A method and an apparatus for increasing the recovery of drill mud from a mixture of solid drill cuttings and liquid drill mud in a recovery plant. The plant comprises a screw press (2) including a filter (6), and a reduced pressure is applied to the outer side of the filter (6), so that the mixture is subjected to an increased differential pressure over said filter (6) causing superfluous amounts of drilling mud to be forced out of the mixture. The apparatus comprises a screw press (2) having at least one input (3) and at least one output port (5, 17); which screw press (2) includes at least one helical feeding screw flight (4) arranged within a filter (6). The screw flight(s) (4) may be provided with at least one mechanical device (28, 30) adapted to disturb an even, helical movement of the transported mixture.
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A METHOD AND AN APPARATUS FOR RECOVERY OF DRILL MUD

The present invention relates to a method and to an apparatus for improving the degree of recovering drilling mud from a mixture of drill cuttings and used drilling mud. This mixture is generated during a drilling operation where a residual amount of drilling mud is discharged along with drill cuttings from conventional solids separation equipment, and where the drilling mud normally would be lost during the drilling operation.

It is earlier known to separate some of the drill solids from circulating drilling mud by using shale shakers, screens, hydrocyclones and/or centrifuges or similar known filtering equipment. All known equipment is designed to effect maximum removal of drill solids, to preserve the low viscosity of the circulating drilling mud. Therefore the finest possible screens have been used and the emphasis has been on maximum solids removal and not on maximum liquid recovery.

However, the drilling mud is an expensive substance. And considerable cost savings as well as reduction in environmental impact are realised by use of this invention.

The main object of the present invention is to recover as much as possible of the used drilling mud from the mixture, in a re-usable form by means of a simple, non-expensive mechanical apparatus.

Further objects are to provide a method and an apparatus applicable to process cuttings generated with use of water as well as oil based drilling muds.

Still a further object is to provide an apparatus of sufficiently small size, low weight and simple construction to be retro-fittable to existing drilling units.

Finally it is an object of the present invention to reduce the amount of solids and associated mud which have to be disposed of, to a minimum, thus reducing the negative impact on the environment. This is obtained by means of methods and apparatus as stated in the claims below.
It is earlier known to use different types of screw presses within various technical fields. From US patent No. 4,587,896 there is earlier known an apparatus for separating and collecting different grades of grape juice by means of an inclined helical screw dejuicer having a plurality of drip pans. However, this technical field is very different from the actual use. It may also be mentioned that DE 3 038 741 shows a device for separating a floating mixture into one liquid and one solid phase by means of an electro-kinetic device comprising an outer container 1 with an internally arranged helical screw 4 connected to a battery 8. This known apparatus separates the colloidal fines from the mixture by means of electrostatical effects while the transportation of the floating mixture is obtained by the screw 4 and the pump 29. It should also be mentioned that from Norwegian patent No. 168,401 there is earlier known a screw press adapted for separating masses of manure into wet and dry components.

However, most of the above solutions relate to quite different technical fields, and it is not at all expected that experts on offshore oil engineering would seek for solutions to their offshore problems in the agricultural sector.

It should also be referred to Norwegian patent No. 164,219 from which it is known a method and a plant for treating drilling mud which is returned from a drilling operation. However, the screw transporter included here is used as a first step in the classifying process, thus it is only used as a transporter and not at all as a device which is building up pressure within the separated mass to enhance mud recovery.

As far as we know screw presses have only once been previously suggested used in connection with separating plants for drilling mud. In this connection it is again referred to DE 3038741. However, it has there been found that an electric DC voltage has to be applied to the apparatus which operates in a recycling manner to obtain a useful result and only colloidal size particles are to be collected. A
compressing action of the screw 4 has not been mentioned. Therefore this publication also shows a quite different separating technique than that of the present invention.

The main feature of this invention is to include a compacting screw press in a drilling mud recovering plant.

One first disadvantage of previously used screw presses for such purposes is that when processing materials which have a high fluid content, so that the solids/liquid mixture is in the form of a mobile slurry, then as the slurry which is being transferred forward by the screw meets the increasing resistance towards the discharge point, then the slurry tends to flow backwards through the small annular gap between the edges of the flights on the screw and the filter unit and remains in the mixture.

The nett result is that when processing slurries it is difficult to generate a sufficiently high differential pressure across the filter unit to achieve a high rate of fluid flow through the filter. This results in an undesirable, very wet, solids discharge from the screw press unit.

A further, second disadvantage of earlier known screw presses when used for this new purpose is that when processing drill cuttings with a conventional screw flight arrangement the cuttings discharged from the periphery of the discharge cone are much drier than cuttings discharged from the centre of the cone, in the area of the drive shaft.

This effect is believed to be due to the fact that the cuttings are transferred through the filter element by the screw as a plug flow. Once the cuttings come into the compaction zone the fluid nearest to the filter element will pass through, but fluid towards the centre of the cuttings plug, i.e. nearest to the drive shaft, will be progressively more difficult to filter out since this fluid must migrate to the filter element, and this will become more difficult as the cuttings are progressively compressed and pore space between the cuttings reduced.

From experiments it has been found that when mixtures which already have passed conventional separating apparatus
used for drill mud recovery are passed through a compacting
device according to said invention, much more drill mud is
recovered, and the volume of the remains which have to be
disposed of, is correspondingly reduced.

According to the present invention a new apparatus is
developed for improving the removal and recovery of drilling
mud from a mixture comprising drill cuttings, as stated in
the claims below.

According to a preferred embodiment of this invention a
mixture of drilling mud and drill cuttings discharged from
primary solids separation equipment is directed together into
a first retaining device comprising a preferably vibrating
feed hopper which separates out a certain amount of the
drilling mud. This hopper is then followed by a screw press
apparatus with a restriction at its output end and preferably
fitted with tubular filter elements having pre-designed
aperture or pore size values. However, the invention may in
its simplest embodiment consist of the screw press alone, and
the press device may be provided with specific means accord-
ing to this invention to enhance drilling mud recovery.

Conventionally a mixture of drilling mud and drill cut-
tings is conveyed, as already briefly mentioned, into a prim-
ary solids separation unit which may include different types
of separating devices arranged in succession, and linked
together by known transport units as conveyor belts shale
shakers and/or transport screws. The separating devices may
include filters, hydrocyclons, flotation chambers and settling
tanks. However, the final solids delivered from such a
conventional plant still include a high degree of used drill
mud. With respect to e.g. shale shakers maximum solids remov-
al is achieved by operating with the finest possible screen
apertures, commensurate with an acceptable loss of drilling
mud being discharged off the screens with the solids. In
practice the shale shakers are frequently running in a
"flooded" condition, with large volumes of mud being dis-
charged with the cuttings, for a considerable period of time,
before the situation is observed and a decision taken to
change to larger aperture screens on the shale shakers.

According to the present invention the liquid mud drains through the filter elements of a perforated container in which the mixture is subjected to an increasing pressure caused by a transportation means which supply more mass into the container. Then the recovered mud is collected in a tank and returned to the circulating supply or bulk of mud, for possible further processing if required through secondary, fine solids separation equipment. According to one, preferred embodiment the container has the shape of a cylindrical, perforated tube, lined with a porous filter. Internally in this assembly a helical screw rotates and feeds the mass toward a possible variable constriction situated at the discharge end of the screw. This constriction causes a compression or squeezing of the cuttings, which again releases more mud from the cuttings and this mud drains through the filter elements for collection and returns to the circulating supply or bulk of mud.

The invention may be implemented in many different ways. The simplest embodiment of this invention is to include a traditional screw press in a drill mud recovery plant. However, it is preferred to modify the invention by altering the screw press and possibly also by including a vibrating, level adjusting feed hopper into the plant, as already mentioned above and described in more detail below.

A first modification to the screw press unit according to this invention is to seal a housing which surrounds the filter unit and apply a vacuum to the housing. By this means the differential pressure across the filter element is increased and hence the rate of fluid transfer through the filter element. This may effectively reduce the effect from the above mentioned first disadvantage. The application of vacuum should also improve screw press performance when processing "normal" cuttings feed.

To alleviate the above mentioned second disadvantage, that the cuttings are much drier at the periphery of the cone than from its centre, mechanical means may be arranged on the
screw to disturb the "plug flow" mentioned above. As one first solution one or more plough vanes may be fixed, preferably to the leading face of the screw flight to impart a rotary movement of the cuttings at right angles to the screw shaft, i.e. the cuttings are 'rotated' from the area of the shaft to the area of the filter. Alternatively an outward rotary movement of the cuttings may be achieved by placing deflector plates between adjacent screw flights as a second solution.

To give a more clear and unambiguous understanding of the present invention it is referred to the detailed description of embodiments of the present invention given below. It is also referred to the accompanying drawings, in which: Fig. 1 describes a preferred embodiment of the last section of equipment for drill mud recovery, according to the present invention including a hopper and a screw press,

Fig. 2 illustrates a simpler solution only comprising a screw press apparatus of a somewhat modified version,

Fig. 3 a schematic drawing demonstrating the principle of enclosing the screw press filter element in a vacuum chamber,

Fig. 4 illustrates a further embodiment of the screw press according to the invention, and

Fig. 5 shows a cross section of the screw press shown in Fig. 4, perpendicular to its axis or shaft.

It should be emphasized that not all details required for the implementation of the invention are shown in the figures which only include elements required to obtain the improved separation. It should also be mentioned that different components may be shown in a different scale and size in the drawings to clarify the function.

In Fig. 1 the apparatus comprises two main parts, the feed hopper 1 and the screw press 2. Here a conventional screw press may be used. It should be emphasized that compacting screw presses earlier have not been used in similar plants.
The feed hopper 1 has an input opening 7 at the top and an output opening at its base 8. It is shown with slanting side walls and may have a pyramidal or conical design. Close to its top it is equipped with an overflow weir 11 and it may be provided with a solid/liquid detector 9 and a vibrator 10.

The screw press 2 comprises a substantially impervious housing 19 in which a rotatable helical screw 4 is arranged on a shaft 16. This shaft 16 may be operated via a motor or gear box 20. The housing 19 may or may not be provided with an internal container 12 which again may or may not be perforated. The housing 19 and/or the container 12 may be provided with a filter 6 having a pre-determined pore size. During operation the mud leaves the screw press via the mud discharge port 17 while the solids leave the screw press at the end of the helical screw at a conical restriction 13.

According to Fig. 1 a mixture of drill cuttings and circulating drilling mud is conveniently directed into the feed hopper 1 arranged in front of the screw press 2. The screw press 2 comprises a perforated container 12, substantially of cylindrical shape, and preferably covered on its inner surface with correspondingly shaped filter elements 6. Mobile drilling mixture, comprising mud will immediately fill the input chamber 3, while, assuming now that the screw 4 is rotating, the solids included in the mixture will be transported by the preferably inclining helical screw 4 to the discharge end 5 of the apparatus. During this transportation of solids more mobile drilling mud will continuously be released from the solids and drain away through the strainer or filter apertures 6, and is then supplied to the bulk of drilling mud (not shown) through the mud discharge port 17.

At the discharge end 5 where solids discharge from the apparatus, the helical screw blade 4 is removed over a certain length 18 of the screw, which hinders the free screw discharge of the solids and hence causes a certain pressure to build up within the cylindrical screw housing 2. The degree of pressure applied may be controlled by adjusting the removed length 18 of the helical transport screw blade 4.
The pressure applied to the solids effectively constitutes a controlled squeezing action which causes more mud to be released from the cuttings, which mud again will drain through the strainer or filter elements 6 and hence will be recovered. The shaft 14 of a short discharge screw 15 is attached to the shaft 16 of the main transport screw 4 by a threaded connection at 22. By screwing the discharge screw 15 inwards or outwards, e.g. by means of a nut 24, the area within the conical pipe section 13 into which the cuttings are compressed, is increased or respectively decreased, and hence the degree of squeezing of the cuttings is controlled accordingly.

The feed hopper 1 included in the apparatus, may consist of a simple tank with sloping sides and a wedge shaped base 8, and has a size adapted to the geometry of the installation space available, but preferably in excess of 1 cubic meter capacity. The hopper 1 may be equipped with a liquid/solid level controlled switch 9 situated a short distance above the base 8 of the tank 1, a vibrating device 10 on at least one of the sides of the tank and an overflow weir 11 at the top of the hopper 1. In this configuration the solids and mud entering the hopper 1 through its input opening 7 will be subjected to a gentle vibration which will act to consolidate solids at the bottom of the hopper 1 and release mud to the surface of the hopper. The level switch 9 controls the stop/start of the screw 16,4 and the screw will only operate when the solids level is at, or above, the switch level 9. By this means mud volume will build up in the hopper 1 and will eventually overflow the top weir 11 and be collected in a catch tank (not shown) for return to the circulating mud system, possibly via an additional particle removing unit as e.g. a filter or centrifuge (not shown). Solids compacted at the bottom 8 of the hopper will still be mud saturated and further mud will be removed on passage through the screw press 4 as described below.

The transition from the hopper 1 to the screw press 2 may simply consist of an input chamber 3. A closure between
the hopper 1 and the input chamber 3 is normally not required. However, a controllable valve which may be actuated by the level switch 9, may be included in the arrangement at this transition. Then a suitable realization may be that a valve is placed at the transition area, and this valve may open when the solids reach the level switch 9, and close when the solids sink below the level switch. As mentioned this controlled valve solution is not deemed essential for the apparatus, and therefore it is preferred that transition area is quite open, so that the input chamber 3 will be filled up by solids falling down from the vibrating hopper 1, and these solids will be transported further and subjected to an increasing pressure in the screw press 2 as soon as this is started, controlled by the level switch 9.

The cylinder 12 in which the transport screw 4 rotates, may, as earlier mentioned, be constructed of perforated plate, woven wire mesh, or wire strands. Preferably perforated plates and wedge wire strands aligned parallel to the direction of cuttings transportation, are employed. And, as mentioned, the surface of this cylinder may be covered by correspondingly shaped filter elements having a predetermined pore size. The cylinder 12 may be constructed in sections e.g. including perforated plate strainers and wedge wire filter sections. The transport screw 4 and cylinder 12 may be used in a horizontal plane or upwardly inclined towards the discharge end 5 of the apparatus.

The mechanism by which the squeezing action is applied to the cuttings may typically consist of a conical pipe section 13 at the end of the filter cylinder 6, within which the short longitudinally adjustable discharge screw 14 rotates.

The discharge system described above may also be similar to the one shown in Norwegian patent No. 168.401 as the helical screw blade 4 is removed along a short length 18, close to or even within the conical restriction. However, many different solutions may also be used instead as explained below, in connection with Fig. 2.
A somewhat simpler and different embodiment is shown in Fig. 2. Here the feed hopper is omitted and the screw press 4 is at its discharge end 5 shaped with an adjustable restriction 21. By changing the closure angle of the conical restriction 21 as suggested by the arrows, the flow resistance will change accordingly and also the squeezing force applied to the mixture.

Various aperture sizes may be used in the perforated plate, woven mesh and/or wedge wire sections, but preferably within the size range 100 to 300 micron.

The cylinder 12 and pressure screw 4 are preferably manufactured in a hardened steel to minimize wear. The screw blade 4 is here shown as a continuous helix without any discontinuity 18.

The restriction and the squeezing area may have different designs to obtain an internal pressure build up during operation, as e.g.:
- the pitch of the helical screw 4 may change along the screw, and more than one screw flight may be used,
- both the screw blade(s) and the housing may have a conical shape,
- the perforation of the encompassing container may be omitted or changed at a portion of the tube,
- the tube may be closed at the discharge end 5 by an adjustable shutter, e.g. an iris shutter 21.
- Or any combination of the above mentioned solutions may be used.

As an alternative, but not limiting, method of applying a compressive force to the cuttings, an inwardly inclined adjustable, iris type conical valve may be attached to the discharge end 5 of the cylinder section. Opening or closing the iris of such a valve will respectively decrease or increase the compressive force applied to the cuttings.

Mechanisms to apply the compressive force may be manually controlled or may be automated by inclusion, for example of a pressure detector 23 incorporated at the solids discharge end 5, the signal from which may be used to control
the adjustable restriction 21 applying the compressive force.

Cuttings discharged from the screw press apparatus will normally be in the form of a compressed cake and may be discharged or containerised in a normal manner.

In Fig. 3 the screw press 2 is arranged within a sealed housing 25 which completely surrounds the filter. In the Figure the housing 25 is shown partly disconnected to give a more clear understanding of the assembly. However, it is presupposed that the housing 25 should be closed and sealed when the apparatus is working. A vacuum source (not shown) should also be connected to the housing via a sealed connection 35 so that the internal pressure in the housing 25 will be lower than the external one during operation. This will, due to the increased differential pressure enhance the efficiency of the apparatus considerably. In this figure it is also shown that the discharge end 5 may be provided with a spring biased closing lid 26 adapted to open at a predetermined internal pressure. The biased spring may be arranged in a protecting casing 27.

In Fig. 4 a further embodiment of a portion of the screw press 16,4 is schematically shown. Mechanical means 30,28 are included, to disturb the otherwise even, progressive motion of the mixture between the screw flights. Deflector plates 30 are here shown fastened between adjacent screw flights 4. The effect of these deflector plates 30, which preferably are arranged with an inwardly tilting leading edge 31 when the screw rotates, is adapted to put the particles in the compacted plug in a radial movement, to counteract clogging of same. In this connection it should also be pointed out that the deflector plates 30 may be arranged non-parallel to the screw axis or shaft 16, and the number of such deflector plates 30 may be one or several along the perimeter of the screw. Thus the illustration on Fig. 4 is only representing a non-limiting example of a section of the mandrel.

In Fig. 4 some protruding plough vanes 28 are shown. These plough vanes 28 are also fastened to the screw flight 4 to disturb the otherwise even movement of the plug flow as
the screw rotates. The plough vanes 28 are preferably protruding perpendicularly to the leading surface of the rotating screw flight(s), may preferably be curved towards the direction of rotation and may preferably have an increasing height towards the screw periphery.

The curvature of the plough vanes 28 is shown more clearly on Fig. 5, which shows a cross section of the screw press 4 of Fig. 4, it is in addition shown that there may be arranged a deflector plate 30 in the interstice between adjacent turns of the screw flights, and that all or some of the plough vanes 28 may be curved as shown, preferably in the direction shown, i.e. concave towards the rotational direction (shown with arrow 29). The effect of this specific vane cross section also is to disturb a solidification of the treated mass. Deflector plates 30 and plough vanes 28 may be combined or used alone.

A test equipment according to the above description using a transport screw rotated at 12 revolutions per minute driven by a 3 kW drive motor operating through a reduction gearbox 23, and using a discharge screw according to the invention has been tested in horizontal mode.

Cuttings were then processed at an approximate rate of 1 ton per hour and analysis showed that the discharged cuttings gave an oil content of 150 grams of oil per kilogram dry solids, which equates to a reduction in the original oil mud content of the cuttings of 23% by volume.

Oil mud recovered by the apparatus had a density of 1.71 as compared the the clean, circulating mud density of 1.60 and was considered to be of good, re-usable quality.

In a second series of tests, using the same apparatus as described above, the drill cuttings were mixed with clean circulating drilling mud in an approximate ratio of 1:3 respectively to simulate a typical discharge from a shale shaker operating in a flooded condition.

Test procedure was as described above. Cuttings and mud discharged from the apparatus were collected over 2 minutes intervals and weighed, whereafter samples of the mud/cuttings
feed and the mud and cuttings discharges were taken for analysis.

The weights of mud and cuttings discharged were 22 and 6 kilogram respectively and the oil content of the cuttings was reduced from 39.5% by weight to 15.9% by weight. This result indicated that the vast majority of the mud had been recovered by the apparatus.

The oil mud recovered had a density of 1.71 and was of good, re-usable, quality.

The method as well as the apparatus may be modified in many manners without leaving the scope of the claimed invention. The main idea is that the solids are gathered in a container by means of a transportation means, operating continuously or in batches, and that the transportation means applies an increasing pressure to the solids which are gathered within said container, while the solids are moving continuously.

A perforated container is not always required. In particular when the container is inclined, the perforations may be omitted as the released mud will find its way out of the container all the same.

The feeding hopper of the specific design including a vibrator and a liquid/solid level detector, also is part of the invention in one complex embodiment, however, a simpler solution only comprising the screw press with no specific feed hopper included, represents a simpler solution, also within the scope of said invention. However, the apparatus according to the invention may also be included in a conventional mud regaining plant.

The output rate of solids may also vary considerably. Thus the solids may only be removed in batches, i.e. in a discontinuous manner, or continuously once a suitable pressure has been built up.

The helical screw 4 may have flights of constant diameter but the screw shaft 16 may progressively increase in diameter towards the discharge end, thus progressively reducing the effective volume between the flights, causing the
solids to be progressively compacted under increasing pressure.

A similar effect can be obtained by reducing the screw flight pitch gradually along the length of the screw, from the input to the discharge end. The mentioned solutions may also be combined in any applicable manner as easily understood by persons skilled in similar technical fields.

Further the number of screw flights, number of deflector plates, the pitch, curvature and height of the screw flight or flights may vary. And of course the value of the applied vacuum may vary, and it may even be pulsating.

It should also be emphasized that the invention includes a method for increasing the differential pressure over the filter, a plant including a conventional screw press; and that all the mentioned modifications may be used alone or combined in any possible manner.
Claims

1. A method for increasing the recovery of drill mud from a mixture of solid drill cuttings and liquid drill mud in a recovery plant, in which the mixture is treated in a plant comprising a screw press (2) including a filter (6), characterized in that
   - a reduced pressure is applied to the outer side of the filter (6);
so that the mixture is subjected to an increased differential pressure over said filter (6) causing superfluous amounts of drilling mud to be forced out of the mixture.

2. A method according to claim 1, characterized in that
   the differential pressure over said filter (6) ranges between 1 and 10 bars.

3. A method according to claim 1 or 2, characterized in that
   the differential pressure is varied slowly or abruptly as a function of time.

4. An apparatus for increasing the recovery of drill mud from a mixture of solid drill cuttings and liquid drill mud in a recovery plant, where re-usable drill mud is regained, characterized in that the apparatus comprises a screw press (2) having at least one input (3) and at least one output port (5,17); which screw press (2) includes at least one helical feeding screw flight (4) arranged within a filter (6).

5. An apparatus according to claim 4, characterized in that the screw flight(s)(4) is(are) provided with at least one mechanical device (28,30) adapted to disturb an even, helical movement of the transported mixture.
6. An apparatus as claimed in any of the claims 4 and 5, characterized in that the screw press (2) is arranged within a sealed housing (25), and that a vacuum source is connected to a sealed outlet (35) leading from the interior of said housing (25).

7. An apparatus as claimed in one of the claims 5-6, characterized in that the mechanical device(s) comprise(s) at least one plough vane (28) fastened to and protruding from at least one side surface of at least one of said screw flights (4).

8. An apparatus as claimed in claim 7, characterized in that the plough vane(s) (28) is(are) arranged substantially perpendicular to the flight surface.

9. An apparatus as claimed in claim 7 or 8, characterized in that the height of said plough vane(s) (28) is(are) higher at the periphery of said screw flight(s) (4) than close to the screw shaft (16).

10. An apparatus as claimed in any of the claims 5-9, characterized in that the mechanical device(s) comprise(s) at least one deflector plate (30) fastened between two adjacent screw flights (4).

11. An apparatus as claimed in claim 10, characterized in that each deflector plate (30) is tilted so that its leading edge (31) is closer to the surface of the screw shaft (16) than its trailing edge (33).

12. An apparatus as claimed in claim 10 or 11, characterized in that each deflector plate (30) is parallel to the screw shaft (16).
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B30B 9/14
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B30B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, CLAIMS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search: 26 January 1996

Date of mailing of the international search report: 01-02-1996

Name and mailing address of the ISA/Swedish Patent Office:
Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

Authorized officer:
Maria Börlin
Telephone No. +46 8 782 25 00

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