinal du poussoir, lequel angle d'hélice est compris entre:

$$0,8 \arctan (r.A_i/k_m) < \beta < 1,2 \arctan (r.A_i/k_m)$$

où

r = rayon extérieur moyen du poussoir;
 A_i = superficie de poussée efficace de la sec-

tion transversale du poussoir;

k_m = constante de moteur, définie comme étant le couple du moteur par perte de charge unitaire à travers le moteur.

2. Poussoir selon la revendication 1, dans lequel ledit premier élément forme un élément extérieur (3) et ledit deuxième élément forme un élément intérieur (5).
3. Poussoir selon la revendication 2, comportant plusieurs desdites cannelures (11) et rainures (15) réparties régulièrement à l'interface entre l'élément intérieur et l'élément extérieur (3, 5).
4. Poussoir selon la revendication 3, dans lequel chaque cannelure (11) est agencée à un angle d'hélice β par rapport à l'axe longitudinal du poussoir, lequel angle d'hélice est compris entre:

$$0,95 \arctan (r.A_i/k_m) < \beta < 1,05 \arctan (r.A_i/k_m)$$

5. Poussoir selon l'une quelconque des revendications 1 à 4, dans lequel l'angle d'hélice de chaque cannelure (11) et de chaque rainure (15) varie sur la longueur du poussoir.
6. Poussoir selon la revendication 5, dans lequel au moins l'une parmi chaque cannelure (30) et chaque rainure (36) peut tourner autour d'un axe radial (42) de manière à adapter son angle d'hélice par rapport à l'angle d'hélice de l'autre parmi chaque cannelure (30) et rainure (36).
7. Poussoir selon l'une quelconque des revendications 1 à 6, dans lequel chaque rainure (11) est prévue sur l'élément intérieur (5) et chaque rainure (15) est prévue sur l'élément extérieur (3).
8. Poussoir selon l'une quelconque des revendications 1 à 7, dans lequel le train de forage comporte un moteur de fond de trou entraînant le trépan de forage, le moteur de fond de trou étant agencé entre le poussoir et le train de forage.

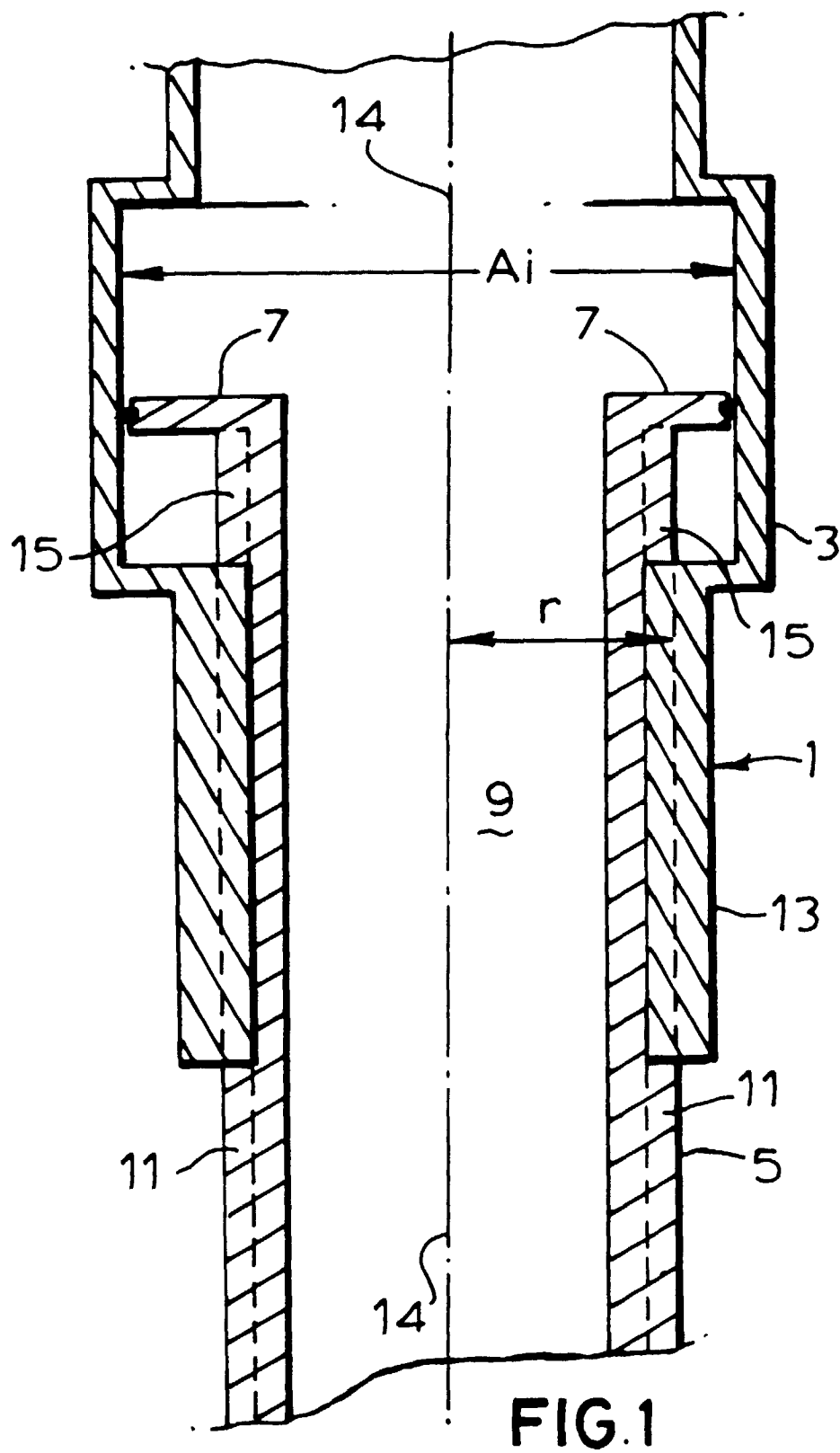


FIG. 2

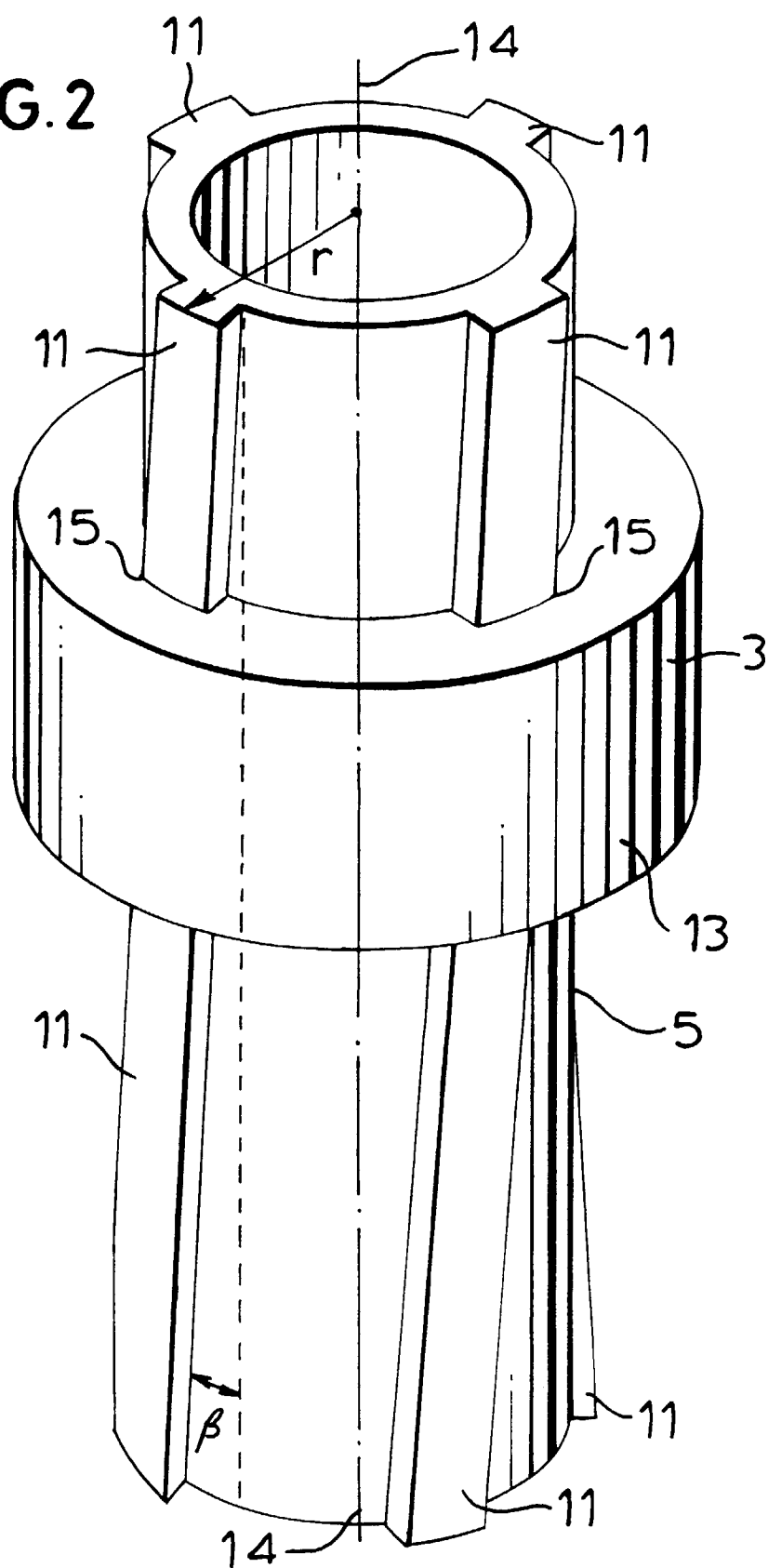
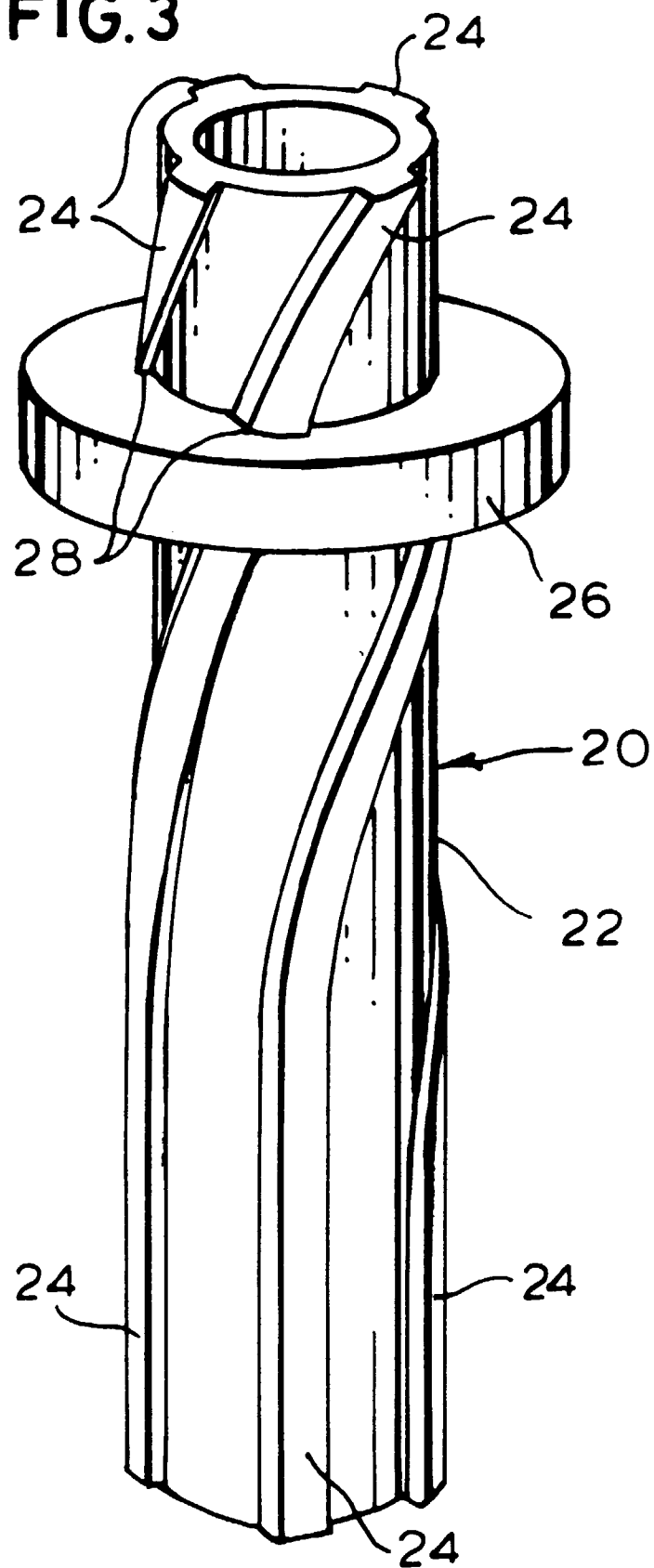


FIG. 3



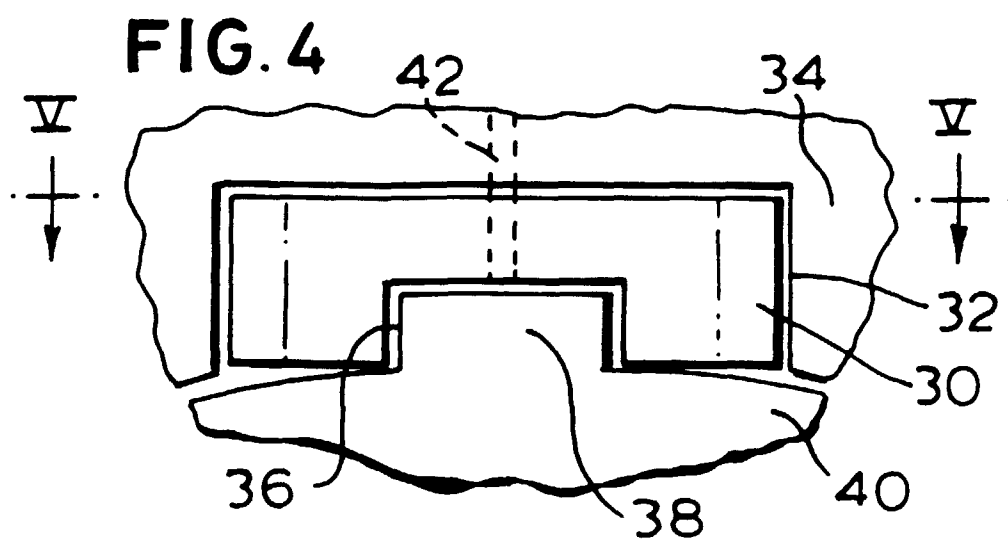


FIG. 5

