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(54) Foil bearings

(57) A metal foil bearing having rings of increased clearance at each end (20) of the metal foil (12) so as to prevent the metal foil from contacting the surface of the rotary shaft (10) whose journal is embraced by the bearing during high speed rotation. An annular groove (22) may be provided at each end of the metal foil, or a pair of shoulders defining a central portion of the outer surface of the rotary shaft acting as a journal embraced by foil, the shaft extending in each direction from a point adjacent the associated end of the foil bearing with a reduced diameter. Alternatively the foil (12) may have an outwardly extending end portion at each end.

FIG.2

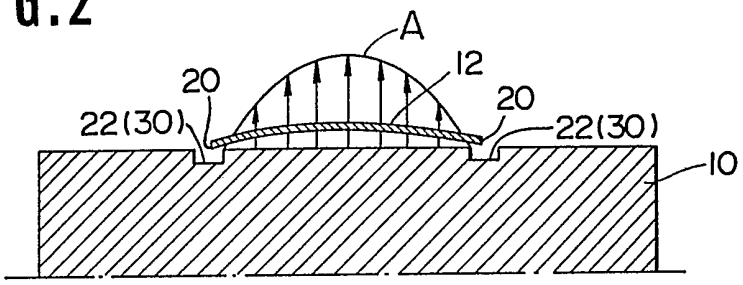

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FIG.1

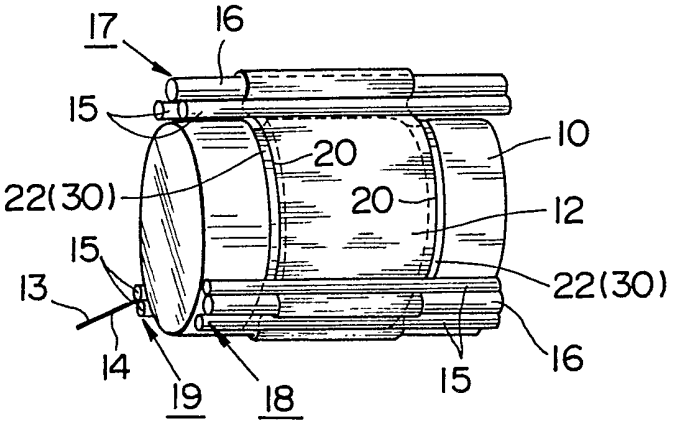


FIG.2

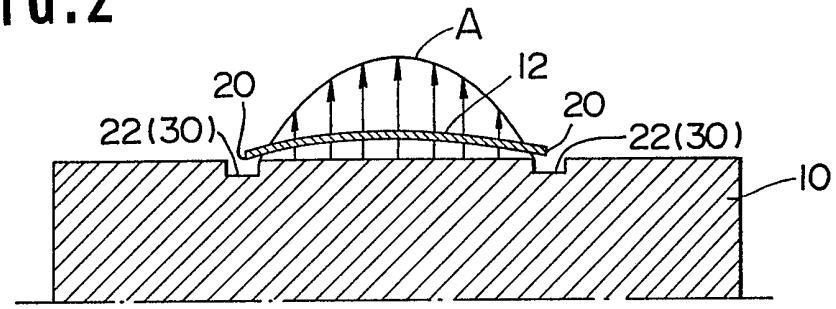


FIG.3

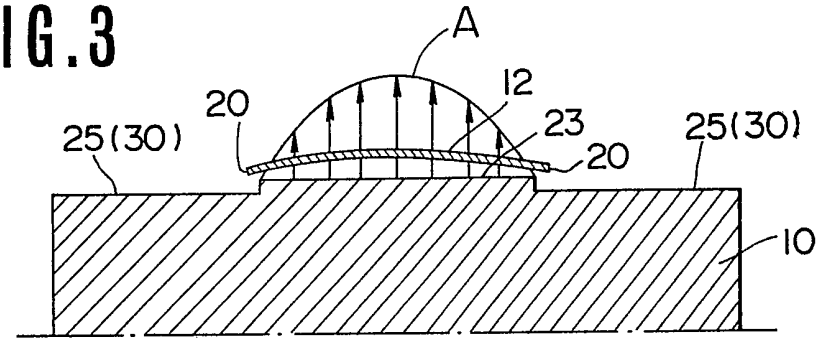
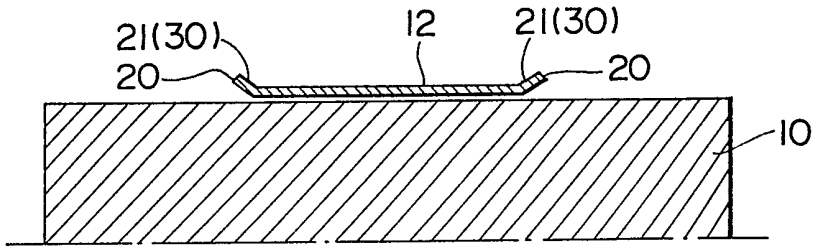


FIG.4



SPECIFICATION

Foil bearings

This invention relates to foil bearings of the type wherein undesirable metal to metal contact between the metal foil and the rotary shaft during high speed rotation of the rotary shaft is substantially prevented from occurring.

Heretofore, known foil bearings have been of a type forming a radial gas containing bearing.

A foil bearing of this kind is constructed in such a manner that the journal of the rotary shaft of the bearing is embraced by a flexible metal foil of aluminium, stainless steel, or the like, such that the pressure of a gas layer formed between the thin foil and the rotary shaft can support the rotary shaft.

It is desirable to maintain the bearing clearance between the metal foil and the rotary shaft substantially constant, even when the rotary shaft rotates at a very high speed, in order to ensure a complete lack of contact between the two mating parts.

However, it is very difficult in the actual fabrication process, to finish each of the metal foils with perfectly uniform smoothness over the entirety of their axial lengths, accordingly, some defects such as burring, warping and/or waved surfaces are liable to be caused at both axial ends or at the margins of the cut metal foil.

Assembled foil bearings using metal foils having such forming defects are liable to cause undesirable metal to metal contact during high speed rotation between the metal foil and the rotary shaft, and it becomes difficult or impossible to assure perfect contact-free operation over the entire surface of the metal foil.

The gas layer in the bearing clearance defined between the metal foil and the rotary shaft has a pressure characteristic such that the pressure distribution curve along the axis of the shaft takes the form of a relatively smooth convex shape when only a small bearing load is applied to a foil bearing having large bearing clearance, and this will not bring about any appreciable amount of excessive pressure, even at the middle of the bearing.

On the other hand, when a large bearing load is applied to a foil bearing having a small bearing clearance, the pressure distribution curve of the bearing will take a convex sharp of shape curvature, resulting in an excessively large pressure level at the middle of the bearing, along the axis of the rotary shaft.

As explained above, if a large load is applied to a foil bearing having small clearance, when the bearing is operated at high speed of rotation the middle of the metal foil of the bearing is subjected to a large level of gas layer pressure, and will extend and deform radially outwardly, probably resulting in the metal foil at each axial end coming into contact with the rotary shaft.

One object of the present invention is to avoid the problems explained above, and provide constructions which effectively avoid any undesirable contact between the metal foil and the rotary shaft which is attributable to the foil fabrication or to the characteristics of the gas layer in the foil bearing, even in a gas bearing operting at a high speed of rotation.

According to one aspect the invention consists in a metal foil bearing comprising a rotary shaft which has its journal embraced by a flexible metal foil or foils to enclose and support said rotary shaft by a gas layer formed between said rotary shaft and said metal foil, at least when operating, said metal foil bearing having a ring of increased clearance between each end of the enclosing foil or foils and the rotary shaft, each said clearance being provided by a section of said shaft having a reduced diameter at each corresponding axial end of said metal foil or foils or by said foil having its ends flared radially outwardly from the outer surface of said rotary shaft.

The invention will now be described with reference to the drawings, in which:-

Figure 1 is a perspective view showing one exemplary embodiment of the present invention;

Figure 2 is a sectional view showing the pressure distribution of the gas layer in the direction of the axis of the rotary shaft;

Figure 3 is a sectional view showing another embodiment together with the pressure distribution of the gas layer in the axial direction; and

Figure 4 is a sectional view showing still another embodiment of the present invention.

Thus, in accordance with the present invention, where the rotary shaft of a foil bearing has its outer journal surface wrapped by a flexible metal foil, so that the rotary shaft is supported by a gas layer formed between the metal foil and the rotary shaft, when operating, and the clearance rings avoid metal to metal contact between the metal foil and the rotary shaft, the requisite portions, that is, either on the opposing axial marginal ends of the metal foil, on the portions of the rotary shaft corresponding to the axial marginal ends of the metal foil or on the portions of the outer surface of the rotary shaft each starting from a point slightly more central than the point corresponding to the respective axial end of the metal foil and extending out to the axial end of the shaft.

In an alternative construction the clearance rings are constructed to prevent the metal foil from contacting the rotary shaft by forming both axial marginal ends of the flexible metal foil or foils with an outward flare to take the ends away from the shaft.

In the embodiment shown in Figure 1, the present invention is applied to a tension type foil bearing, in which a rotary shaft 10 has a journal surface that is surrounded by a flexible metal foil 12.

In this embodiment a single sheet of metal foil 12 is threaded through passages defined by a first guide member 17 and a second guide member 18 each of which consists of a pair of guide pins 15 disposed parallel to the axis of the rotary shaft and a support pin 16 so as to wrap the rotary shaft 10 and the two opposite end portions 13 and 14 are put together and passed through a further pair of guide pins 15. The foil is then stretched fixed under tension imparted by a tensioning means, not shown.

At the ends of the outer journal surface of the rotary shaft 10, a pair of annular grooves 22 of

relatively small width are formed around the shaft, each of which grooves is formed at a position overlapping the associated end 20 of the metal foil 12. The width of each of the annular grooves is selected to have a suitable length in an axial direction, with a mid-point aligned with the respective end 20 of the metal foil 12.

By virtue of this construction, the annular grooves 22 formed on the rotary shaft 10 constitute clearance rings for avoiding undesirable contact of the metal foil 12 with the rotary shaft 10, and there arise no possible chance of contact of the metal foil with the rotary shaft even if the metal foil has any fabrication defect such as burring, warping or waving, which are liable to be found in its axial ends, because these failures will be accommodated in the grooves.

Where the clearance between the metal foil 12 and the rotary shaft 10 is relatively less, and a considerable load is applied, the pressure distribution of the gas layer formed within the clearance will be as shown graphically in Figure 2 as a convex curve "A" of large curvature in cross-section, and the metal foil 12 will be bent radially outwardly under the influence of the pressure of the gas layer.

This will result in one or both axial ends of the metal foil 12 toward the surface of the rotary shaft 10, but even under this situation the ends 20 of the metal foil can enter in the respective annular grooves 22 and prevent contact with the rotary shaft.

The provision of the above-mentioned annular grooves 22 on the rotary shaft 10 may give rise to some difference in the manner of forming a gas layer from that when there is no annular groove, however, there arises little difference with respect to the axial pressure distribution of the gas layer due to the fact that the metal foil 12 has a considerable degree of stiffness, and differences in the axial pressure distribution of the gas layer, if any, will not have any appreciable influence on the metal foil 12.

Figure 3 shows another embodiment of the present invention, in which two shoulders are formed at opposite ends of the journal portion of a rotary shaft 10, each forming a clearance ring starting from points axially and slightly central of the respective end of a metal foil 12 and extending out to the axially outward extremity of the rotary shaft, formed by portions of reduced diameter 25 having a diameter smaller than the central portion 23, so as to let each of the portions of reduced diameter 25 play a roll as a clearance ring 30 for avoiding contact of the metal foil 12 with the rotary shaft 10.

Both of the faces defining the shoulders between the central portion 23 and the portions of reduced diameter 25 are positioned axially slightly central with respect to the ends 26 of the metal foil 12, so that the axial length of the central journal portion of larger diameter becomes shorter than the width of the metal foil 12.

Figure 4 shows still another embodiment of the present invention, wherein the clearance rings 30 for avoiding mutual contact between the rotary shaft 10 and the metal foil 12 are provided at the ends of the metal foil 12.

Each of the ends of the metal foil 12 are radially expanded to form a frusto-conical end portion 20 of enlarged diameter.

In each embodiment mentioned above, explanations have been made on the cases where the device of the present invention is applied to a tension type foil bearing, but the present invention can, of course, be applied to other types of bearing, without tension, for example multi-leaved types, hydrocele types, multi-ringed typed foil bearings and so forth, in a generally similar manner.

Although a single foil is referred to in the description of Figure 1, to form three segments of a bearing surface between the adjacent sets of support pins 15, it will be appreciated that separate axial strips can be used, one between each adjacent set of support pins. Furthermore, if machine characteristics should make it desirable a plurality of foils can be applied, one on top of the other.

Further details of the constructional steps and a preferred processing step are described in our co-pending United Kingdom Patent Application of even date, Serial No.....(Our Ref Y775).

This particularly refers to the use of a mandrel of diameter greater than the rotating shaft during the initial assembly and tensioning steps, in order to provide a predetermined clearance, and preferably an accurately contoured bearing surface on the interior of the foil or foils.

CLAIMS

1. A metal foil bearing comprising a rotary shaft which has its journal embraced by a flexible metal foil or foils to enclose and support said rotary shaft by a gas layer formed between said rotary shaft and said metal foil, at least when operating, said metal foil bearing having a ring of increased clearance between each end of the enclosing foil or foils and the rotary shaft, each said clearance being provided by a section of said shaft having a reduced diameter at each corresponding axial end of said metal foil or foils or by said foil having its ends flared radially outwardly from the outer surface of said rotary shaft.

2. A metal foil bearing as claimed in Claim 1, wherein said clearance rings are a pair of frusto-conical cylindrical portions each formed by radially and outwardly expanding axial end portions of said metal foil.

3. A metal foil bearing as claimed in Claim 1, wherein said clearance rings are formed on the outer surface of said rotary shaft as a pair of annular grooves around the shaft, one extending axially in each direction at each end of said metal foil.

4. A metal foil bearing as claimed in Claim 1, wherein said clearance rings are formed by producing a pair of shoulders giving two lengths of reduced diameter in said shaft, each extending axially from a respective point enclosed by foil adjacent its corresponding end, out to the end of said rotary shaft.

5. A metal foil bearing substantially as described with reference to any one of Figures 1 to 4.

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