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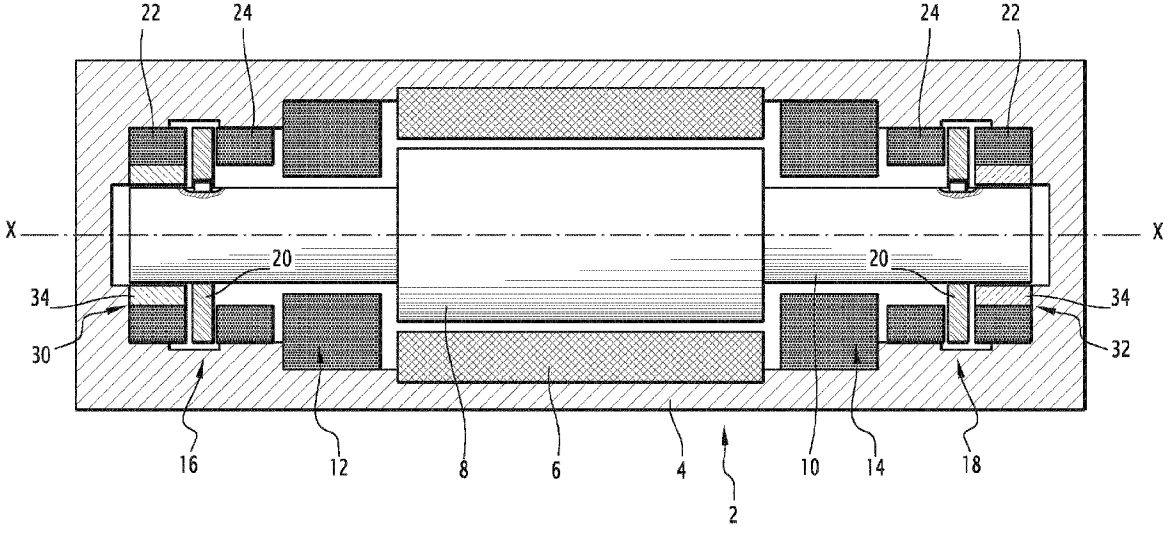


(57) Abrégé/Abstract:
This electrical machine, more specifically a motor (2) comprising a stator (6), a rotor (8), a first main bearing (12), suitable for supporting the rotor (8) with respect to the stator (6) in a main speed range and a first secondary bearing (16) suitable for supporting the rotor with respect to the stator should the first main bearing fail. The or each secondary bearing (16) is a passive electrodynamic bearing comprising at least one permanent magnet and a mobile electrically conducting element. Application to electrical machines, in particular to asynchronous or synchronous motors.

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# ELECTRICAL MACHINE


## ABSTRACT

This electrical machine, more specifically a motor (2) comprising a stator (6), a rotor (8), a first main bearing (12), suitable for supporting the rotor (8) with respect to the stator (6) in a main speed range and a first secondary bearing (16) suitable for supporting the rotor with respect to the stator should the first main bearing fail. The or each secondary bearing (16) is a passive electrodynamic bearing comprising at least one permanent magnet and a mobile electrically conducting element.

Application to electrical machines, in particular to asynchronous or synchronous motors.

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# ELECTRICAL MACHINE

The present invention concerns an electrical machine, more specifically a motor comprising:

- a stator,

- a rotor,

-at least a first main bearing, in particular an active magnetic bearing, suitable for supporting the rotor with respect to the stator over a main speed range, and

- at least a first secondary bearing suitable for supporting the rotor with respect to the stator should the main bearing fail.

Such electric motors are known to have main bearings which are active magnetic bearings, in order to support in rotation, the rotor with respect to the stator.

These motors also comprise for each main bearing an auxiliary bearing suitable for supporting the rotor with respect to the stator should the associated main bearing fail.

The auxiliary bearings used in the technique only function in a given speed range, that is a relatively low speed range. The auxiliary bearings are plain bearings.

However, roller bearings do not allow motors to be used under specific environmental conditions, e.g. in environments subject to pollution.

In addition, roller bearings have only a limited service life.

The purpose of the invention is to compensate for at least one of the above inconveniences. The aim is to propose an electric motor that allows use in an environment subject to pollution and/or that is reliable.

To this effect, the subject of the invention is, an electric motor such as indicated above, characterised in that the or each secondary bearing is a passive electrodynamic

bearing comprising at least one permanent magnet and a mobile electrically conducting element.

Depending on the production methods, the electrical machine according to the invention includes one or several of the following features:

- a second main bearing, notably a magnetic bearing, suitable for supporting the rotor with respect to the stator in the main speed range and a second, secondary bearing suitable for supporting the rotor with respect to the stator should the second main bearing fail;

- the or each secondary bearing is suitable for supporting the shaft in the secondary speed range and the secondary speed range is limited at the lower limit by a stability threshold speed;

- a first auxiliary bearing which is associated with the first main bearing and/or if need be a second auxiliary bearing which is associated with a secondary main bearing and the or each auxiliary bearing is suitable for supporting the rotor with respect to the stator in an auxiliary speed range different from the main speed range, in particular whose upper limit of the auxiliary speed range is greater than or equal to the stability threshold speed;

- the or each auxiliary bearing is a plain bearing;

- the plain bearing either comprises a bearing ring and is specifically composed of a bearing ring, or a pad journal bearing;

- the or each auxiliary bearing comprises at least one roller bearing;

- the or each secondary bearing comprises a ring fixed to the rotor and two elements fixed with respect to the stator, the ring comprising an electrically conducting element or is composed of an electrically conducting element and each fixed element comprises one of the permanent magnets;

- the two fixed elements are arranged on one side or another of the associated ring;

- at least one of the fixed elements axially covers the associated auxiliary bearing;

- each auxiliary bearing is offset from the secondary bearing such that the bearing ring of the auxiliary bearing is offset axially from all the fixed elements.

The invention will be better understood by reading the following description, given only as an example and made in reference to drawings, in which:

Figure 1 shows very schematically an electric motor according to the invention in axial cross-section and

- Figure 2 shows the range of operation of the different motor bearings according to the invention.

Figure 1 shows the electric motor according to the invention, designated by the general reference 2.

The motor 2 is an example of an asynchronous motor. The electric motor 2 is a motor have a very high nominal rotation speed. The nominal rotation speed can be e.g. greater than 5000 rpm and can be greater than 10,000 rpm.

The electric motor 2 comprises a box 4, a stator 6, a rotor 8 and a shaft 10.

The rotor 8 and the shaft 10 are housed in the box 4 around an axis of rotation X-X. In the following, the expressions "axially", "radially" and "circumferentially" are used with respect to the axis of rotation X-X. The axes belonging to the elements described hereafter are considered to be co-axial with the axis of rotation, unless otherwise specified.

The shaft (10) and the rotor (8) taken together have a mass greater than 300 kg and more specifically greater than 750 kg.

The electric motor 2 also comprises a first main bearing 12 and a second main bearing 14.

The first and second main bearings 12, 14 are identical and support the rotor 8 with respect to the stator 6 in rotation around the axis X-X. The two main bearings 12, 14 are arranged axially on either side of the rotor 8. The first main bearing 12 and the second main bearing 14 are both active magnetic bearings. An active magnetic bearing being a bearing comprising electromagnets, must be supplied with electric current and continuously controlled in order to centre the shaft 10 and the rotor 8 with respect to the axis of rotation X-X.

The first and the second main bearings 12, 14 support the shaft in a main speed range. This main speed range is for example limited by 0 rpm. The main speed range is also limited by the nominal speed of rotation of the electric motor 2 or by a speed greater than this nominal speed of rotation (overspeed, other).

The electric motor 2 also comprises a first secondary bearing 16 and a second secondary bearing 18. The first secondary bearing 16 is suitable for supporting the rotor 8 with respect to the stator 6 should the first main bearing 12 fail. The second secondary bearing 18 is suitable for supporting the rotor 8 with respect to the stator 6 should the second main bearing 14 fail. Each of the first and second secondary bearings 16, 18 is therefore a bearing whose function corresponds to that of a landing bearing, without being strictly speaking a landing bearing given that there is no physical contact created between the shaft 10 and the secondary bearings 16, 18 when the secondary bearings support the shaft.

The two secondary bearings 16, 18 are arranged axially on either side of the rotor 8.

The two secondary bearings 16, 18 are identical and subsequently only one of the secondary bearings 16, 18 will be described.

The secondary bearing 16, 18 is an electrodynamic bearing. An electrodynamic bearing is a passive bearing, i.e. it operates without the provision of an external electricity supply.

The secondary bearing 16, 18 comprises a ring 20 and two fixed elements 22, 24.

The ring 20 is fixed in rotation and in translation to the shaft 10 and therefore to the rotor 8. The ring 20 is therefore a rotating ring. The ring 20 comprises an electrically conducting but non-magnetic or weakly magnetic element. It is e.g; made of metal or light alloy such as aluminium.

Each fixed element 22, 24 is fixed with respect to the stator 6 and is fixed to the box 4. Each fixed element 22, 24 is comprised of permanent magnets.

The properties of the permanent magnet-conductor pair determines the range of operation of the electrodynamic bearing. The direction of circulation of the current depends on the speed of rotation. This direction determines the stability threshold described hereafter. An electrodynamic bearing is a passive magnetic bearing combining the permanent magnets with the circulating currents (Foucault current) generated in the conducting elements of the ring 20.

The two fixed elements 22, 24 are arranged on either side of the ring 20 considered along the axis of rotation X-X. The two fixed elements 22, 24 cover the ring 20 radially.

The secondary bearing 16, 18 defines the secondary speed range in which it is suitable for supporting the rotor 8 and the shaft 10 with respect to the box 4. This secondary speed range is e.g. limited at the upper end by maximum speed limit of the main speed range, by the nominal speed of the electric motor 2 or a speed greater than this nominal speed. The secondary speed range is limited at the lower end by a speed that is at the stability threshold of the secondary bearing 16, 18. The stability threshold speed is strictly greater than 0 rpm and lies for example between 1000 rpm and 10,000 rpm.

The electric motor 2 also comprises a first auxiliary bearing 30 and a second auxiliary bearing 32. The first auxiliary bearing 30 is associated with the first main bearing 12 while the second auxiliary bearing 32 is associated with the second main bearing 14.

Each of the first and second auxiliary bearings 30, 32 is suitable for supporting the rotor 8 and the shaft 10 with respect to the stator 6 should the first main bearing 12 or the second main bearing 14 fail, and when the secondary bearings 16, 18 do not support the shaft 10 given that the speed of rotation is less than the stability threshold speed. Each of the first and second auxiliary bearings 30, 32 is therefore a landing bearing. Each of the first and second auxiliary bearings 30, 32 is a landing bearing at low speed of rotation when the speed of rotation is less than the stability threshold speed of the secondary bearing.

The first auxiliary bearing 30 and the second auxiliary bearing 32 are examples of plain bearings. Each plain bearing comprises a bearing ring 34 and in particular includes this bearing ring 34. The plain bearing can also be a pad journal bearing. In this case, the pads are formed by annular segments. The bearing ring 34 or the pads are e.g. made of copper or a copper based alloy, or a PEEK (polyetheretherketone) based plastic material. The ring 34 or the pads can also be of a composite material, such as a material comprised of glass-fibre, carbon or PEEK.

Each auxiliary bearing 30, 32 is suitable for supporting the shaft 10 in an auxiliary speed range that is different from the main speed range.

The auxiliary speed range is also different from the secondary speed range. Generally, the auxiliary speed range is less that the secondary speed range but it can overlap the secondary speed range. The auxiliary speed range includes speeds lower than the stability threshold speed of the associated secondary bearing 16, 18. The auxiliary speed range is lies between 0 rpm and a speed greater than or equal to the stability threshold speed (lower limit of secondary bearings speed). Thus, one has an overlap of speeds between the auxiliary speed range and the secondary speed range. Thus, if there is a failure of the main bearings 12, 14, whatever the speed of rotation that

is decreasing, the rotor 8 and the shaft 10 will be supported by the secondary bearings and by the auxiliary bearings until the motor comes to a stop.

The auxiliary bearings 30, 32 have each a speed range of operation less than the speed range of the secondary bearings 16, 18. The upper limit of this auxiliary speed range of the auxiliary bearings 30, 32 is greater than or equal to the lower limit of the speed range of the secondary bearings.

One or both of the fixed elements 22, 24 axially covers the associated auxiliary bearing 30, 32. In the case illustrated in the figure, it is element 22 that axially covers the auxiliary bearing 30, 32. Thus, the dimensions of the motor 2, for a given power, are relatively small.

The electric motor 2 according to the invention operates in the following manner.

During the correct operation of the main bearings, each main bearing 12, 14 supports the shaft 10 and the rotor 8 with respect to the stator 6 around the axis of rotation X-X. In this case, none of the auxiliary bearings 30, 32 supports the shaft 10 and the secondary bearings 16, 18 contribute to supporting the shaft 10. In this case, the shaft lies at a radial distance from the auxiliary bearings 30, 32.

When the rotor 8 and the shaft 10 are driven to a speed of rotation situated in the secondary speed range of the first secondary bearing 16 and the second secondary bearing 18, during failure of the main bearings 12, 14, the shaft 10 is first of all supported only by the associated secondary bearings 16, 18, but is not in contact with the auxiliary bearings 30, 32. Thus, at high rotation speeds, the auxiliary bearings 30, 32 cannot be damaged since the shaft lies at a radial distance from the auxiliary bearings (no contact), providing a reliable operation that is one of the goals of the invention.

Once the shaft 10 and the rotor 8 have been slowed down such that the speed of rotation lies in the auxiliary speed range of the auxiliary bearings 30, 32 and in particular when the speed leaves the secondary speed range, only the auxiliary bearings 30, 32 support the shaft 10.

The secondary electrodynamic bearings 16, 10 are robust by design since there is never any contact whatever the speed of rotation unlike landing roller bearings. Thus, in case of failure of the main bearings, the operation is more reliable for a much greater possible number of slow-downs from a high speed, due to the secondary electrodynamic bearings 16, 18 without contact, than the current technologies which use roller landing bearings. In fact the electrodynamic bearings are frictionless and do not wear. Also, this is why the auxiliary landing bearings 30, 32 which are plain bearings, are more suitable for the aggressive environmental conditions described below.

In addition, the motor according to the invention can work in environmental conditions that would not be allowed for a motor having landing roller bearings, such as the presence of humid gas, dirty gas or acid gas (in particular presence of $H_2S$, $CO_2$, Hg, etc.). This is the 2nd goal of the invention in addition to reliable operation.

Fig. 2 shows the operating ranges of the different bearings of the motor according to the present invention. Curve 100 shows the speed of rotation over time. A point 102 indicates a stability threshold speed for the electrodynamic secondary bearings. A main range of speeds of the main bearings (active magnetic bearings 12, 14) A, a secondary range of speeds (electrodynamic bearings 16, 18) B and an auxiliary range of speeds (landing auxiliary bearings 30, 32) C are shown. An upper limit of the auxiliary range of speeds C is greater than or equal to the stability threshold speed 102. A lower limit of the secondary range of speeds B is delimited by the stability threshold speed 102.

In a variant not shown, each auxiliary bearing 30, 32 is offset from the secondary bearing 16, 18 such that the bearing ring 34 is offset from all the fixed elements 22 or 24.

In another variant, the or each auxiliary bearing 30, 32 comprises or is composed of one or several bearings.

Lastly, the invention has been described by referring to a motor. It could be applied to any rotating electrical machine, for example a generator, an asynchronous or synchronous motor.

WHAT IS CLAIMED IS:

1. An electrical machine comprising:

at least one main bearing supporting a rotor relative to a stator, wherein the main bearing is disposed at an end of a shaft supporting the rotor;

at least one secondary bearing configured to support the rotor relative to the stator when the main bearing becomes faulty, wherein the at least one secondary bearing includes a permanent magnet fixed to a casing of the electric machine and a moveable amagnetic electric conductor element fixed relative to the shaft and the rotor; and

an auxiliary bearing disposed adjacent to the at least one secondary bearing, wherein the permanent magnet included in the at least one secondary bearing axially covers the auxiliary bearing;

wherein the at least one secondary bearing is an electrodynamic bearing.

2. The electric machine according to claim 1, comprising two main bearings, each having a corresponding secondary bearing.

3. The electric machine according to claim 1, wherein the at least one secondary bearing supports the shaft in a secondary range of speeds.

4. The electric machine according to claim 1, wherein the at least one auxiliary bearing is associated with the at least one main bearing, the at least one auxiliary bearing supporting the rotor relative to the stator in an auxiliary range of speeds different from the main range of speeds.

5. The electric machine according to claim 4, wherein the at least one auxiliary bearing is a smooth bearing.

6. The electric machine according to claim 5, wherein the smooth bearing includes a bearing ring or includes pads.

7. The electric machine according to claim 4, wherein the at least one auxiliary bearing includes at least one bearing with rolling elements.

8. The electric machine according to claim 1, wherein the at least one secondary bearing includes a ring attached to the rotor and two fixed elements, the ring including the electric conductor element and each fixed element including one of the at least one permanent magnets.

9. The electric machine according to claim 8, wherein both fixed elements are positioned on either side of the associated ring.

10. The electric machine according to claim 4, wherein the at least one secondary bearing includes a ring attached to the rotor and two fixed elements.

11. The electric machine according to claim 4, wherein the at least one secondary bearing includes a ring attached to the rotor and two fixed elements, the ring includes the electric conductor element and each fixed element includes one of the at least one permanent magnets, and each auxiliary bearing includes a bearing ring.

12. The electric machine according to claim 2, wherein the two main bearings are magnetic bearings.

13. The electric machine according to claim 1, further comprising a first main bearing for supporting the rotor relative to the stator in a main range of speeds, a first auxiliary bearing associated with the first main bearing, the first auxiliary bearing and the first main bearing supporting the rotor relative to the stator in an auxiliary range of speeds different from the main range of speeds.

14. The electric machine according to claim 3, wherein the secondary range of speeds is delimited by a stability threshold speed as a low limit.

15. The electric machine according to claim 4, wherein an upper limit of the auxiliary range of speeds is greater than or equal to a stability threshold speed.

16. The electric machine according to claim 10, wherein an upper limit of the auxiliary range of speeds is greater than or equal to a stability threshold speed.

17. The electric machine according to claim 13, wherein an upper limit of the auxiliary range of speeds is greater than or equal to a stability threshold speed.

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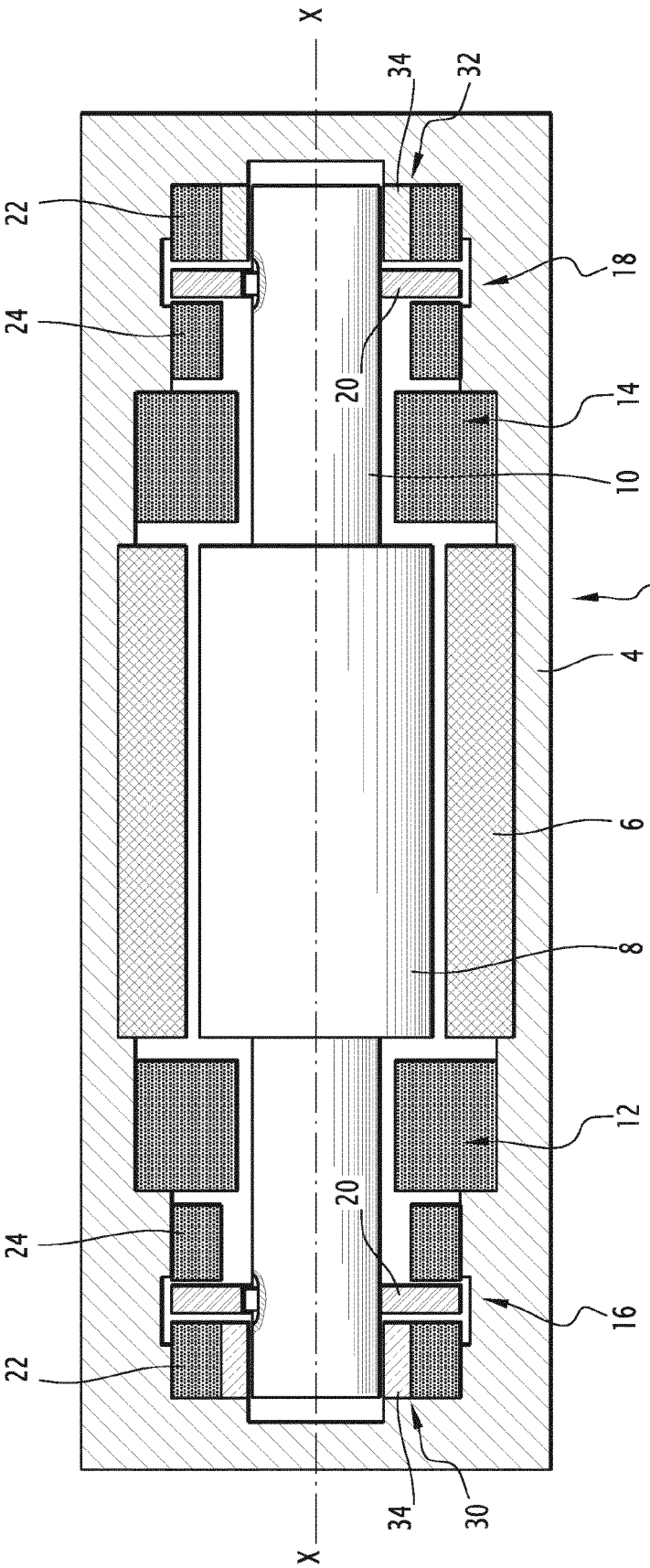



FIG.1

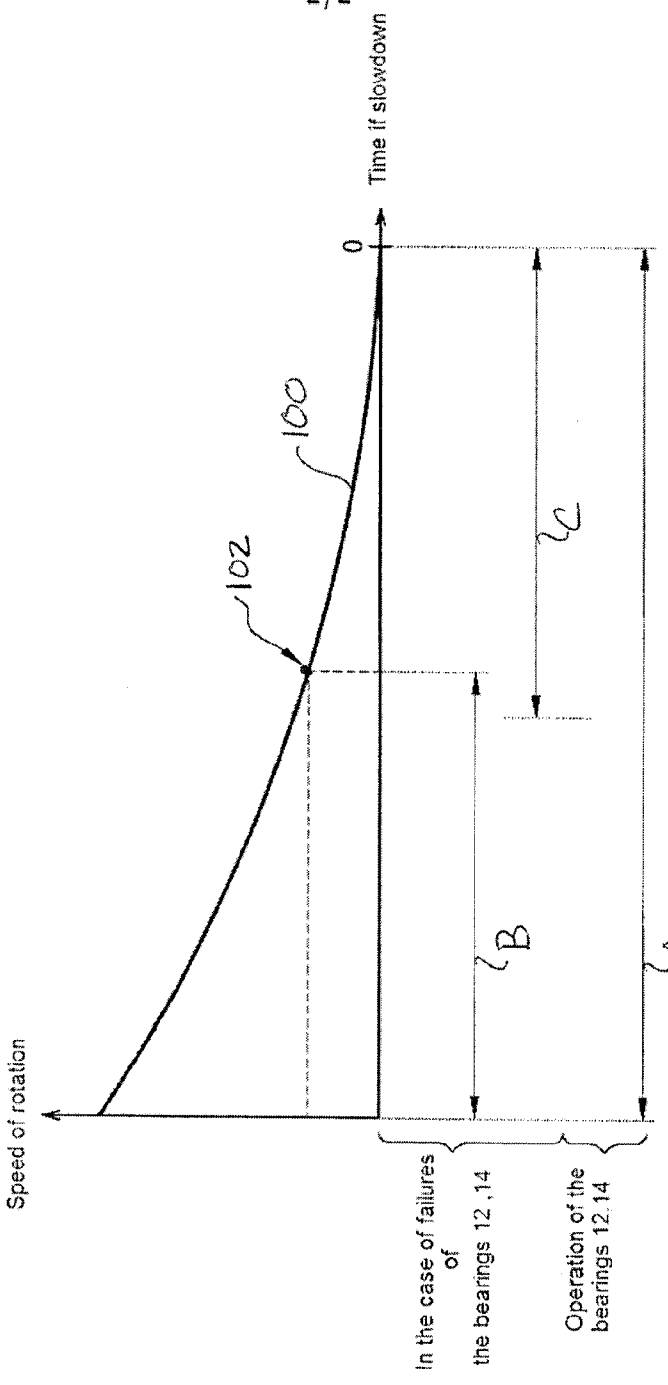
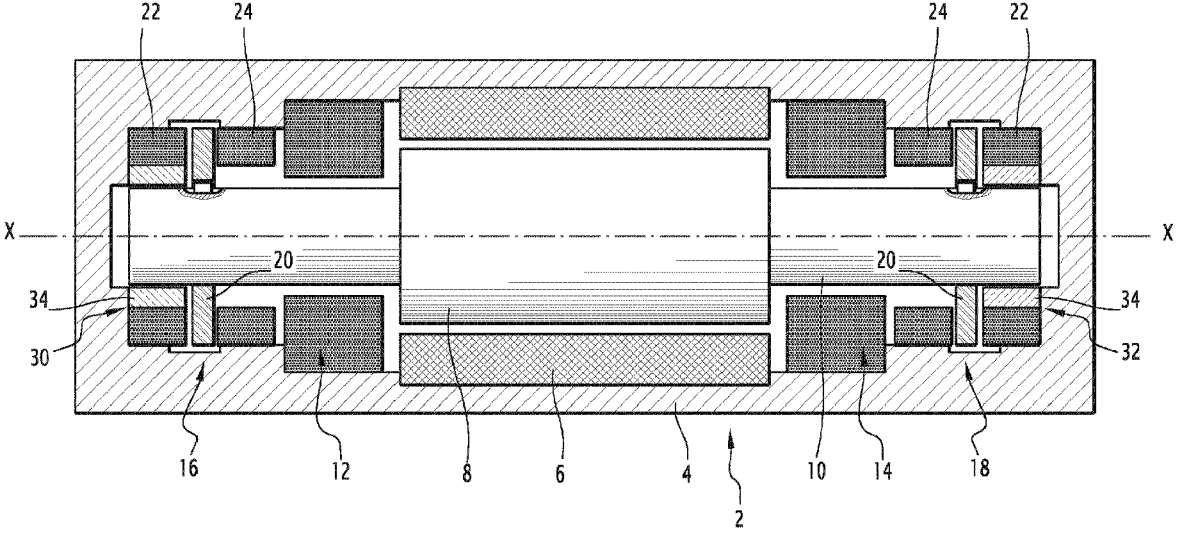

Time if slowdown
0
100
102
C
B
A
Speed of rotation
In the case of failures of the bearings 12,14
Operation of the bearings 12,14

FIG.2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