

Description

The invention relates to a method of forming a coating on the wall of a borehole penetrating a subsurface earth formation.

During the course of drilling a well the wall of the borehole being drilled is generally sealed and stabilized by means of a protective steel casing which is after retrieval of the drilling assembly lowered through the borehole and cemented in place. Setting a steel casing in a well is time consuming and expensive therefore several methods have been suggested to eliminate the need for such steel casings. In one method a cement plug is set in the borehole, and after the cement has hardened a hole is drilled through the cement plug. In another method the mud cake on the wall of the borehole is solidified by fusing sulphur particles contained in the mud cake. In a further method a continuous casing is formed by extruding plastics material along the borehole wall.

Although known methods of stabilizing a borehole provide useful alternatives to a conventional steel casing they still have the inherent disadvantage of application of equipment which is inserted in the well after retrieving the drilling assembly therefrom. It will be appreciated that pulling a drill string is a time consuming and hazardous method. A major hazard resides in the fact that the upwardly moving drill bit at the lower end of the drill string can cause underpressure at the bottom of the borehole; in which case formation fluids may be sucked into the borehole which can lead to a well blow out.

British patent application No. 380 451 discloses a method of forming an impermeable coating on the wall of a borehole comprising (a) separating coating forming components from a slurry containing coating forming components and a carrier fluid in a centrifuge; (b) packing the separated components against the borehole wall as a continuous layer; and (c) allowing the layer of packed coating to harden to an impermeable coating.

In the known method the slurry containing coating forming components is prepared in-situ substantially at the depth in the borehole where the coating is needed from raw materials carried on the device used to carry out the known method. The carrier fluid is water carried on the device.

A disadvantage of the known method is that only a limited amount of coating can be prepared and that the quality of the prepared slurry cannot be controlled.

It is an object of the present invention to provide a method of continuously applying coating on the wall of a borehole wherein the quality of the slurry of coating forming components can easily be controlled. In addition the present invention aims to

provide a safe and quick method of forming a casing inside a borehole which remedy drawbacks of the known methods.

To this end the method of forming an impermeable coating on the wall of a borehole according to the present invention is characterized in that the carrier fluid is drilling fluid, that the centrifuge is located close to the end of a drill string present in the borehole, in that the slurry is injected through the drill string, and in that the coating forming components in the slurry are in a pelletized form.

It is an advantage of the method according to the invention that the borehole remains filled with drilling fluid during coating the borehole wall. As drilling fluid in the borehole stops reservoir fluids from flowing into the borehole, this method is a safe method.

Reference is now made to U.S.A. patent specification No. 3 713 488. This publication relates to sealing the lower end of a borehole in which a drill string with an air hammer is present. Sealing is done using a blocking agent which is supplied through the drill string. When the blocking agent is supplied drilling is interrupted. The blocking agent is not supplied together with the drilling fluid which operates the air hammer. U.S.A. patent specification No. 3 935 910 relates to casing the wall of a borehole in which a drill string is present. The material used to produce the casing is not supplied together with the drilling fluid. U.S.S.R. patent specification No. 171 703 relates to casing the wall of a borehole in which a drill string provided with an air drill is present. The material used to produce the casing is not supplied together with the drilling fluid. In these known methods the coating forming composition is supplied to the lower end of the drill string separately so that no down-hole separation from a slurry is required.

The invention will now be explained in more detail and by way of example with reference to the accompanying drawings, in which:

Fig. 1 illustrates the bottom of a borehole in which simultaneously with the drilling process a coating is formed using the method according to the invention;

Fig. 2 shows a borehole in which alternately a borehole section is drilled and a coating is formed; and

Fig. 3 shows an alternative method of alternately drilling a borehole section and forming a coating on the wellbore.

In Fig. 1 there is shown the bottom of a borehole 1 penetrating a subsurface earth formation 2. The hole 1 is being drilled by a rotary drill bit 3, which is provided with a pair of underreamers 4 and connected to the lower end of a drill string 5. The drill string 5 is at a location close to the bit 3

provided with a decanting centrifuge 6 which is tended to separate pellets 7 of coating forming components from a carrier fluid which is circulated down through the drillstring 5 during drilling. In the example shown the pellets 7 have a higher density than the carrier fluid so that the pellets 7 are packed against the inner wall of the centrifuge 6 by centrifugal force where they form a liquid mass 8 of coating forming components, which mass 8 is allowed to escape from the centrifuge 6 through orifices 9 and to form a continuous coating 10 on the borehole wall.

The centrifuge 6 looks externally like a stabilizer having a plurality of wings in which the separation chambers 11 are arranged. Between each pair of adjacent stabilizer wings a straight or helical flow channel (not shown) is present via which the carrier fluid and drill cuttings may pass upwardly into the pipe-formation annulus 12. It is preferred to use as carrier fluid a low viscosity fluid such as gas, oil, an oil-water emulsion, clear water or brine. The pellets 7 of coating forming components preferably consist of hydraulic cement mixed with fibrous reinforcing material e.g. steel, kevlar, carbon fibres and/or a thermosetting resin. The individual pellets may further be encapsulated in a protective skin which stops the gelling in the drill string or annulus or on surface, but which disintegrates with time or under downhole conditions of heat, pressure, centrifugal force, magnetic field or radioactive radiation.

During operation of the assembly the slurry of carrier fluid and pellets 7 is passed through the interior of the drill pipe 5 in turbulent flow so that the pellets cannot react together. In the centrifuge 6 the combination of centrifugal forces and internal geometry of the separation chambers 11 force the fluid mixture in laminar flow.

The pellets 7 then are carried to the outer radial edge of the separation chambers 11 where they are transported along by the laminar flow and gravity. During this stage or prior to this stage the pellets' protective coating, if any, should become inactive.

The pellets 7, then combined to a continuous mass 8, are subsequently forced through the orifices 9 with a centrifugal force of several hundreds or even thousand 'G' against the hole wall. There they set and form a continuous coating 10 on the wellbore, thus eliminating the need for a steel casing. Some pellets may be forced into the pores of the formation, thus greatly enhancing borehole stability, even if no or only a thin casing is cast. At the lower exit 13 of the separation chambers 11 the geometry is such that the carrier fluid is forced into turbulence. Excess cement protruding into the main flow is eroded away and redistributed in the carrier fluid. This is then circulated up the

annulus 12 to surface where the excess cement is then removed by solids removal equipment such as shale shakers, hydrocyclones, decanting centrifuge, disk centrifuges, filters, etc.

In the example shown after leaving the centrifuge 6 the carrier fluid is passed through the bit 3 and alongside the underreamers 4 prior to being returned up the annulus 12 thereby cooling the bit and removing drill cuttings. It will be understood that the diameter of the bit body 3 is chosen slightly less than the outer diameter of the stabilizer/centrifuge wings 7 to enable retrieval of the bit 3 through the coated wellbore. The thickness of the coating 10 is governed by the lateral distance at which the underreamers 4 protrude from the bit body 3.

To allow the centrifuge 6 to obtain a high rotational speed while forming the coating a hydraulically or electrically driven down-hole motor may be mounted in the drill string above the centrifuge 6, which motor is able to rotate the centrifuge at about 800-1000 revolutions per minute.

The coating 10 may be formed while drilling takes place simultaneously. It may however be preferred to drill a borehole section of say 27 m without forming the coating, to raise subsequently the drill string 27 m such that the orifices are located at the top of the interval where a coating is to be formed and to subsequently lower the string gradually through said interval, while the centrifuge is rotated at high speed and pellets are circulated down through the drill string, until the bit reaches the bottom of the hole, whereafter the next hole section is drilled which is subsequently plastered using a similar procedure.

If the pellets of coating forming components are lighter than the carrier fluid then the design of the decanting centrifuge should be modified such that the pellets, which then concentrate in the centre of the centrifuge, are led by radial flow conduits to the outside of the stabilizer wings. The pellets may have any suitable shape and size. The size of the pellets is preferably selected between 1 μ and a few centimetres.

Fig. 2 shows a drilling assembly which is able to drill a pilot hole section and to subsequently underream and plaster the thus drilled section while pulling the drilling assembly slowly in upward direction. The assembly shown in Fig. 2 comprises a drillstring 20 carrying a conventional bit 21. Above the bit 21 there are mounted a pair of underreamers 22 which are activated to underream the hole to a selected size while the drill string 20 is pulled in upward direction through the hole but which are retracted during pilot hole drilling. Between the bit 21 and the underreamers 22 there is mounted a decanting centrifuge 23 having a keyhole-shaped orifice 24 in each wing.

In the centrifuge 23 there is mounted a switch 3 (not shown) which directs during pilot hole drilling the drilling mud via interior of the drill string 20 and the bit 21 into the annular space 25. After drilling a pilot hole section the valve is switched (e.g. by activating the valve by a mud pulse telemetry system) such that fluid flow into the bit 21 is blocked and the fluid is induced to escape via the orifices 24 from the interior of the drill string 20. Then the underreamers 22 (e.g. also by means of said mud pulse telemetry system) are moved to the extended position thereof and a fluid containing e.g. cement pellets is pumped via the drill string 20 into the centrifuge 23.

Simultaneously the drill string is rotated at high speed and slowly raised while the pump pressure of the injected fluid is being monitored. If the string 20 is raised too fast the top 26 of the cement column 27 will be at level A and the monitored pump pressure will be low. If the string 20 is raised too slow then the top 26 of the cement column 27 will reach level B at the top of the orifices 24 and a very high pump pressure will be monitored. In the above manner the rate of raising the drill string 20, and thus the built-up rate of the cement sheath 27, may be adjusted in response to the monitored pump pressure such that during cementation the top 26 of the cement sheath 27 is located near the middle of each orifice 24.

The above described process of underreaming and placing a cement sheath 27 after drilling a pilot hole may be carried out each time when replacement of the bit 21 is required. In that situation the cement sheath 27 may be placed during the upstroke when the bit 21 is tripped out of the hole so that the cement sheath 27 will have time to harden while the bit is replaced and run back into the hole.

If desired, alternative decanting devices may be used to separate the pellets from the carrier fluid. For example, a strainer or a grill may be installed in the drill string, or a device which is able to generate a magnetic or electrostatic field. Additionally a device may be mounted in the drill string which enhances the speed of coagulating of the coating forming components once they are plastered to the wellbore. Suitable coagulating enhancing devices are sources which generate heat, or a strong magnetic field or radioactive radiation. Since such devices are known per se, no detailed description of their operation is required.

Any suitable coating forming material may be used to plaster the wellbore. Injection of pellets containing hydraulic cement, fibres and a polymeric resin has the advantage that a strong coating can be formed having a strength equivalent to a steel casing but which coating can be formed without raising the drill string from the borehole or even while drilling takes place simultaneously. In stable

but permeable formations it may be desired to plaster the wellbore with a coating which seals off the wellbore without necessarily increasing the wall stability. In such formations the coating may be formed by a plastic material only, such as a thermosetting epoxy resin.

The drilling fluid containing coating forming components may further be injected through the interior of the drill string in slugs which are alternated by slugs of drilling fluid, or separate from the drilling fluid through a separate conduit which extends along at least part of the length of the drill string. In that case the drill string consists of a multibore or multiconduit drill string. The conduits may be coaxial as disclosed in US patent specification No. 3,416,617. The drill string may be made of steel or other material.

Fig. 3 shows a drilling assembly comprising a multibore drill string 30 carrying at the lower end thereof a drill bit 31 and a pair of underreamers 32. During drilling a drilling mud is pumped via the interior of the inner drill pipe 30A and the bit 31 into the pipe-formation annulus 33. After having drilled a borehole section of a desired length the drill string 30 is pulled upwardly through the hole while drilling fluid containing coating forming components is injected via the outer drill pipe 30B and a series of orifices 34 into the pipe-formation annulus 33. Above the orifices 34 there is mounted a packer 35 which is inflated by the pressure of the injected cement. The inflated packer 35 centralizes the drill string 30 in the hole during cementation and simultaneously prevents the hydraulic cement to flow upwardly through the pipe-formation annulus 33. Below the orifices 34 there is mounted a cementing mandrel 36 which controls the inner diameter of the cement sheath 38 being placed.

The length of the cementing mandrel 36 is selected in conjunction with the time required for hardening of the cement mass and the desired speed of pulling of the drill string 30 during cement injection. To compensate for the increasing borehole volume below the bit 31 when the drill string 30 is pulled upwardly during the cementation process either drilling mud is injected slowly through the inner drill pipe 30A to the bit 31 or a by-pass is created between the interior of the inner drill pipe 30A and the pipe-formation annulus 33 above the packer 35.

It will further be understood that instead of using a bit provided with one or several underreamers to drill the oversized hole an eccentric bit or a bit provided with jet reaming means may be used as well. If desired, the bit may be a fluid jet bit as described in British patent specification No. 1,469,525.

An important advantage of the method according to the invention over the known borehole sta-

bilization techniques is that it enables the borehole wall to be reinforced simultaneously with or directly after drilling a borehole section.

In this manner the coating increases the stability of the borehole immediately upon drilling so that the possibility of deformation of the borehole wall owing to in-situ stresses in the surrounding formation and changes in the fluid pressure inside the borehole is reduced to a minimum.

It is preferred to tailor the stiffness characteristic of the coating to the surrounding formation and to ensure that the outer surface of the sheath remains in contact with the surrounding formation for any deformation either during or after placement. This necessitates that the coating material must have the appropriate strength requirements for compressional and expansional loads. Rapid curing of the coating will allow sufficient sheath integrity to withstand the loading conditions outlined above immediately upon drilling of a borehole section. A suitable hydraulic cement composition for forming a coating having a stiffness tailored to suit a number of different rock types can be made by mixing about 792 grams of cement, 348 ml of water and 15 grams of polypropylene fibres.

It is furthermore preferred to maintain during the period that the coating is plastered to the borehole wall and hardened a pressure in the borehole which is significantly higher than the pressure in the surrounding formation. If after hardening of the coating the pressure in the borehole is reduced the hoop stress exerted by the formation to the coating creates a pre-stressed coating which is firmly anchored to the borehole wall.

Claims

1. A method of forming an impermeable coating on the wall of a borehole (1) comprising
 - (a) separating coating forming components from a slurry containing coating forming components and a carrier fluid in a centrifuge (6);
 - (b) packing the separated components against the borehole wall as a continuous layer (10); and
 - (c) allowing the layer (10) of packed coating to harden to an impermeable coating,
 characterized in that the carrier fluid is drilling fluid, that the centrifuge (6) is located close to the end of a drill string (5) present in the borehole (1), in that the slurry is injected through the drill string (5), and in that the coating forming components in the slurry are in a pelletized form.

1. Verfahren zum Ausbilden einer undurchlässigen Auskleidung der Wand eines Bohrlochs (1), das folgende Schritte beinhaltet:

- (a) Abscheiden von auskleidungsbildenden Bestandteilen aus einem Brei, der die auskleidungsbildenden Bestandteile und ein strömendes Trägermedium enthält, in einer Zentrifuge (6);
- (b) Verdichten der abgeschiedenen Bestandteile an der Bohrlochwand zu einer kontinuierlichen Schicht (10); und
- (c) Aushärtenlassen der Schicht (10) der verdichteten Auskleidung zu einer undurchlässigen Schicht,

dadurch gekennzeichnet, daß es sich beim strömenden Trägermedium um Bohrflüssigkeit handelt, daß die Zentrifuge (6) ganz am Ende des Bohrstrangs (5) im Bohrloch (1) angebracht ist, daß der Brei durch den Bohrstrang (5) eingespritzt wird und die schichtbildenden Bestandteile im Brei in Pelletform vorliegen.

Revendications

1. Procédé pour former un revêtement imperméable sur la paroi du trou de forage (1) comprenant les étapes consistant

- (a) à séparer les composants formant le revêtement à partir d'une bouillie contenant les composants formant le revêtement et un fluide porteur dans une centrifugeuse (6);
- (b) à plaquer les composants séparés contre la paroi du trou de forage en une couche continue (10); et
- (c) à permettre à la couche (10) de revêtement plaqué de durcir en donnant un revêtement imperméable;

caractérisé en ce que le fluide porteur est le fluide de forage, en ce que la centrifugeuse (6) est située près de l'extrémité d'une tige de forage (5) présente dans le trou de forage (1), en ce que la bouillie est injectée à travers la tige de forage (5), et en ce que les composants formant le revêtement sont dans la bouillie sous forme de grains.

Patentansprüche



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In this manner the coating increases the stability of the borehole immediately upon drilling so that the possibility of deformation of the borehole wall owing to in-situ stresses in the surrounding formation and changes in the fluid pressure inside the borehole is reduced to a minimum.

It is preferred to tailor the stiffness characteristic of the coating to the surrounding formation and to ensure that the outer surface of the sheath remains in contact with the surrounding formation for any deformation either during or after placement. This necessitates that the coating material must have the appropriate strength requirements for compressional and expansional loads. Rapid curing of the coating will allow sufficient sheath integrity to withstand the loading conditions outlined above immediately upon drilling of a borehole section. A suitable hydraulic cement composition for forming a coating having a stiffness tailored to suit a number of different rock types can be made by mixing about 792 grams of cement, 348 ml of water and 15 grams of polypropylene fibres.

It is furthermore preferred to maintain during the period that the coating is plastered to the borehole wall and hardened a pressure in the borehole which is significantly higher than the pressure in the surrounding formation. If after hardening of the coating the pressure in the borehole is reduced the hoop stress exerted by the formation to the coating creates a pre-stressed coating which is firmly anchored to the borehole wall.

Claims

1. A method of forming an impermeable coating on the wall of a borehole (1) comprising
 - (a) separating coating forming components from a slurry containing coating forming components and a carrier fluid in a centrifuge (6);
 - (b) packing the separated components against the borehole wall as a continuous layer (10); and
 - (c) allowing the layer (10) of packed coating to harden to an impermeable coating,characterized in that the carrier fluid is drilling fluid, that the centrifuge (6) is located close to the end of a drill string (5) present in the borehole (1), in that the slurry is injected through the drill string (5), and in that the coating forming components in the slurry are in a pelletized form.

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dadurch gekennzeichnet, daß es sich beim strömenden Trägermedium um Bohrflüssigkeit handelt, daß die Zentrifuge (6) ganz am Ende des Bohrstrangs (5) im Bohrloch (1) angebracht ist, daß der Brei durch den Bohrstrang (5) eingespritzt wird und die schichtbildenden Bestandteile im Brei in Pelletform vorliegen.

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- (c) à permettre à la couche (10) de revêtement plaqué de durcir en donnant un revêtement imperméable;

caractérisé en ce que le fluide porteur est le fluide de forage, en ce que la centrifugeuse (6) est située près de l'extrémité d'une tige de forage (5) présente dans le trou de forage (1), en ce que la bouillie est injectée à travers la tige de forage (5), et en ce que les composants formant le revêtement sont dans la bouillie sous forme de grains.

Patentansprüche