A centrifuge of the type having an internal helical screw conveyor within the centrifuge bowl, and which is subjected to a high internal gaseous pressure, is provided with a lubricating and sealing arrangement for lubricating the conveyor bearings, i.e., the bearings located between the centrifuge bowl and the conveyor. This arrangement includes a rotatable reservoir chamber located within the conveyor, which contains a reserve supply of lubricant, the lubricant being supplied via a passageway to the bearing cavity during operation of the centrifuge via the action of centrifugal force upon the lubricant supply. The chamber includes a flexible wall which is subjected to the internal gaseous pressure, thus transmitting this pressure throughout the lubricant to the bearing cavity. The bearing seals are subjected directly to the gaseous pressure on the exterior surfaces thereof, while the gaseous pressure is transmitted to the internal surfaces thereof via the flexible wall and lubricant. Thus, the pressure is substantially equalized on opposite sides of the bearing seals which results in better sealing. In addition, a collection chamber is provided to collect the total volume of lubricant within the reservoir chamber which will eventually leak past the bearing seals.
Fig. 1

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HIGH PRESSURE CENTRIFUGE LUBRICATION SYSTEM

BACKGROUND OF THE INVENTION

This invention relates in general to a centrifugal separator (centrifuge) of the liquid-solids discharge type, the separator comprising a bowl with a coaxially mounted "plow" or helical screw conveyor located therein; a separation chamber is defined between the bowl and the conveyor, and as the conveyor rotates with the bowl but at a slightly different speed, separated solids are axially moved by the conveyor towards solids discharge openings located at one end of the bowl while separated liquid is simultaneously discharged through liquid discharge openings located at the other end of the bowl.

In particular, the present invention relates to helical screw conveyor centrifuges which are internally pressurized up to 150 psig for processes requiring operation under gaseous pressure.

Centrifuges of this type differ widely in structural detail, and are well known in the art, but suffer generally from a major limitation; there is a problem in providing an adequate sealing arrangement for the conveyor bearings, when the centrifuge is subjected to a very high internal gaseous pressure. Currently, the approach is to use costly mechanical seals on either side of the conveyor bearings to define a bearing cavity, the bearing cavity being filled and pressurized by an external source of lubricant through a rotary joint, the gear box, and then through a passage in the conveyor to the bearing cavity.

The disadvantage of such an arrangement is that first, very costly mechanical seals are employed which require great precision in the manufacture of adjacent parts, and extreme care must be exercised in handling and assembling the overall sealing arrangement. Second, any leakage around the seals can result in the entire content of the external lubricant reservoir being discharged into the solids discharge area of the centrifuge. Even though means are provided to collect and dispose of this lubricant, there is always the danger that windage generated by bowl rotation can result in some loss of lubricant into the solids discharged from the centrifuge bowl.

The rotatably mounted centrifuge bowl is confined within a casing, the interior of the casing being pressurized to the desired degree depending upon the particular process being carried out. Thus, during rotation of the centrifuge bowl, material (feed) introduced into the bowl is separated into its liquid and solid components. The solids having a higher specific gravity than the separated liquid, accumulate against the inner annular surface of the centrifuge bowl; the conveyor (with helical flights arranged thereon) rotates at a slightly different speed than the bowl, thus conveying the accumulated solids along the inner annular surface toward a solids discharge opening or openings located at one end of the bowl. The liquid is simultaneously discharged through a liquid discharge opening at the other end of the bowl.

Since the interior of the bowl or separation chamber communicates with the interior of the casing through the solids and liquid discharge openings, the pressure within the bowl and within the casing substantially are the same. Thus, the seals enclosing the conveyor bearings are subjected on one side to the high gaseous pressure within the centrifuge bowl or the interior of the casing, while on the other side, the seals are subjected to the pressure of the lubricant within the bearing cavity. Thus, with current arrangements, if either the lubricant pressure or the process pressure changes during the operation of the centrifuge, the sealing arrangement will be upset and process gases may vitiate the lubricant, or the lubricant may be discharged into the solids discharge zone of the casing.

Thus, it can be seen that a sealing arrangement is needed which will prevent the lubricant from being vitiated by process gases, and prevent lubricant from escaping or leaking into the solids discharge zone of the casing.

SUMMARY OF THE INVENTION

The present invention relates to a centrifuge of the type described above (one having a helical screw conveyor within a centrifuge bowl) wherein the bearings disposed between the conveyor and the centrifuge bowl are provided with a simplified sealing arrangement wherein the seals located on each side of the bearings are subjected to substantially the same pressure from within the bearing cavity as they are from the exterior when the centrifuge bowl is not rotating; when the bowl is rotating, a greater pressure exists within the bearing cavity due to centrifugal force.

This is accomplished by providing a reservoir or reserve chamber partially defined by a flexible "boot" or wall, the external surface of the flexible wall being exposed to the gaseous pressure existing within the centrifuge bowl which, as stated above, is the same as that existing within the interior of the casing which surrounds the bowl; a passageway extends between the reservoir chamber and the bearing cavity for the conveyor bearings. This gaseous pressure is transmitted via the flexible wall to the fluid type grease contained with the reservoir chamber and passageway leading to the bearing cavity; thus, the pressure is substantially balanced on both sides of the seals, and there is no danger of the seals being forced open due to a pressure differential between the external gaseous pressure and the lubricant pressure per se within the bearing cavity.

Another advantage in the present arrangement is that frequent external relubrication is unnecessary since a reserve supply of lubricant is provided in the reservoir chamber. Upon initially filling the reservoir chamber, lubricant is pumped in until the flexible wall is in contact with an inner annular sleeve which limits further inward movement of the flexible wall. Thus, since the external surface of the flexible wall is subjected to substantially the same pressure as that existing within the interior of the casing, the seals will be substantially balanced as stated above. During operation of the centrifuge, the bearing cavity will always be charged with lubricant because the reservoir chamber is positioned with respect to the bearing cavity and the passageway between them so that centrifugal pressure will force the lubricant from the reservoir chamber into the bearing cavity, the latter extending between the sealing members arranged on each side of the conveyor bearings. The outer extent of the reservoir chamber is defined by the inner annular surface of the outer annular sleeve, this surface limiting the outward movement.
of the flexible wall. Thus, the volume of the reservoir chamber provides for the reserve supply of lubricant for the bearing cavity. The centrifugal force acting upon the grease or lubricant provides the pressure necessary to force the lubricant through the passageway leading to the bearing cavity. The centrifugal pressure generated insures that the bearing cavity is maintained completely full of lubricant, and that lubricant is provided at the seal lips.

Also, any leakage which might occur is collected in a collecting compartment which is disposed adjacent at least one of the sealing members. Lubricant collected in this compartment, being inherently sticky, is much less likely to be moved by windage once it has adhered to the walls of the compartment.

With the provision of a reservoir chamber, any leakage from the bearing cavity is replenished until the capacity of the reservoir chamber is used up. Since the centrifugal force creates a pressure bias in the outflow direction, lubrication of the seal lip of each of the annular sealing members is insured and long life can be expected. The collecting compartment is also sized so that the entire amount of lubricant contained within the reserved chamber can be eventually collected within this compartment at which time the reservoir can be refilled and the collecting compartment emptied.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is an elevational cross-sectional view of a centrifuge embodying the present invention, showing a rotatably mounted centrifuge bowl located within a pressurized casing.

FIG. 2 is an enlarged cross-sectional view taken through line 2—2 of FIG. 1, and showing a reservoir chamber for containing a reserve supply of lubricant.

FIG. 3 is an enlarged cross-sectional view taken through line 3—3 of FIG. 1, showing the conveyor bearings and sealing arrangement in detail.

FIG. 4 is an enlarged cross-sectional view of the annular sealing members located above the conveyor bearings.

**DESCRIPTION OF THE INVENTION**

As shown in FIG. 1, a centrifuge embodying the invention is designated generally by numeral 10. Centrifuge 10 includes an outer sealed casing 12, the interior of which is pressurized by a gas for processes requiring operation under pressure. A centrifuge bowl 14 is rotatably mounted within the casing, and is adapted to rotate about its longitudinal axis 16 by connection through a belt and pulley arrangement 17, to a drive motor 19.

Located within the rotatably mounted bowl 14, is a helical screw conveyor 18 which is mounted for rotation in the same direction, but at a slightly different rotational speed than that of the bowl 14, by means of a gear box 21. Conveyor 18 is comprised of a hub 20 having helical flights 22 mounted thereon, the distal edges of the flights complementing the interior contour of the centrifuge bowl. As the centrifuge bowl rotates, feed is introduced via a feed pipe 24 into a feed chamber 25 located within the interior of hub 20. The feed passes from the feed chamber 25 through an opening 26, and into a separation chamber 28 located between the interior annular surface of the bowl and the exterior surface of the hub.

The feed being comprised of a mixture of liquids and solids, is separated into its individual components via centrifugal force, the solids accumulating against the inner annular surface of bowl 14 while the separated liquid forms an inner annular pond. The solids accumulate adjacent the inner annular surface of the bowl due to their higher specific gravity, and as the bowl rotates, the conveyor 18 (rotating at a slightly different speed than bowl) moves the solids to one end of the bowl where they are "plowed" up the end portion 30 (which is convergent or frusto-conical in form) toward a solids discharge openings 32. Because the end portion 30 of the centrifuge bowl gradually decreases in diameter as it approaches the solids discharge openings 32 this provides a drying "beach" so that the solids can be plowed up the beach, and out of the liquid layer prior to being discharged through the solids discharge opening 32.

The operation of the centrifuge is similar to that described in U.S. Pat. No. 3,061,181 issued to Fred P. Gooch on Oct. 30, 1962.

Simultaneously, the separated liquid is being discharged through liquid discharge openings 34 located at the opposite end of the centrifuge bowl. It is noted that the interior of the casing 12 is separated into an upper portion 36 and a lower portion 38 which are separated by a partition arrangement 40, the latter cooperating with a groove in the centrifuge bowl as indicated at 42, so that the separated liquids are prevented from reaching the lower portion 38.

Thus, liquids discharged into the upper portion 36 of the casing are directed via a transverse helical partition 41 through a suitable tangential opening such as indicated at 44 from where it flows into a closed system 46 where it is collected. Solids discharged through solids discharge openings 32 are collected in the lower portion 38, and may be allowed to accumulate therein or be conveyed away by a suitable opening (not shown). It is noted that casing 12 may be separated at joints 39 and 41. In any event, the upper portion 36 and lower portion 38 of the casing 12 are maintained at the same internal pressure, by a suitable arrangement of interconnecting passageways.

As stated above, one of the problems with this type of centrifuge is that of maintaining equal pressure on opposite sides of the seals which enclose the conveyor bearings. In present arrangements, if the pressure of the lubricant being supplied to the conveyor bearings changes, or if the process pressure (the gaseous pressure within casing 12, and consequently within separation chamber 28) changes, then process gases may enter the bearing cavity to vitiate the lubricant, or the lubricant may escape from the bearing cavity into the lower portion 38 of the casing, and consequently become mingled with the solids which have been discharged into the latter portion.

Referring to FIG. 2, the specific details of the present invention will be discussed. Located within the interior of hub 20 is an upper transverse partition 48 and a lower transverse partition 50, each being suitably supported therein. Located between these partitions is an outer annular cylindrical sleeve 52 having a plurality of openings 54 arranged therein, and an annular flexible wall or "boot" 56. In its innermost position as shown in
FIG. 2, the exterior surface 57 of flexible wall 56 contacts an inner cylindrical sleeve 58 which has a plurality of openings 60 extending therethrough. Located between the outer cylindrical sleeve 52 and flexible wall 56, is an inner annular space which is referred to as the reservoir or reserve chamber 64. Located between the outer cylindrical sleeve 52 and the interior surface of the hub 20 is a second or outer annular space 66. Connecting the second or outer annular space 66 with the bearing cavity is a line 68. Referring to FIG. 3, it can be seen that line 68 extends from the annular chamber 66 to bearing cavity 70 in which conveyor bearings 72 are supported between the centrifuge bowl 14 and the conveyor 18. Bearing cavity 70 is the annular space defined by the annular flexible lip type sealing members 74 located on the upper and lower sides of the conveyor bearings between the bowl 14 and the conveyor 18.

Thus, upon initially setting up the centrifuge for operation, lubricant is pumped via a suitable opening into reservoir chamber 64, annular chamber 66, line 68, and bearing cavity 70, filling this entire space until the exterior surface 57 of flexible wall 56 is in contact with the inner cylindrical sleeve 58. The centrifuge is then ready for long periods of operation without frequent re-lubrication, because of the reserve supply of lubricant contained within the reservoir chamber 64.

The interior of casing 12 is pressurized with a gas to the desired level, thus pressurizing the interior of the centrifuge bowl or in other words the separation chamber 28; this is due to the fact that the separation chamber is in communication with the interior of the casing 12 via the solids discharge openings 32 and the liquid discharge openings 34. During operation of the centrifuge, gaseous pressure within separation chamber 28 above the liquid level is transmitted via connecting passageway 84 and openings 60 to the exterior surface 57 of flexible wall 56. Because the reservoir chamber 64 has been filled so that the interior surface 59 of flexible wall 56 contacts the lubricant, the pressure is transmitted throughout the lubricant to the bearing cavity 70 via the passageway extending between reservoir chamber and bearing cavity; this latter passageway includes openings 54, annular chamber 66, and the line 68.

The gaseous pressure within separation chamber 28 is therefore transmitted throughout the lubricant to bearing cavity 70; this pressure acts upon interior surfaces 80b and 80c of lip seals 74b and 74c respectively. This same gaseous pressure acts upon exterior surface 76a of seal 74a via passageway 77, and upon exterior surface 76d of seal 74d via passageways 79 and 81. The gaseous pressure is also transmitted to annular spaces 98a and 98b via passageways 88a and 88b respectively, the latter passageways serving as combined vent and leakage passageways. It is noted at this point that annular seals 74a and 74d are primarily utilized to keep discharged solids away from annular seals 74b and 74d respectively. Thus, it can be seen that upon internally pressurizing the centrifuge 10, the seals are in a substantially balanced condition since the pressures acting upon the internal and external surfaces thereof are substantially the same when the centrifuge bowl 14 is not rotating. During rotation of the bowl, the pressure within bearing cavity 70 increases due to centrifugal force which forces the lubricant from chamber 64 into bearing cavity 70.

As the centrifuge continues to operate over a period of time, lubricant gradually leaks past seals 74b and 74c into annular spaces 98a and 98b respectively. Via centrifugal force, this leakage within annular spaces 98a and 98b is discharged through passageways 88a and 88b respectively into collecting compartment 84, the latter being formed by an annular generally cup-shaped member 86. It is noted that the volume of collecting compartment 84 is sufficiently large to collect all of the reserve supply of lubricant contained within chamber 64. Due to centrifugal force and the inherent sticky nature of the lubricant, the latter will adhere to the outer peripheral wall of compartment 84.

It is noted at this point that over a period of time, all of the reserve supply of lubricant contained within reservoir chamber 64 will eventually be collected within compartment 84 because centrifugal force effects movement of lubricant from chamber 64 into the bearing cavity 70 and eventually past seals 74b and 74c into compartment 84. To maximize the volume of chamber 64, inner annular surface 90 of outer sleeve 52 is located at the same radius as the outermost surface 92 of the innermost portion of line 68. If surface 90 is located radially inwardly from surface 92, the outward travel of flexible wall 56 (the means for transmitting the gaseous pressure to the lubricant) is limited before utilizing the entire theoretical reservoir lubricant. Locating surface 90 radially outwardly from surface 92 would not effect movement of lubricant into line 68 and into the entrance of bearing cavity 70 via centrifugal force. Bearing cavity 70 includes the entire annular space located radially outwardly from surface 92 at the lower end of line 68, the upper and lower ends of cavity 70 being defined by seals 74b and 74c respectively. When the entire reserve supply of lubricant within chamber 64 has been utilized, flexible wall 56 will assume dotted line position 61.

Bowl 14 and Conveyor 18 rotate with respect to member 86 and feed pipe 24 respectively, member 86 and feed pipe 24 being stationarily mounted (FIG. 3). Because of the difference in the distances from axis 16 to the passageway 79 and space 95 respectively, there would normally be a tendency for the centrifuge to act similarly to a centrifugal pump, and consequently pump gas from the power portion 38 inside centrifuge casing 12 through passageway 79, and into space 95. The gas which is present in lower portion 38 contains some airborne solids, since separated solids are discharged into this area through openings 32 of the centrifuge bowl. Consequently, as a result of the tendency for this gas to be pumped into space 95, solids would accumulate within this space which would eventually result in damage to the centrifuge.

To prevent such a situation, the present invention utilizes means to create a demand for gas flow into space 95 from an area free or relatively free of airborne solids. Referring to FIGS. 1 and 3, it can be seen that a connecting passageway 94 extends from space 106 below member 86 to the upper portion of tangential opening or passageway 44. Since separated liquid is being discharged through the latter passageway from upper portion 36, the gas within this upper portion is
free or relatively free of airborne solids. Again, the rotating centrifuge bowl tends to act as a centrifugal pump; because the outer periphery of the bowl top adjacent openings 34 is farther from vertical axis 16 than is either passageway 79 or space 95 from that axis, a demand is created which pumps gas from an area free of airborne solids (i.e., portion 36, opening 44) rather than from the lower portion 38 through passageway 79. Thus, flow through passageway 79 from the lower portion 38 is prevented because a sufficient flow of gas is now pumped through passageway 94 into space 106, through passageway 100 of assembly 96, and into space 95. Assembly 96 includes a bumper pad 104 to absorb any shock from any lateral displacement of conveyor 18 during operation, and bellows member 102.

Thus, the present invention relates to a relatively simple arrangement for providing lubricant to the conveyor bearings without having to frequently re-lubricate the same as was heretofore necessary, and for substantially equalizing the pressures acting upon the seals surrounding the bearings when the centrifuge has been internally pressurized by gas, but before the bowl has begun to rotate. After the bowl begins to rotate, the lubricant is forced from chamber 64 into bearing cavity 70 via centrifugal force, thus transmitting additional internal pressure to the seals. The seals are externally directly subjected to gaseous pressure from a pressure zone (comprising separation chamber 28 plus upper and lower portions 36 and 38 respectively); internally, the same gaseous pressure is transmitted to the seals via flexible wall 56 and the lubricant within the lubrication system. This gaseous pressure is transmitted directly to wall 56, the latter transmitting this pressure either directly or indirectly to the lubricant depending on whether or not some gas may be trapped between wall 56 and the supply of lubricant contained within reservoir chamber 64. Ideally, as stated above, the entire lubrication system is initially completely filled with lubricant, forcing all or most gas from the lubrication system and moving flexible wall 56 inward until the latter contacts annular sleeve 58; in this situation, flexible wall 56 is in direct contact with the lubricant in chamber 64 and directly transmits pressure thereto.

I claim:

1. An improved centrifuge for separating liquid and solids from feed comprising a liquid-solids mixture, said centrifuge comprising an enclosed stationarily mounted casing, an elongated hollow bowl of circular cross-section disposed within and spaced from said casing to define a first zone therebetween, the latter being adapted for pressurization, said bowl being mounted for rotation about the longitudinal axis thereof, said bowl having at least a portion of its inner annular surface decreasing in diameter approaching one end of said bowl, said bowl having a solids discharge opening at said one end of said bowl and a liquid discharge opening at the other end of said bowl, a helical screw conveyor disposed within said bowl, said conveyor including an axially elongated hub spaced from said inner annular surface of said bowl to define an annular separating chamber therebetween, said hub having flights mounted thereon for movement therewith, the distal edges of said flights generally complementing the inner annular contour of said bowl, bearing means disposed between said bowl and said conveyor for permitting rotation of said conveyor about said axis relative to said bowl, each of said openings communicating said separation chamber with said first zone, means defining a pressure zone, the latter comprising said first zone and said separation chamber, feed means having an outlet for introducing feed into said separation chamber, said centrifuge being constructed and arranged such that feed, upon being introduced into said separating chamber during rotation of said bowl, separates into liquid and solids, the solids adapted to accumulate against said inner annular surface and adapted to be conveyed toward said solids discharge opening by said conveyor while the liquid is adapted to be simultaneously discharged through said liquid discharge opening, the improvement comprising:

a. annular sealing means disposed between said bowl and said conveyor on each side of said bearing means so as to define an annular bearing cavity, a surface of each of said sealing means being in communication with said pressure zone;

b. means, including a movably mounted wall, defining a reservoir chamber for containing a supply of lubricant, the exterior surface of said wall being in communication with said pressure zone, and said reservoir chamber being mounted for rotation about said axis;

c. means defining a lubricant passageway extending between said reservoir chamber and said bearing cavity, said lubricant passageway being disposed so that lubricant flow from said reservoir chamber into said bearing cavity will be effected by centrifugal force during rotation of said reservoir chamber.

2. A centrifuge according to claim 1, and further including means defining a collecting compartment for collecting leakage from said bearing cavity around at least one of said sealing means.

3. A centrifuge according to claim 2, wherein at least one of said sealing means includes two annular sealing members spaced apart to define an annular leakage chamber therebetween, and means defining a leakage passageway between said collecting compartment and said annular leakage chamber for collecting lubricant which may leak from said bearing cavity past the annular sealing member immediately adjacent thereto.

4. A centrifuge according to claim 3, wherein said reservoir chamber is annular and disposed around said axis within said hub, said wall being flexible and defining the annular inner wall of said chamber, and means defining a connecting passageway extending from said separation chamber to the exterior surface of said flexible wall.

5. A centrifuge according to claim 4 wherein the distance between said axis and the outermost extent of said reservoir chamber is equal to or less than the distance between said axis and the outermost surface defining the innermost position of said lubricant passageway.

6. A centrifuge according to claim 5 wherein said means defining said reservoir chamber includes an outer annular sleeve having a plurality of openings extending therethrough, the inner annular surface of said outer annular sleeve defining the outermost limit of said reservoir chamber, and said lubricant passageway including a second annular chamber surrounding said reservoir chamber.
A centrifuge according to claim 2 wherein said reservoir chamber is annular and disposed around said axis within said hub, said movably mounted wall being flexible and defining the inner annular wall of said chamber, means defining a connecting passageway from said separation chamber to the exterior surface of said flexible wall.

8. A centrifuge according to claim 7 wherein said means defining said reservoir chamber includes an outer annular sleeve having a plurality of openings extending therethrough, the inner annular surface of said outer annular sleeve defining the outermost limit of said chamber, and said lubricant passageway including a second annular chamber surrounding said reservoir chamber.

9. A centrifuge according to claim 8, wherein the distance between said axis and the outermost extent of said reservoir chamber is equal to or less than the distance between said axis and the outermost surface defining the innermost portion of said lubricant passageway.

10. A centrifuge according to claim 9 wherein said axis is upright, said compartment being annular and surrounding and spaced from said bowl to define a passageway therebetween, the uppermost and lowermost sealing means each including two annular sealing members spaced apart to define an annular leakage chamber therebetween, and means defining a leakage passageway between said collecting compartment and each said leakage chamber for collecting lubricant which may leak from said bearing chamber past the annular sealing member disposed immediately adjacent thereto and into said leakage chamber.

11. A centrifuge according to claim 2, wherein said feed means includes a stationarily mounted feed pipe extending into and spaced from the interior of said hub, said collecting compartment being annular and surrounding and spaced from said bowl to define a passageway therebetween, the latter passageway communicating said collecting compartment with the lower portion of the interior of said casing, said lower portion being adapted to receive separated solids from said bowl, and means for preventing solids from being pumped from said lower portion into the space between said hub and said feed pipe.

12. A centrifuge according to claim 11 wherein said means for preventing pumping of solids includes a passageway extending from the space between said feed pipe and said hub to the outer periphery of the upper portion of the interior of said casing.

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