

[54] **METHOD AND APPARATUS FOR PREVENTING AND DETECTING ROTARY DRILL BIT FAILURE**

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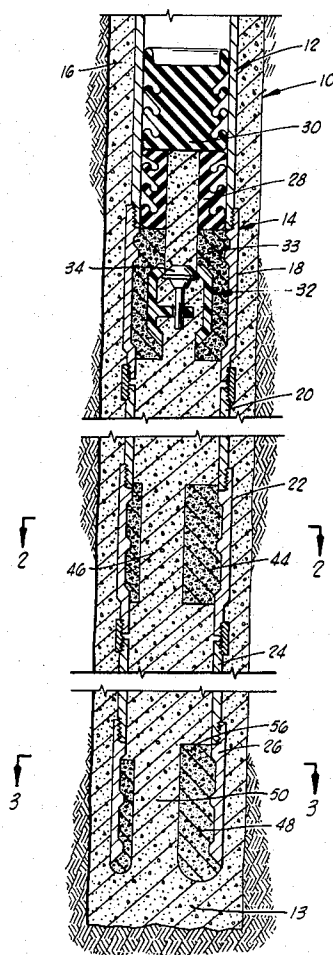
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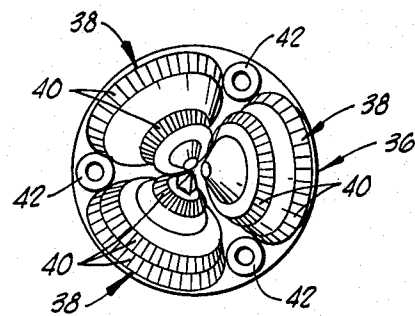
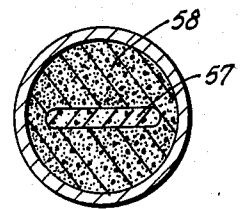
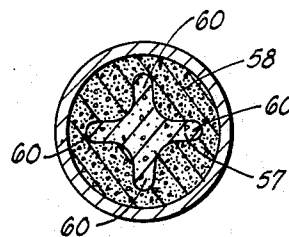
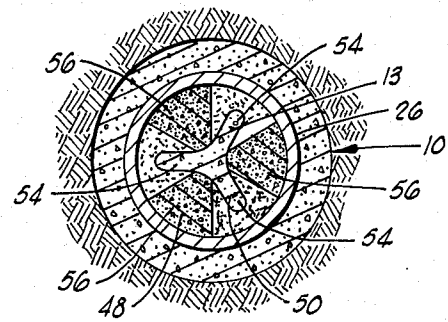
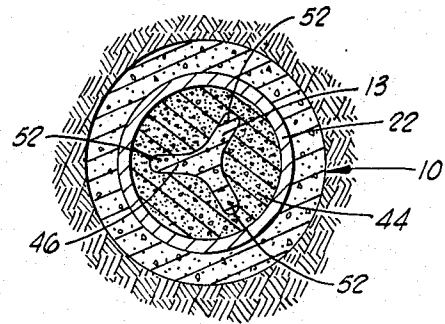
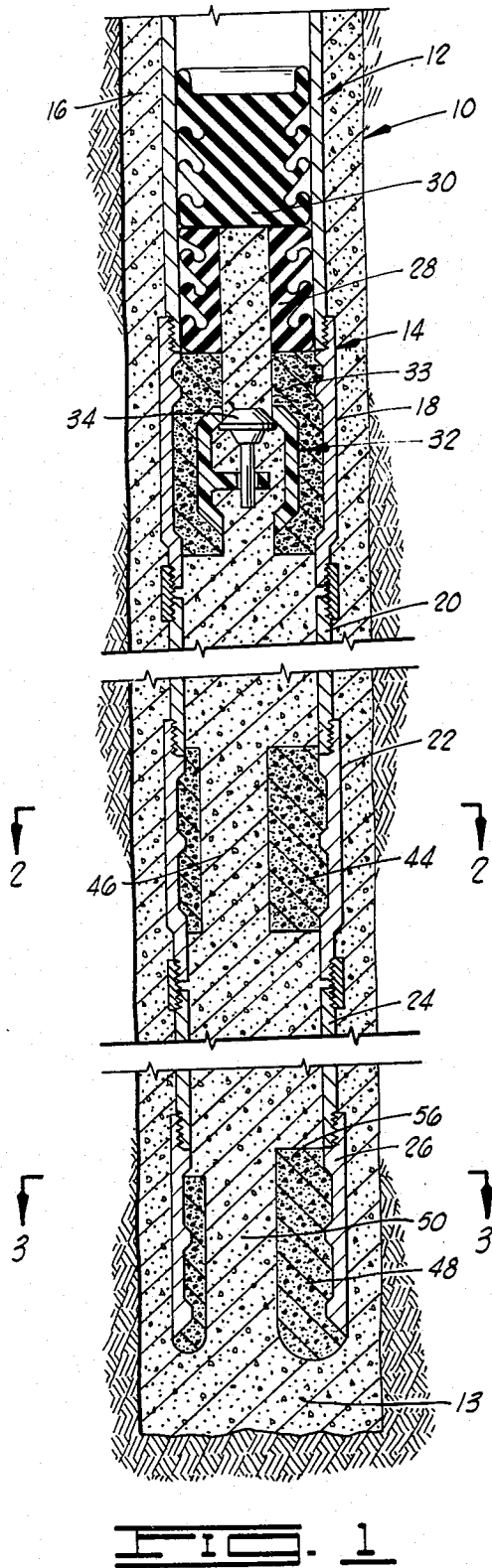
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[57] **ABSTRACT**

Methods and apparatus for preventing the failure of a rotary drill bit as a result of the roller cutters thereof becoming jammed when drilling out disposable materials blocking a string of conduit. A drillable core which includes an abutment formed therein for engaging the roller cutters of the drill bit is provided in the string of conduit below the disposable materials.

21 Claims, 6 Drawing Figures





METHOD AND APPARATUS FOR PREVENTING AND DETECTING ROTARY DRILL BIT FAILURE

In the drilling and completion of a well bore penetrating a subterranean earth formation, a continuous string of casing is usually cemented in the well bore. Typically, during the drilling of the well bore portions of the casing string are suspended therein and cement is displaced downwardly through the casing and then upwardly into the annulus between the casing and the well bore so that upon curing the cement rigidly holds the casing in the well bore. After the cementing of one casing string is completed and drilling is resumed, an additional casing string is cemented in the well bore and the process of drilling and installing additional casing is repeated until the well bore reaches the desired depth.

In carrying out casing and liner cementing procedures in well bores such as those described above, special cementing tools are utilized for separating the cement slurry from displacing fluids used, for preventing overdisplacement of the cement slurry into the well bore, and for preventing reentry of the cement slurry into the casing after being displaced into the annulus between the casing and the well bore. In addition, tools for facilitating lowering the casing into the well bore before cementing and for cleaning cement slurry and displacing fluid from the interior of the casing are often utilized. At the end of the cementing procedure, these tools as well as a portion of the cement slurry used are left in the casing and must be removed before the well bore can be deepened or the well produced. Generally, the cementing tools are formed of disposable drillable materials and as soon as the cement between the casing and the well bore has set up to a strength permitting drilling within the casing, the cementing tools and hardened cement remaining within the casing are drilled out using conventional rotary drilling techniques and conventional roller cutter type drill bits.

Because the cement inside the casing is often only partially cured and relatively soft when it is drilled out, if the roller cutters of the drill bit used have become jammed as a result of cement or impediments such as debris from the disposable cementing tools becoming lodged in the cutter teeth or bearings, the drilling of the cement does not provide sufficient resistance to drill pipe weight and torque to cause the roller cutters to roll and crush the impediments lodged therein. Further, because of the soft condition of the partially cured cement, the penetration rate of the drill bit through the cement may be normal even though the roller cutters of the drill bit are not turning. The extremely abrasive cement quickly brings about extreme wear at the points of contact with the jammed roller cutters of the drill bit resulting in flat spots being formed thereon which in turn tend to prevent the roller cutters from turning even after the soft cement has been drilled out. Continued drilling with the drill bit in this condition may result in the drill bit being irreparably damaged or the roller cutter bearings being exposed and the cutters eventually falling off the bit into the well bore. This occurrence constitutes a very serious problem in that the extreme hardness of the cutters prevents continued drilling of the well bore until either the cutters are removed or the well bore is side-tracked, both of which operations are costly and time consuming to carry out.

By the present invention methods and apparatus are provided for preventing or at least detecting the failure

of a rotary drill bit as a result of the roller cutters thereof becoming jammed when drilling through disposable materials blocking a conduit string. Broadly described, the method comprises the steps of placing a drillable core near the lower end of the string of conduit below disposable materials blocking the conduit, which core includes an abutment formed therein for engaging the roller cutters of a rotary drill bit. The materials blocking the conduit string are drilled out in a conventional manner and then the core is drilled so that the cutters of the rotary drill bit alternately drill or strike the material of the core and the softer cement within the convoluted hole through the core impacting the core and the abutment formed therein and forcefully causing the cutters to roll thereby crushing and removing impediments lodged therein. If the cutters are not impeded, or once impediments have been removed therefrom, the core is drilled out normally without damaging the drill bit or reducing its penetration capability.

In the drawings forming a part of this disclosure:

FIG. 1 illustrates in cross-section the lower end of a string of casing which has been cemented in a well bore and which includes drillable cementing tools, cement and the apparatus of the present invention therein;

FIG. 2 is a cross-sectional view taken along line 2—2 of FIG. 1;

FIG. 3 is a cross-sectional view taken along line 3—3 of FIG. 1;

FIG. 4 is a cross-sectional view of apparatus of the present invention similar to that shown in FIG. 1 but illustrating an alternate arrangement.

FIG. 5 is a cross-sectional view similar to FIG. 4 showing another alternate arrangement of the apparatus of the present invention; and

FIG. 6 is a bottom plan view of a conventional rotary jet type drill bit which includes roller cutters.

Referring now to the drawings, and particularly to FIGS. 1 through 3, a portion of a well bore 10 extending into a subterranean earth formation is illustrated. The bottom end of a string of casing 12 having a cementing tool assembly 14 attached thereto is shown cemented in the well bore 10, i.e., cement 13 has been displaced through the casing 12 and tool assembly 14 into the annular space 16 between the casing 12 and the well bore 10.

The cementing tool assembly 14 includes a conventional float collar 18 threadedly attached to the lower end of the casing string 12. A connecting conduit 20 is threadedly attached to the lower end of the float collar 18, and apparatus of the present invention in the form of a collar 22 is threadedly attached to the lower end of the conduit 20. A second connecting conduit 24 is threadedly attached to the lower end of the collar 22 and apparatus of the present invention in the form of a guide shoe 26 is threadedly attached to the lower end of the conduit 24.

As will be understood by those skilled in the art, the cementing tool assembly 14 can be made up from a variety of component tools threadedly attached together as shown in FIG. 1, or the various tools can be included as integral parts of a single combination tool. Further, optional tool arrangements can be used which include one or more float collars, a float shoe or a guide shoe.

In accordance with the present invention, one or more apparatus including special drillable cores of the invention are included in the tool assembly 14, prefera-

bly below float collars included therein. These drillable core apparatuses, which will be described in detail hereinbelow, can take a variety of individual forms, e.g., the collar 22 and guide shoe 26 illustrated in FIG. 1 or they may be included as integral parts of float collars, float shoes or other combination tools.

Referring now particularly to FIG. 1, a conventional bottom cementing plug 28 and a top cementing plug 30 are shown landed on the top of the float collar 18. The plugs 28 and 30 are shown in the position they attain after being utilized in a conventional manner to facilitate the displacement of cement through the casing 12 and the tool assembly 14 into the annulus 16. Other plugs for special cementing operations such as stage cementing, inner string cementing, etc., can also be used.

The guide shoe 26 is used for guiding the casing 12 and tool assembly 14 as it is being lowered into the well bore and the float collar 18 is used for floating the casing 12 in fluids contained in the well bore thereby minimizing strain on the derrick caused by the weight of the casing string. A float valve assembly generally designated by the numeral 32 is illustrated disposed within an annular core 33 rigidly attached within the float collar 18. The assembly 32 includes a spring loaded valve 34 which functions in seating relationship with the annular core 33 to prevent well bore fluids and cement from freely flowing upwardly into the casing 12, but which allows cement and other fluids contained within the casing 12 to readily pass downwardly through the tool assembly 14.

In carrying out a conventional casing cementing procedure, the bottom cementing plug 28 is caused to flow downwardly through the casing string 12 so that drilling mud and other contaminants contained therein are forced out of the casing 12 through the tool assembly 14. A quantity of cement slurry 13 is flowed through the casing 12 behind the bottom plug 28 followed by the top cementing plug 30. The cement slurry 13 is displaced through the casing 12 through the bottom plug 28 and tool assembly 14 into the well bore 10 and the annulus 16. When the top cementing plug 30 reaches the bottom cementing plug 28, as illustrated in FIG. 1, displacement of the cement slurry 13 is stopped leaving a quantity of the cement slurry 13 below the displacement plug 30 within the casing 12 and the tool assembly 14. Thus, at the end of the cementing procedure the casing 12 is blocked by the plugs 28 and 30, the valve assembly 32 of the float collar 18 and the cement remaining in the casing 12 and tool assembly 14 below the plug 30.

In order to facilitate the removal of cementing tools left in the casing after carrying out a cementing procedure, the tools have heretofore been formed of drillable materials, and the technique employed for their removal has been simply to drill out the casing using a conventional rotary drill bit of a type like that illustrated in FIG. 6. After the casing is drilled out it is sometimes desirable to deepen the well bore by continued drilling using the same drill bit.

The drill bit illustrated in FIG. 6 is a typical jet type rotary drill bit and is generally designated by the numeral 36. The bit 36 usually includes three roller cones or cutters 38 and as is understood by those skilled in the art, in drilling well bores utilizing the bit 36, downward pressure is applied to the surface of the earth formation being drilled as the drill bit is rotated. Each of the roller cutters 38 include rows or projecting teeth 40

which contact the formation as the bit 36 is rotated bringing about a chipping action against the formation. The roller cutters 38 are normally kept free of the chips and debris produced by drilling fluid which is circulated via the drill string through jet nozzles 42 provided in the drill bit 36.

Referring again to FIGS. 1 and 2, in accordance with the present invention a core 44 containing an opening 46 is rigidly attached within the collar 22 and a core 48 having an opening 50 disposed therethrough is rigidly attached within the guide shoe 26. The openings 46 and 50 of the cores 44 and 48 are preferably convoluted and are disposed longitudinally through the cores 44 and 48 so that cement and other fluids can pass therethrough from the casing 12. Further, the cores 44 and 48 and the convoluted openings 46 and 50 therein are formed in shapes which provide abutments for engaging the roller cutters of a rotary drill bit when the cores 44 and 48 are drilled out of the collar 22 and guide shoe 26 respectively. The cores 44 and 48 are formed of a drillable material preferably the same as that used to form the annular core 33 of the float collar 18, e.g., concrete, having a hardness greater than the cement 13 to be drilled out of the tool assembly 14.

While a variety of materials can be used to form the cores 44 and 48 into a variety of shapes whereby the abutments described above are provided, they are preferably formed of concrete and the abutments are preferably provided by the shapes of the convoluted openings 46 and 50 therein. That is, the openings 46 and 50 are positioned so that when the cores 44 and 48 are drilled, the roller cutters of the drill bit used alternately strike the material of the cores 44 and 48 and softer cement 19 filling the convoluted openings through the cores, impacting the lateral wall portions of the openings 46 and 50 thereby causing the cutters to turn.

Referring specifically to FIG. 2, the opening 46 in the core 44 attached within the collar 22 is illustrated in a preferred cross-sectional shape. That is, the opening 46 is positioned coaxially with the core 44, and includes three essentially symmetrical lobes 52 extending to near the periphery of the core 44 and located about a central point. This trilobal cross-sectional shape of the opening 46 provides drill bit roller cutter abutments for causing the roller cutters to turn. That is, the lateral wall portions of the lobes 52 provide abutments or shoulders which engage the teeth 40 (FIG. 6) of the roller cutters 38 as the drill bit 36 is rotated against the top surface of the core 44, and as drilling through the core 44 continues, the roller cutters 38 continue to impact lateral portions of the opening 46 forceably causing the cutters to roll.

Referring now to FIGS. 1 and 3, the core 48 attached within the guide shoe 26 is illustrated. The opening 50 in the core 48 is identical to the opening 46 in the core 44 described above and includes three essentially symmetrical lobes 54 located about a central point. However, as best shown in FIG. 1, the core 48 includes one or more raised portions 56 at the top thereof which creates an additional abutment for engaging the roller cutters of a drill bit. The raised portion may be in the form of one or more radial ridges separated by radial grooves or lowered portions.

Referring now to FIGS. 4 and 5, alternate preferred cross-sectional shapes of openings 57 in cores 58 for providing drill bit roller cutter abutments are shown. As illustrated in FIG. 4, the opening 57 can be of quad-

rilobal cross-sectional shape, i.e., it can include four essentially symmetrical lobes 60 located around a central point positioned coaxially with the core 58. The lateral wall portions of the lobes 60 provide longitudinally extending shoulders which engage the teeth of the roller cutters of a rotary drill bit.

Yet another cross-sectional shape which can be used for the opening 57 is illustrated in FIG. 5 and consists of two opposite lobes extending from a central point, i.e., a substantially rectangular shape extending across the face of the core 58. Also other cross-sectional geometrical shapes, such as rectangles, triangles, ovals or the like, may be used for the convoluted openings through the cores.

In carrying out the method of the present invention for preventing or detecting the failure of a rotary drill bit as a result of the rotor cutters becoming jammed when drilling through materials blocking a string of conduit, apparatus of the invention is placed at optional locations within the string of conduit below the uppermost float collar and other materials which are to be drilled out. As mentioned above, the apparatus can comprise a combination tool which may or may not include tools other than those of the invention. When utilized in tool assemblies which include float collars, the apparatus of the invention is preferably placed below the float collars. After the apparatus has been placed in the string of conduit, the conduit can be lowered into a well bore and cemented therein. When it is desirable to drill out the cementing tools and cement blocking the conduit, the materials are drilled using a rotary drill bit in a conventional manner. Following this, the core or cores of the present invention are drilled so that the roller cutters of the drill bit impact the abutments provided thereby and impediments jamming the cutters, if any, are removed.

Referring specifically to FIGS. 1 through 3, when the drill bit has drilled out the plugs 28 and 30, the annular core 33 and valve assembly 32 of the float collar 18, and the cement above the collar 22, if the roller cutters of the drill bit used are jammed, when the bit bites into the hard material of which the core 44 of the collar 22 is formed a greater resistance is applied to the roller cutters tending to cause them to turn. In addition, the cutters forceably impact the lateral wall portions of the opening 46 provided in the core 44 forcing the cutters to turn. However, if the resistance and impact brought about by drilling the core 44 and insufficient to free the roller cutters of the impediments jamming them, the drilling of the core 44 will be erratic and detectable at the surface due to the constant impact of the jammed cutters with the abutments provided by the core 44. That is, an erratic jerky motion will be imparted to the drill string while the core 44 is being drilled which will serve as a warning to the drilling rig operator that the roller cutters of the drill bit are jammed. The core 48 of the guide shoe 26 functions in the same way as the core 44 of the collar 22 described above.

Thus, the method and apparatus of the present invention is well adapted to prevent or detect the failure of a rotary drill bit as a result of the roller cutters thereof becoming jammed when drilling through materials blocking a string of conduit, e.g., a string of casing disposed and cemented in a well bore. While presently preferred embodiments of the invention have been described for purposes of this disclosure, numerous changes in the arrangement of parts, the location of the

cores of the invention and the type and shape of abutments provided therein can be made by those skilled in the art, which changes are encompassed within the spirit of this invention and the scope of the appended claims.

What is claimed is:

1. A method, of preventing the failure of a rotary drill bit as a result of roller cutters thereof becoming jammed when drilling through a first material blocking a conduit and remaining jammed during continued drilling through a softer second material blocking said conduit, comprising the step of:

a. drilling through an interrupted annular portion of a core of hardness greater than said second softer material, so that when said interrupted annular portion is drilled the roller cutters of said drill bit impact with lateral portions of said interrupted annular portion so as to forcibly urge said roller cutters to rotate; and

b. concurrently drilling through said softer second material.

2. A method of preventing the failure of a rotary drill bit as a result of roller cutters thereof becoming jammed when drilling through a first material blocking a conduit and remaining jammed during continued drilling through a softer second material blocking said conduit, comprising the steps of:

a. disposing, within said softer second material blocking said conduit, a core of drillable material, said core including an annular portion of hardness greater than said softer second material, and a plurality of openings located in and essentially symmetrically about the central axis of said portion; and

b. drilling through said portion during said continued drilling through said softer second material.

3. The method of claim 2, wherein:

said conduit is oil well casing;

said first material is casing cementing tools; and

said softer second material is casing cement.

4. The method of claim 2 wherein the number of said openings is at least two but not more than four.

5. The method of claim 4 wherein the number of said openings is three.

6. A method of preventing the failure of a rotary drill bit as a result of roller cutters thereof becoming jammed when drilling through a first material blocking a conduit and remaining jammed during continued drilling through a second softer material blocking said conduit, comprising the steps of:

a. applying a plurality of distinct rotational impact forces to said roller cutters during drilling of said second softer material, so as to forcibly urge said roller cutters to rotate; and

b. generating a signal in response to jammed condition of any of said roller cutters during said drilling of said second softer material.

7. Apparatus, for preventing the failure of a rotary drill bit as a result of roller cutters thereof becoming jammed while drilling through a first material blocking a conduit and remaining jammed during continued drilling through a softer second material blocking said conduit, comprising:

a. a housing adapted to be connected in said string of conduit; and

b. a drillable core rigidly attached within said housing, said core including an interrupted annular por-

tion of hardness greater than said softer second material.

8. The apparatus of claim 7 wherein said drillable core is formed of concrete.

9. The apparatus of claim 7 wherein the number of interruptions in said portion is at least two but no more than four.

10. The apparatus of claim 7 wherein all interruption of said portion are symmetrically placed about the central axis of said annular core.

11. The apparatus of claim 10 wherein the number of said interruptions is three and said interruptions recesses are symmetrically placed about the central axis of said annular core.

12. The apparatus of claim 10 wherein the number of said interruptions is four and said interruptions are symmetrically placed about the central axis of said annular core.

13. Apparatus, for preventing the failure of a rotary drill bit as a result of roller cutters thereof becoming jammed while drilling through cementing tools and remaining jammed during continued drilling through casing cement below said cementing tools contained with a string of casing, comprising:

- a. a housing adapted to be connected in said string of casing below said cementing tools; and
- b. a drillable core rigidly attached within said housing, said core having a longitudinal axis and including an interrupted annular portion of hardness greater than said casing cement.

14. The apparatus of claim 13 wherein said housing is an integral part of a combination tool and is placed

below drillable cementing equipment.

15. The apparatus of claim 13 wherein said housing encloses said drillable cementing tools and said interrupted annular portion of core is formed of concrete.

16. The apparatus of claim 13 wherein said portion includes at least one substantially radially extending raised portion formed on the upper end thereof.

17. The apparatus of claim 13 wherein said opening has a substantially rectangular cross-sectional shape.

18. The apparatus of claim 17 wherein said symmetrically lobed non-circular bore has at least two but not more than four symmetrical lobes.

19. The apparatus of claim 18 wherein said symmetrically lobed non-circular axial bore has a trilobal cross-sectional shape.

20. The apparatus of claim 18 wherein said symmetrically lobed non-circular axial bore has a quadrilobal cross-sectional shape.

21. An apparatus, for preventing the failure of a rotary drill bit as a result of roller cutters thereof becoming jammed while drilling through cementing tools in a casing string and remaining jammed during continued drilling of casing cement below said cementing tools, comprising:

- a. a housing adapted to be connected in said casing string below said cementing tools; and
- b. a drillable core rigidly attached within said housing, said core having a longitudinal axis, a symmetrically lobed non-circular bore and an outer impact portion about said bore, said portion being harder than said casing cement.

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