Sept. 24, 1968 H. C. F. OYEN 3,402,822

SCREENING CENTRIFUGES

Filed Aug. 17, 1966

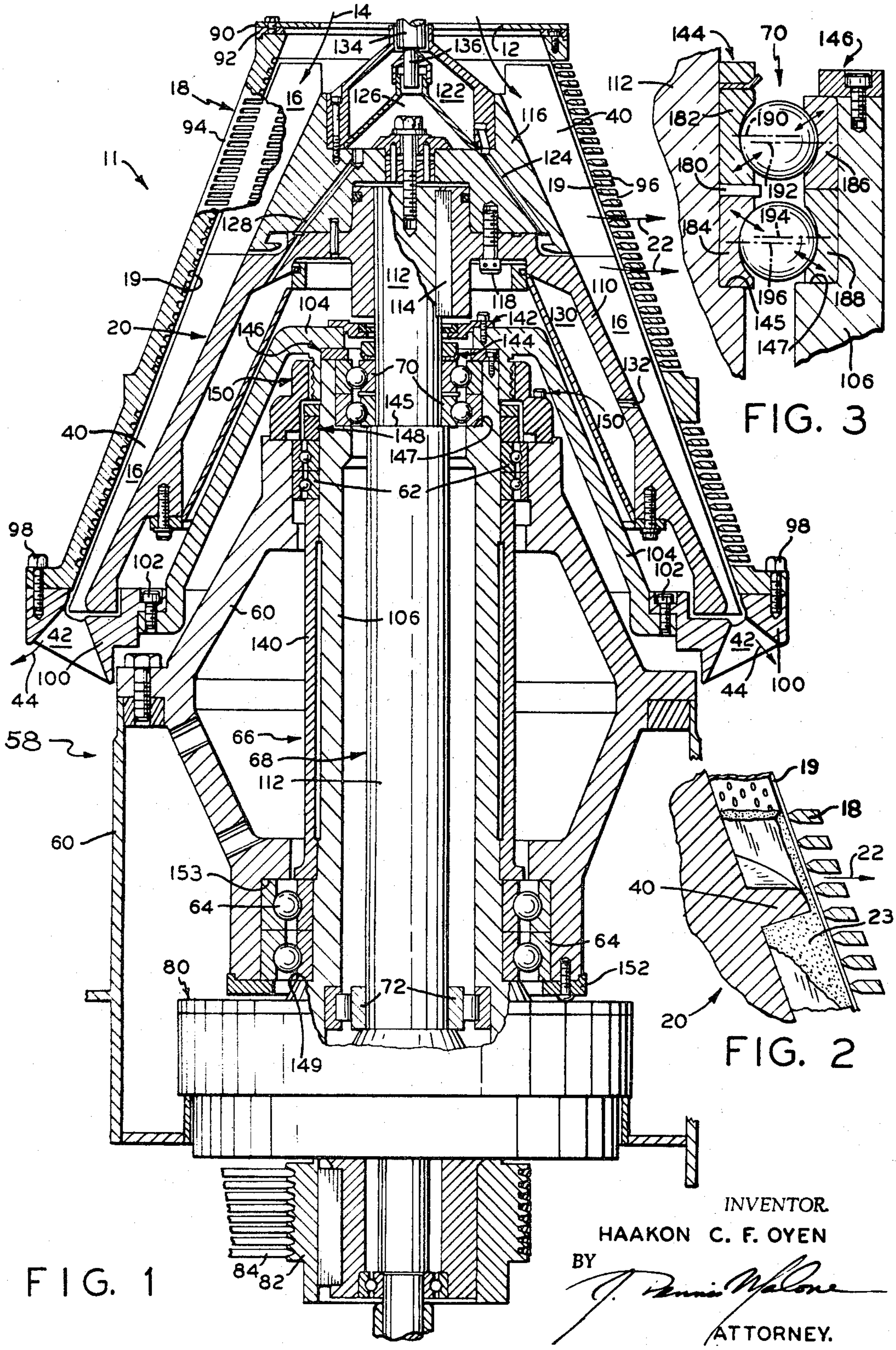

FIG. 3

FIG. 2

FIG. 1

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3,402,822

Patented Sept. 24, 1968

1

3,402,822

SCREENING CENTRIFUGES

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Filed Aug. 17, 1966, Ser. No. 572,981
5 Claims. (Cl. 210—374)

The present invention relates to screening centrifuges of the type having a conical screen and a helical conveyor therein to move solids along the screen. In such centrifuges, it is common to introduce the feed material at the narrow end of the screen. Centrifugal force urges the feed material radially outwardly against the screen where there occurs a separation of one fraction of the feed material, for example a liquid, which passes through the screen, from a second fraction, for example solids, which is retained on the screen.

Because of the conicity of the screen, the component of the radial centrifugal force parallel to the screen urges the solids toward the wide discharge end of the screen. The conveyor of the centrifuge has helical vanes and is positioned within the screen with a predetermined clearance therebetween. As is conventional, the conveyor is rotated with the screen but at a speed differential whereby the helical vanes effect an apparent traverse from the narrow to the wide end of the screen and thus control the axial transfer of the solids along the screen.

This control of the solids fraction by the vaned conveyor or helix is effected under certain conditions by pushing the solids down the screen and under other conditions by keeping the solids from sliding down the screen too fast. Which of these two control techniques exists in a given centrifuge application is dependent on a great many factors and, at the present state of the art, is generally unpredictable. It should be noted that observation of the action within a centrifuge during operation is not practically possible. However, from examination of wear patterns on the helix vanes, there is an indication that in certain applications, the helix operates to retard the solids near the feed end of the rotor and to push the solids along near the discharge end.

The present invention results from a problem occurring in the use of such prior art screening centrifuges. The problem phenomenon occurred when the centrifuge feed rate was increased above the point which was presumed by the art to be maximum machine capacity. Such increased feed rates were met with marked vibration and with a rapidly increasing torque between the differentially rotating screen and helix.

As is conventional in such machines, the differential transmission which drives the screen and the conveyor is protected from torque overloads by a cut-out device which permits screen and helix to rotate at the same speed while stopping the feed to the centrifuge. Consequently the result of attempting a feed rate increase was to trip the transmission cut-out. Yet, from a theoretical viewpoint, the machine was nowhere near a maximum capacity as determined by the available space for the solids between the screen and the helix.

Numerous unsuccessful attempts to determine the causes of the vibration and the torque overloads and to eliminate same were tried. Although slower operating speeds alleviated the vibrational problems, the torque overload condition persisted. A proposed solution was to increase the clearance between the helix vanes and the screen which is normally in the range of .010" to .100". However, even with increased clearances the torque overloads still occurred when the feed rates were increased above the conventional maximum.

Finally it was theorized that at a certain critical value

2

of the feed rate, the upward reaction on the helix from the solids being pushed downwardly equaled or exceeded the downward reaction from the solids being retarded plus the weight of the helix. Consequently, the helix was lifting within the screen as permitted by the customary axial play in the ball bearings which rotatably support the helix. This lifting of the helix with respect to the screen effected a wedging of the helix toward the screen. This wedging action was squeezing a layer of solids which remains between the opposite surfaces of the vane and the screen after passage of the leading edge of the vane. This compression of the solids layer was causing greatly increased drag and resulting torque on the differential transmission.

Additionaly, at the above-mentioned critical feed rate, the helix was "floating" and was therefore free to oscillate vertically within the limits of the axial bearing play. Coincident to this vertical freedom, the helix ball-bearings, which when unloaded axially have a conventional degree of radial play, were allowing radial helix motion. Consequently, at the critical feed rate, the prior art bearing arrangement permitted vertical oscillation and radial wobbling of the helix. These factors combined to create the severe vibration experienced.

To check these theories, a scribing point was mounted on a screen-associated component of the prior art centrifuge with a .005" vertical clearance from a horizontal surface on the helix. The centrifuge was run up to the vibration and overload value of feed rate. Subsequent examination showed a score in the helix and a broken scribe point, thus indicating the helix had lifted at least .005".

With a view to the newly discovered causes of the vibrational and overload problems, the present invention provides a solution to these problems by restraining the helix axially with respect to the screen. In the illustrated embodiment, this restraint is provided by a zero-end-play bearing arrangement as fully described below. Centrifuges with this unique bearing arrangement have been tested and found to be free of the vibrational problem. Further, the improved centrifuges can handle, at the maximum permissible torque for the differential drive, a feed rate approximately 240% greater than the same centrifuges having the prior art bearing arrangement.

Accordingly it is a primary object of the present invention to provide screening centrifuges having greatly improved capacity and vibrational characteristics as compared to prior art devices.

Further objects of the invention include:

(1) The provision of screening-centrifuge rotors having zero axial end-play between the helix and the screen;

(2) The provision of an improved screening-centrifuge bearing arrangement which prevents axial movement of the helix with respect to the screen;

(3) And the provision of screening centrifuges having a preloaded bearing between the drive shafts for the screen and the helix to prevent helix-shift-induced drag between the screen and the helix.

These and other objects of the present invention will appear from the following description and appended claims when read in conjunction with the accompanying drawings wherein:

FIGURE 1 is a vertical section of the screening centrifuge of the present invention incorporating a zero-end-play bearing between the drive shafts for the centrifuge screen and helix to prevent axial movement therebetween.

FIGURE 2 is a detail section showing the clearance between the opposite faces of the helix vanes and the screen of FIGURE 1 and shows the layer of solids which occupies this clearance during operation.

FIGURE 3 is an enlarged, fragmentary, vertical section showing in exaggerated manner the raceway offsets of the novel bearing of FIGURE 1, which offsets create the desired zero-end-play characteristics of the bearing.

Considering the detail structure of the illustrated rotor of FIGURE 1, the screening centrifuge of the present invention includes a rotor **11** having an inlet opening **12** for feeding process material to the rotor as indicated by arrows **14**. The feed material passes to an annular conical space **16** in the rotor between a foraminous conical screen **19** (FIGURE 2), which is carried on the interior surface of a rapidly rotating perforated cage or screen support **18**, and a rotating conveyor or helix **20**. The rotation of cage **18** and screen **19** urges the process material against the screen. The screen retains one portion of the feed material, for example solids, while another portion of the feed material, for example a liquid, is centrifugally forced through the screen as indicated by arrows **22**. The liquid is collected in one or more chambers of the centrifuge housing (not shown) in conventional manner. The material **23** (FIGURE 2) retained on screen **19** moves downwardly under control of vanes **40** on the helix. The pictorial representation of helical vanes **40** has been simplified in FIGURE 1 to show the screen-to-helix clearance throughout the axial length of the rotor whereas in FIGURE 2 the true sectional appearance of a helical vane is shown. The helix rotates in the same direction as screen **19** but at a speed differential whereby an axial conveying action is effected. The solids are finally discharged from rotor **11** through openings **42** as indicated by arrows **44** and are collected in a solids chamber of the centrifuge housing (not shown) in conventional manner.

A drive head assembly **58** is provided to rotatably support and drive the screen and the helix of the rotor. Drive head assembly **58** includes a fixed, double-cone-shaped, support housing **60** having bearing assemblies **62** and **64**. An annular outer shaft assembly **66**, which drives cage **18**, is mounted to rotate within these bearing assemblies. A coaxial inner shaft assembly **68**, which drives helix **20**, is mounted by bearing assemblies **70** and **72** to rotate within outer shaft assembly **66**.

The lower ends of shaft assemblies **66** and **68** are driven at differential speeds by a suitable drive arrangement such as transmission **80** which is completely described in U.S. Patent 3,332,300, issued July 25, 1967. The transmission is powered by a belt pulley **82** which is in turn driven by a belt or belts **84** which extend from a power source such as a motor (not shown).

Now referring to the above-mentioned major components of the centrifuge in greater detail, rotor **11** includes annular rings **90** and **92** suitably secured to the upper open end of cage **18** to form feed inlet opening **12**. Cage **18** is formed by a conical member **94** which has a plurality of perforations or slots **96** therein for passage of effluent to the fluid chambers of the centrifuge housing (not shown) which surrounds the rotor. The cage is secured by screws **98** to a spider ring **100** containing the solids apertures **42**. The ring is in turn secured by screws **102** to a bell-like hub **104**, and the hub is non-rotatably connected to a hollow shaft **106** of outer shaft assembly **66** by any suitable means such as cap screws (not shown).

Helix **20** includes a lower conical portion **110** secured by a key **114** to rotate with a shaft **112** of inner shaft assembly **68**. An upper conical portion **116** of the helix is connected to lower portion **110** by cap screws **118**. In the particular embodiment illustrated, helix **20** of the screening centrifuge is provided with two series of passages **122**, **124** and **126**, **128**, **130**, **132** to supply a wash fluid or fluids from concentric wash fluid feed pipes **134** and **136** to the material being processed in the rotor.

Outer shaft assembly **66** further includes a bearing spacer **140** between the inner races of outer shaft bearing assemblies **62** and **64**; a lock nut assembly **148** to clamp the inner races of bearing assembly **62**, bearing spacer **140**, and the inner races of bearing assembly **64** all in place against a shoulder **149** of outer rotor shaft **106**; and a clamping ring **146** to retain the outer races of inner shaft bearing assembly **70** against an outer shaft shoulder **147**. Inner shaft assembly **68** is provided with a sealing arrangement **142** between cage hub **104** and inner shaft **112** and a lock nut assembly **144** to clamp the inner races of bearing assembly **70** upon a shoulder **145** of inner shaft **112**. Support housing **60** includes a seal assembly **150** to provide a seal between the stationary housing and the rotating hub **104**. Housing **60** is further provided with a retainer **152** to maintain the outer races of bearing assembly **64** in position against shoulder **153** of the housing.

Bearing arrangements

Considering the bearing arrangements and their functions in greater detail, it is customary in conveyor-type screening centrifuges to support each of the rotary components in two spaced-apart anti-friction bearing assemblies. One of these bearing assemblies serves to position the component axially, within the limits of the bearing play, and the other bearing assembly is arranged to permit axial floating to compensate for manufacturing tolerances and for differential thermal expansion of the housing and/or shafts. Thus in the present invention outer shaft **106** is axially positioned with respect to the housing by lower bearing assembly **64**, the inner and outer races of which are rigidly mounted on the shaft and housing, respectively. However, the outer shaft upper bearing assembly **62** is mounted with its outer races floating in the housing for the above-mentioned purposes. Similarly, inner shaft **112** is positioned axially with respect to outer shaft **106** by upper bearing assembly **70**, the inner and outer races of which are rigidly mounted on inner shaft **112** and in outer shaft **106**, respectively. But, the lower end of inner shaft **112** is free to float axially with respect to the outer shaft in roller bearing assembly **72**.

The bearings supporting the inner and the outer shafts conventionally have quite different characteristics for the following reasons. Because of the differential drive arrangement, the relative speed between the inner shaft and the outer shaft is much less than the relative speed between the outer shaft and the housing. For example, in one specific centrifuge the outer shaft rotates at 1100 r.p.m. while the differential speed between shafts is only 44 r.p.m. The differential speed between shafts is generally in the range of 25 to 120 r.p.m. in screening centrifuges. Accordingly, the outer shaft bearings assemblies **62** and **64** operate at much higher speeds than inner shaft bearing assemblies **70** and **72**. Consequently, it is conventional to provide outer shaft bearings which are heavier duty than the inner shaft bearings and which in many cases are double-row, zero-radial-play bearings to alleviate vibrational problems at these relatively high rotational speeds. In contrast, the prior art inner shaft bearings commonly have been single row bearing arrangements.

It should be noted that single-row rolling-element bearings inherently have a degree of end play. This end play can be eliminated only if special provisions or procedures are utilized in a double-row bearing arrangement. Therefore, in order to prevent axial helix movement within the screen, a zero-end-play, double-row bearing is provided in the present invention as the upper bearing between the shafts. By positioning the zero-end-play bearing between the upper or helix/screen proximate ends of the shafts, helix shift due to differential thermal expansion of the shafts is avoided.

In the invention as illustrated, a double-row, zero-end-play bearing assembly **70**, in which the rolling elements are balls, is utilized between the shafts. A shim or shims **180** are inserted during installation between the respective inner races **182** and **184**. Outer races **186** and **188** are forced together during assembly by clamping ring **146** so as to preload the bearing. This forcible clamping creates an offset between the centerlines **190** and **192** of the raceways of races **182** and **186**. A similar but oppositely directed offset is created between centerlines **194** and **196** of the raceways of races **184** and **188**, respectively. The effect of these raceway offsets is depicted in exaggerated manner in FIGURE 3 by the contact relationships between the balls and the raceways and by the illustrated force arrows indicating the direction of preload forces between the races and the balls.

As exemplary of this technique for a specific centrifuge application, shims were selected to create an axial preload in the range of 90 to 130 pounds. It should be noted that alternatively a similar although inverse preload relationship could be effected by a shim between the outer races with the inner races being clamped together. Other zero-end-play bearing techniques are visualized for incorporation in the present invention. For example, instead of installing shims between either the inner or the outer bearing races, a portion of one or both of the inner or outer races can be removed as by grinding to achieve analogous raceway offsets and preloads. Other conventional zero-end-play bearing arrangements can also be used in the present invention.

As this invention may be embodied in several forms without departing from the spirit or essential characteristics thereof, the present embodiment is illustrative and not restrictive. The scope of the invention is defined by the appended claims rather than by the description preceding them, and all embodiments which fall within the meaning and range of equivalency of the claims are therefore intended to be embraced by those claims.

I claim:

1. In a screening centrifuge having a conical screening means, a coaxial conical conveying means therein, and respective coaxial shaft means connected at one end to said screening means and to said conveying means to rotatably drive same, said conveying means including helical vanes and rotating at a speed differential with respect to said screening means to move material along said screening means away from the apex end thereof; the improvement comprising zero-end-play bearing means between the respective coaxial shaft means to prevent said conveying means from moving axially toward said screening means during operation, said bearing means being a double-row rolling-element bearing system arranged with an axial preload on one of the rows of rolling-elements reacted against a preload on the other row of rolling elements.

2. An apparatus as defined in claim **1**, wherein said bearing system is a double-row ball bearing arrangement with a preload in the range of 90 to 130 pounds axially.

3. An apparatus as defined in claim **1**, said zero-end-play bearing means being located adjacent the ends of the respective coaxial shaft means which are connected to said screening means and to said conveying means.

4. A screening centrifuge rotor comprising:

(a) a conical screen-supporting perforated cage;

(b) a conical screen fitted upon the internal surface of said cage to screen material being treated in the rotor;

(c) a conical conveyor having helical vanes positioned coaxially within said screen with a predetermined clearance between said vanes and said screen;

(d) respective inner and outer coaxial drive shafts connected at one end to said cage and to said conveyor;

(e) differential drive means connected to the other end of said shafts to drive the shafts in the same direction at different speeds, the speed differential being such as to effect an apparent motion of said helical vanes from the narrow end of said conical screen toward the wide end thereof;

(f) and respective anti-friction bearings between said shafts at the drive proximate ends thereof and at the screen/helix proximate ends thereof, said screen/helix proximate bearing having a double row of bearing balls, each row having a respective inner and outer raceway, the inner and outer raceways for each ball row being rigidly positioned on the respective shafts with an axial offset between the raceways to axially preload each row of balls, the raceway offset for one row of balls being opposite to that of the other row whereby the axial preloads on the respective rows of balls are reacted against each other thereby preventing shifting of said helix with respect to said screen during operation.

5. A centrifuge rotor as defined in claim **4** wherein each said row of balls has separate inner and outer races and wherein a shim means is installed between the respective races on one of said shafts with the respective races on the other shaft being clamped together to establish said opposite axial raceway offsets.

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