

GROOVED STAVED BEARING ASSEMBLYBACKGROUND OF THE INVENTION

This invention relates to a bearing assembly and more particularly to a new and novel bearing assembly for use in supporting a water lubricated propeller shaft as in large naval ships. Bearing assemblies with elastomeric bearing elements are particularly suited for this purpose because of their excellent ability to withstand the effects of corrosive fluids and to abrasion resulting from particles of foreign matter carried in suspension in the sea water in which the shaft and bearing assembly operates. Such bearing assemblies with their elastomeric bearing elements have been made and are still being made with outer non-corrosive support or shell with a plurality of circumferentially evenly spaced elastomeric staves therein.

SUMMARY OF THE INVENTION

The present invention is directed to a novel bearing assembly utilizing an outer shell and a plurality of circumferentially spaced bearing elements in contact with the shaft, the bearing elements having transverse grooves or a hydrodynamic pattern provided therein to thereby reduce the bearing friction torque thus enhancing the performance of the bearing.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross sectional view of a bearing

assembly in accordance with the present invention.

Fig. 2 is an isometric view of a bearing stave in accordance with the present invention.

5 Figs. 3a-3b are isometric views of alternate embodiments for bearing material for use in a bearing assembly in accordance with the present invention.

Fig. 4 is a cross sectional view of a second embodiment of a bearing assembly in accordance with the present invention.

10

DETAILED DESCRIPTION

Referring now to Fig. 1, wherein a bearing assembly 210 in accordance with the present invention includes a housing 215 having three staves 240 provided around the radial inner portion thereof. Each stave 240 is held in place by a pair of elastomeric members 260. A rigid plate or bar 264 is disposed on top of each elastomeric member 260. A screw or bolt 266 extends through a clearance shaft (not shown) in each bar 264 and elastomeric member 260 and engages with threaded hole 267 in housing 215. Tightening screw 266 pulls rigid plate 264 toward housing 215, thereby compressing and deforming each elastomeric member 260 to expand sideways and put compression on each stave 240 and hold them in place.

25

Each stave 240 has a grooved bearing surface 241, a substantially flat back side 282 and is supported by one or more shims or pads 284, 286. Preferably, each stave

240 backside 282 is in contact with a top shim 284 comprised of a hard material, (such as metal, composite material or other hard plastic), which is supported by a bottom pad 286 comprised of a resilient or compressible material, (such as soft plastic, rubber or other elastomer). Flat backed staves are more economical to produce compared with round backed staves. Lower stave 240 supports drive shaft 223, and the two upper staves 240 tangentially engage the drive shaft 223 in cooperative action with the lower stave 240 to prevent extraneous flexing of the shaft 223.

Housing 215 is preferably made from a metallic structure such as brass, a plastic shell or a composite non-metallic structure. Housing 215 is most preferably comprised of fiberglass reinforced epoxy, with a glass content on the order of 70% by weight.

Staves 240 are preferably made from an elastomeric/plastic composite, such as that described in commonly owned US Patent 3,993,371 or a homogeneous slippery polymer alloy (SPA) such as is disclosed in US Patent 4,725,151 and 4,735,982, all of which are hereby fully incorporated herein by reference. SPA is a thermoplastic and a thermoset rubber compound, along with a smaller amount of a lubricant. SPA is a heterogeneous composition wherein the thermoplastic exists in a continuous phase and the thermoset is dispersed therein as a discontinuous phase. In other words a thermoplastic matrix is formed, having the thermoset compound and the

lubricant dispersed therein, as opposed to an admixture.

The thermoplastic compound can be any polymer which exhibits tough, low friction and good wear resistant properties. A specific group of such polymers are the various ultra high molecular weight polyethylenes (UHMWPE) which are known to the art as well as to the literature. Ultra high molecular weight polyethylene are generally classified as those having a weight average molecular weight of greater than 2.5 million, that is from about 3.0 million to about 7.0 million using the solution viscosity method. A desired range is from about 4 million to about 6.5 million with a preferred range being from about 5 million to about 6 million. Such polyethylene are commercially available from Hoechst Celanese Corporation under the name GUR 413.

The ultra high molecular weight polyethylene as well as other polymers generally suitable for use in the present invention typically have low friction properties such as a breakaway coefficient of static friction at 0 rpm of 0.25 or less, desirably 0.20 or less and preferably 0.15 or less. The desired thermoplastic material of the present invention also have a toughness as measured by a Izod notch impact test (ASTM D256) of 20 or greater and preferably of 30 or greater. However, unnotched test samples did not fail. The thermoplastic material of the present invention also have good wear resistance as measured by a sand slurry abrasion test. The sand slurry abrasion test is a test of Hoechst

Celanese Corporation wherein generally a test specimen (1" X 3" X 1/8") is rotated at 1200 RPM over a 24 hour period in a slurry containing 2 parts of water and 3 parts of sand.

5 An effective amount of the ultra high molecular polyethylene is utilized such that it forms a continuous phase in the SPA. Generally, the amount of a thermoplastic compound is sufficient to coat the thermoset rubber compound which generally exist in the
10 form of particles and more desirably an amount in excess of that required to coat the rubber particles. Based upon the total weight of the SPA, the amount of the thermoplastic often utilized is from about 25% to about 90% by weight, desirably from about 40% to about 75% by
15 weight and preferably from about 55% to about 65% by weight.

 The thermoset compound is a cured rubber compound which typically has low friction as well as good oil and water resistant properties. By "low friction" it is
20 meant that rubber bearings of a desired thickness range, when water lubricated, develop hydrodynamic lubrication at normal journal (shaft) operating speeds. Thin rubber bearings develop hydrodynamic friction at lower shaft speeds than any other known bearing material due to the
25 Plasto-Elastohydrodynamic effect. Hydrodynamic lubrication is the developing of a fluid film between the bearing and a rotating shaft. By the terms "oil and water resistant", it is meant that the elastomer is

unaffected (not dissolved or softened) and the volume increase caused by swell in water is under 5%, and preferably under 3%.

5 Generally any rubber compound having such friction and water resistant properties can be utilized. A specific group of such compounds are various nitrile rubbers which are known to the art and to the literature. For example, the various Hycar nitrile rubber compounds manufactured by the BFGoodrich Company can be utilized.

10 The various harder nitrile rubber compounds are generally preferred. A specific example of such a rubber is compound H-201 (85 +/- 5 Shore A hardness) manufactured by the BFGoodrich Company. Another example is a softer nitrile rubber such as compound H-203, also manufactured

15 by the BFGoodrich Company which has a Shore A hardness of about 65 ± 5 . Other rubbers include Butyl rubber, EPDM, that is rubber made from ethylene-propylene-diene monomers, and fluorelastomers based on the copolymer of vinylidene fluoride and hexafluoropropylene thought to

20 have the following repeating structure $-\text{CF}-\text{CH}-\text{CF}-\text{CF}(\text{CF})-$. Such copolymers are sold under the Trademark "Viton" by DuPont. Although these other rubber compounds can be utilized, the nitrile rubbers are highly preferred.

25 It is an important aspect of the present invention that the rubber compound can be initially dry blended or mixed with the thermoplastic compound before the alloy is formed.

Accordingly, the rubber compound is cured and in order to mix the two components, it is ground to a suitable size. Conventional grinding methods can be utilized such as mechanical or cryogenic grinding.

5 Particle size of the cured rubber compound is generally important. The particle size is generally measured as being finer, that is being able to pass through, a specific Tyler mesh screen. The cured rubber compounds thus generally have a particle size smaller than 35 mesh,
10 desirably smaller than 65 mesh, and preferably smaller than 100 mesh. The amount of the cured rubber in the SPA is generally from about 10% to about 70% by weight, desirably from about 12% to about 40% by weight and preferably from about 15% to about 30% by weight based
15 upon the total weight of the SPA.

The lubricant is generally added in the form of a solid and hence is non-liquid. In order to ensure a good dispersal thereof, the lubricant typically is in the form of a powder. By the term powder, it is meant that a
20 majority, and at least 70%, 80% or 90% and more desirably at least 95% of the particles are smaller than a Tyler 100 mesh screen, that is 150 microns. Desirably, a majority of the powder, typically 80%, 90%, or even 95% is smaller than 200 mesh, that is 75 microns. Preferably
25 a majority of the graphite powder, that is 70%, 80%, or 90% is smaller than 325 meshes, that is 44 microns. Any lubricant known to the art as well as to the literature can be utilized which imparts lubricating properties to

the SPA. By lubricating properties it is meant that the coefficient of friction of the surface of the formed SPA is reduced, as for example, on the order of at least 10% and more desirably at least 20% or 30% when wear starts.

5 The lubricant also should be nonabrasive. Graphite constitutes a preferred lubricant. An example of a specific graphite is grade 117-A, manufactured by Asbury Graphite Mills, Inc. Another specific lubricant is molybdenum disulfide. Although not generally preferred,
10 molybdenum disulfide is desirable in dry end use applications where moisture is not available, even as atmospheric moisture vapor. Silicone oils can also be utilized in an amount of from about 2% to about 10% by weight and desirably from about 3% to about 6% by weight
15 based upon the total weight of the SPA. Examples of specific silicone oils include 200 Fluid manufactured by Dow Corning.

The amount of the lubricant generally is from about 0.5% or 3% by weight to about 25% by weight, desirably
20 from about 1.0% to about 20% by weight, and preferably from about 2% to about 10% by weight based upon the total weight of the SPA.

To this end, it has been discovered that certain material factors for staves 240 are important. First,
25 hydrophobic materials are preferred. Second, the elastomer hardness should be about 70 shore A. Third, the ratio of journal diameter of the shaft to the top width of the stave should be about 4 to 7. Fourth, the

elastomer thickness should be about 0.125 inch to 0.312 inch. Fifth, the surface finish of the stave should be under 10 micro inches. Sixth, harder polymer alloy bearing contact material, such as the SPA material described above provides preferable wear and friction characteristics.

Elastomeric members 260 are preferably comprised of natural or nitrile rubber compounds, and are preferably 0.75 to 1.5 inches wide before compression. Rigid plates 264 are preferably comprised of a metal, such as stainless steel, or a hard plastic, such as fiber reinforced epoxy. The compressed elastomeric members 260 expand to grip the sides of the staves 240. They also distort around the ends of the staves to provide an axial locking feature.

Bottom pads 286 offer alignment capability. Top shim 284 is utilized to control the operating clearance between the bearing bore and the shaft 223 to eliminate the grinding of critical stave surface and to simplify the bearing renewal and replacement process. Each stave in a stave type bearing functions as an individual and independent bearing surface. The deflection capability of bearing 210 provides for a zero clearance bearing (ZCB). ZCB's are more stable because, among other things, the unloaded staves can be depressed by the rotating shaft 223 as it develops hydrodynamically pressurized lift-off pressure on the load carrying staves. Furthermore, gritty water stave wear in a ZCB

will be greatly reduced because the reverse flow particle rejection process is most efficient when the shaft (journal) is in contact with all of the staves (no unloaded clearance space). In a ZCB there is zero clearance between all of the staves and the shaft. In a conventional stave bearing designed with initial clearance, the side or top staves are unloaded with the shaft not touching them. The efficiency of the reverse flow particle rejection process is reduced with any clearance present, thereby causing wear of surfaces of the side or top staves. The grit particles pass through the clearance space instead of being rejected back, thereby flowing out through the water grooves.

The three staves are preferably located approximately 120° apart (angle A), with the two upper staves located approximately 30° (angle B) above horizontal line 280 and the lower stave located approximately 90° below horizontal 280.

Referring now to Fig. 2, wherein a stave 240 for the bearing 210 of Fig. 1 is illustrated. Staves 240 have a plurality of transverse grooves 290 provided therein and distributed along the axial length of the stave thereby leaving a plurality of lands or protrusions 241 protruding towards the axial centerline. The grooves may be either molded into the material or machined into the material, with machining the preferred method. The particular dimensions for the staves will differ for each application. For a stave on the order of 0.75 inches

thick, the grooves 290 are preferably on the order of 0.25 inches deep and 0.33 inches wide, with a separation between grooves of on the order of 1 inch. Machining grooves in the staves increases the amount of contact pressure in between grooves. The stave dimensions and groove dimensions must be picked such that the applied load is high enough for low friction and wear to occur, but the bulge ratio must be also low enough for the staves to adjust and form a lubricant trapping pocket.

Referring now to Fig. 3a-3b, wherein alternate embodiments for staves 240 is illustrated. The bearing material is molded in large flexible slabs. The material is molded and shaped against a plate or rough fabric with many protuberances lands, or contact points, 414, 424 wherein the protuberances can each individually become hydrodynamic bearing surfaces when fluid lubricated. The material is molded and shaped against a rough fabric (Fig. 3a) or plate with many protuberances. The molded staves consist of an elastomeric/plastic composite, such as that described in commonly owned US Patent 3,993,371 or most preferably a homogeneous slippery polymer alloy (SPA) such as is disclosed in US Patent 4,725,151 and 4,735,982, all of which are hereby fully incorporated herein by reference. The SPA bearing material layer is preferably on the order of 0.125 inches thick. It is then adhered during slab cure to a nitrile rubber backing sheet. The rubber backing makes the slab flexible, and when abraded, is easy to bond to the metal or composite

bearing housing using room temperature curing epoxy adhesives or contact cement. The rubber backing is rapidly and easily sanded or ground by means of a machine to give the correct overall slab thickness for the particular bearing size. The adhesive layer adds around 0.001 inches to the bearing total wall thickness. There is therefore no need to grind or machine the bearing surface. Grinding the bearing surface increases friction and wear. The full stave thickness is preferably 0.625 inches to 1.1 inches.

It is to be noted that the staves in Fig.s 3a-3b may be made completely from the aforementioned SPA material. That is, the staves 240 may not have a bottom layer 410 and therefore would be comprised of a single layer comprised of the material for layer 412.

Referring now to Fig.3a, an alternate stave material 240 may be manufactured by providing a patterned bottom layer 410 of elastomer in a mold. The preferred elastomer is catalog number H-201 available from the B.F.Goodrich Company. Next, a top layer 412 of slippery polymer alloy (SPA) is provided on the elastomer. A thermoplastic and a thermoset rubber compound, along with a smaller amount of a lubricant form the SPA. The SPA is a heterogeneous composition wherein the thermoplastic exists in a continuous phase and the thermoset is dispersed therein as a discontinuous phase. In other words a thermoplastic matrix is formed, having the thermoset compound and the lubricant dispersed therein,

as opposed to an admixture.

The thermoplastic compound can be any polymer which exhibits tough, low friction and good wear resistant properties. A specific group of such polymers are the various ultra high molecular weight polyethylenes (UHMWPE) which are known to the art as well as to the literature. Ultra high molecular weight polyethylene are generally classified as those having a weight average molecular weight of greater than 2.5 million, that is from about 3.0 million to about 7.0 million using the solution viscosity method. A desired range is from about 4 million to about 6.5 million with a preferred range being from about 5 million to about 6 million. Such polyethylene are commercially available from Hoechst Celanese Corporation under the name GUR 413.

The ultra high molecular weight polyethylene as well as other polymers generally suitable for use in the present invention typically have low friction properties such as a breakaway coefficient of static friction at 0 rpm shaft speed of 0.25 or less, desirably 0.20 or less and preferably 0.15 or less. The desired thermoplastic material of the present invention also have a toughness as measured by a Izod notch impact test (ASTM D256) of 20 or greater and preferably of 30 or greater. However, unnotched test samples did not fail. The thermoplastic material of the present invention also have good wear resistance as measured by a sand slurry abrasion test. The sand slurry abrasion test is a test of Hoechst

Celanese Corporation wherein generally a test specimen (1" X 3" X $\frac{1}{8}$ ") is rotated at 1200 RPM over a 24 hour period in a slurry containing 2 parts of water and 3 parts of sand.

5 An effective amount of the ultra high molecular polyethylene is utilized such that it forms a continuous phase in the SPA. Generally, the amount of a thermoplastic compound is sufficient to coat the thermoset rubber compound which generally exist in the
10 form of particles and more desirably an amount in excess of that required to coat the rubber particles. Based upon the total weight of the SPA, the amount of the thermoplastic often utilized is from about 25% to about 90% by weight, desirably from about 40% to about 75% by
15 weight and preferably from about 55% to about 65% by weight.

 The thermoset compound is a cured rubber compound which typically has low friction as well as good oil and water resistant properties. By "low friction" it is
20 meant that rubber bearings of a desired thickness range, when water lubricated, develop hydrodynamic lubrication at normal journal (shaft) operating speeds. Thin rubber bearings develop hydrodynamic friction at lower shaft speeds than any other known bearing material due to the
25 Plasto-Elastohydrodynamic effect. Hydrodynamic lubrication is the developing of a fluid film between the bearing and a rotating shaft. By the terms "oil and water resistant", it is meant that the elastomer is

unaffected (not dissolved or softened) and the volume increase caused by swell in water is under 5%, and preferably under 3%.

5 Generally any rubber compound having such friction and water resistant properties can be utilized. A specific group of such compounds are various nitrile rubber compounds which are known to the art and to the literature. For example, the various nitrile rubber compounds manufactured by the BFGoodrich Company can be
10 utilized. The various harder nitrile rubber compounds are generally preferred. A specific example of such a rubber is compound H-201 (85 ± 5 Shore A hardness) manufactured by the BFGoodrich Company. Another example
15 is a softer nitrile rubber such as compound H-203, also manufactured by the BFGoodrich Company which has a Shore A hardness of about 65 ± 5 . Other rubbers include Butyl rubber, EPDM, that is rubber made from ethylene-propylene-diene monomers, and fluorelastomers based on the copolymer of vinylidene fluoride and
20 hexafluoropropylene thought to have the following repeating structure $-CF -CH -CF -CF(CF)-$. Such copolymers are sold under the Trademark "Viton" by DuPont. Although these other rubber compounds can be utilized, the nitrile rubbers are highly preferred.

25 It is an important aspect of the present invention that the cured rubber compound can be initially easily dry blended or mixed with the thermoplastic compound before the alloy is formed.

Accordingly, the rubber compound is cured and in order to mix the two components, it is ground to a suitable size. Conventional grinding methods can be utilized such as mechanical or cryogenic grinding.

5 Particle size of the cured rubber compound is generally important. The particle size is generally measured as being finer, that is being able to pass through, a specific Tyler mesh screen. The cured rubber compounds thus generally have a particle size smaller than 35 mesh,
10 desirably smaller than 65 mesh, and preferably smaller than 100 mesh. The amount of the cured rubber in the SPA is generally from about 10% to about 70% by weight, desirably from about 12% to about 40% by weight and preferably from about 15% to about 30% by weight based
15 upon the total weight of the SPA.

The lubricant is generally added in the form of a solid and hence is non-liquid. In order to ensure a good dispersal thereof, the lubricant typically is in the form of a powder. By the term powder, it is meant that a
20 majority, and at least 70%, 80% or 90% and more desirably at least 95% of the particles are smaller than a Tyler 100 mesh screen, that is 150 microns. Desirably, a majority of the powder, typically 80%, 90%, or even 95% is smaller than 200 mesh, that is 75 microns. Preferably
25 a majority of the graphite powder, that is 70%, 80%, or 90% is smaller than 325 meshes, that is 44 microns. Any lubricant known to the art as well as to the literature can be utilized which imparts lubricating properties to

the SPA. By lubricating properties it is meant that the coefficient of friction of the surface of the formed SPA is reduced, as for example, on the order of at least 10% and more desirably at least 20% or 30% when wear starts.

5 The lubricant also should be nonabrasive. Graphite constitutes a preferred lubricant. An example of a specific graphite is grade 117-A, manufactured by Asbury Graphite Mills, Inc. Another specific lubricant is molybdenum disulfide. Although not generally preferred,

10 molybdenum disulfide is desirable in dry end use applications where moisture is not available, even as atmospheric moisture vapor. Silicone oils can also be utilized in an amount of from about 2% to about 10% by weight and desirably from about 3% to about 6% by weight

15 based upon the total weight of the SPA. Examples of specific silicone oils include 200 Fluid manufactured by Dow Corning.

The amount of the lubricant generally is from about 0.5% or 3% by weight to about 25% by weight, desirably

20 from about 1.0% to about 20% by weight, and preferably from about 2% to about 10% by weight based upon the total weight of the SPA.

Next, a pattern is transferred into the top layer of the bearing surface of bearing material 22. The

25 preferred method of transferring this pattern is to place a polyester sheet between a piece of heavy, loose knit or loose weave fabric which presses the polyester sheet and fabric into the surface of SPA bearing material 22 before

melting and molding takes place. The fabric is preferably catalog no. 8708 available from Georgia Duck. The polyester release sheet is preferably 0.003 inch thick Mylar. The polyester sheet smooths out the resultant SPA layer and rounds the edges so the protuberances, lands, or contact points 414 can each individually become hydrodynamic bearing surfaces when fluid lubricated. It is to be noted that prior to pressing the polyester and fabric into the material, the fabric should be sprayed with a mold release, such as catalog no. RTC 9110, manufactured by Chem-Trend, in a manner well known in the art to ensure the fabric can be removed after curing. After the fabric and polyester sheet have been placed on top of the uncured bearing section it should be pressed in, such as by closing the mold. The material is then cured for approximately 4.5 hrs. under pressure of approximately 1000 to 1500 psi at approximately 350°F. After this curing process, the temperature of the mold is allowed to return to ambient while the pressure is maintained. The mold should be allowed to cool down for approximately 1 hr. after curing. It has been found that cooling the composite under pressure helps to prevent warping of the final article. Application of water to the outside of mold may also be utilized to reduce the mold cooling time to 1 hour to prevent warping of the finished product.

Referring now to Fig. 3b, an alternate bearing material may be manufactured in accordance with the

procedure for the composite illustrated in Fig. 3a, thereby yielding a composite having a bottom layer 420 of elastomer and a top layer 422 of SPA having diamond shaped protuberances, lands, or contact points 424 provided therein. The protuberances 424 protrude axially inward and can each individually become hydrodynamic bearing surfaces when fluid lubricated. The diamond shaped pattern in the top layer 422, however, is provided by utilizing a rubber mold having the appropriate impression or pattern provided therein. A polyester sheet, such as Mylar, may be placed between the rubber mold and the SPA before curing. The polyester sheet is preferably on the order of 0.003 inches thick. The polyester sheet smooths out the resultant SPA layer and rounds the corners of the protuberances.

It is to be noted that other shape and size patterns not specifically disclosed herein maybe provided in the top alloy layer in order for the bearing to be hydrodynamic.

Referring now to Fig. 4, wherein a bearing assembly 310 in accordance with an alternate embodiment of the present invention is generally similar to the bearing assemblies illustrated hereinbefore in the previous figures and is thus indicated by reference numerals corresponding to those discussed above, except that a 300 "prefix" is utilized.

A housing 315 has three staves or lands 340 provided around the radial inner portion thereof. Staves 340 are

formed as a unitary or integral inner housing or lining 390, which is preferably made from the SPA elastomeric/plastic composite described hereinbefore. Housing 315 is preferably made from the housing materials also described hereinbefore. Lining 390 is preferably manufactured in the manner described in U.S. Patent No. 4,735,982 referenced hereinbefore, and installed in the housing 315 while it is still hot from the transfer molding process. Lining 390 is attached to the housing preferably utilizing an adhesion promoter and cross-linking agent, such as Vanchem HM-50 available from R.T.Vanderbilt Co.. The prime advantage of this adhesive over others is it's hot strength. Other attachment means, however, may be utilized to secure the lining into the housing.

The length to diameter ratio (L/D) of prior elastomer landed stave type bearings is required to be on the order of four to one for wear and life reasons. Bearing 310 permits much lower L/D, possibly on the order of two to one or even one to one, thereby reducing manufacturing costs. Also, lining 390 is relatively simple to manufacture and alleviates the need for machine finishing of the bore of housing 315. The bearing surface 341 of each land 340 has either grooves or a pattern provided therein in accordance with the staves shown and described hereinbefore in Figs. 2 and 3a-3c.

It will be apparent that, although a specific embodiment and a certain modification of the invention

has been described in detail, the invention is not limited to the specifically illustrated and described constructions since variations may be made without departing from the principles of the invention.

CLAIMS

1. A bearing assembly for holding a shaft comprising:

an outer shell having a central opening with a
5 central axis and an inner surface defined by said central
opening; and,

a plurality of staves disposed on said inner surface
for contacting and supporting the shaft, said staves
having transverse grooves provided therein.

10

This Sheet Has Been Replaced

* C L M S *