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(54) **Flexible Drill Shaft**

(57) A flexible drill shaft for drilling lateral boreholes comprising:
a helical outer wire coil spring; and
at least one inner helical wire coil spring residing concentrically within the outer coil spring, with the coils of adjacent springs having an opposite pitch;
wherein the wire forming each helical spring has a cross section such that when the drill shaft is in a straight alignment there is planar contact between adjacent coils of the spring. There may be grooves (3) and ridges (2) on the contact surface of the coils.

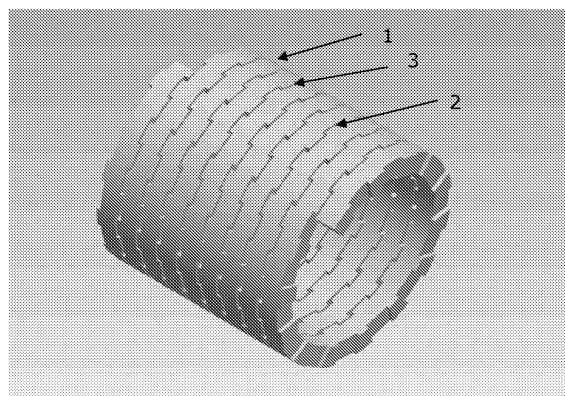


Figure 4

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Description

Technical field

[0001] This invention relates to flexible drill shafts and in particular flexible drill shafts able to transmit a high torque during drilling of lateral boreholes.

Background art

[0002] In oil and gas wells, it is often desirable to drill holes laterally out from a main vertical borehole to increase the communication with the formation surrounding the main borehole and the drainage area. These lateral holes are generally known as drainholes. They provide a passageway through the surrounding formation and can increase the flow rate of the hydrocarbons into the well casing of the main borehole and improve the amount of hydrocarbon extracted.

[0003] In order to have drainholes having a significant length, the equipment or apparatus used to drill the drainholes generally have a flexible shaft to have the ability to change the direction of the apparatus from the main borehole and the lateral borehole and to transmit the rotational power and the rate of penetration to the drill bit.

[0004] US 6,220,372 discloses an apparatus for drilling lateral drainholes comprising a flexible shaft formed from at least two helically wound coil springs. The document discloses that the springs should be formed from wire having a circular cross section.

[0005] US 4,658,916 discloses a flexible drill shaft formed from at least two helically wound coil springs formed from wires having rectangular cross section. This document describes that the wire used to form the coils springs has a rectangular cross section. However if a coiled spring is formed from rectangular cross sectional wire, during the winding process the wire can be distorted due to the pressures altering the final cross section shape of the wire that is forming the spring, such that is no longer rectangular, as shown in figure 1.

[0006] One of the difficulties of having a flexible shaft is that while the flexibility allows it curve to direct the drill bit at an angle away from the main borehole to drill a drainhole and therefore help the drilling apparatus negotiate the bend in the bore hole so that it can drill in a path at an angle away from the main borehole. The flexibility of the shaft can reduce stability of the shaft when it is required to drill in a straight path and can reduce the torque that is provided to the drill bit.

[0007] Therefore it is an object of the invention to provide a flexible shaft with planar contact between coils of the springs, for stably transmitting torque and axial load in a straight guide path or in a curved guide path, to a drill bit.

Disclosure of the invention

[0008] One aspect of the invention comprises a flexible

drill shaft for drilling lateral boreholes comprising: a helical outer wire coil spring; and at least one inner helical wire coil spring residing concentrically within the outer coil spring, with the coils of adjacent springs having an opposite pitch; wherein the wire forming each helical coil springs has a cross section such that when the drill shaft is in a straight alignment there is planar contact between the wire of adjacent coils of the spring. There is planar contact between the adjacent coils when a rotational force and an axial load are applied to the drill shaft during drilling in a straight pathway. Having planar contact between the coils forming each coiled spring helps prevent buckling of the drill shaft. The cross section of the wires is such that planar contact between adjacent coils is maintained even when the drill shaft is drilling in a straight direction.

[0009] Preferably the cross section of the wire is prismatic. More preferably the cross section of the wire of the flexible drill shaft is square, rectangular or lozenge. These cross section shapes allows for planar contact between the adjacent coils of a coil spring.

[0010] The coils of coiled spring can have ridges on the contact surface of the coils and/or grooves on the contact surface on the coils. Having ridges and/or grooves increases the friction ratio between the coils of each coiled spring.

[0011] The coiled springs can be formed from at least two wires coiled in parallel. Having two or more wires coiled in parallel allows more torque to be transmitted and reduces the coiling angle.

[0012] A flexible drill shaft can be formed from coil springs having a preload. Having a preload between spires gives the springs a longitudinal stiffness which helps provide the shaft with stability during drilling in a straight trajectory.

[0013] The flexible drill shaft can further comprise a torque spike filter. This protects the shaft from damage caused by a torque spike. The filter can be placed at any place along the shaft.

[0014] The flexible drill shaft can further comprise a drill bit at the lower end of the shaft.

[0015] A another aspect of the invention comprises a method of making a flexible drill shaft as described above comprising: winding wire to form a helical coil spring; applying a mechanical deformation to the wire as it is being wound; and using the helical coil spring to form a flexible drill shaft; wherein the mechanical deformation applied results in the wire after being wound having a cross section such that when an axial load is applied to the drill shaft there is planar contact between adjacent coils of the spring.

[0016] Preferably the method comprises applying a preload to the wire as it is being wound.

[0017] The method can comprise using dimensional or thermal expansion to tightly assemble two or more coil springs together. This can help reduce the gap between coil springs of the flexible drill shaft.

Brief description of the drawings

[0018] Figure 1 shows a schematic view of the deformation of wire after winding;

Figure 2 shows a schematic view of the wire before and after the winding process;

Figure 3 shows a schematic view of one wire cross section for use in making a coiled spring of the invention;

Figure 4 shows a schematic view of one of the coiled spring that can be used for the invention; and

Figure 5 shows the forces taking place on a coiled spring.

Mode(s) for carrying out the invention

[0019] The flexible shaft is formed of a helically wound outer coil spring and one or more helically wound and smaller inner coils springs residing concentrically therein. Each successively smaller inner coil spring has an outer diameter substantially the same as the inner diameter of the adjacent larger coil spring. Each coil spring is wound in the opposite direction to that of the adjacent coil springs, the outer coil spring sets the winding reference direction, and is wound in the same direction as the direction that the drill bit will rotate. The springs are held rigid in relation to each of the other coil springs at the drill shafts upper and lower ends. The springs are close wound with axially adjacent coils of each coil spring in contact with each other. During assembly dimensional or thermal expansion can be used to remove any gaps between adjacent coil springs, so that the coil springs are assembled tightly together.

[0020] Each of the springs is formed of wound wire, having a geometric cross section. However the winding process can cause the initial cross section of the wire to deform as it is being coiled to form a spring. Therefore the wire forming the spring has a different final cross section, once formed into the spring than what it initially starts off with before it is coiled.

[0021] For example, as shown in figure 1, a wire with an initial square cross section is deformed into a wire having a trapezium cross section due to the compression forces placed on the wire as it is being formed into the coil spring. A coil spring that is formed from wire having a trapezium cross section along its length, as in figure 1, does not have planar contact between adjacent coils of the spring.

[0022] To form a coiled spring with planar contact between adjacent coils the initial cross section of the wire before winding has to be corrected in order to take into account the deformation that occurs during the winding process. With reference to figure 2, a wire having an initial trapezium cross section when used to form a coiled spring the final shape of the cross section of the wire once formed into the spring is a square due to the compression forces placed on the wire during the winding

process. The angle, β , is the angle by which the cross section of the wire is corrected by to compensate for the deformation that the wire will under go during the winding process to form the spring. The final square cross section allows for planar connect between the adjacent coils. With planar contact between the coils of the spring, the flexible drill shaft is able to have improved transmittal of torque and axial load to an out put device such as a drill bit, when the drill shaft is in a curved and straight form.

[0023] The angle correction to the initial wire used for forming the spring can be done by either applying an opposite mechanical deformation to the wire during the winding process, or by directly wire drawing with a cross section that when altered due to the compression forces applied during the winding process will result in a final cross section that allows planar connect between coils.

[0024] Having planar contact between the coils improves the performance of the flexible shaft when drilling in a straight path. Planar contact between the adjacent coils gives the shaft a better anti- buckling effect and ensures rigidity of the shaft, when placed under an axial load, such as during drilling.

[0025] Planar contact between the surfaces of coils increases the friction this reduces the shrinking of the diameter of the spring under torque. Reducing the shrinking of the diameter of the spring under torque can also be helped by having a spring with a lozenge cross section. When the wire has a lozenge section as indicated in figure 3, there will be planar connect between adjacent coils. Wire having a lozenge cross section to be used to form a coiled spring will have an angle α , where angle α is equal to the corrected angle β , to take into account deformation that occurs due winding process, and an additional angle such that the wire maintains a lozenge cross section after the winding process.

[0026] When the spring coils forming the flexible drill shaft are subjected to torque this can cause either a decrease in the diameter with a corresponding increase in length or an increase in diameter with a corresponding decrease in length. Having alternate winding of the springs forming the shaft, when the springs are placed under torque one spring expands in diameter and its adjacent spring decreases in diameter thereby creating a strong, stable and flexible shaft.

[0027] The springs used to form the flexible shaft can be preloaded springs. A preload is applied during the winding process of the spring. This gives the drill shaft a lengthwise stiffness allowing the shaft to have stability when drilling in a straight direction.

[0028] With reference to figure 4, to increase the friction ratio of the contact between adjacent coils 1, ridges 2 and/or grooves 3 are added to the wire forming the coils. Processes for forming the ridges and grooves on the wire can include mechanical deformation of the formed wire or directly wiredrawing, however other methods may be used. Increasing the friction ratio between adjacent coils, will reduce the slippage that can occur between the adjacent surfaces, and therefore improve

the stability of the drill shaft.

[0029] In operation, a drilling apparatus comprising the flexible drill shaft according to the invention with a drill bit attached to the lower end of the shaft is lowered down into the wellbore. To drill drainholes, the flexible shaft is guided so as to turn and direct the drill bit to drill laterally into the side of the main borehole. The flexibility of the shaft enables the shaft to turn in a short radius. A rotary motor enables rotation of the shaft and the drill bit. Rotation is imparted by a motor and axial load is transmitted through to the flexible drill shaft causing the drill bit to rotate and drilling to proceed. A rotating torque and an axial force are applied to the drill bit through the flexible drill shaft.

[0030] With reference to Figure 5, with the flexible drill shaft having planar contact between adjacent coils of the spring, the applied torque and axial force is more effective in the drilling process. The torque transmitted to the drill bit is improved. The transmissible torque is the sum of the rotational torque 4 and clutch effect which is due to the combination of the axial force 5 down the length of the shaft and the friction ratio between the contact surfaces of adjacent coils.

[0031] Further changes can be made without departing from the scope of the invention.

Claims

1. A flexible drill shaft for drilling lateral boreholes comprising:

a helical outer wire coil spring; and
at least one inner helical wire coil spring residing concentrically within the outer coil spring, with the coils of adjacent springs having an opposite pitch;

wherein the wire forming each helical spring has a cross section such that when the drill shaft is in a straight alignment there is planar contact between adjacent coils of the spring.

2. A flexible drill shaft according to claim 1 wherein the cross section of the wire is square, rectangular or lozenge.
3. A flexible drill shaft according to any of claims 1 or 2 wherein there are ridges on the contact surface of the coils.
4. A flexible drill shaft according to any of claims 1-3 wherein there are grooves on the contact surface of the coils.
5. A flexible drill shaft according to any of claims 1-4 wherein the coil springs are formed from at least two wires coiled in parallel.

6. A flexible drill shaft according to any of claims 1-5 wherein the coil springs have a preload.

7. A flexible drill shaft according to any of claims 1-6 comprising a torque spike filter.

8. A drilling apparatus comprising the drill shaft according to any of claims 1-7 and a drill bit attached to the lower end of the shaft.

9. A method of making a flexible drill shaft according to any of claims 1-8 comprising:

winding wire to form a helical coil spring;
applying a mechanical deformation to the wire as it is being wound; and
using the helical coil spring to form a flexible drill shaft;

wherein the mechanical deformation applied results in the wire after being wound having a cross section such that when an axial load is applied to the drill shaft there is planar contact between adjacent coils of the spring.

10. A method of making a flexible drill shaft according to claim 9 comprising:

applying a preload as the wire is being wound.

11. A method according to claims 9 or 10 comprising using dimensional or thermal expansion to tightly assemble two or more coil springs.

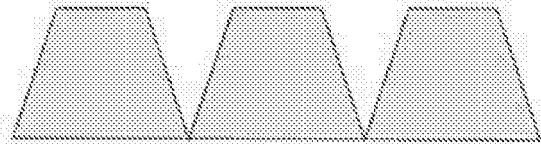
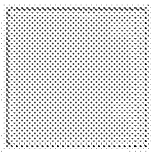


Figure 1

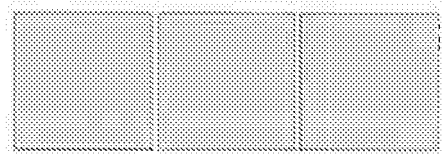


Figure 2

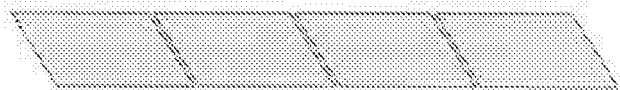
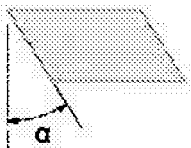


Figure 3

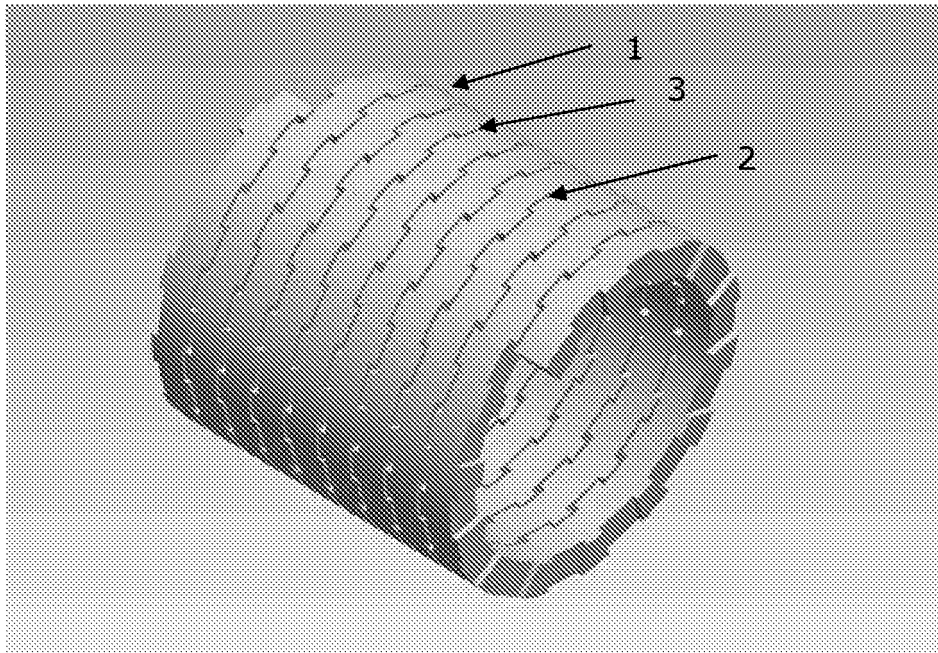


Figure 4

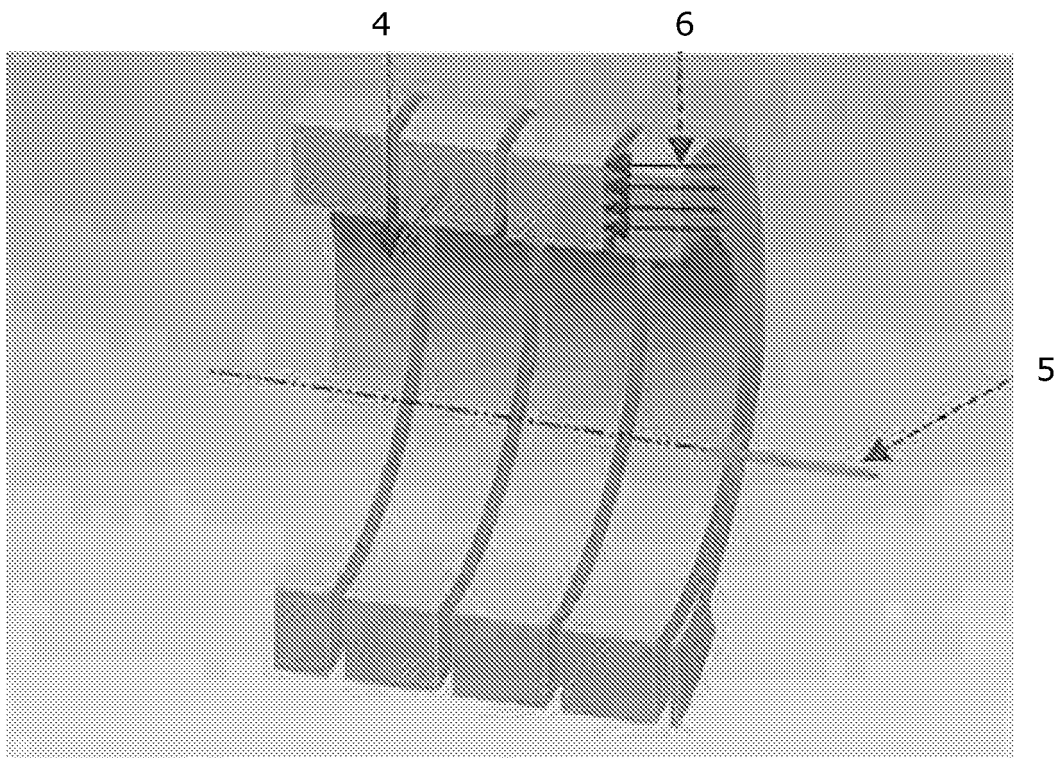


Figure 5



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 10 6674

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Place of search The Hague		Date of completion of the search 11 September 2007	Examiner van Berlo, André
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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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