

DESCRIPTION

LOAD DISTRIBUTION DEVICES AND INSULATED BEARING ASSEMBLIES

CROSS-REFERENCE(S) TO RELATED APPLICATION(S)

This application claims priority to U.S. Patent Application Serial No. 10/841,209,
5 filed May 7, 2004, the entire contents of which are expressly incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates generally to the field of rotating machines, such as motors and
generators. More particularly, it relates to bearing assemblies used with such machines and
10 devices useful when removing the bearing assemblies.

2. Description of Related Art

Rolling element bearings, also known as anti-friction bearings, are widely used on
many types of rotating machinery and have a limited life span. That life span can be reduced
by misuse and adverse operating conditions. Bearing removal is frequently required in the
15 field as part of the rotating machinery's maintenance.

Traditionally, bearing assemblies have been designed such that the removal of the
bearing requires the removal of the entire bearing bracket that houses the bearing and that is
mounted to the frame of the rotating machine (e.g., a motor or a generator). **FIGS. 1 and 2**
show an example of such a prior art bearing assembly.

20 Bearing **10** was positioned, or housed, in bearing bracket **20**. Inner race **12** of bearing
10 contacted shaft **30** of the rotating machine (the body of which is not shown). Outer race
14 of bearing **10** contacted machined cavity **22** of bearing bracket **20**. Rolling elements **16**
(balls in this case) were positioned between, and in direct contact with, the two races. An
inner cap **28** was bolted to bearing bracket **20** with bolts **25** positioned through bolt holes **27**.

The bearing bracket had a machined rim **24** near its outer edge that fit with very little radial clearance into the machined frame of the rotating machine. That tight fit between the frame and bearing bracket **20** is commonly known as a spigot fit, and bearing bracket **20**'s rim **24**, which fit tightly inside of the machined frame, is known as a spigot. Mounting bolts (not shown, but see **FIG. 1**, which shows mounting holes **32**) secured bracket **20** to the frame of the rotating machine to ensure that spigot **26** remained in contact with the frame. During normal operation, the rotor weight was transmitted through the bearings to the bearing brackets (there is typically one at each end of the machine) and through each bracket's spigot to the frame of the rotating machine, which was supported by the site foundation.

Bearing **10** has been removed from rotating machines, such as motors and generators, using jacking bolts. Jacking holes **34** were positioned in bearing bracket **20**. Jacking bolts are normal bolts that were screwed into jacking holes **34**, which were located evenly around the outside of the bearing bracket such that they aligned with flat, solid steel surfaces on the frame of the rotating machine. As the jacking bolts were placed in jacking holes **34** and tightened, the bottom of the bolts came into contact with the steel surface of the frame. Gradual and even tightening of all the jacking bolts caused the jacking bolts to pull bearing bracket **20** out of the frame. Bearing **10** typically stayed in place on shaft **30** because inner cap **28** was first un-bolted from bearing bracket **20**. Because **10** normally stayed in place on shaft **30**, bearing bracket **20** could only be removed a short distance before it had to be supported to keep it from falling onto and possibly damaging shaft **30**. The weight of bearing bracket **20** (potentially over 200 pounds for a 300 horsepower (HP) rotating machine) generally required a crane or other large lifting device to be used for bearing removal on 300 HP (and larger) motors.

To summarize, the following steps have been taken during removal of the bearing shown in **FIGS. 1** and **2**. The end of shaft **30** has been supported using any suitable

mechanism, such as a crane or jacks. The mounting bolts positioned in mounting holes **32** that held bearing bracket **20** to the frame of the rotating machine have been removed, as have bolts **25** positioned in bolt holes **27** that held inner cap **28** to bearing bracket **20**. Jacking bolts have been inserted into jacking holes **34**. The jacking bolts have been tightened gradually and evenly until spigot **26** of bearing bracket **20** has been completely pulled out of the frame. The supported shaft end has been lowered down until the rotor core (not shown) surrounding shaft **30** contacts the stator core (not shown) surrounding the rotor core. The shaft support has been removed. A crane has been attached to bearing bracket **20** and removed bearing bracket **20**. A traditional bearing puller has been used to remove bearing **20** from around shaft **30**.

An advance was made with the creation of the bearing assembly shown in **FIGS. 3** and **4**. Bearing assembly **40** (sometimes called a bearing cartridge) is positioned in a bearing assembly opening **42** of bearing bracket **20**. Bearing **10** is seated inside of bearing assembly **40** instead of directly in bearing bracket **20**, as shown in **FIG. 2**. As a result, the end user only had to remove bearing assembly **40** – not bearing bracket **20** – in order to remove bearing **10**. Bearing assembly **40** is considerably lighter than bearing bracket **20** and eliminates the need for a crane.

Bearing assembly **40** includes a cylindrical insert **44**, an inner cap **28**, an outer cap **46**, and bearing **10**. Insert **44** was machined on its inside to hold bearing **10** tightly and had a spigot fit with bearing bracket **20**. Insert **44** also had mounting bolt holes **48** through which bolts were placed to secure insert **44** to bearing bracket **20**. Insert **44** also had insert jacking holes **49** that allowed for removal of the bearing assembly from bearing bracket **20**. Insert **44**, outer cap **46**, and inner cap **28** each had aligned openings (designated generally at **50**) that allowed them to be bolted together with bolts **52**. Outer cap **46** was a disk that bolted onto insert **44** and that had a small clearance fit with shaft **30** to hold the bearing grease inside of

bearing assembly 40. Inner cap 28 also was a disk that had a small clearance fit with shaft 30 for grease retention, but also had two ring-shaped projections 51 and 53, positioned to align with inner race 12 and outer race 14, respectively, of bearing 10. Those projections allowed inner cap 28 to act as a bearing puller.

5 During bearing removal, the jacking bolts positioned in insert jacking holes 49 pulled bearing assembly 40 out of bearing bracket 20. Because inner cap 28 was bolted insert 44, ring-shaped projections 51 and 53 contacted bearing 10's inner race 12 and outer race 14, respectively, and pulled bearing 10 off of shaft 30 during removal. This eliminated the need for the end user to use a bearing puller. Also, the lighter weight of bearing assembly 40
10 (versus bearing bracket 20) and the presence of bearing 10 in bearing assembly 40 reduced the risk of the bearing assembly falling sizable distances and damaging the shaft as the bearing assembly was pulled off of the end of the shaft.

To summarize, the following steps have been taken to remove bearing assembly 40. The end of shaft 30 has been supported. The mounting bolts running through mounting bolt
15 holes 48 have been removed. Those same bolts have then been used as jacking bolts, inserted into insert jacking holes 49 and tightened gradually and evenly until bearing assembly 40 was removed from bearing assembly opening 42 of bearing bracket 40. Shaft 30 was lowered until the rotor core (not shown) surrounding the shaft contacted the stator core (not shown) surrounding the rotor core. The shaft support was removed. The loose bearing assembly 40
20 was removed by sliding it off of the end of the shaft.

The inventors have discovered certain shortcomings associated with the removal of bearing assembly 40 shown in FIG. 4. While removing bearing assembly 40 from bearing assembly opening 42, a large friction force is induced between bearing 10 and shaft 30 tends to move shaft 30 in the same direction as bearing 10. This shaft motion or force is transferred
25 to, and undertaken by, the bearing or coupling at the other end of the shaft. If that bearing

(i.e., at the other end) is a rolling element bearing, the friction force between that bearing and the shaft will cause the entire rotor assembly to be moved in the direction of bearing 10. Alternatively, the load will be undertaken by the rolling elements of the bearing or the inner cap located at the other end of shaft 30.

5

SUMMARY OF THE INVENTION

The present load-balancing devices and methods, the present bearing removal devices, and the present methods useful in removing a bearing from around a shaft provide mechanisms and steps that address the force transfer problems described above. The present load-balancing devices are configured for use with a rotating machine that has a shaft, a bearing bracket surrounding the shaft, and a bearing surrounding the shaft. Certain
10 embodiments of these load-balancing devices include a shaft engagement element that is configured to engage an end of the shaft; a bearing bracket engagement element that is configured to engage the bearing bracket; and a connector element connecting the shaft engagement element to the bearing bracket engagement element; where the shaft engagement
15 element, the bearing bracket engagement element, and the connector element are configured with respect to each other such that at least a portion of the connector element will be positioned outside the bearing bracket (i.e., closer to the exterior of the bearing bracket than to the interior of the bearing bracket).

In another embodiment, the rotating machine is capable of producing at least ¼
20 horsepower. In a further embodiment, the shaft engagement element comprises at least one bolt. In a further embodiment, the bearing bracket engagement element comprises at least two bolts. In a further embodiment, the connector element comprises a plate.

In another embodiment, the shaft engagement element, the bearing bracket engagement element, and the connector element are integral with each other.

In another embodiment, the rotating machine is capable of producing at least $\frac{1}{4}$ horsepower, the bearing bracket includes a bearing assembly opening, and the bearing is part of a bearing assembly positioned in the bearing assembly opening.

Certain embodiments of the present load-balancing methods include providing a rotating machine that has a shaft that has an end and a shaft position; a bearing bracket surrounding the shaft and having an outer surface and a bearing bracket position; and a bearing surrounding the shaft. These methods also include fixing the shaft position relative to the bearing bracket position to achieve a fixed shaft; and moving the bearing along a portion of the fixed shaft.

In another embodiment, the rotating machine is capable of generating at least $\frac{1}{4}$ horsepower. In a further embodiment, the bearing bracket includes a bearing assembly opening, the bearing is part of a bearing assembly positioned in the bearing assembly opening, and the method further includes removing the bearing assembly from around the shaft. In a further embodiment, the fixing includes: contacting the end of the shaft with a shaft engagement element; contacting the outer surface of the bearing bracket with a bearing bracket engagement element; and connecting the shaft engagement element to the bearing bracket engagement element. In a further embodiment, the end of the shaft includes a flat surface and a recess extending into the shaft from the flat surface, and the contacting the end includes inserting a portion of the shaft engagement element into the recess. In a further embodiment, the contacting the bearing bracket includes inserting bolts into bolt openings in the bearing bracket. In a further embodiment, a rotor core surrounds the shaft, a stator core surrounds the rotor core, and the moving includes inserting jacking bolts into openings in the bearing assembly and tightening the jacking bolts until the bearing assembly is removed from the bearing assembly opening; the method further comprising: supporting the end of the

shaft; removing mounting bolts that hold the bearing assembly to the bearing bracket; and lowering the shaft so as to cause the rotor core to contact the stator core.

The present bearing removal devices are configured for use with a rotating machine that has a shaft, a bearing bracket having a bearing assembly opening, and a bearing assembly
5 positioned in the bearing assembly opening. The bearing assembly includes a bearing surrounding a shaft. Certain embodiments of the present bearing removal devices include a shaft contacting element configured to contact an end of the shaft; a bearing assembly engagement element configured to engage the bearing assembly; and a connector element connecting the shaft contacting element to the bearing assembly engagement element; where
10 the shaft contacting element, the bearing assembly engagement element, and the connector element are configured with respect to each other such that at least a portion of the connector element will be positioned outside the bearing assembly (i.e., closer to the exterior of the bearing assembly than to the interior of the bearing assembly).

In another embodiment, the rotating machine is capable of producing at least $\frac{1}{4}$
15 horsepower. In a further embodiment, the shaft contacting element comprises at least one bolt. In a further embodiment, the bearing assembly engagement element comprises at least two bolts. In a further embodiment, the connector element comprises a plate.

In another embodiment, the bearing assembly includes: an outer cap configured to contact the bearing bracket; and an inner cap configured to contact the outer cap; where the
20 bearing is positioned between at least a portion of the outer cap and a portion of the inner cap; and the bearing assembly engagement element is configured to engage the outer cap.

Certain embodiments of the present methods useful in removing a bearing from around a shaft include providing a rotating machine that has a shaft having an end; a bearing bracket surrounding the shaft and having a bearing assembly opening; and a bearing

assembly positioned in the bearing assembly opening, the bearing assembly including a bearing surrounding the shaft. These methods also include using a device that (a) causes the bearing assembly to move in a first direction and (b) directs a force on the shaft in a second direction that is substantially opposite the first direction.

5 In another embodiment, the rotating machine is capable of generating at least $\frac{1}{4}$ horsepower. In a further embodiment, the device includes: a shaft contacting element configured to contact the end of the shaft; a bearing assembly engagement element configured to engage the bearing assembly; and a connector element connecting the shaft contacting element to the bearing assembly engagement element. In a further embodiment,
10 the using includes: engaging the bearing assembly with the bearing assembly engagement element so as to cause the bearing assembly to move in the first direction; and contacting the shaft with the shaft contacting element so as to direct the force on the shaft in the second direction.

 In a further embodiment, the end of the shaft includes a flat surface and the contacting
15 the shaft includes contacting the flat surface.

 Alternatively, in a further embodiment, the engaging the bearing assembly includes inserting bolts into bolt openings in the bearing assembly.

 Alternatively, in a further embodiment, a rotor core surrounds the shaft, a stator core surrounds the rotor core, and the engaging the bearing assembly includes inserting at least
20 one jacking bolt into an opening in the connector element and tightening the jacking bolt until the bearing assembly moves in the first direction; the method further comprising: supporting the end of the shaft; removing mounting bolts that hold the bearing assembly to the bearing bracket; and lowering the shaft so as to cause the rotor core to contact the stator core.

Also disclosed are apparatuses that include a bearing assembly having an insulation assembly. Certain embodiments of the present apparatuses include a bearing assembly that is configured to be positioned in a bearing assembly opening of a bearing bracket of a rotating machine. These bearing assemblies include a rolling element bearing that is configured to surround a shaft of the rotating machine; an inner cap having a portion that is positioned on one side of the rolling element bearing; an outer cap having a portion that is positioned on another side of the rolling element bearing; and an insulation assembly that is configured to substantially insulate the rolling element bearing.

In another embodiment, the rotating machine is capable of generating at least $\frac{1}{4}$ horsepower.

In a further embodiment, the insulation assembly is configured to substantially insulate the rolling element bearing from current having a frequency of at least 500 hertz.

Alternatively, in a further embodiment, the shaft has a terminal point and a middle, and the insulation assembly includes an inner insulating ring positioned between the rolling element bearing and the middle.

In a further embodiment, the inner insulating ring is made of glass cloth and resin.

Alternatively, in a further embodiment, the insulation assembly includes an insulated bushing having a portion positioned around at least a portion of the rolling element bearing.

In a further embodiment, the insulated bushing is made of glass cloth and resin.

Alternatively, in a further embodiment, the insulation assembly includes an outer insulating ring positioned nearing the terminal point of the shaft than is the inner insulating ring.

In a further embodiment, the outer insulating ring is a seal made of the same material as the inner insulating ring.

Other embodiments of the present load-balancing devices, load-balancing methods, bearing removal devices, methods useful in removing a bearing from around a shaft, and apparatuses that include insulation assemblies—and details associated with those embodiments—are described below.

5

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings illustrate by way of example and not limitation. The use of identical reference numerals does not necessarily indicate an identical structure. Rather, the same reference numeral may be used to indicate a similar feature or a feature with similar functionality.

10

FIG. 1 is a front view of a prior art bearing assembly.

FIG. 2 is a cross-sectional view taken along line A-A in **FIG. 1**.

FIG. 3 is a front view of another prior art bearing assembly.

FIG. 4 is a cross-sectional view taken along line A-A in **FIG. 3**.

FIG. 5 is a cross-sectional view of one of the present load-distribution devices and one of the present insulation assemblies.

FIG. 6 is a front view of another of the present load-distribution devices.

FIG. 7 is a cross-sectional view of one of the present bearing removal devices.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The terms “comprise” (and any form of comprise, such as “comprises” and “comprising”), “have” (and any form of have, such as “has” and “having”), and “include” (and any form of include, such as “includes” and “including”) are open-ended linking verbs. As a result, a device or method that “comprises,” “has,” or “includes” one or more elements or steps possesses those one or more elements or steps, but is not limited to possessing only

those one or more elements. Likewise, an element of a device or a step of a method that “comprises,” “has,” or “includes” one or more features possesses those one or more features, but is not limited to possessing only those one or more features.

Thus, and by way of example, a load-balancing device “comprising” a shaft
5 engagement element configured to engage an end of a shaft; a bearing bracket engagement element configured to engage a bearing bracket; and a connector element connecting the shaft engagement element to the bearing bracket engagement element, has, but is not limited to having only, the recited elements and features. That is, the load-balancing device possesses at least the recited elements and features, but does not exclude other elements or features that
10 are not expressly recited.

The terms “a” and “an” are defined as one or more than one unless this disclosure explicitly requires otherwise.

FIG. 5 shows one embodiment of the present load-balancing devices. The term “load-balancing” does not mean that a perfect balance of forces is achieved using any of the
15 present devices or methods. Load-balancing device **100** is configured for use with a rotating machine (not shown). “Rotating machine” is defined as any machine having an element – such as a shaft – that rotates as part of the machine’s operation. Rotating machines with which the present load-balancing devices are particularly useful include motors and generators, and more specifically those that are capable of producing at least $\frac{1}{4}$ horsepower.

20 The rotating machine includes a shaft **110**, a bearing bracket **120** surrounding shaft **110**, and a bearing **130** surrounding shaft **110**. “Surrounding” is defined such that a first structure that surrounds a second structure need not necessarily (but can) be in direct contact with the second structure, and other structures may be disposed between the first and second structures.

Load-balancing device **100** includes a shaft engagement element **140** that is configured to engage an end **115** of shaft **110**. The “end” of a shaft is defined as including the outermost border of the shaft (also described in this disclosure as the terminal point of the shaft, e.g., flat surface **117** of shaft **110** shown in **FIG. 5**) through at least that portion of the shaft that contacts the bearing in the bearing assembly. “Engage” is defined as connect to. The types of engagements disclosed include engagement through the use of mating threads, friction, magnetic forces, and any suitable mechanism or means for connecting two things.

Load-balancing device **100** also includes a bearing bracket engagement element **150** that is configured to engage bearing bracket **120**, and a connector element **160** that connects shaft engagement element **140** to bearing bracket engagement element **150**. As **FIG. 5** shows, these three elements are configured with respect to each other such that at least a portion (and, in this embodiment, all) of connector element **160** is positioned on the outside **165** of bearing bracket **120**. “Outside,” in this context, is defined as closer to the exterior of the bearing bracket than to the interior of the bearing bracket.

In the embodiment shown in **FIG. 5**, shaft engagement element **140** includes at least a bolt **142**, which includes bolt head **144** and which is held to connector element **160** by a nut **146**. Bolt **142** is configured to engage, and engages, shaft **110** by being threaded at least partially into a recess **112** that starts at flat surface **117** of shaft **110** and extends into shaft **110**. For a rotating machine that generates approximately 1000 horsepower, a one-inch bolt may be used for bolt **142**, and a recess depth of 1.5 inches may be used for recess **112**. Although only one bolt is shown as being used, multiple bolts may be used to better suit a given application.

In the embodiment shown in **FIG. 5**, bearing bracket engagement element **150** includes at least two bolts **152**, each of which includes a bolt head **154**. Bolts **152** may be configured to engage (and, in use, engage) bearing bracket **120** by each being threaded at

least partially into recesses **122** in bearing bracket **120**. Recesses **122** start at the outer surface of bearing bracket **120** and extend into bearing bracket **120**. Alternatively, bolts **152** may be not configured to engage bearing bracket **120**, may be not provided with threads, and may simply rest against an unthreaded version of recess **122**. Bolts **152** are held to connector
5 element **160** by their threads engaging the holes, or openings, **162** in connector element **160**.

For a rotating machine that generates approximately 1000 horsepower, one-inch bolts may be used for bolts **152**, and a recess depth of 1.5 inches may be used for recesses **122**. Although only two bolts are shown as being used for bearing bracket engagement element **150**, more than two bolts (e.g., 3, 4, 5, 6, 7, 8, 9, 10, or more bolts) may be used to better suit
10 a given application.

In the embodiment shown in **FIG. 5**, connector element **160** includes plate **164**. Plate **164** may have any suitable shape, including circular, rectangular (e.g., square), oval, etc. Plate **164** may have a series of fingers that extend like spokes from a central section where opening **166** is positioned through which bolt **142** is threaded or otherwise placed. Any shape
15 that is suited to the application may be used, provided the three elements are configured with respect to each other such that at least a portion of connector element **160** is on the outside **165** of bearing bracket **120**.

Load-balancing device **100** may be used to solve the problem (discussed above) with friction between the bearing being removed and the shaft of the rotating machine causing
20 either the shaft or the entire assembly connected to the shaft (e.g., the rotor assembly) from moving in the same direction as the shaft. Consistent with the present load-balancing methods, using load-balancing device **100** will serve to fix the position of shaft **110** relative to the position of bearing bracket **120**, thus yielding a fixed shaft. "Fixing" the shaft position relative to the bearing bracket position does not require that the two be prevented from all
25 movement with respect to each other – slight movement is permitted owing to tolerances and

the flexing or compaction of materials. Bearing 130 may then be moved along at least a portion of the fixed shaft 110, and the resulting friction force between the moving bearing and the shaft is balanced by the reaction force provided by load-bearing device 100. As a result, no loading will be placed on the opposite end of the rotating machine.

5 **FIG. 5** also shows one embodiment of a bearing assembly that includes an insulation assembly. Apparatus 200 includes bearing assembly 250, which is positioned in bearing assembly opening 125 of bearing bracket 120.

Bearing assembly 250 includes an outer bearing cap 255, an inner bearing cap 260 bolted to outer bearing cap 255 with bearing assembly bolts 257, and bearing 130, which, as shown in this embodiment, may be a rolling element bearing. Bearing 130 includes inner
10 race 132, outer race 134, and rolling elements 136, which may, as shown in this embodiment, be balls. As this embodiment shows, bearing 130 is configured to surround, and surrounds, shaft 110; inner cap 260 has a portion (the entire cap in this embodiment) positioned on one side 131 of bearing 130; and outer cap 255 has a portion positioned on another side 133 of
15 bearing 130. Inner cap 260 and outer cap 255 may be made from any suitable material, including an industry-standard material such as A36 steel or gray cast iron. Any commercially-available bearing may be used for bearing 130.

Bearing assembly 250 also includes insulation assembly 300, which is configured to substantially insulate bearing 130. The term “substantially” is defined as at least close to
20 (and can include) a given value or state (preferably within 10% of, more preferably within 1% of, and most preferably within 0.1% of).

The embodiment of insulation assembly 300 shown in **FIG. 5** includes inner insulating ring 310; insulated bushing 320; and outer insulating ring 330. Inner insulating ring 310 is positioned between bearing 130 and the middle (not shown) of shaft 110.

Insulated bushing **320** has a portion **322** positioned around at least a portion of bearing **130**. Outer insulating ring **330** is positioned nearing the terminal point (e.g., flat surface **117**) of shaft **110** than is inner insulating ring **310**. Outer insulating ring **330** may be a seal that functions to retain bearing grease. Insulated bushing **320**, inner insulating ring **310**, and
5 outer insulating ring **330** (which functions as (and is) a seal in certain embodiments) may be made from any suitable dielectric material that possesses sufficient mechanical strength for the application. One such material is a glass cloth laminate impregnated and cured with epoxy resin, which material meets the NEMA G11 standard and is sold commercially as an epoxy fiberglass laminate sheet by International Paper (Stamford, CT). Outer insulating ring
10 **330** may also be made a seal commercially available from Inpro/Seal Corporation that has part no. M0098. Insulation assembly **300** may be configured to substantially insulate bearing **130** from both high frequency current (current having a frequency of from about 500 hertz (Hz) to about 3000 Hz), and/or both high frequency and low frequency current (current having a frequency of from about 0 Hz to about 500 Hz) by making insulated bushing **320** at
15 least 0.25 inches thick.

Although the basic embodiment of the present load-balancing methods was described above, additional embodiments will now be discussed. The fixing of the shaft position relative to the bearing bracket position of shaft **110** and bearing bracket **120** in **FIG. 5** may be accomplished by, generally, contacting end **115** of shaft **110** with shaft engagement element
20 **140**; contacting bearing bracket **120** with bearing bracket engagement element **150**; and connecting shaft engagement element **140** to bearing bracket engagement element **150** using, for example, connector element **160**. It should be understood that any suitable construction of these three elements may be accomplished to achieve one of the present load-balancing devices.

One feature of the present load-balancing devices is that the various elements be configured with respect to each such that pressure can be applied to shaft 110 and bearing bracket 120, or pressure from shaft 110 and/or bearing bracket 120 can be resisted, at the same time. Thus, the three elements may be made from a single piece of material, such as the embodiment of load-balancing device 100 shown in FIG. 6. In this embodiment, shaft engagement element 140 and bearing bracket engagement element 150 are the result of machining a single piece of material. Shaft engagement element 140 takes the shape of a central projection 141, which extend from and are integrally connected to connector element 160 (which is a portion of the original piece of a material). Similarly, bracket engagement element 150 takes the form of end projections 151, which extend from and are integrally connected to connector element 160. The connecting step discussed above may, in instances where the shaft engagement element is integrally formed with the bearing bracket engagement element, take the form of the manufacturing process that leaves those two elements integrally formed with each other.

Continuing with embodiments of the present load-balancing methods, the contacting of the end 115 of shaft 110 with shaft engagement element 140 may include inserting a portion of shaft engagement element 140 (e.g., bolt 142) into recess 112 of shaft 110. That inserting may include screwing bolt 142 into recess 112, where recess 112 is provided with one or more threads. Similarly, the contacting of the bearing bracket 120 with bearing bracket engagement element 150 may include insert bolts 152 into recesses 122 in bearing bracket 120.

Another of the present load-balancing methods includes removing bearing assembly 250 from around shaft 110. In still another embodiment, where a rotor core (not shown) surrounds shaft 110 and a stator core (not shown) surrounds the rotor core, the removing of bearing assembly 250 may include supporting end 115 of shaft 110 (using a crane, one or

more jacks, or any other suitable mechanism); removing the bolts (not shown) that hold bearing assembly **250** to bearing bracket **120** (the holes, or openings, for such bolts are designated generally in both structures by element **259** in **FIG. 5**); inserting those bolts (which may be characterized as jacking bolts) into openings (which may be described as jacking holes, or jacking openings) in bearing assembly **250** (and, more specifically, in outer cap **255**) that are aligned with flat portions of bearing bracket **120**; tightening the jacking bolts (e.g., gradually and evenly; as many jacking bolts as are needed may be used, for example, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more jacking bolts may be used) until bearing assembly **250** is removed from bearing assembly opening **125** in bearing bracket **120**; and lowering shaft **110** so as to cause the rotor core to contact the stator core.

The removing of the various bolts (discussed throughout this disclosure) may be achieved, in appropriate circumstances, without removing some or all of the bolts all of the way out of all the openings through which they are threaded. Furthermore, the tightening of the jacking bolts will serve to move bearing **130** along at least a portion of fixed shaft **110** and, more specifically, will ultimately move bearing assembly **250** out of bearing assembly opening **125** because inner cap **260** is connected to outer cap **255**, and inner cap **260** can be provided with a protruding shoulder **261** that is configured to contact outer race **134** of bearing **130**. Protruding shoulder **261** will, therefore, contact bearing **130** at outer race **134** and help to move bearing **130** along fixed shaft **110** as bearing assembly **250** is jacked out of bearing assembly opening **125**. Furthermore, in this embodiment, inner insulating ring **310** has a female notch **311** that is in contact with a portion of inner cap **260**, as shown in **FIG. 5**. Inner insulating ring **310** is configured (by virtue of its inner diameter) to contact inner race **132** of bearing **130** and help to move bearing **130** along fixed shaft **110** as bearing assembly **250** is jacked out of bearing assembly opening **125**.

FIG. 7 shows one embodiment of the present bearing removal devices. Bearing removal device **400** is configured for use with a rotating machine (not shown) having at least one shaft-mounted rolling element bearing. Rotating machines with which the present bearing removal device are particularly useful include motors and generators. The rotating machine can include the features of the rotating machine discussed above.

Bearing removal device **400** includes a shaft contacting element **440** that is configured to engage an end **115** of shaft **110**. Bearing removal device **400** also includes a bearing assembly engagement element **450** that is configured to engage bearing assembly **250**, and a connector element **460** that connects shaft contacting element **440** to bearing assembly engagement element **450**. As **FIG. 7** shows, these three elements are configured with respect to each other such that at least a portion (and, in this embodiment, all) of connector element **460** is positioned on the outside **165** of bearing assembly **250**. "Outside," in this context, is defined as closer to the exterior of the bearing assembly than to the interior of the bearing assembly.

In the embodiment shown in **FIG. 7**, shaft contacting element **440** includes at least one bolt **442** and, more specifically, at least two bolts **442**. Bolts **442**, which can be characterized as jacking bolts, can be threaded and placed through openings **466**, which can also be threaded. Thus, the connection between connector element **460** and shaft contacting element **440** can be a threaded one. Bolts **442** contact end **115** of shaft **110** (and, more specifically, flat surface **117** of shaft **110**) and tighten to move connector element **460** – and, thus bearing assembly element **450** and bearing assembly **250** – directing a force through shaft **110** that a balanced reaction force to the force that pulls bearing assembly **250** out of bearing assembly opening **125**. The reaction force shaft contacting element **440** delivers to shaft **110** keeps shaft **110** from moving with bearing **130** and/or bearing assembly **250** during

that removal process. For a rotating machine that generates approximately 1000 horsepower, one-inch bolts may be used for bolts 442.

In the embodiment shown in FIG. 7, bearing assembly engagement element 450 includes at least two bolts 452, each of which includes a bolt head 454. Bolts 452 are
5 configured to engage, and do engage, bearing assembly 250 – and, more specifically, outer cap 255 – by each being threaded at least partially into recesses in outer cap 255. In the embodiment shown, those recesses may take the form of openings 259, which are the same threaded openings through which bolts may be placed to connect bearing assembly 250 to bearing bracket 120. The openings 462 in connector element 460 may be threaded such that
10 no nuts are needed to secure bolts 452 to connector element 460. Alternatively, however, non-threaded openings 462 and nuts (not shown) may be used to make that connection. For a rotating machine that generates approximately 1000 horsepower, one-inch bolts may be used for bolts 452. Although only two bolts are shown as being used for bearing assembly engagement element 450, more than two bolts (e.g., 3, 4, 5, 6, 7, 8, 9, 10, or more bolts) may
15 be used to better suit a given application.

In the embodiment shown in FIG. 7, connector element 460 includes plate 464. Plate 464 may have any suitable shape, including circular, rectangular (e.g., square), oval, etc.

Bearing removal device 400 may be used to solve the problem (discussed above) with friction between the bearing being removed and the shaft of the rotating machine causing
20 either the shaft or the entire assembly connected to the shaft (e.g., the rotor assembly) from moving in the same direction as the shaft. Consistent with the present methods useful in removing a bearing from around a shaft, using bearing removing device 400 will cause bearing assembly 250 to move in a first direction (designated by arrow 473) and direct a force on shaft 110 in a second direction (designated by arrow 477) that is substantially the opposite
25 of the first direction. The force with which it causes bearing assembly 250 to move in the

first direction will be equal to the force that is directed, or transferred, to shaft 110 in the substantially opposite second direction. As a result, no loading will be placed on the opposite end of the rotating machine.

To be clear, the use of bearing removal device 400 can include engaging bearing assembly 250 (and, more specifically, outer cap 255) with bearing assembly engagement element 450 so as to cause bearing assembly 250 to move in the first direction, and contacting shaft 110 with shaft contacting element 440 so as to direct force on the shaft in the second direction. Bearing 130 will move as bearing assembly 250 (of which it is a part) move for the same reasons given above. In one embodiment, the contact of the shaft may include contacting flat surface 117, as shown in FIG. 7. In another embodiment, the engagement of the bearing assembly includes inserting bolts 452 into openings 259 in bearing assembly 250 (and, more specifically, in outer cap 255).

One feature of the present bearing removal devices is that the shaft contacting element and the bearing assembly engagement element be configured with respect to each such that pressure can be applied to shaft 110 at the same time that bearing assembly 250 is withdrawn from bearing assembly opening 125 in bearing bracket 120.

Continuing with embodiments of the present methods useful in removing a bearing from around a shaft, the engaging of the bearing assembly may include inserting (e.g., by threading) one or more bolts 442 through openings 466 in connector element 460 and tightening the bolts (e.g., gradually and evenly if more than one is used) until bearing assembly 250 moves in first direction 473. In still another embodiment, where a rotor core (not shown) surrounds shaft 110 and a stator core (not shown) surrounds the rotor core, the method may include supporting end 115 of shaft 110 (using a crane, one or more jacks, or any other suitable mechanism); removing the bolts (not shown) that hold bearing assembly 250 to bearing bracket 120 (the holes, or openings, for such bolts are designated generally in

both structures by element **259** in **FIG. 7**); and lowering shaft **110** so as to cause the rotor core to contact the stator core.

It should be understood that the present load-balancing devices and methods, the present bearing removal devices, and the present methods useful in removing a bearing from
5 around a shaft are not intended to be limited to the particular forms and steps disclosed. Rather, they are to cover all modifications, equivalents, and alternatives falling within the scope of the claims. For example, although rolling element bearings having balls for rolling elements have been shown in the present figures, other rolling elements—such as rollers—may be used. Furthermore, the claims are not to be interpreted as including means-plus- or
10 step-plus-function limitations, unless such a limitation is explicitly recited in a given claim using the phrase(s) “means for” or “step for,” respectively.

CLAIMS

1. A load-balancing device configured for use with a rotating machine having a shaft, a bearing bracket surrounding the shaft, and a bearing surrounding the shaft, the load-transferring device comprising:

a shaft engagement element configured to engage an end of the shaft;

a bearing bracket engagement element configured to engage the bearing bracket; and

a connector element connecting the shaft engagement element to the bearing bracket engagement element;

where the shaft engagement element, the bearing bracket engagement element, and the connector element are configured with respect to each other such that at least a portion of the connector element will be positioned outside the bearing bracket.

2. The device of claim 1, where the rotating machine is capable of producing at least $\frac{1}{4}$ horsepower.

3. The device of claim 1, where the shaft engagement element, the bearing bracket engagement element, and the connector element are integral with each other.

4. The device of claim 2, where the shaft engagement element comprises at least one bolt.

5. The device of claim 4, where the bearing bracket engagement element comprises at least two bolts.

6. The device of claim 5, where the connector element comprises a plate.

7. The device of claim 2, where the bearing bracket includes a bearing assembly opening, and the bearing is part of a bearing assembly positioned in the bearing assembly opening.

5 8. A load-balancing method comprising:
providing a rotating machine having:

a shaft having an end and a shaft position;

a bearing bracket surrounding the shaft, the bearing bracket having an outer
surface and a bearing bracket position; and

10 a bearing surrounding the shaft;

fixing the shaft position relative to the bearing bracket position to achieve a fixed
shaft; and

moving the bearing along a portion of the fixed shaft.

15 9. The method of claim 8, where the rotating machine is capable of generating at least $\frac{1}{4}$
horsepower.

10. The method of claim 9, where the bearing bracket includes a bearing assembly
opening, the bearing is part of a bearing assembly positioned in the bearing assembly
20 opening, and the method further includes removing the bearing assembly from around the
shaft.

11. The method of claim 10, where the fixing includes:
contacting the end of the shaft with a shaft engagement element;

contacting the outer surface of the bearing bracket with a bearing bracket engagement element; and
connecting the shaft engagement element to the bearing bracket engagement element.

5 12. The method of claim 11, where the end of the shaft includes a flat surface and a recess extending into the shaft from the flat surface, and the contacting the end includes inserting a portion of the shaft engagement element into the recess.

10 13. The method of claim 12, where the contacting the bearing bracket includes inserting bolts into bolt openings in the bearing bracket.

14. The method of claim 13, where a rotor core surrounds the shaft, a stator core surrounds the rotor core, and the moving includes inserting jacking bolts into openings in the bearing assembly and tightening the jacking bolts until the bearing assembly is removed from
15 the bearing assembly opening; the method further comprising:

supporting the end of the shaft;

removing mounting bolts that hold the bearing assembly to the bearing bracket; and

lowering the shaft so as to cause the rotor core to contact the stator core.

20 15. A bearing removal device configured for use with a rotating machine having a shaft, a bearing bracket having a bearing assembly opening, a bearing assembly positioned in the bearing assembly opening, the bearing assembly including a bearing surrounding the shaft, the bearing removal device comprising:

a shaft contacting element configured to contact an end of the shaft;

a bearing assembly engagement element configured to engage the bearing assembly;
and

a connector element connecting the shaft contacting element to the bearing assembly engagement element;

5 where the shaft contacting element, the bearing bracket assembly engagement element, and the connector element are configured with respect to each other such that at least a portion of the connector element will be positioned outside the bearing assembly.

10 16. The device of claim 15, where the rotating machine is capable of producing at least $\frac{1}{4}$ horsepower.

17. The device of claim 16, where the shaft contacting element comprises at least one bolt.

15 18. The device of claim 17, where the bearing assembly engagement element comprises at least two bolts.

19. The device of claim 18, where the connector element comprises a plate.

20 20. The device of claim 15, where the bearing assembly includes:
an outer cap configured to contact the bearing bracket; and
an inner cap configured to contact the outer cap;

where the bearing is positioned between at least a portion of the outer cap and a portion of the inner cap; and
the bearing assembly engagement element is configured to engage the outer cap.

- 5 21. A method useful in removing a bearing from around a shaft comprising:
providing a rotating machine having:
a shaft having an end;
a bearing bracket surrounding the shaft, the bearing bracket having a bearing
assembly opening; and
10 a bearing assembly positioned in the bearing assembly opening, the bearing
assembly including a bearing surrounding the shaft; and
using a device that (a) causes the bearing assembly to move in a first direction and (b)
directs a force on the shaft in a second direction substantially opposite the first
direction.

- 15 22. The method of claim 21, where the rotating machine is capable of generating at least
¼ horsepower.

- 20 23. The method of claim 22, where the device includes:
a shaft contacting element configured to contact the end of the shaft;
a bearing assembly engagement element configured to engage the bearing assembly;
and
a connector element connecting the shaft contacting element to the bearing assembly
engagement element.

25

24. The method of claim 23, where the using includes:

engaging the bearing assembly with the bearing assembly engagement element so as

to cause the bearing assembly to move in the first direction; and

contacting the shaft with the shaft contacting element so as to direct the force on the

shaft in the second direction.

25. The method of claim 24, where the end of the shaft includes a flat surface and the contacting the shaft includes contacting the flat surface.

26. The method of claim 24, where the engaging the bearing assembly includes inserting bolts into bolt openings in the bearing assembly.

27. The method of claim 24, where a rotor core surrounds the shaft, a stator core surrounds the rotor core, and the engaging the bearing assembly includes inserting at least one jacking bolt into an opening in the connector element and tightening the jacking bolt until the bearing assembly moves in the first direction; the method further comprising:

supporting the end of the shaft;

removing mounting bolts that hold the bearing assembly to the bearing bracket; and

lowering the shaft so as to cause the rotor core to contact the stator core.

28. An apparatus comprising:

a bearing assembly configured to be positioned in a bearing assembly opening of a bearing bracket of a rotating machine, the bearing assembly including:

a rolling element bearing configured to surround a shaft of the rotating

machine;

an inner cap having a portion positioned on one side of the rolling element bearing;

an outer cap having a portion positioned on another side of the rolling element bearing; and

5 an insulation assembly configured to substantially insulate the rolling element bearing.

29. The apparatus of claim 28, where the rotating machine is capable of generating at least $\frac{1}{4}$ horsepower.

10 30. The apparatus of claim 29, where the insulation assembly is configured to substantially insulate the rolling element bearing from current having a frequency of at least 500 hertz.

15 31. The apparatus of claim 29, where the shaft has a terminal point and a middle, and the insulation assembly includes an inner insulating ring positioned between the rolling element bearing and the middle.

20 32. The apparatus of claim 31, where the inner insulating ring is made of glass cloth and resin.

33. The apparatus of claim 31, where the insulation assembly includes an insulated bushing having a portion positioned around at least a portion of the rolling element bearing.

25 34. The apparatus of claim 33, where the insulated bushing is made of glass cloth and resin.

35. The apparatus of claim 33, where the insulation assembly includes an outer insulating ring positioned nearing the terminal point of the shaft than is the inner insulating ring.

36. The apparatus of claim 35, where the outer insulating ring is a seal made of the same
5 material as the inner insulating ring.