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STEP BEARING

DESCRIPTION

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The invention relates to bearings for the rotors of electrical motors or magnetic couplings driven by a motor, which have spherical magnetic air gaps between a driven rotor and a driving stator or driving outer magnetic ring. Such spherical motors or spherical magnetic couplings are becoming more and more important in modern pump design. The rotors or spherical motors or couplings are held in position by magnetic forces pressing the rotor against a stationary mounted ball.

10 The impellers of pumps which form a unit with the driven rotor produce hydraulic thrust counteracting the magnetic thrust. When the electricity is switched off, the magnetic force of the drive stator ceases immediately. In contrast, the hydraulic thrust, caused by the difference of pressure between the suction side of the impeller and its backside, generated by the rotation, slowly decreases with decreasing rpm of the impeller. This results in these hydraulic forces

tending to lift the impeller with the rotor away from the step bearing after switching the electricity off. The same change in the direction of the axial thrust occurs in magnetic couplings, if the hydraulic forces can exceed the magnetic forces during operation. Therefore it is necessary to support the rotor, not only in the direction of the magnetic forces during constant operation but also to prevent movement in the opposite direction by a ring-shaped, rotating annular member. Spherical bearings consisting of a cap and a ball made from metal are known. Metal balls can be brazed on the tip of a strut. Unfortunately, metal bearings have the tendency to seize when dry friction causes very small fractions of the surface to reach the melting temperature of the metal causing the cap and the ball to fuse together. Cylindrical bearings produce a film of lubricating liquid which, by hydrodynamic principle, generate high dynamic forces preventing contact between the two members of the bearing. Spherical bearings do not build up such liquid film and therefore, run either dry or semi-dry. Consequently, the probability of seizing is much larger in spherical bearings than in cylindrical bearings.

This is the reason that metal balls have been replaced by balls made from ceramic materials such as aluminum oxide, zirconium oxide or silicon carbide. The melting point of these oxides is so high that it will never be reached by heat of friction; the same applies to silicon carbide, which in addition sublimates as it has no melting point at all.

The disadvantage of ceramic balls is that the ball can be neither welded nor brazed onto the strut. It is known to the art to pressfit the ball into a hollow strut by pressing the ball into a hole slightly deeper than the radius of the ball, resulting in a useable surface smaller than a hemisphere. These bearings with ceramic balls act only as a step bearing because they can only bear the axial forces in one direction. This restricts their application to spherical rotors in applications where under no circumstances hydraulic forces will not exceed the magnetic forces under any circumstances.

The invention overcomes this restriction in the application of ceramic balls. It relates to spherical bearings having a second annular bearing member.

5 According to a first aspect of the present invention there is provided a centrifugal pump-motor assembly comprising: an impeller having a magnetically interactive rotor; a driving unit for generating a rotating magnetic field for driving the impeller; a
10 bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the impeller; a support member attached to a stationary part of the assembly for supporting the ceramic ball; a magnetically permeable wall, separating the rotor from
15 the driving unit; and means for restraining motion of the concave surface away from the convex surface; wherein the ceramic ball is partially encompassed by a metal shell and the shell is fixed to the support member.

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According to a second aspect of the present invention there is provided a centrifugal pump-motor assembly comprising: an impeller having a magnetically

interactive rotor; a driving unit for generating a rotating magnetic field for driving the impeller; a bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the impeller; a support member attached to a stationary part of the assembly for supporting the ceramic ball; a magnetically permeable wall, separating the rotor from the driving unit; and means for restraining motion of the concave surface away from the convex surface; wherein the ceramic ball has a flattened portion with a stem extending therefrom, and the ceramic ball is retained on the support member by press-fitting the stem into a complementary hole in the support member.

According to a third aspect of the present invention there is provided a centrifugal pump-motor assembly comprising: an impeller having a magnetically interactive rotor; a driving unit for generating a rotating magnetic field for driving the impeller; a bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the impeller; a support member attached to a stationary part of the assembly for supporting the ceramic ball; a

magnetically permeable wall, separating the rotor from the driving unit; and means for restraining motion of the concave surface away from the convex surface; wherein the ceramic ball has a flattened portion with a stem extending therefrom, and a collar element has a hole receiving the stem and a lug press-fitted into a hole in the support member, the collar element being shaped such that the surface of the collar element is an extension of the convex surface of the ceramic ball.

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According to a fourth aspect of the present invention there is provided a centrifugal pump-motor assembly comprising: an impeller, having a magnetically interactive rotor; a driving unit for generating a rotating magnetic field for driving the impeller; a bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the impeller; a support member attached to a stationary part of the assembly for supporting the ceramic ball; a magnetically permeable wall, separating the rotor from the driving unit; and means for restraining motion of the concave surface away from the convex surface; wherein the ceramic ball has an axial annular groove

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therein and the support member has a tubular end portion of polygonal cross-section received into the annular groove.

- 5 According to a fifth aspect of the present invention there is provided a centrifugal pump-motor assembly comprising: an impeller, having a magnetically interactive rotor; a driving unit for generating a rotating magnetic field for driving the impeller; a
10 bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the impeller; a support member attached to a stationary part of the assembly for supporting the ceramic ball; a magnetically permeable wall, separating the rotor from
15 the driving unit; and means for restraining motion of the concave surface away from the convex surface; wherein the support member includes a tubular portion, an axial extremity of which defines a rim, the ceramic ball has a hole therethrough and a screw extends
20 through the hole into the tubular portion whereby the ball is pressed against the rim.

According to a sixth aspect of the present invention there is provided a centrifugal pump-motor assembly comprising: an impeller, having a magnetically interactive rotor; a driving unit for generating a rotating magnetic field for driving the impeller; a bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the impeller; a support member attached to a stationary part of the assembly for supporting the ceramic ball; a magnetically permeable wall, separating the rotor from the driving unit; and means for restraining motion of the concave surface away from the convex surface; wherein the ceramic ball has a hole therethrough accomodating a screw, the support member includes a rod-like portion, having an end face in which a substantially conical depression defines a seat for the ball, and the ball is retained in the seat by means of the screw.

20 According to a seventh aspect of the present invention there is provided a centrifugal pump-motor assembly comprising: an impeller, having a magnetically interactive rotor; a driving unit for generating a

rotating magnetic field for driving the impeller; a bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the impeller; a support member attached to a stationary part of the assembly for supporting the ceramic ball; a
5 magnetically permeable wall, separating the rotor from the driving unit; and means for restraining motion of the concave surface away from the convex surface; wherein the ceramic ball has a radial blind bore
10 therein, and a rod-shaped member located in the bore fixedly attaches the ball to the support member.

According to a eighth aspect of the present invention there is provided a centrifugal pump-motor assembly
15 comprising: an impeller, having a magnetically interactive rotor; a driving unit for generating a rotating magnetic field for driving the impeller; a bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the
20 impeller; a support member attached to a stationary part of the assembly for supporting the ceramic ball; a magnetically permeable wall, separating the rotor from the driving unit; and means for restraining motion of

the concave surface away from the convex surface; wherein a bolt is attached at one end to the ball, a spring member is attached to the other end of the bolt and retained by the support member, and a bearing ring is attached to the rotating part of the assembly and has an aperture smaller than the diameter of the ball and larger than the diameter of the concave surface, the bearing ring shaped and positioned to form a bearing against axial forces acting in a direction away from the support member.

According to a ninth aspect of the present invention there is provided a method of producing a centrifugal pump-motor assembly comprising: an impeller having a magnetically interactive rotor; a driving unit for generating a rotating magnetic field for driving the impeller; a bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the impeller; a support member attached to a stationary part of the assembly for supporting the ceramic ball; a magnetically permeable wall, separating the rotor from the driving unit; and means for restraining motion of the concave surface away from the convex surface; wherein the ceramic ball has a flattened portion with a stem extending therefrom, the ceramic ball is retained on the support member by press fitting the stem into a complimentary hole in the support member and the support member is provided with an annular shoulder, about the complimentary hole, so shaped that when the ball is mounted on the support member, a surface of the shoulder becomes an extension of the convex surface of the ball; said method including the production of a bearing from a support member billet, a ceramic ball and a stem attached to

the ball, comprising:

(a) grinding a recess on one hemisphere of the ball having a radius shorter than the radius of the ball;

5 (b) deep drawing the support member billet in the form of a body of rotation with a hollow cylindrical end portion, whereby the inner diameter of said end portion is slightly smaller than the diameter of the stem;

10 (c) bending a rim of the end portion outwardly forming a flange;

(d) slightly increasing the inner diameter of the end portion at both sides of a remaining ring portion forming an annular shoulder;

15 (e) driving the stem attached to the ball through the shoulder until the axial surface of the flange sits on the surface of the ball; and

(f) machining the outer surface of the flange so that it becomes spherically shaped whereby the spherically shaped surface matches the sphere of the ball.

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Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

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Figure 1 is a cross-section of a pump with a magnetic coupling;

Figure 2 shows an enlarged design of the bearing with a shell;

30 Figure 3 shows an alternative way to fasten the shell to a strut;

Figure 4 shows a cross-section of a pump whereby the

ball has a groove;

Figures 5 and 6 show designs of balls with a stem;

Figure 7 shows a design with a ball having a hole;

Figures 8a and 8b show a ball with an axial groove;

5 Figure 9 shows a ball with a hole forming a slight undercut;

Figure 10 shows a ball screwed to a strut

Figures 11a and 11b show a variant of Figure 10 with a nut in a hole;

10 Figures 12a and 12b show a variant of Figure 10 with a nut positioned in a slot;

Figure 13a and 13b show a variant of Figure 10 with a nut in a hole;

15 Figure 14 shows a design with a ball being springloaded by a spring washer; and

Figure 15 shows a similar design as in Figure 14 with a screw type spring.

20 Figure 1 illustrates a cross section through a centrifugal pump with a housing 1, having an outlet opening 2 and inlet opening 3. The duct 4 leads fluid to the eye region 5 of the impeller 6. The impeller 6 with the veins 7 and the convex magnet 8 forms a

rotating unit. This rotating unit is driven by the concave magnet 9 mounted on the shaft 10 of the motor 11. Between the convex magnet 8 and the concave magnet 9 lies the separation wall 12 which separates the wet compartment 13 from the dry compartment 14. The rotating impeller-magnet unit 6, 7, 8 is attracted by magnetic forces in the direction of the arrow 15. The step bearing is formed by the rotating cap 16 and the stationary ball 17. The cap is part of the rotating impeller-magnet unit. The ball is fixed on strut 18 which forms a part of the separation wall. Annular bearing member 19 made from slightly elastic material prevents movement of the rotating unit in the direction opposite to arrow 15. Instead of a rotating concave magnet 9, a stationary stator with windings can also produce a rotating magnetic field. The convex magnet 8 will then be substituted by a convex armature.

Figure 2 shows an enlargement of the region encircled by circle II in Figure 1. The ball is encased by a shell 20. The rim 21 of said shell slightly overlaps the equator 22. The spherical ring portion 23 of the ball 17 forms the gliding surface with the concave

region of the cap 24. The shell 20 has a spherical surface 25 forming a narrow clearance 26 with the annular bearing member 19. If the rotating unit 6, 7, 8 starts to move in the direction opposite to arrow 15, the annular bearing member 19 gets in sliding contact with the spherical outer surface of the shell 20. The shell 20 has a protrusion 28 which is fixed to the strut by snap action or brazing. Alternatively the protrusion 28 itself could form the strut.

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Figure 3 shows a different design whereby the shell 30 forms a semi-spherical body. This body is fixed to the struct 18' by brazing material 29.

15 Figure 4 shows a spherical pump motor unit with inlet opening 40, outlet opening 43 forming together with space 42 the wet part of the pump motor unit. Magnetically permeable separation wall 44 encases together with the flange portion 45 and the pump housing 46 said wet compartment. The impeller 47 with veins 48 and armature 49 form a rotating unit. The hub portion 50 of the impeller 47 contains the bearing cap 51. This cap and stationary ball 52 make up the step

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bearing. The ball 52 has a circular groove 53. The rim 54 of the stationary mounted shell 55 is slightly bent inward entering groove 53. The shell 55 is mounted on a strut 57. The cap 51 reaches beyond the equator 56.

Figure 5 shows the end portion of strut 58, consisting of a hollow body made of stainless steel sheet metal. Said strut 58 has a collar 59 which defines the seat of the annular axial surface 60 of the ball 61 produced by grinding. The inner part of the ground portion forms a stem 62. The inner diameter 63 of the strut is slightly larger than the stem 62, except in the region of the annular shoulder 64. This shoulder 64 holds the stem 62 by pressfit. The periphery of the collar 59 has a spherical configuration, matching the sphere of the ball 61. The larger diameter of said collar 59 is identical with the diameter of the ball 61 or preferably slightly smaller so that the surface 60 has a slight axial distance from the equator 66. The smaller diameter of the collar 59 matches the inner diameter of the annular member 19 shown in Figures 1

and 2. The method to produce the device consists of the following steps:

- 5 a) by a grinding process, a recess on one hemisphere of the ball 61 is produced, by which process a stem 62 is formed, its length being shorter than the radius of the ball,
- 10 b) a strut 58 in the form of a body of rotation with a hollow cylindrical end portion is produced by a deep drawing process, whereby the inner diameter of said end portion is slightly smaller than the diameter of the stem 62,
- 15 c) the rim of said end portion is bent outwardly forming a flange 67a,
- d) the inner diameter of said end portion is slightly increased at both side of an annular should 64,
- e) the stem 62 of the ball 61 is driven through said shoulder 64 until the axial surface of the flange 67a sits on the flat annular surface 60 of the ball 61,
- 20 f) by tool machining for removal of chips, the outer surface 59 of the collar 67a becomes spherically shaped whereby the sphere matches the sphere of the ball 61.

Figure 6 shows the same ball configuration, but between the strut 58a and the ball 61a a body of rotation 68 forming a collar member is arranged, which is held by pressfit in a hole of the strut 58a. The stem 62a of the ball 61a is held by pressfit in the hole 64a of the body of rotation 68.

Figure 7 shows a ball 71 with a blind end bore 77. The base around the blind end bore 77 rests on the upper rim 74 of the strut 72. A screw 73 is used as a fixture. The outer diameter of said screw 73 is slightly larger than the diameter of the hole. This results in high friction forces. The screw 73 is preferably lubricated with a viscous lubricant. After mounting the lubricant evaporates under heat treatment. It is also anticipated to use a two component resin such as epoxy which hardens and provides high shear forces. To prevent contact between the epoxy and the liquid to be conveyed an O-ring 75 will be placed into a groove. The screw 73 may be hollow.

Figure 8a shows a ball 91 with an axial annular groove 97. The end portion 93 of the struct 92 is formed as a hexagon providing high friction on the surface of the stem 98.

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Figure 8b shows a cross-section through plane C-C in Figure 8a.

Figure 9 shows a ball 111 with a blind end bore having a slight undercut, its blind end bore in the region 117 being wider than the opening 119. The hole will be filled with hot metal. The metal body 118 will then be brazed to the end of the strut 112.

15 Figure 10 shows a ball with a bore hole and a widened resess for the screw head. The strut 81 has a conical end portion with an opening angle equal or smaller than the complement angle to be angle 82 which matches the angle of the tangents 83. The screw 66 fits into the screw hole 85 and the ball is pressed against the rim 84.

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Figure 11a shows a variation of the design in Figure 10, whereby a nut 88a is pressed into a hole 100 to hold the screw 86b.

5 Figure 11b shows the view of the strut from above.

Figure 12a shows a strut with a slot 87, its width matching the width of the nut 88, holding the screw 86a.

10 Figure 12b shows a cross-section along the line A-A in Figure 12a.

Figure 13a shows a similar design whereby the nut 88b is placed inside a hole 89. The screw head rests on an annular plane 113.

Figure 13b shows a cross-section through line B-B in Figure 13a.

20 Figure 14 shows a cross-section through a strut 115 with a tapering end portion 116. The ball 117 rests on the rim 118. The ball is pressed against this rim 118

by the forces of a prestressed spring washer 119, which forces are transmitted to the ball 117 by a screw 120 and the nut 121. The direction of rotation to fasten said screw 120 is identical to the direction of rotation of the bearing cap 122 which is also held in position by the bearing ring 123.

In the case of exorbitant forces acting on the ball 117, as may happen if a pump is dropped, the ball moves away from the rim 118 and the spring washer 119 gives way. Immediately thereafter the ball snaps back into the operation position and will be centered by the rim 118.

Figure 15 shows a similar design as in Figure 14, suitable for cylindrical struts 125 which have a tapering rim portion 126. The spring 127 is formed as a screw type spring, supported by three latches 128, which are bent inwardly.

CLAIMS

1. A centrifugal pump-motor assembly comprising:
an impeller having a magnetically interactive rotor;
5 a driving unit for generating a rotating magnetic field
for driving the impeller;
a bearing including a ceramic ball having a convex
surface which cooperates with a concave surface on the
impeller;
10 a support member attached to a stationary part of the
assembly for supporting the ceramic ball;
a magnetically permeable wall, separating the rotor
from the driving unit; and
means for restraining motion of the concave surface
15 away from the convex surface;
wherein the ceramic ball is partially encompassed by a
metal shell and the shell is fixed to the support
member.
- 20 2. A centrifugal pump-motor assembly according to
claim 1, wherein the shell encompasses more than half
of the surface of the ball.



* C L H S *

3. A centrifugal pump-motor assembly according to claim 1, wherein the ball is retained within the shell by means of a circular groove about the ball between the equator of the ball and the support member into
5 which the edge of the shell is turned.

4. A centrifugal pump-motor assembly comprising:
an impeller having a magnetically interactive rotor;
a driving unit for generating a rotating magnetic field
10 for driving the impeller;
a bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the impeller;
a support member attached to a stationary part of the
15 assembly for supporting the ceramic ball;
a magnetically permeable wall, separating the rotor from the driving unit; and
means for restraining motion of the concave surface away from the convex surface;
20 wherein the ceramic ball has a flattened portion with a stem extending therefrom, and the ceramic ball is retained on the support member by press-fitting the stem into a complementary hole in the support member.



5. A centrifugal pump-motor assembly according to claim 4, wherein the support member is provided with an annular shoulder, about the complementary hole, so shaped that when the ball is mounted on the support member, a surface of the shoulder becomes an extension of the convex surface of the ball.

6. A centrifugal pump-motor assembly comprising:
an impeller having a magnetically interactive rotor;
a driving unit for generating a rotating magnetic field for driving the impeller;
a bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the impeller;
a support member attached to a stationary part of the assembly for supporting the ceramic ball;
a magnetically permeable wall, separating the rotor from the driving unit; and
means for restraining motion of the concave surface away from the convex surface;
wherein the ceramic ball has a flattened portion with a stem extending therefrom, and a collar element has a hole receiving the stem and a lug press-fitted into a



hole in the support member, the collar element being shaped such that the surface of the collar element is an extension of the convex surface of the ceramic ball.

- 5 7. A centrifugal pump-motor assembly comprising:
an impeller, having a magnetically interactive rotor;
a driving unit for generating a rotating magnetic field
for driving the impeller;
a bearing including a ceramic ball having a convex
10 surface which cooperates with a concave surface on the
impeller;
a support member attached to a stationary part of the
assembly for supporting the ceramic ball;
a magnetically permeable wall, separating the rotor
15 from the driving unit; and
means for restraining motion of the concave surface
away from the convex surface;
wherein the ceramic ball has an axial annular groove
therein and the support member has a tubular end
20 portion of polygonal cross-section received into the
annular groove.



8. A centrifugal pump-motor assembly comprising:
an impeller, having a magnetically interactive rotor;
a driving unit for generating a rotating magnetic field
for driving the impeller;
- 5 a bearing including a ceramic ball having a convex
surface which cooperates with a concave surface on the
impeller;
a support member attached to a stationary part of the
assembly for supporting the ceramic ball;
- 10 a magnetically permeable wall, separating the rotor
from the driving unit; and
means for restraining motion of the concave surface
away from the convex surface;
- wherein the support member includes a tubular portion,
15 an axial extremity of which defines a rim, the ceramic
ball has a hole therethrough and a screw extends
through the hole into the tubular portion whereby the
ball is pressed against the rim.
- 20 9. A centrifugal pump-motor assembly according to
claim 8, wherein the screw cooperates with a
prestressed spring, located within the support member,
thereby urging the ball against the rim.



10. A centrifugal pump-motor assembly according to claim 9, wherein the support member comprises a cylindrical portion and a tapering portion extending coaxially therefrom, the spring is of the washer type and is retained within the cylindrical portion of the support member, and the rim is defined by the smaller diameter axial extremity of the tapering portion of the support member.

10 11. A centrifugal pump-motor assembly comprising:
an impeller, having a magnetically interactive rotor;
a driving unit for generating a rotating magnetic field for driving the impeller;
a bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the
15 impeller;
a support member attached to a stationary part of the assembly for supporting the ceramic ball;
a magnetically permeable wall, separating the rotor
20 from the driving unit; and
means for restraining motion of the concave surface away from the convex surface;
wherein the ceramic ball has a hole therethrough



accomodating a screw, the support member includes a rod-like portion, having an end face in which a substantially conical depression defines a seat for the ball, and the ball is retained in the seat by means of the screw.

12. A centrifugal pump-motor assembly according to claim 11, wherein the screw is also held by an nut located in a hole within and extending perpendicular to the rod-like portion.

13. A centrifugal pump-motor assembly comprising:
an impeller, having a magnetically interactive rotor;
a driving unit for generating a rotating magnetic field for driving the impeller;
a bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the impeller;
a support member attached to a stationary part of the assembly for supporting the ceramic ball;
a magnetically permeable wall, separating the rotor from the driving unit; and
means for restraining motion of the concave surface



away from the convex surface;

wherein the ceramic ball has a radial blind bore therein, and a rod-shaped member located in the bore fixedly attaches the ball to the support member.

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14. A centrifugal pump-motor assembly according to claim 13, wherein the rod-shaped member is a screw, the head of the screw being inside the support member.

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15. A centrifugal pump-motor assembly according to claim 14, wherein the screw is hollow.

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16. A centrifugal pump-motor assembly according to claim 13, wherein the screw is glued within the blind bore whereby a water tight seal is arranged between the ball and the support member.

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17. A centrifugal pump-motor assembly according to claim 13, wherein the rod-shaped member is brazed onto the support member.



18. A centrifugal pump-motor assembly comprising:
- an impeller, having a magnetically interactive rotor;
- a driving unit for generating a rotating magnetic field for driving the impeller;
- 5 a bearing including a ceramic ball having a convex surface which cooperates with a concave surface on the impeller;
- a support member attached to a stationary part of the assembly for supporting the ceramic ball;
- 10 a magnetically permeable wall, separating the rotor from the driving unit; and
- means for restraining motion of the concave surface away from the convex surface;
- wherein a bolt is attached at one end to the ball, a
- 15 spring member is attached to the other end of the bolt and retained by the support member, and a bearing ring is attached to the rotating part of the assembly and has an aperture smaller than the diameter of the ball and larger than the diameter of the concave surface,
- 20 the bearing ring shaped and positioned to form a bearing against axial forces acting in a direction away from the support member.



19. A centrifugal pump-motor assembly according to any preceding claim wherein the support body is a strut.

20. A method of producing a centrifugal pump-motor assembly according to claim 5, including production of a bearing from a support member billet, a ceramic ball and a stem attached to the ball, comprising:

(a) grinding a recess on one hemisphere of the ball having a radius shorter than the radius of the ball;

(b) deep drawing the support member billet in the form of a body of rotation with a hollow cylindrical end portion, whereby the inner diameter of said end portion is slightly smaller than the diameter of the stem;

(c) bending a rim of the end portion outwardly forming a flange;

(d) slightly increasing the inner diameter of the end portion at both sides of a remaining ring portion forming an annular shoulder;

(e) driving the stem attached to the ball through the shoulder until the axial surface of the flange sits on the surface of the ball; and

(f) machining the outer surface of the flange so



that it becomes spherically shaped whereby the spherically shaped surface matches the sphere of the ball.

- 5 21. A centrifugal pump-motor assembly substantially as hereinbefore described with reference to the accompanying drawings.
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