United States Patent [19]

Vranish

[54] **MECHANICAL SPIN BEARINGS**

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[52] **U.S. Cl.** **384/565**; 384/44; 384/568; 384/569; 384/573

[58] **Field of Search** 384/44, 56, 565, 384/568, 548, 550, 569, 618, 619, 571, 573

[56] **References Cited**

U.S. PATENT DOCUMENTS

1,220,345	3/1917	Koster	384/571
2,266,888	12/1941	McCurdy et al.	384/550
3,734,584	5/1973	Studer	384/565
4,040,689	8/1977	Stanley	384/550

FOREIGN PATENT DOCUMENTS

750031	12/1944	Germany	384/548
2908787	9/1980	Germany	384/568
1319591	6/1973	United Kingdom	384/550

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[57] **ABSTRACT**

A spin bearing assembly including, a pair of mutually opposing complementary bearing support members having mutually spaced apart bearing support surfaces which may be, for example, bearing races and a set of spin bearings located therebetween. Each spin bearing includes a pair of end faces, a central rotational axis passing through the end faces, a waist region substantially mid-way between the end faces and having a first thickness dimension, and discrete side surface regions located between the waist region and the end faces and having a second thickness dimension different from the first thickness dimension of the waist region and wherein the side surface regions further have respective curvilinear contact surfaces adapted to provide a plurality of bearing contact points on the bearing support members.

19 Claims, 10 Drawing Sheets
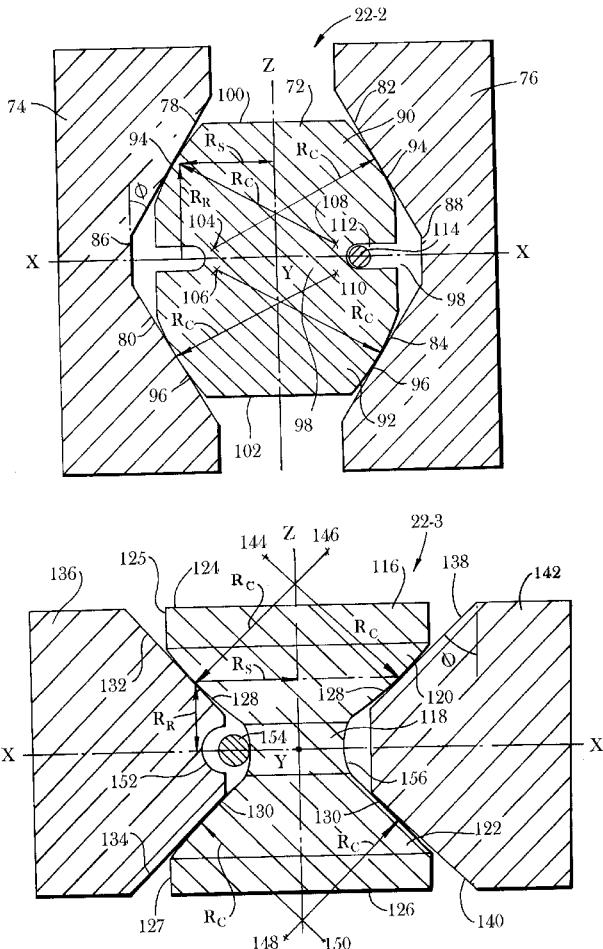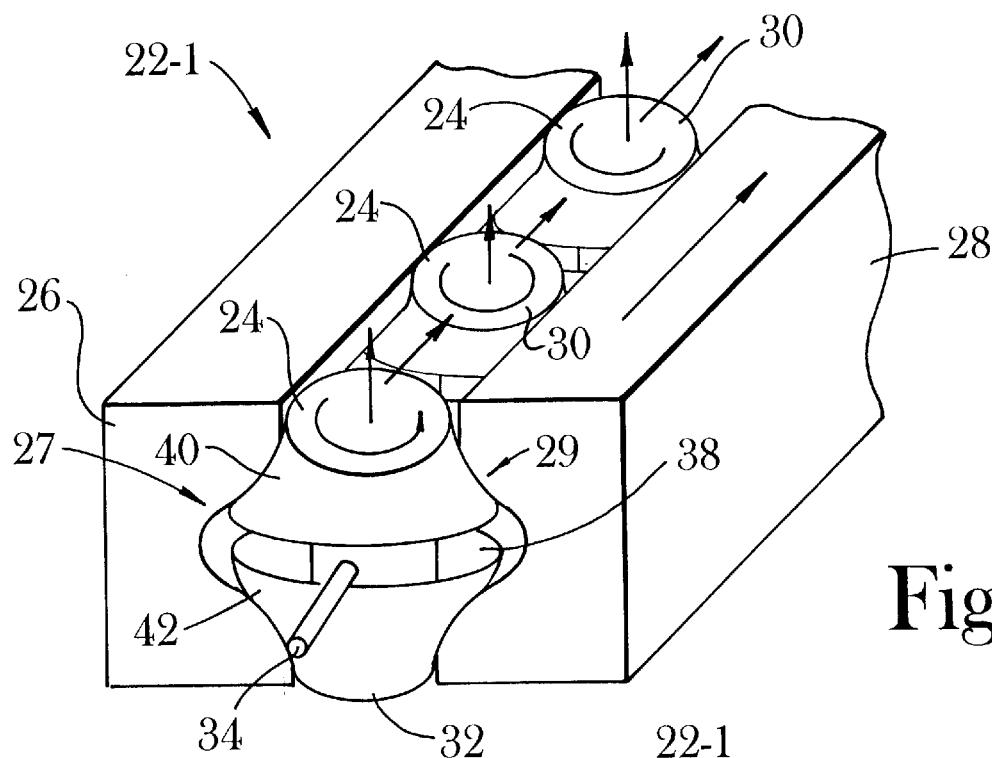
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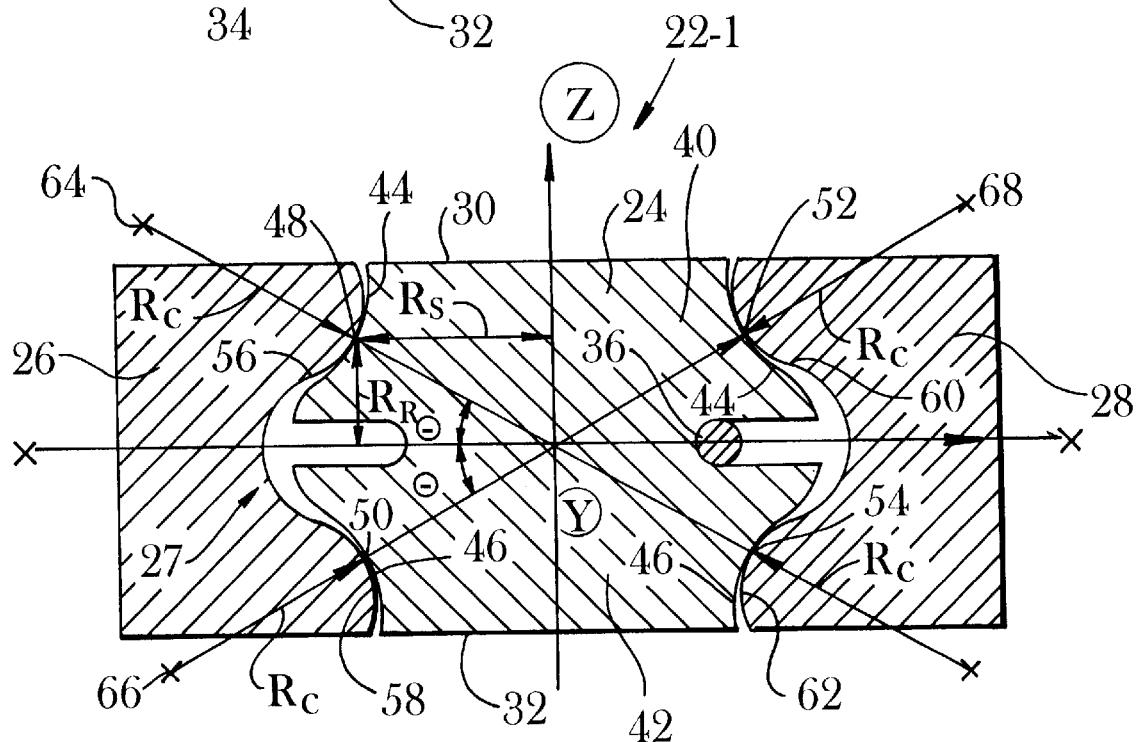
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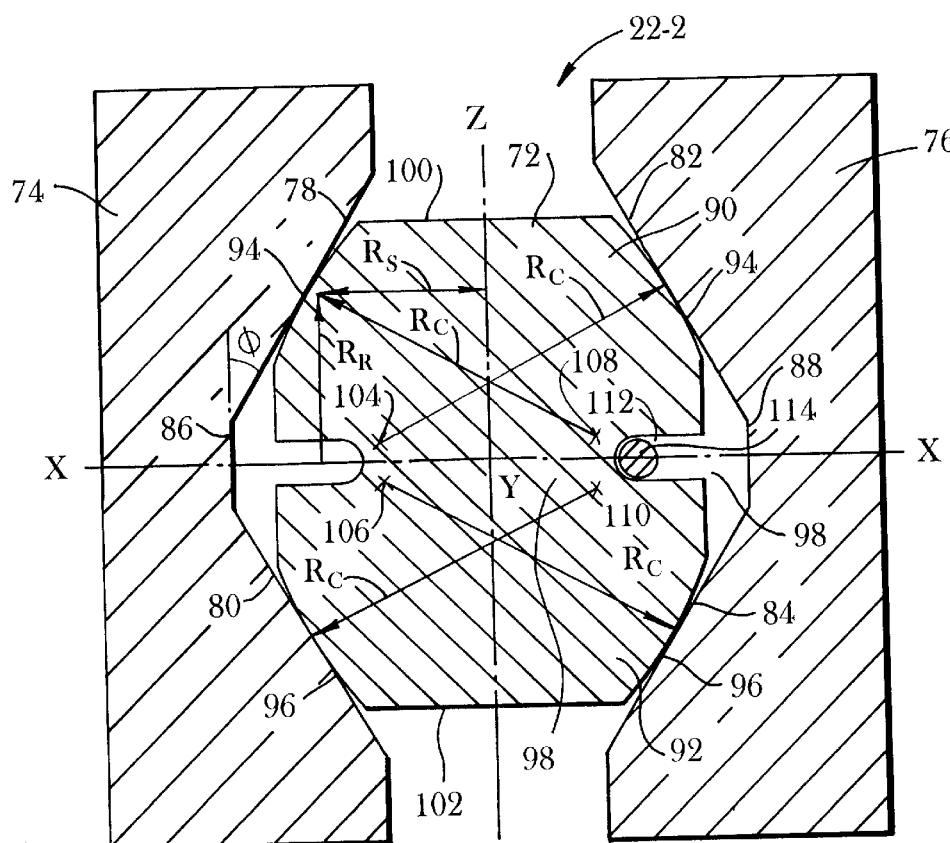
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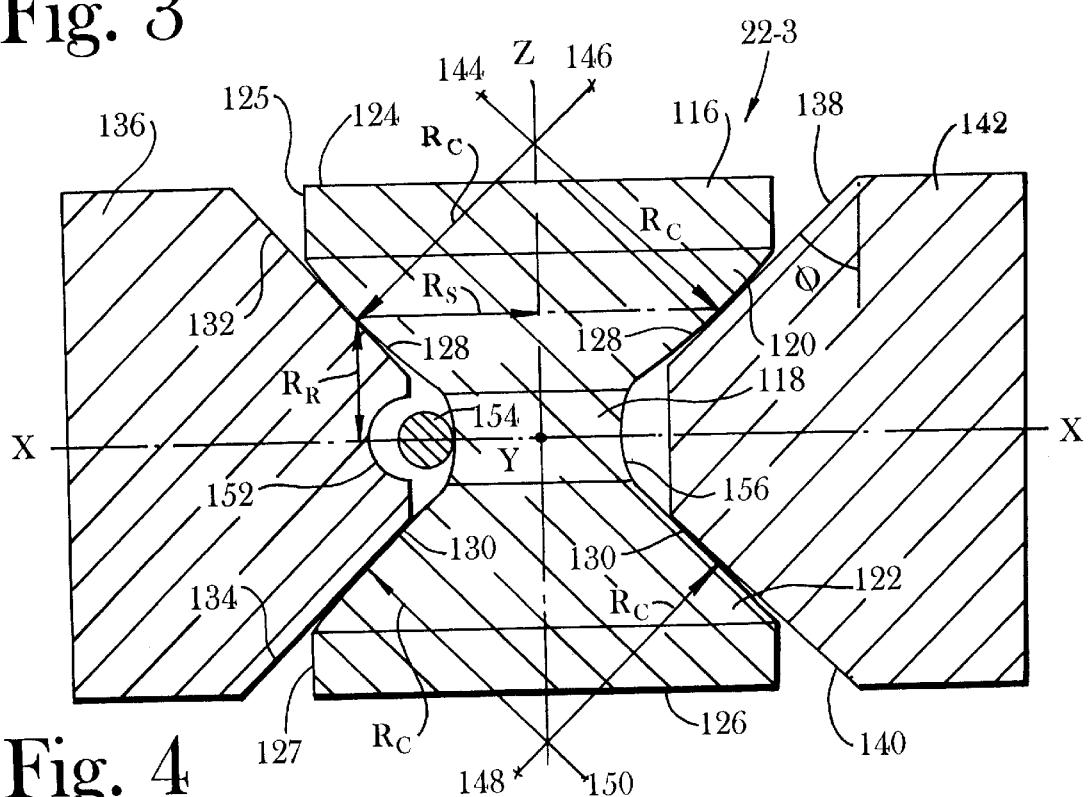
Fig. 4

Fig. 5
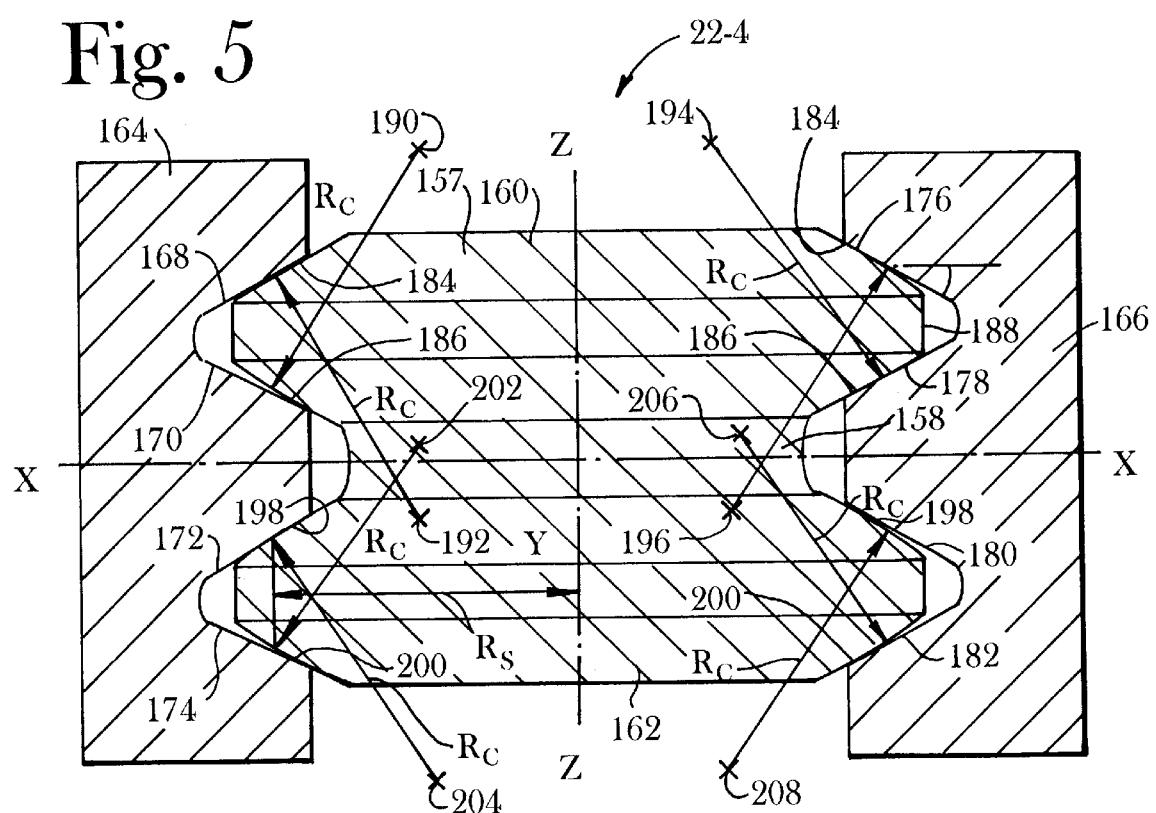
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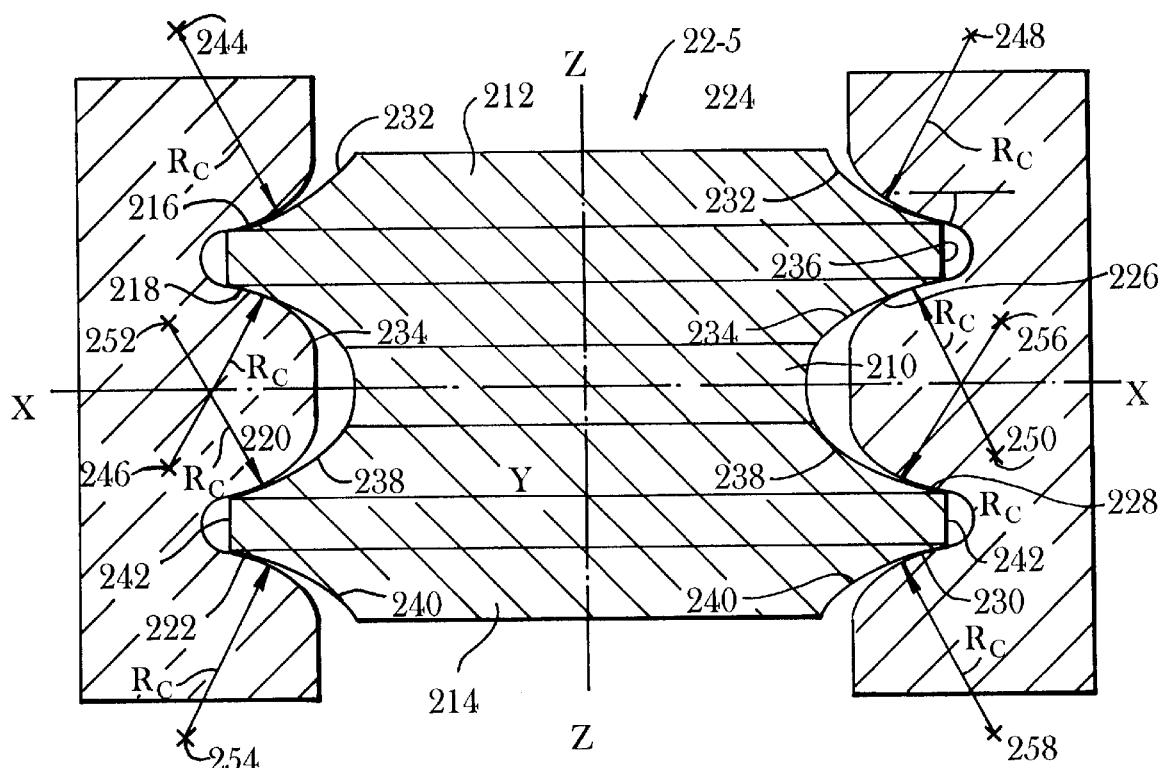
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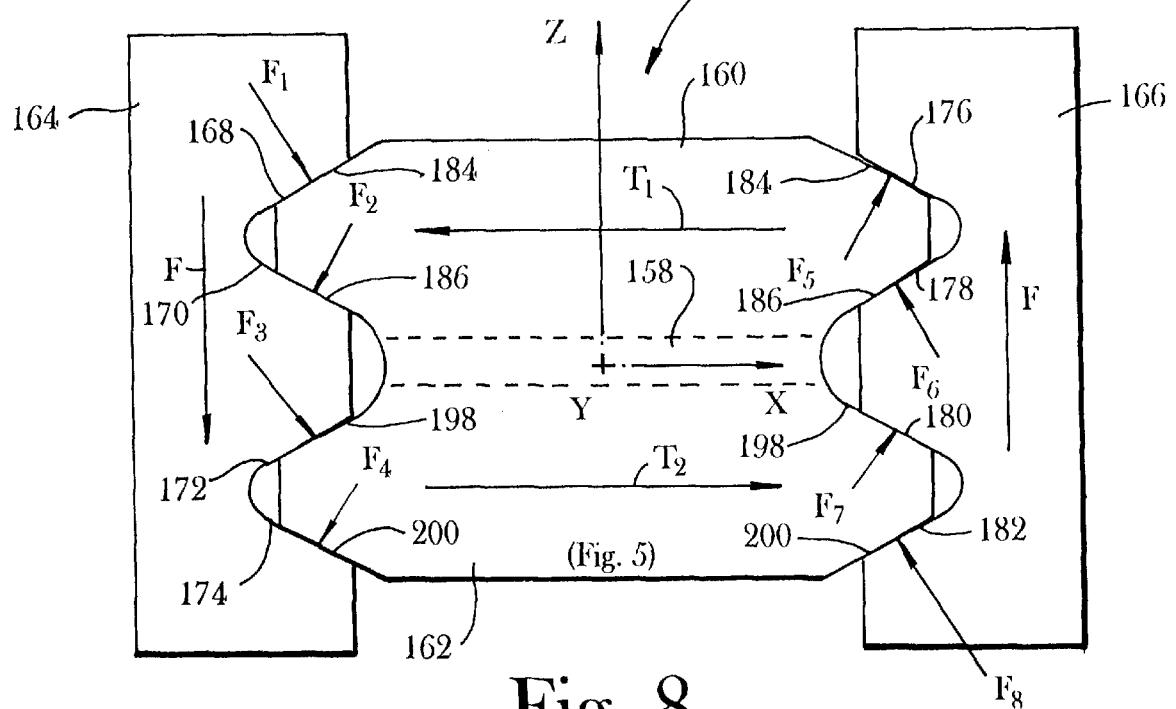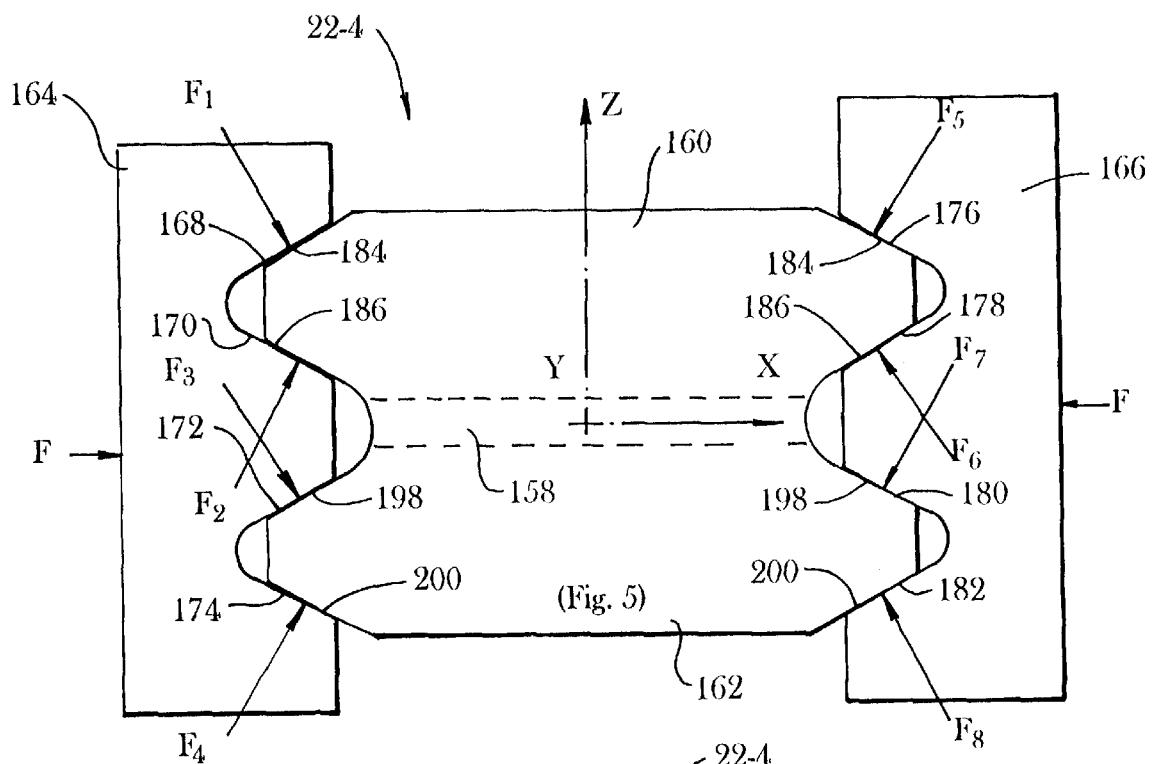
Fig. 8

Fig. 9
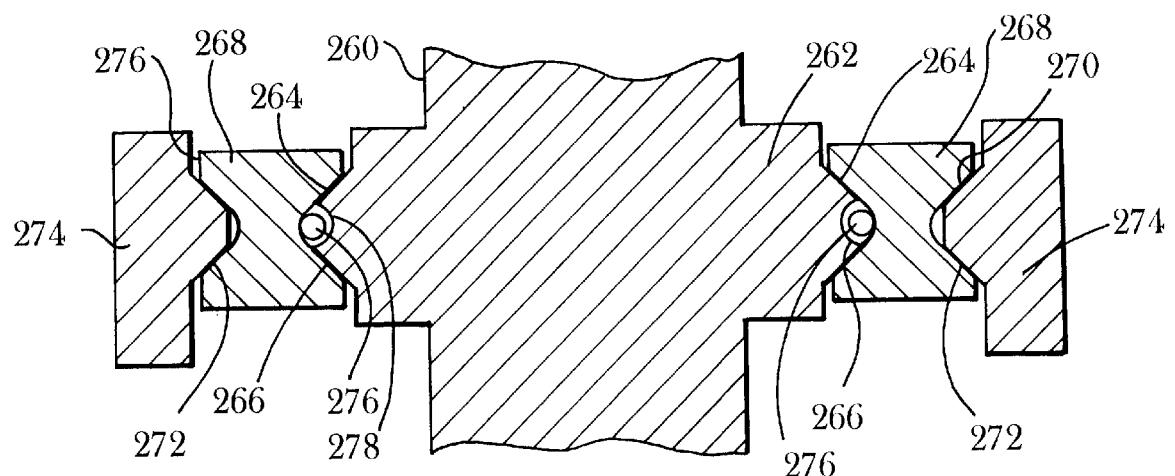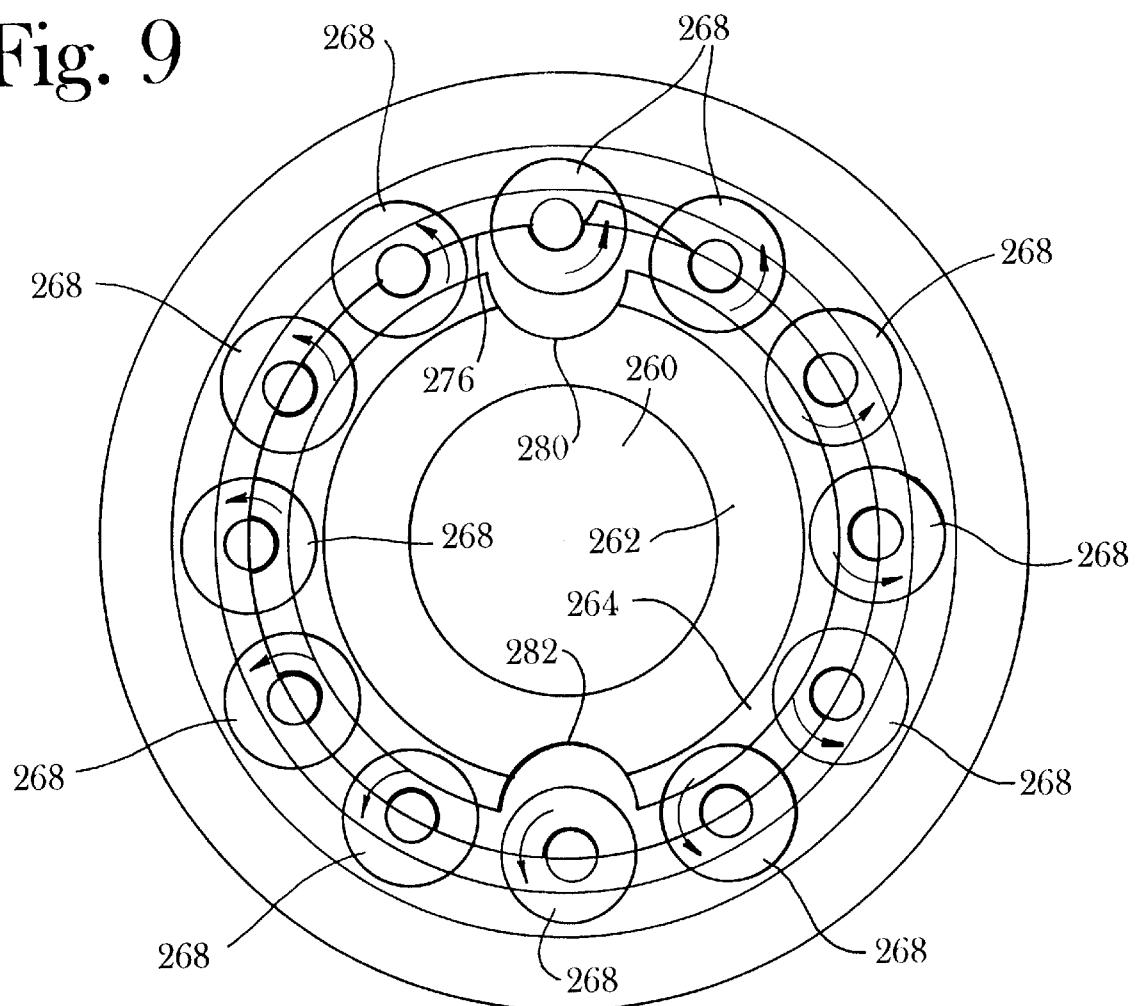
Fig. 10

Fig. 11
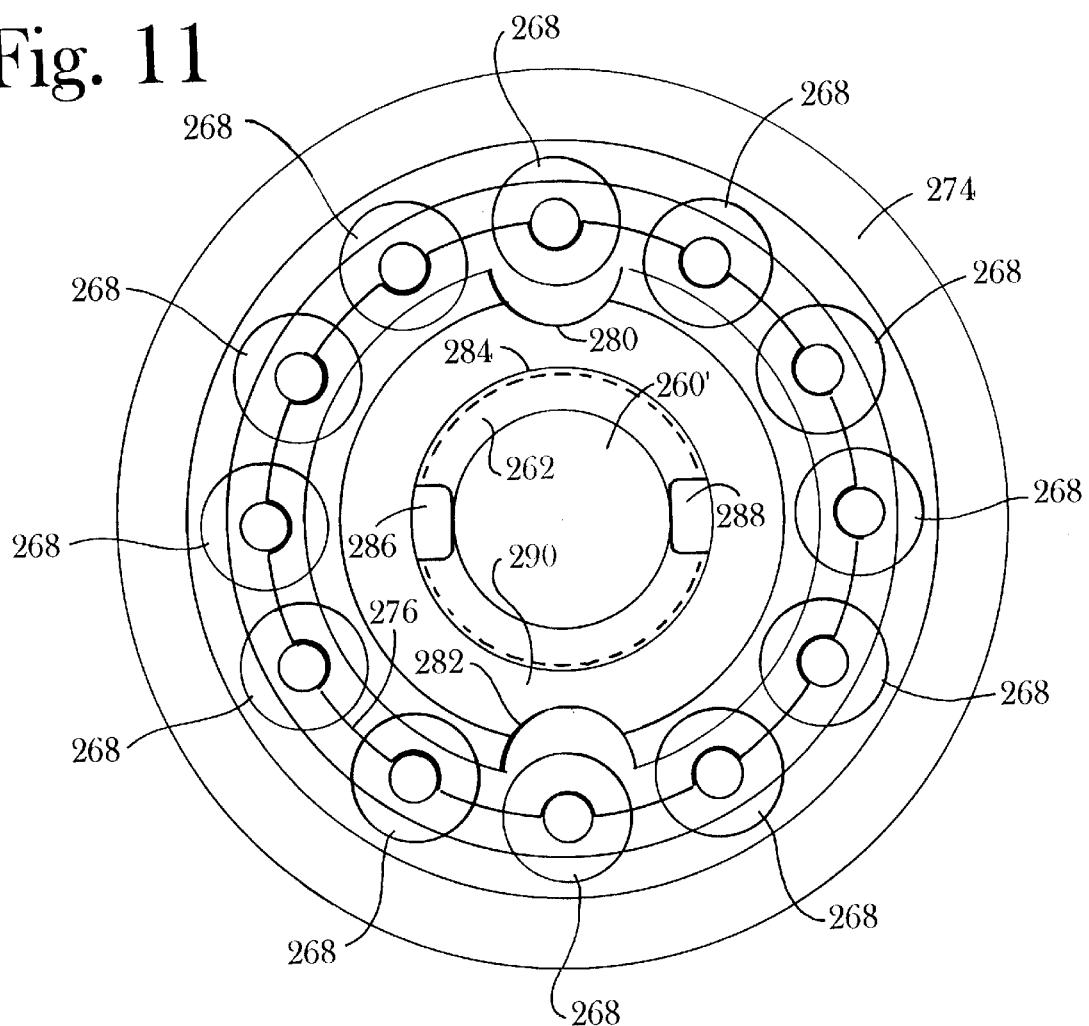
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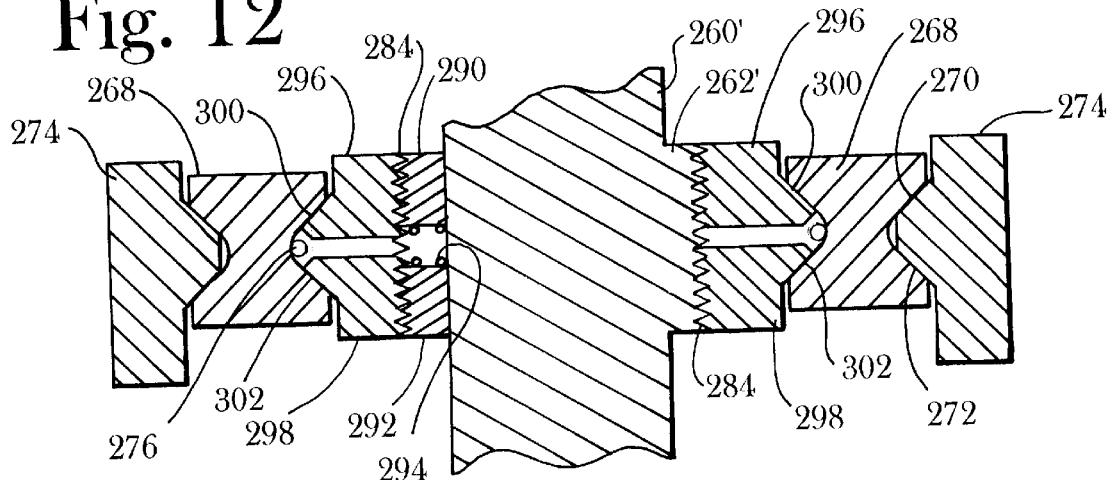
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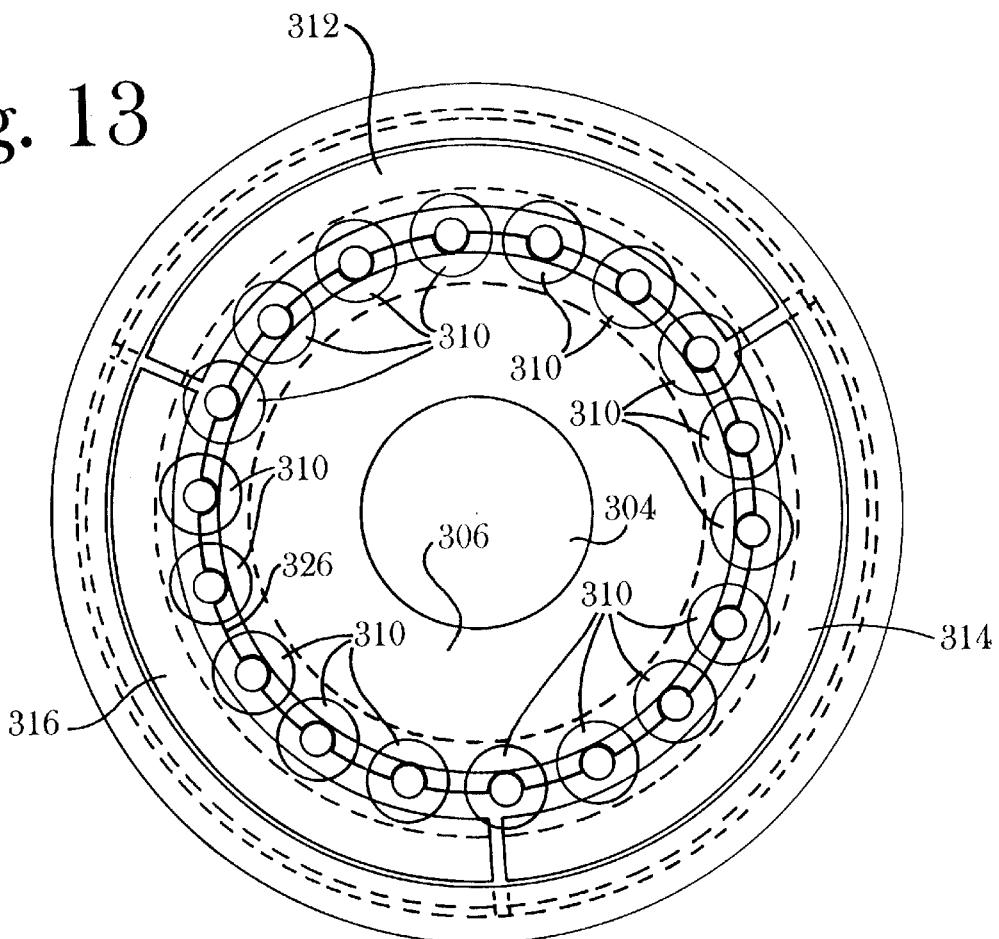
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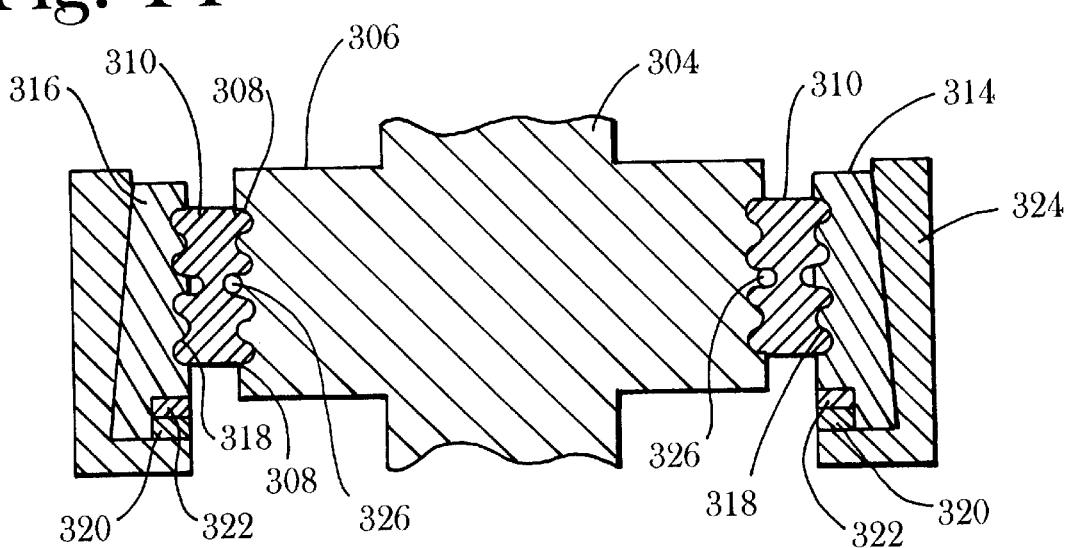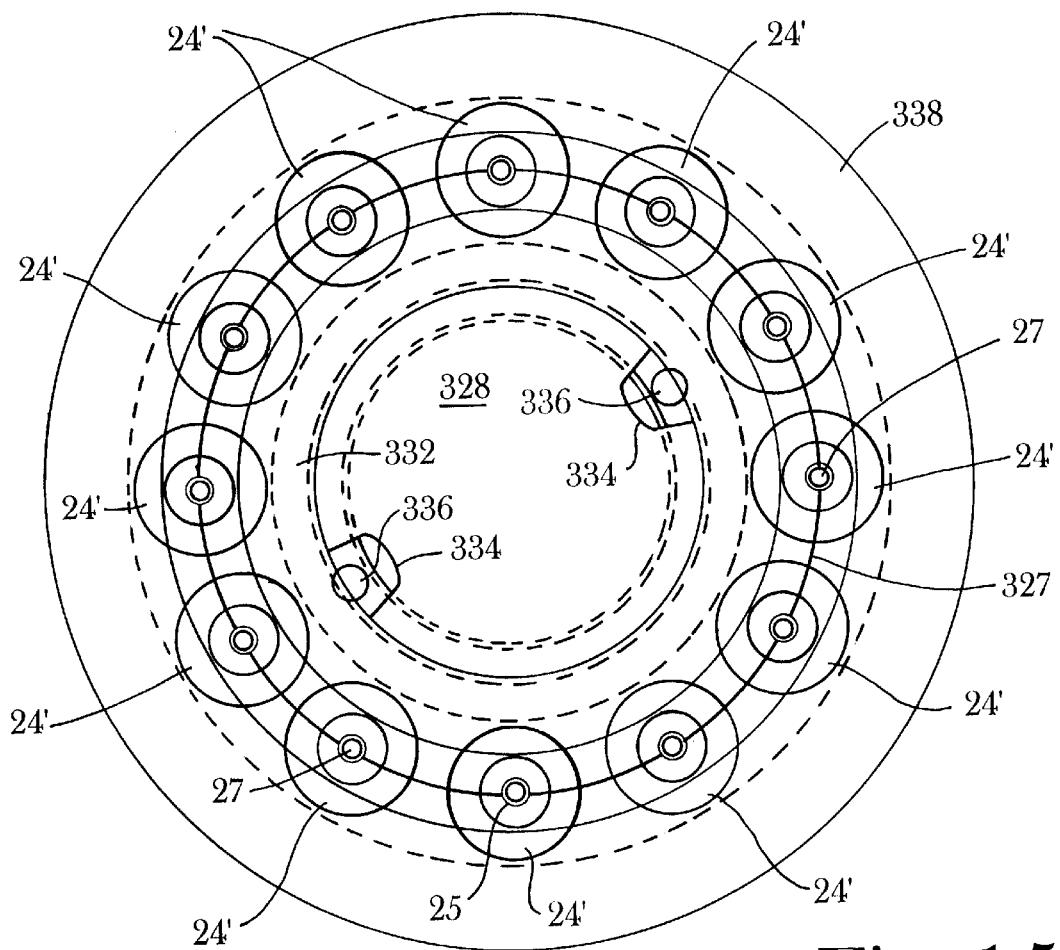
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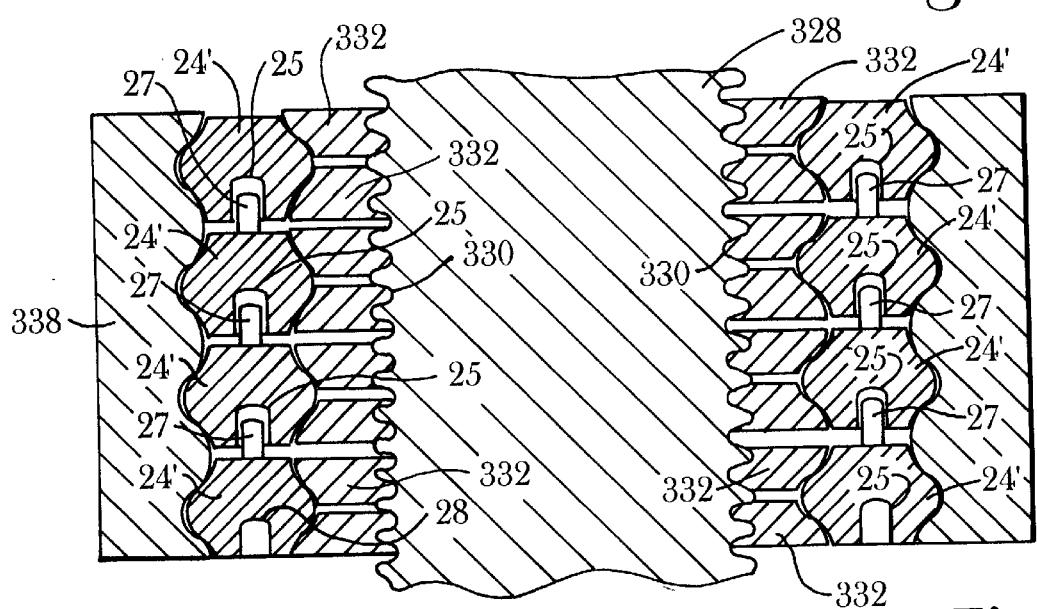
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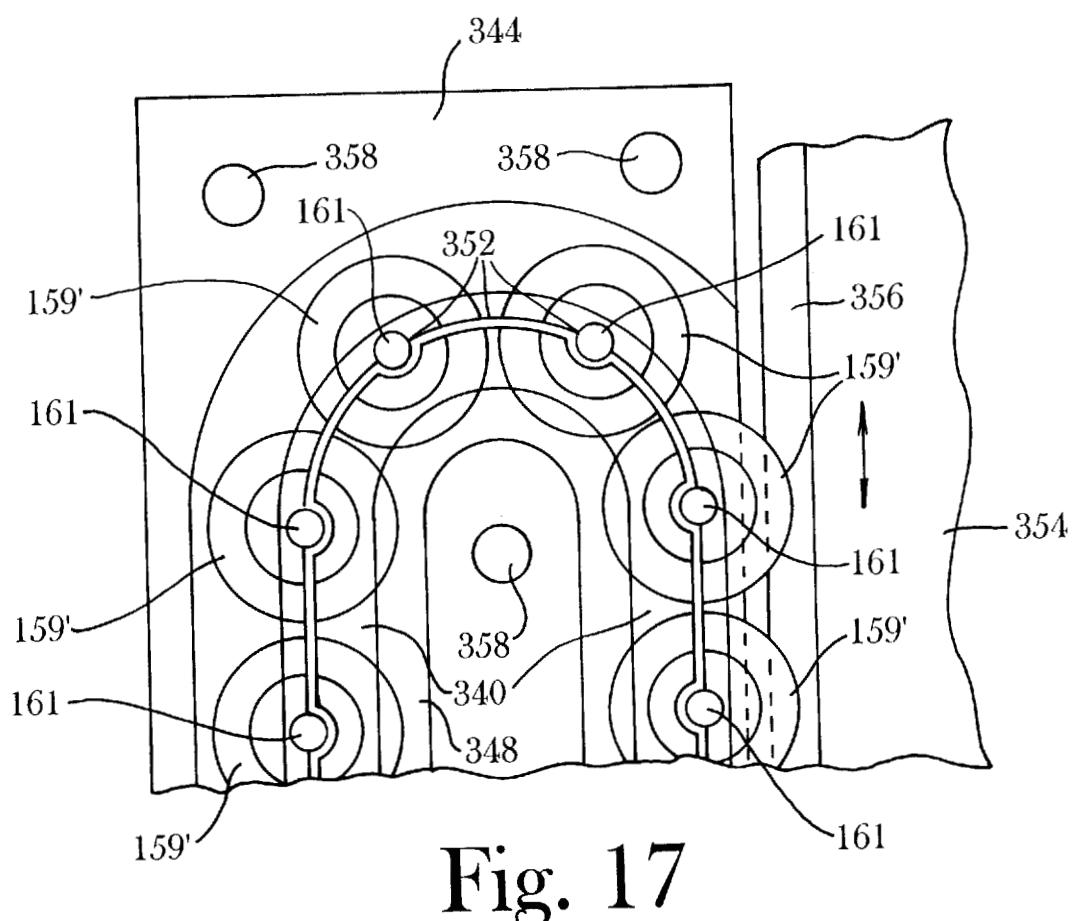
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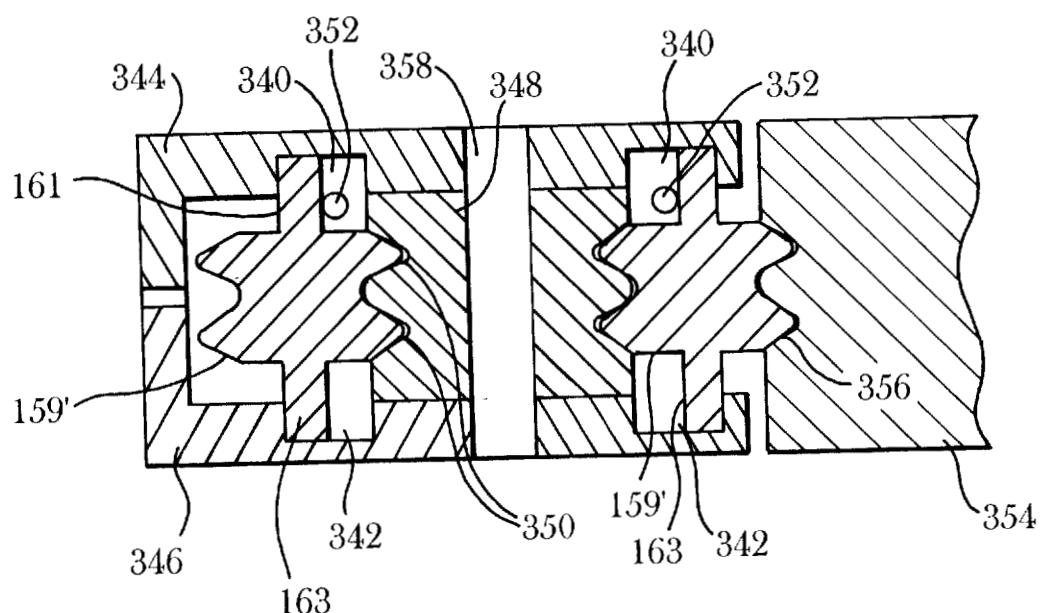
Fig. 18

Fig. 19
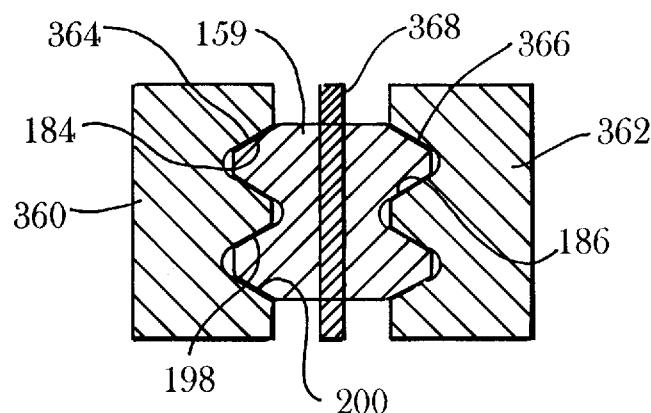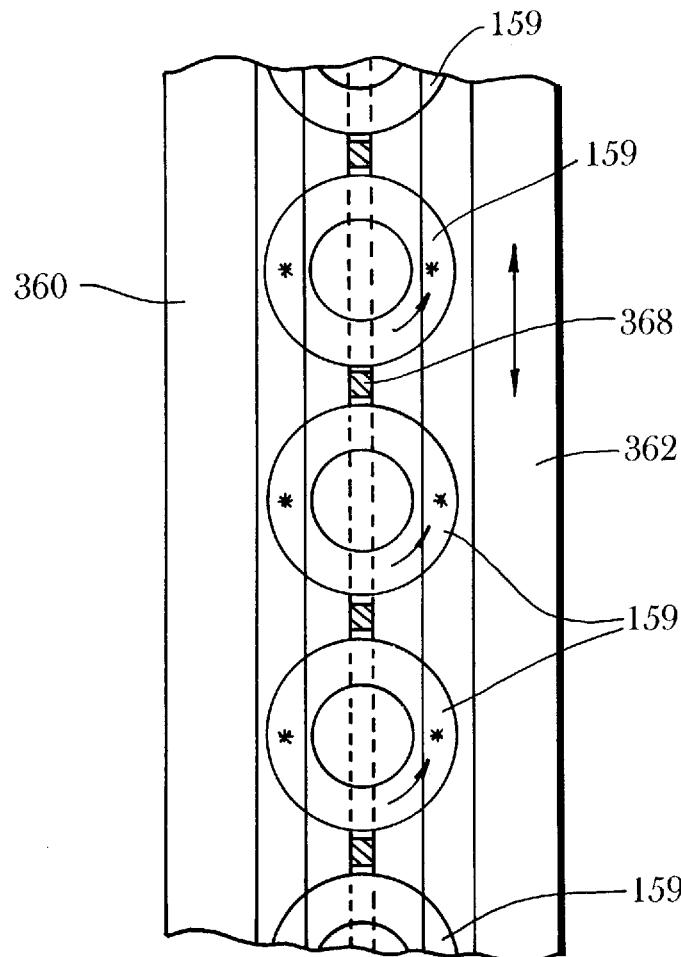
Fig. 20

MECHANICAL SPIN BEARINGS

ORIGIN OF THE INVENTION

This invention was made by an employee of the United States Government and, therefore, may be made and used by and for the Government without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention relates generally to mechanical bearings and more particularly to three dimensional spin bearings which are capable of providing improved bearing contact surfaces for handling both thrust and radial loads.

Roll bearings for providing relative rotary and linear motion between two mutually opposing bodies are well known and include, among other things, ball bearings, roller bearings, spherical bearings, tapered roller bearings, cross-roller bearings etc. While the load carrying characteristics of these types of bearings are generally known, such elements have their inherent limitations. Nevertheless, there always exists a need for improvements in such devices and particularly those which exhibit superior performance over the known prior art.

SUMMARY

Accordingly, it is an object of the present invention to provide an improvement in mechanical type bearings.

It is another object of the invention to provide an improvement in rolling type bearings.

It is a further object of the invention to provide a new type of rolling bearing which has improved load bearing capabilities.

It is yet another object of the invention to provide a new type of rolling bearing which is termed a spin bearing.

And it is still yet another object of the invention to provide a bearing assembly which includes spin bearings.

The foregoing and other objects are fulfilled by a spin bearing assembly, comprising, inter alia,: first and second complementary bearing support members having mutually spaced apart bearing support surfaces; a set of spin bearings located between the bearing support members; and wherein each of the spin bearings includes a body having a pair of end faces, a central rotational axis passing through the end faces, a waist region substantially mid-way between the end faces and having a first thickness dimension, and first and second discrete side surface regions located between the waist region and the end faces and having a second thickness dimension different from the first thickness dimension of the waist region and wherein the first and second side surface regions further have respective curvilinear contact surfaces adapted to provide a plurality of bearing contact points.

The foregoing and other objects of the invention are also fulfilled by a mechanical spin bearing for both thrust and radial loads located between two mutually adjacent complementary bearing support members, each having respective mutually spaced apart bearing contact surfaces, and comprising: a bearing body having a pair of end faces; a central rotational axis passing through the end faces; a waist region substantially mid-way between the end faces and having a first thickness dimension; and first and second discrete side surface regions between the waist region and the end faces and having a second thickness dimension different from the first thickness dimension, the first and second side surface regions further having respective contact surfaces adapted to provide a plurality of bearing contact points.

The foregoing and other objects are further fulfilled by a mechanical spin bearing race assembly, comprising: first and second mutually adjacent complementary body members wherein each of the body members includes a bearing contact surface; and wherein the bearing contact surfaces comprise mutually spaced apart and opposing convex bearing contact surfaces.

Further scope of applicability of the present invention will become apparent from the detailed description provided hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are provided by way of illustration only, since various changes, alterations, modifications, coming within the spirit and scope of the invention will become apparent to those skilled in the art from the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood when considered together with the accompanying drawings which are given by way of illustration only, and thus are not limitative of the invention, and wherein:

FIG. 1 is a perspective view generally illustrative of a concave spin bearing assembly;

FIG. 2 is a lateral cross section of the concave spin bearing assembly shown in FIG. 1;

FIG. 3 is a lateral cross section of a convex spin bearing assembly in accordance with the subject invention;

FIG. 4 is an hour glass spin bearing assembly in accordance with the subject invention;

FIG. 5 is a lateral cross section of a convex compound spin bearing assembly in accordance with the subject invention;

FIG. 6 is a concave compound spin bearing assembly in accordance with the subject invention;

FIG. 7 is a diagram illustrative of the thrust bearing forces which exist in a compound bearing assembly shown in FIG. 5;

FIG. 8 is a diagram illustrative of the torsion forces existing in a compound bearing assembly shown in FIG. 5;

FIG. 9 is a plan view of a circular bearing assembly including a set of spin bearings;

FIG. 10 is a central cross section of the bearing assembly shown in FIG. 9 and being illustrative of a set of hour glass spin bearings located therein;

FIG. 11 is a modification of the circular bearing assembly shown in FIG. 9 and including a preload assembly;

FIG. 12 is a central longitudinal cross section of the bearing assembly shown in FIG. 1 and being further illustrative of the preload assembly included thereon;

FIG. 13 is a top plan view illustrative of a circular bearing assembly including an outside collette type preload scheme in accordance with this invention;

FIG. 14 is a transverse cross section diagram being further illustrative of the assembly shown in FIG. 13 and including a set of compound spin bearings;

FIG. 15 is a top plan view of a circular bearing assembly utilizing a set of preload rings along with a set of compound spin bearings;

FIG. 16 is a longitudinal cross section illustrative of the bearing assembly shown in FIG. 15 and being further illustrative of the preload rings and the compound bearings included therein;

FIG. 17 is a top plan view illustrative of a linear slide including a recirculating spin bearing assembly;

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FIG. **18** is a longitudinal cross section of the linear slide assembly shown in FIG. **17**;

FIG. **19** is a top plan view illustrative of a linear slide assembly including a non-circulating spin bearing assembly; and

FIG. **20** is a longitudinal cross sectional view illustrative of the linear slide assembly shown in FIG. **19** and having a set of convex compound spin bearings therein.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings and more particularly to FIG. **1**, shown thereat is a perspective view of a first embodiment of the invention which comprises a spin bearing assembly **22-1** consisting of a plurality of concave spin bearings **24** located in a circular race comprised of an annular outer race **26** and a complementary annular inner race **28** having mutually spaced apart bearing support surfaces **27** and **29** and where the inner race **28** is shown rotating in a clockwise direction relative to the outer race **26**, causing the spin bearings **24** to rotate in a counterclockwise direction about a central rotational Z axis which passes through a pair of end faces **30** and **32**. A bearing carrier spring **34** separates the spin bearing **24** from each other by partially encircling an inner portion **36** of a waist region **38**. Each concave spin bearing **24** includes a pair of outer bearing regions **40** and **42**, which are relatively narrower in thickness than the intermediate waist region **38**.

As further shown in FIG. **2**, the outer regions **40** and **42** of each concave spin bearing **24** include respective concave contact surfaces **44** and **46** which are adapted to provide four bearing contact points **48**, **50**, and **52**, **54** between convex contact surfaces **56** and **58** of the outside bearing surface **27** and the convex contact surfaces **60** and **62** of the inside bearing surface **29**. Each concave spin bearing **24**, moreover, has a spin radius R$_s$ which extends from the Z axis to the contact four points as shown, for example, to the contact point **48** which exists between the concave surface **44** of the spin bearing **24** and the convex surface **56** of the outer race **26**. The designation R$_r$ signifies the roll radius about the X axis which extends from the contact surfaces, and the contact points, e.g. contact point **48**, to the X axis. There are also four contact radii R$_c$ which have centers **64**, **66**, **68** and **70** which are located outside of the bearing races **26** and **28**. It should also be noted that R$_c$ is not perpendicular or normal to the axis of rotation, i.e. the Z axis, but is at an angle θ<90° with respect to the X axis. In ball and roller bearings, the opposite normally holds true. Additionally, R$_c$ is typically greater than R$_s$ for concave spin bearings. Stated another way, the geometry of a concave spin bearing permits a very small spin radius R$_s$ to co-exist with a very large contact radius R$_c$. This results in reducing contact stresses for compact bearings.

It is intuitively obvious that a concave spin bearing **24** as shown in FIG. **2** is stable and self-aligning about the Z and Y axes for both radial and axial loads; however, it can be demonstrated that the concave spin bearing is also stable against tumbling or spinning about the X axis even though it could be constrained, if need be, by any carrier member, e.g. the spring **34** shown in FIG. **1** partially encircling the waist region **38**.

Considering now FIG. **3**, shown thereat in a transverse cross-sectional view is a second embodiment of the invention comprising a convex spin bearing structure **22-2** and which includes a convex spin bearing **72** located between concave outer and inner races **74** and **76** having linear

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bearing contact surfaces **78**, **80** and **82**, **84** which are angulated at an angle φ relative to the pair of flat intermediate faces **86** and **88**. As shown, the convex spin bearing **72** includes outer bearing regions **90** and **92**, which include convex peripheral faces **94** and **96**, an intermediate waist region **98** and a pair of end faces **100** and **102**.

As before, the convex bearing **72** as shown in FIG. **3**, includes contact radii R$_c$ which are greater than the spin radius R$_s$; however, the centers thereof as shown by reference numerals **104**, **106**, **108** and **110** lie inside the bearing structure **22-2** as opposed to being outside the bearing structure **22-1** as shown with respect to the concave bearing in FIG. **2**. Also, the convex spin bearing **72** includes an annular slot **112** in the waist region **98** for the passage of a carrier spring member **114**.

While the convex spin bearing **72** shown in FIG. **3** is stable about the Z and Y axes, it can be seen that such a spin bearing could be unstable about the X axis, depending upon the particular design and the specific dimensions. However, this can be solved simply by utilizing a carrier member **114** as shown, even though the tendency to tumble about the X axis would be lessened by making the linear contact faces **78**, **80**, **82** and **84** of the races **74** and **76** concave faces. Conversely, instability would be enhanced if the surfaces **78**, **80**, **82** and **84** were convex so that a convex on convex contact exists.

Attention is now directed to FIG. **4**. Shown thereat is an hour-glass type of spin bearing assembly **22-3** which forms a third embodiment of the invention. This structure now includes a spin bearing **116** having a waist region **118** which has a narrower thickness dimension than the adjoining outer regions **120** and **122** adjacent a pair of end faces **124** and **126** and a pair of flat rim surfaces **125** and **127**. The outer regions **120** and **122** include convex peripheral contact surfaces **128** and **130** which contact the faces **132** and **134** of an outer race **136** and the faces **138** and **140** of an inner race **142**. Four contact radii R$_c$ are thus defined and having centers **144**, **146**, **148** and **150**. These centers lie outside of the bearing assembly **22-3** and pairs of contact radii R$_c$ on either side of the waist region **118** intersect the Z axis. Whereas the first two embodiments of spin bearing assemblies **22-1** and **22-2** included a carrier spring slot in the body of the bearing, the hour-glass configuration of the spin bearing shown in FIG. **4** now includes a slot **152** in the outer race **136** to accommodate a carrier spring **154** which is also adapted to reside on the outer surface **156** of the waist region **118**.

Such a configuration is inherently stable about all three axes (X, Y and Z), while operating as both thrust and radial bearings. Thus any force applied, for example, to the upper region **120**, will be immediately countered by an opposing reactive force in the lower region **122**, with the Y axis and the X axis acting as a fulcrum.

Having thus considered three different types of spin bearings, i.e. concave, convex and hour-glass spin bearings, two embodiments of a compound spin bearing will now be considered.

With respect to the bearing configuration **22-4** shown in FIG. **5**, it depicts a convex compound bearing assembly that includes a hybrid spin bearing **157** incorporating features of both the convex spin bearing **72** shown in FIG. **3**, and the hour-glass spin bearing **116** shown in FIG. **4**. The compound spin bearing **157** of FIG. **5** resembles the hour-glass version of the spin bearing in that it includes a relatively narrow waist region **158** which connects a pair of convex spin bearing members **160** and **162** together, and which are shown residing, for example, in a pair of complementary

races **164** and **166**, each having two pairs of mutually spaced apart bearing support surfaces. For example, race **164** includes bearing surfaces **168, 170** and **172, 174** while race **166** includes contact surfaces, **176, 178**, and **180, 182**. The upper convex spin bearing member **160**, moreover, includes a pair of convex arcuate peripheral contact surfaces **184** and **186** which are separated by a rim surface **188**. The two convex surfaces **184** and **186**, moreover, define four contact surface radii R_c having centers **190, 192, 194** and **196**, which typically lie both within and outside the bearing **157**. In a like manner, the lower convex spin bearing member **162** includes a pair of convex arcuate peripheral contact surfaces **198** and **200** which are separated by a second rim surface **201** and which define a second set of four contact radii R_c having centers **202, 204, 206** and **208** which also typically lie within and without the bearing **157**. If R_c is extremely large, the centers **192, 196, 202** and **206** will lie outside the spin bearing **157**.

In the assembly shown in FIG. **5**, the magnitude of the contact radius R_c should be made relatively large in relation to that of the spin radius R_s in order to reduce contact stresses. It can be seen that although in the other embodiments of the spin bearing, R_c is generally greater than R_s. Such a relationship need not be maintained here because the spin bearing when located between the races **164** and **166** becomes inherently stable about the three X, Y and Z axes.

Considering the embodiment depicted in FIG. **6**, shown thereat is a concave compound spin bearing assembly **22-5**. The primary difference between this structure and that of the bearing assembly **22-4** shown in FIG. **5** is the shape of the bearing and race contact surfaces. As shown in FIG. **6**, a relatively narrow waist region **210** separates upper and lower concave spin bearing members **212** and **214** located between a pair of races **216** and **218**, each respectively having two pairs of convex contact surfaces **216, 218** and **220, 222** and **224, 226** and **228, 230**.

The upper bearing member **212** includes two concave peripheral bearing surfaces **232** and **234** separated by an intermediate section having a rim surface **236**. The lower bearing member **214** likewise includes a pair of concave peripheral bearing surfaces **238** and **240**, separated by a second intermediate section also having a flat peripheral surface **242**. Now, however, four contact surface radii R_c having centers **244, 246, 248** and **250** are provided which diverge outwardly, as opposed to that shown in FIG. **5**. Similarly, the lower spin bearing member **214** includes four contact surface radii R_c having centers **252, 254, 256** and **258**, which also diverge outwardly from the bearing. The stability about the X, Y and Z axes is, again, inherent in such a configuration. Stability of the compound bearings as shown in FIGS. **5** and **6**, can further be demonstrated by reference to FIGS. **7** and **8**, which depict the forces acting, for example, on a convex compound spin bearing such as shown in FIG. **5**.

As depicted in FIG. **7**, a thrust force F applied on the race **164** parallel to the X axis will cause inward forces F_1, F_2, F_3 and F_4 to be applied inwardly via the angulated faces **168, 170, 172** and **174**, while a force F exerted on the race **166** causes inward forces F_5, F_6, F_7 and F_8, to be applied via the angulated faces **176, 178, 180** and **182**.

Insofar as axial forces are concerned, which would result from motion of either of the races **164** and **166**, parallel to the Z axis, a downward force F as shown in FIG. **8** exerted on the race **164**, causes inwardly applied forces F_1 and F_3 to be applied to the faces **168** and **172** with outwardly directed reactionary forces F_2 and F_4 being applied to the faces **170**

and **174** via the peripheral bearing contact surfaces **186** and **200**. An upward force F exerted for example on the opposite race **166** would cause inwardly directed forces F_6 and F_8 to be applied to the surfaces **178** and **182** with outward reactionary forces being applied to the surfaces **176** and **180** via the peripheral convex bearing surfaces **184** and **198**. These forces are also accompanied by torques T_1 and T_2 about the Y axis. It can be seen that inherent bearing stability exists for both trust and radial forces which might be encountered.

Having thus described the preferred embodiments of spin bearings in accordance with this invention, reference will now be made to FIGS. **9** through **20**. FIGS. **9** and **10**, for example, are intended to show a relatively simple circular spin bearing system including a rotatable drive shaft **260** which includes an enlarged diameter race portion **262** having a pair of inclined bearing faces **264** and **266** for receiving a set of hour-glass spin bearings **268** which are also in contact with the bearing faces **270** and **272** of an outer race comprised of a reaction ring member **274**.

A carrier spring member **276** positioned in a carrier access slot **278** formed in the inner race **262** of the drive member **260** keeps the spin bearings **268** mutually separated from one another and biased outwardly from the drive shaft **260**. Two semicircular openings **280** and **282** are shown in FIG. **9** formed in the inner race portion **262** and comprise bearing assembly slots for the hour-glass spin bearings **268**. Thus when outer reaction ring **274** remains fixed, the drive shaft **260** can spin within the reaction ring **274**, such that if the drive shaft **260** is rotated in a clockwise direction as shown in FIG. **9**, the hour-glass spin bearings **268** will rotate in a counterclockwise direction.

The configuration shown in FIGS. **11** and **12** is intended to show an axial preload scheme for an hour-glass bearing system such as shown in FIGS. **11** and **12** and is essentially the same as that shown therein with the exception that the center drive portion is modified so that the drive shaft which is shown now by reference No. **260'** includes a relatively larger diameter race portion **262'** which is both threaded, as shown by the threads **284**, and two access ways **286** and **288** are provided for the insertion of one or more upper and lower preload shims **290** and **292** (FIG. **12**) having a preload shim spring **94** located therebetween. Additionally, a pair of preload rings **296** and **298** respectively including bearing faces **300** and **302** are screwed onto the threads **84** to provide an outwardly biasing force against the hour-glass spin bearings **268**. Also, the faces **300** and **302** are shaped to accept a carrier spring member **276** as before.

Referring now to FIGS. **13** and **14**, shown thereat is a compound spring bearing system where preloading is accomplished by means of collette type of an arrangement. As shown, the system includes a center drive element consisting of a shaft **304** having an enlarged diameter region **306** including a plurality of bearing faces **308** for accepting a set of compound bearings shown by reference number **310** which oppose three annular collette members which include a set of bearing faces **318** which match the bearing faces **308** of the shaft **304** so that the compound bearing members **310** can rotate. Spacing and preloading forces are applied by a preload spring member **320** and a washer **322**. The collette members **312, 314, 316** and the underlying preload spring **318** and washer **320** are further held in place by a reaction ring member **324**. As before, as spin is imparted to the shaft **304**, spin bearings **310** will rotate in opposite direction relative to the reaction ring member **324** while being held in place by a carrier spring **326**.

Turning attention now to FIGS. **15** and **16**, shown thereat is another configuration of a compound spin bearing system

which is comprised of a plurality of stacked concave spin bearings **24** such as shown in FIG. **2**, and which are designated by reference No. **24'** inasmuch as each spin bearing **24'** now includes an axial bore **25** for receiving a respective spindle **27** of a carrier **327** (FIG. **15**). The set of concave spin bearings **24'** are caged between a reaction ring **338** and a center drive shaft member **328** including a set of threads **330** formed on a section thereof for receiving thereon sets of preload rings **332** which provide bias contact surfaces for the spin bearings **24'** . A pair of access ways **334** are formed in the shaft **328** for receiving a pair of preload springs **336**, as shown in FIG. **15**.

Next, a pair of linear slide assemblies will be considered. FIGS. **17** and **18**, for example, disclose a linear slide which include a set of recirculating spin bearings, while FIGS. **19** and **20** disclose a linear slide including non-recirculating spin bearings.

With respect to the configuration of FIGS. **17** and **18**, shown thereat is a set of convex compound spin bearings **159'** similar to the compound spin bearing **159** shown in FIG. **5**, with the exception that now a pair of spindles **161** and **163** project from their upper and lower ends so as to fit into and engage the outer side walls of recessed tracks **340** and **342** formed in upper and lower frame members **344** and **346** which adjoin an inner frame member **348**, the latter including a plurality of bearing surfaces **350** for engaging the convex bearing surfaces of the spin bearings **159'** . Reference number **352** denotes a carrier spring member which engages the upper spindle **161** of the spin bearings **159**. A linear slide member **354** is shown located adjacent the frame members **344** and **346**. The slide member **354** includes plural spin bearing surfaces **356** for engaging the convex bearing surfaces **350** of the compound spin bearings **159'**. Accordingly, the linear slide member **354** is adapted to translate linearly in either direction relative to the frame members **344** and **346**. Reference number **358** denotes a plurality of mounting holes, one of which is shown in cross-section in FIG. **18**.

Referring now lastly to FIGS. **19** and **20**, shown thereat is a slide assembly including a linear set of non-recirculating convex compound spin bearings **159** located between a pair of linear rails **360** and **362**, each including a plurality of bearing surfaces **364** and **366** (FIG. **20**), respectively, for contacting the convex bearing surfaces **184**, **186** of the spin bearings **159**. A linear carrier member **368** maintains the spin bearings **159** in an aligned position between the rails **360** and **362**. Thus, relative movement is facilitated between the rails as shown in FIG. **19**.

Having thus shown and described what a present is considered to be the preferred embodiments of the invention, it will readily be appreciated that the spin bearings of the subject invention provide significant advantages over the known prior art. For example, spin bearings are typically much stronger than equivalent sized ball bearings. From another perspective, spin bearings can be made significantly smaller than ball bearings while still retaining the same load carrying capability. This is, in part, because the geometry of spin bearings is such that the races that support the bearings can be made smaller than the races that support comparable ball bearings. Also, spin bearings, particularly concave bearings, can have significantly shorter axial length than ball bearings of equivalent diameters. It is also true that the carrier system for spin bearings is significantly simple and more compact than the carrier system for ball bearings. This is inherent because of the relatively large contact radii that can be realized with spin bearings as compared to ball bearings.

Spin bearings are also typically much stronger than roller and needle bearings. Roller bearings are not four way bearings as are spin bearings and require long axial lengths. Roller and needle bearings can sustain side or radial loads only. They have no effectiveness against axial loads. Needle bearings are primarily used where their thinness is a very important factor in where the loads are relatively low. They represent a design consideration where packaging, particular width, is more important than load bearing capability. Spin bearings, on the other hand, tend to be short and squat. They are not as thin as needle bearings and are much shorter in axial length and thus have inherent caging advantages.

With respect to spherical bearings, they could be thought of as roller bearings which have a rounded contact surface. The term "spherical bearing" comes from the fact that the rounded portion has its own radius which is considerably larger than that of the roll radius. Spherical bearings can rock when the members on each side of the bearing are rocked and twisted back and forth toward each other. Thus, they are very good against brinelling failures which often occur in structures near the extremities of needle and roller bearings. These bearings do provide some limited capabilities as thrust bearings, but they are primarily used against side loads. However, it is impossible for them to form load concentrations anywhere including their extremities. Spin bearings, on the other hand, are as strong or stronger than spherical bearings, and they are much more compact, particularly in axial length. Also, spin bearings are much better as four-way bearings, since they are equally good against axial loads as they are against side or radially loads. Furthermore, spin bearings prevent structural members from rocking and twisting back and forth toward each other so that they are better in stabilizing and positioning the structural members upon which they bear. Additionally, spin bearings are superior to spherical bearings in precision movement operations.

With respect to tapered roller bearings, spin bearings can perform everything that tapered bearings can do, and more, while performing them in a much more simple and direct way. Spin bearings are much simpler and less expensive than tapered roller bearings. Spin bearings are, moreover, relatively more compact for equivalent performance, since the actual length of spin bearings is less than that of tapered roller bearings and because a special tilted bearing race is not required.

Finally, spin bearings are also typically much stronger than crossed-roller bearings, and are much more compact. Crossed-roller bearings mean that every other roller must be tilted at 90° to the one preceding it to achieve a four-way load bearing effect. This is not the case with spin bearings.

Accordingly, it will be obvious that this invention may be varied in many ways. Such variations are not meant to be considered as a departure from the spirit and scope of the invention, and therefore all such modifications, alterations and changes as would be obvious to one skilled in the art as set forth in the appended claims are intended to be included.

I claim:
1. A spin bearing assembly, comprising:
   first and second mutually opposing complementary bearing support members having mutually spaced apart bearing support surfaces wherein said first support member includes a carrier access slot for receiving a carrier spring member;
   a set of spin bearings located between said bearing support members
   such that each of said spin bearings is mutually separated and biased towards said second support member by

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said carrier spring; and wherein said spin bearings include a body having a pair of end faces,

a central rotational axis passing through said end faces,

a waist region substantially midway between said end faces and having a first thickness dimension, and

first and second discrete side surface regions located between said waist region and said end faces and having a second thickness dimension different from said first thickness dimension of said waist region, said first and second side surface regions further having respective curvilinear contact surfaces adapted to provide a plurality of bearing contact points.

2. A spin bearing assembly according to claim **1** wherein said curvilinear contact surfaces of said first and second side surface regions comprise concave or convex contact surfaces.

3. A spin bearing assembly according to claim **2** wherein each of said contact surfaces are arcuate and have a contact radius to a respective bearing contact point which is non-normal to the central rotational axis of said body of the spin bearings.

4. A spin bearing assembly according to claim **3** wherein said first thickness dimension is greater than said second thickness dimension.

5. A spin bearing assembly according to claim **3** wherein said first thickness dimension is less than said second thickness dimension.

6. A spin bearing assembly according to claim **2** and additionally including at least a third and a fourth outer side surface region including arcuate concave or convex contact surfaces located between said end faces and said first and second side surface regions.

7. A spin bearing assembly according to claim **1** wherein one of said bearing support members comprises a drive member and the other of said bearing support members comprises a reaction member.

8. A spin bearing assembly according to claim **1** wherein said bearing support members each include a pair of bearing contact surfaces and wherein said spin bearings contact said bearing contact surfaces.

9. A spin bearing assembly according to claim **1** wherein said first and second bearing support members comprise a pair of mutually parallel bearing races.

10. A spin bearing assembly according to claim **9** wherein said races are circular.

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11. A spin bearing assembly according to claim **10** wherein one of said races comprises a rotatable drive member and the other of said races comprises a reaction member.

12. A spin bearing assembly according to claim **9** wherein at least one of said races comprises a linear slide member.

13. A spin bearing assembly according to claim **9** wherein both of said races comprise a pair of rails in a linear slide assembly.

14. A mechanical spin bearing for both thrust and radial loads between two mutually opposing complementary bearing support members, each having at least two spaced apart bearing contact surfaces, comprising:

a bearing body having a pair of end faces;

a central rotational axis passing through said end faces;

a waist region having a first thickness dimension substantially midway between said end faces wherein said waist region includes an annular slot for the passage of a carrier spring member; and

first and second discrete side surface regions between the waist region and the end faces and having a second thickness dimension different from said first thickness dimension of said waist region, said first and second surface regions further having respective contact surfaces adapted to provide a plurality of bearing contact points.

15. A spin bearing according to claim **14** wherein said contact surfaces comprise curvilinear contact surfaces.

16. A spin bearing according to claim **15** wherein said curvilinear contact surfaces of said first and second side surfaces comprise arcuate contact surfaces and wherein each of said contact surfaces has a contact radius to a respective bearing contact point of said plurality of bearing contact points which is non-normal to the central rotational axis of the bearing body.

17. A spin bearing according to claim **16** wherein said arcuate contact surfaces are concave with respect to said bearing contact surfaces of said two mutually adjacent members.

18. A spin bearing according to claim **16** wherein said arcuate contact surfaces are convex with respect to said bearing contact surfaces of said two mutually adjacent members.

19. A spin bearing according to claim **16** wherein the first thickness dimension of said waist region is greater than the second thickness dimension of said side surface regions.

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