

The present invention relates to a fluid bearing and more particularly the improvement of the load-bearing capacity and stability of such a bearing.

Fluid bearings are increasingly used in machines
5 for various applications rotating at great speed, in which oil lubrication is not practicable in view of technical or economic conditions to which they are subject. These bearings are based on the principle of producing a pressurised wedge of air between a rotating body in motion
10 and a fixed surface.

These bearings are intended to support a rotating shaft. They consist in general of a bore hole with an assembly of sheets distributed about the periphery of said bore hole. These sheets have, on the side facing the
15 rotating shaft, a self-lubricating coating so as to ensure that the supported shaft starts up subject to a minimum of wear. A stiffening element is located between the sheets and the bore hole. This stiffening element controls the degree to which the shaft is thrown off centre due to the loading
20 and it also controls the damping by friction between sheet and stiffening element, this damping being necessary in order to increase the top speed up to which the bearing can operate.

The problems associated with the operation of a
25 bearing differ according to whether they relate to the start-up phase or to the phase of operating under load.

At start-up the sheets must be very flexible and subject to a slight prestress in order to minimise the frictional force between the shaft and the sheet.

30 During operation under load, the reaction of the sheet to the loading characteristics necessitates a more effective stiffening element than in the start-up phase. This more effective stiffening element is constituted by a stiffening element acting in such a way as to cause, after
35 the start-up phase, the sheet to be inclined in a suitable position according to the load applied to it.

During operation under load it is also necessary to dampen the fluid bearing in order to avoid or reduce the effect of resonances capable of causing a fracture at critical speeds lower than the rated operating speed. In the case of air, which is a fluid of low viscosity, damping is achieved primarily by energy dissipation due to dry frictional effects, so-called Coulomb friction.

Various attempts have been made to resolve these problems, and to this end devices have been described notably in US patent 1,684,693 (Böhn) and French patents No. 1,517,739 and No. 2,352,985.

French patent No. 2,352,985 describes in particular a radial hydrodynamic fluid-film bearing comprising a sleeve in which a shaft is free to rotate, whereby the sleeve and the shaft form between them an annular space accommodating a plurality of bearing sub-assemblies, each of which has:

- a flexible strip separated from the shaft, the course of which it partly follows, by a layer of fluid film, said strip being firmly connected with a bar secured by insertion in a recess provided in the sleeve, and

- upper and lower stiffening elements located between the flexible strip and the sleeve, said stiffening elements being secured to said sleeve and so designed as to counteract the deformations of the flexible strip.

In this patent, however, the upper and lower stiffening elements are firmly connected with a single bar. As a result, such a bearing has slight damping characteristics since the stiffening elements do not enable any major dissipation of energy.

Hence the present inventors have attempted to bring about a further improvement in the fluid bearings and have designed a radial hydrodynamic fluid-film bearing characterised in that the upper stiffening element and the lower stiffening element of each bearing sub-assembly are secured to two separate bars of two adjacent sub-assemblies and overlap on at least part of one of their faces so as to

slide in relation to one another in opposite directions.

At start-up the bearing should present a marked wedge of air for initiating the fluid film. To this end, a prestressing spring will advantageously be located, in each bearing sub-assembly, between the bar and the sleeve.

Another solution consists in preforming the flexible strips, the lower stiffening elements or the upper stiffening elements. In this case the preformed element has a function analogous to that of the prestressing spring.

10 The start-up stiffness attained by one of these processes is low by comparison with the stiffness in operation.

In each bearing sub-assembly upper stiffening element 3 preferably has projecting parts on its upper face and lower stiffening element 4 preferably has projecting parts on its lower face, with the projecting parts of one of the stiffening elements alternating with the projecting parts of the other stiffening element, whereby said projecting parts constitute supports.

20 In such a device, friction of the smooth part of each upper and lower stiffening element situated opposite occurs in the course of vertical movements generated via the supports as a result of load fluctuations. To this end the stiffening elements are held at one of their ends without being able to move in the direction of movement of the sub-assembly. One of the stiffening elements is held against the upstream bar and the other against the downstream bar. The undulations produced during deformation under a load give rise to a relative sliding motion of the two stiffening elements in opposite directions, thus causing friction and energy absorption.

The smooth parts opposite each stiffening element may be provided with a coating selected with a view to adjusting the damping effect.

35 During operation under load the assembly of strips and stiffening elements comes to act in supporting manner while taking up the deformation induced by the effect of the

start-up spring or the element taking its place. Elasticity is brought about by vertical depression of the supports against the stiffening elements. The upper and lower supports are arranged in such a way that, in the presence of
5 a load, the inclination of the bearing is close to the optimal inclination. In fact, if the inclination deviates excessively from the ideal inclination, the load-bearing capacity may become zero.

Change of inclination as a function of the load
10 results from depression of the assembly, whereby the front, the centre and the rear of the bearing are not depressed by the same amount as a function of the load.

With a preferred embodiment, cut-outs can be provided in upper stiffening elements 3 or in both the lower
15 and the upper stiffening elements so as to cause local weakening of said elements in order to achieve the desired optimal deformation.

With another embodiment of the invention each flexible strip 2 is so dimensioned that its free end covers
20 the fixed end of the adjacent strip. This results in supplementary damping due to friction of said flexible strips against one another.

Moreover, flexible strip 2 of a bearing sub-assembly can be perforated directly downstream of the
25 preceding sub-assembly so that the active part of the following strip is correctly supplied with gas.

Preferably these strips can be provided with a coating consisting of a material comprising a self-lubricating constituent such as polytetrafluoroethylene
30 (PTFE).

A bearing according to the invention preferably comprises from two to nine bearing sub-assemblies such as defined above.

The present invention will be explained in greater
35 detail and in non-restrictive manner with reference to the attached drawings.

In these drawings each of Figures 1 to 3 shows a cross-sectional view of three different bearings according to the invention.

Figures 4 and 5 show sectional views of two types of stiffening element.

Figure 6 shows a part of a cross-section of a fourth embodiment.

Figure 7 shows a schematic view of an aeroplane equipped with bearings according to the invention.

10 The bearing illustrated in Figure 1, the purpose of which is to support shaft 1, comprises a sleeve 7 in which are inserted bars 5. Springs 6 are located between bars 5 and sleeve 7.

To each bar 5 are secured a lower stiffening 15 element 4, an upper stiffening element 3 and a flexible strip 2. The two stiffening elements of any one bearing sub-assembly slide radially against the adjacent bars. Flexible strips 2 partly overlap.

Stiffening elements 3 and 4 each consist of a 20 metallic sheet bent so as to form an assembly part. The face of each stiffening element provided with projecting parts is grooved so as to form ribs and recesses which alternate and are arranged longitudinally in relation to the shaft.

Such a stiffening element is shown in Figure 4, in 25 which 12 designates the assembly part, 8 designates the ribs and 9 designates the recesses of the face provided with projecting parts.

In the stationary state rib 2 is applied to shaft 1 by bar 5, which in turn is subject to pressure from 30 prestressing spring 6. Strip 2 is not applied to upper stiffening element 3 and operates by virtue of its own stiffness. So as to optimise at start-up the product of pressure and speed between the shaft and the self-lubricating coating of strip 2, the prestress is adjusted 35 independently of all other bearing functions by selection of the stiffness and force of spring 6. The stiffness is considerably lower than that of the two stiffening elements

3 and 4. Spring 6 only exerts a significant influence when starting up.

During stable operation a pressure range generated by the rotation of shaft 1 is established between shaft 1 and strip 2. This range causes strip 2 to be applied to stiffening elements 3 and 4 which are depressed radially depending on the intensity of the load.

During operation tending to be unstable the pressure range fluctuates, causing radial displacement of strip 2. This radial displacement gives rise to a relative peripheral displacement between two strips, which in turn brings about a first damping by reciprocal friction of the parts while said strips, which then come to be located on a different diameter, overlap.

A second, more significant, form of damping by friction is due to the relative peripheral displacement of strip 2 and stiffening element 3.

A third form of damping by friction is caused by the relative peripheral displacement of upper stiffening element 3 and lower stiffening element 4.

Moreover, the presence of a prestressing spring makes it possible to add in a single element the advantages of damping due to friction between the coatings of different elements and the advantages of improved loading and damping of the two stiffening elements.

Figure 2 illustrates a bearing of the same type as that in Figure 1 except for the prestressing spring. In this Figure the elements corresponding to those of the bearing in Figure 1 are designated by the same reference numbers. The sleeve consists of two parts: an inner sleeve 10 through which pass bars 5 and an outer sleeve 11. A blade spring 13 is located at the end of the bar facing away from the shaft, between inner sleeve 10 and outer sleeve 11. The bearing illustrated in this Figure 2 operates in a manner analogous to that of the bearing in Figure 1, both at start-up and during stable operation or operation tending to be unstable.

Figure 3 illustrates a bearing equipped with a blade spring 13 identical with that in Figure 2. Outer stiffening element 4 is of the type illustrated in Figure 5. It consists of a metallic sheet having a curvature and bent so as to form an assembly part 12. Supports 14 consist of hollow rods with semi-circular cross-section, point-welded to the metallic sheet. Flexible strip 2 of a bearing sub-assembly is the extension of upper stiffening element 3 of the adjacent sub-assembly so as to form a single sheet. The zone by which said single sheet is secured to bar 5 constitutes the boundary between the flexible strip and the upper stiffening element. The projecting parts of the upper stiffening element are identical with those of lower stiffening element 4 and arranged alternately with those of stiffening element 4. With this embodiment flexible strips 2 and the stiffening elements act in the same way as with the embodiments in Figures 1 and 2.

Figure 6 shows a sectional view of a part of a bearing according to the invention in another embodiment. Lower stiffening element 3 is of the type shown in Figure 5. Upper stiffening element 4 is of analogous type. The curvatures of the two stiffening elements differ so as to create the equivalent of a prestressing spring. After start-up the load causes the upper stiffening element to abut the lower stiffening element. Moreover, there is no coating between two adjacent flexible strips 2. These strips are separate.

Figure 7 illustrates an aeroplane 15 equipped with jet engines 16. Jet engines 16 comprise turbine engines 17 comprising in turn bearings 18 according to the invention.

The improvements of the bearings according to the invention make it possible to increase the loading of the bearings. This characteristic is of particular interest when the bearings are used in turbine engines, especially when the latter pertain to aircraft, in particular military aircraft.



CLAIMS

1/ - Radial hydrodynamic fluid-film bearing comprising a sleeve (7, 10, 11) in which a shaft (1) is free to rotate, whereby sleeve (7, 10, 11) and shaft (1) form
5 between them an annular space accommodating a plurality of bearing sub-assemblies, each having:

- a flexible strip (2) separated from shaft (1), the contour of which it partly follows, by a layer of fluid film, said strip (2) being firmly connected with a bar (5)
10 secured by insertion in a recess provided in sleeve (7, 10, 11), and

- stiffening elements - an upper stiffening element (3) and a lower stiffening element (4) - located between flexible strip (2) and sleeve (7, 10, 11), said
15 stiffening elements being secured to said sleeve and so designed as to counteract the deformations of the flexible strip,
characterised in that upper stiffening element (3) and lower stiffening element (4) of each bearing sub-assembly are
20 attached to two different bars (5) of two adjacent sub-assemblies and overlap on at least part of one of their faces so as to slide in relation to one another and in opposite directions.

2/ - Bearing according to claim 1, characterised
25 in that, in each bearing sub-assembly, upper stiffening element (3) has projecting parts (8, 14) on its upper face, whereas lower stiffening element (4) has projecting parts (8, 14) on its lower face, with the projecting parts of one of the stiffening elements alternating with the projecting
30 parts of the other stiffening element.

3/ - Bearing according to claim 2, characterised in that each stiffening element (3, 4) consists of a metallic sheet of suitable curvature, one of the faces of which is alternately provided with ribs (8) and recesses
35 (9).

4/ - Bearing according to claim 2, characterised in that the projecting parts are constituted by rods (14)



with semi-circular cross-section, point-welded to the sheet constituting each stiffening element.

5/ - Bearing according to one of claims 1 to 4, characterised in that flexible strip (2) of a bearing sub-assembly is the extension of upper stiffening element (3) of an adjacent sub-assembly so as to form a single sheet, whereby the zone by which said single sheet is secured to bar (5) constitutes the boundary between flexible strip (2) and upper stiffening element (3).

10 6/ - Bearing according to any one of claims 1 to 5, characterised in that the fixed end of a flexible strip (2) secured to a bar (5) is covered by the free end of flexible strip (2) of the adjacent bearing sub-assembly.

7/ - Bearing according to any one of claims 1 to 15 6, characterised in that bar (5) is connected with sleeve (7) by means of a prestressing spring (6).

8/ - Bearing according to claim 7, characterised in that, with the sleeve comprising an inner sleeve (10) and an outer sleeve (11), bar (5) passes through inner sleeve 20 (10) and is connected with outer sleeve (11) by means of a blade spring located between the sleeves (10 and 11).

9/ - Bearing according to any one of claims 1 to 6, characterised in that one of the elements of each bearing sub-assembly, i.e. flexible strip (2), upper stiffening 25 element (3) or lower stiffening element (4), is preformed in such a manner as to ensure the formation of a marked wedge of air when the bearing is started up.

10/ - Bearing according to any one of claims 1 to 9, characterised in that each upper stiffening element (3) 30 or all upper stiffening elements (3) and lower stiffening elements (4) are provided with cut-outs.

11/ - Bearing according to any one of claims 1 to 10, characterised in that flexible strip (2) of each bearing sub-assembly is provided with perforations directly 35 downstream of the adjacent sub-assembly.

12/ - Turbine engine, characterised in that it comprises a radial hydrodynamic fluid-film bearing according



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to any one of claims 1 to 11.

13/ - Aircraft, characterised in that it comprises
at least one bearing according to one of claims 1 to 11.