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[Continued on next page]

(54) Title: **BLADE ASSEMBLY WITH PRELOADED BEARING ASSEMBLY**

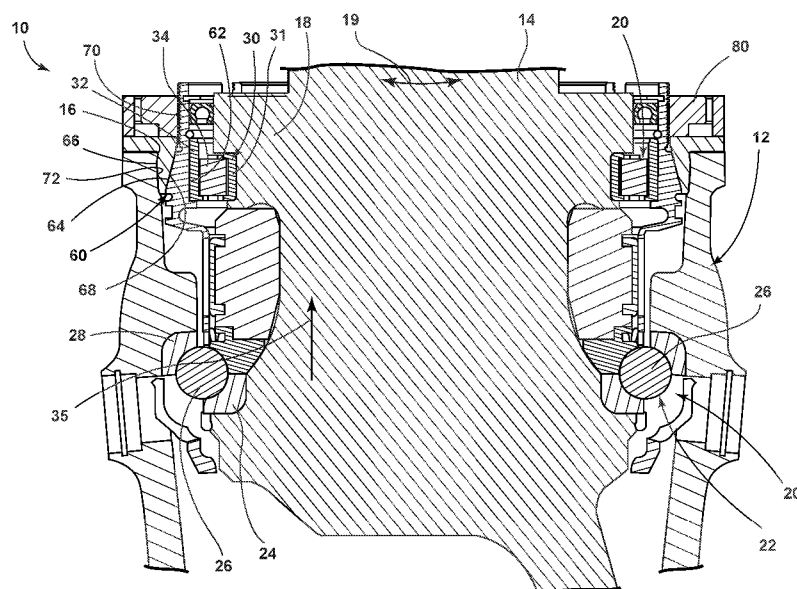


FIG. 3

(57) Abstract: A bearing assembly (30) is supported in a blade assembly such as a propeller (10), turbine or fan assembly and a blade assembly for a structure or craft having a hub having at least one blade opening (16), a blade (14) having an outer sleeve (18) received within the blade opening (16), and at least one preloaded bearing assembly (30) provided between the outer sleeve (18) and the hub (12) and where the at least one preloaded bearing assembly (30) is preloaded by means of a wedge assembly, allows the blade (14) to rotate within the hub (12) and is subject to the effects of rotational centrifugal force acting on the blade (14).

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BLADE ASSEMBLY WITH PRELOADED BEARING ASSEMBLY

BACKGROUND OF THE INVENTION

Contemporary propeller assemblies may have a means of varying the blade pitch via a pitch control unit, to optimize efficiency of thrust delivery. In this manner, the propeller may be designed to vary pitch in flight, to give optimum thrust, from takeoff and climb to cruise. Varying the pitch angle may allow the aircraft to maintain an optimal angle of attack or maximum lift to drag ratio on the propeller blades as aircraft speed varies. Variable pitch propeller blades utilize bearings to enable blades to rotate within a hub in which they are fitted.

BRIEF DESCRIPTION OF THE INVENTION

In one aspect, an embodiment of the invention relates to a blade assembly for an aircraft including a hub having at least one blade opening, a blade having an outer sleeve received within the blade opening, at least one preloaded bearing assembly provided between the outer sleeve and the hub and where the at least one preloaded bearing assembly allows the blade to rotate within the hub and is subject to the effects of rotational centrifugal force acting on the blade, and a secondary preload system operably coupled to the bearing assembly and radially preloading the bearing assembly against the hub wherein the secondary preload system divorces the radial preloading of the bearing assembly against the hub from the effects of the centrifugal force such that centrifugal loading on the bearing assembly has no effect on the radial preloading between the bearing assembly against the hub.

In another aspect, an embodiment of the invention relates to a method for supporting a bearing assembly in a blade assembly where the bearing assembly enables a blade of the blade assembly to rotate within a hub and is subject to the effects of rotational centrifugal force acting on the blade including preloading the bearing assembly for blade retention purposes and radially preloading a portion of the bearing assembly against the hub such that centrifugal loading on the bearing assembly has no effect on the radial preload between the bearing assembly and the hub.

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BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Figure 1 is a side view of an aircraft having a blade assembly in the form of a propeller assembly.

- 5 Figure 2 is a partially cut-away perspective view of a portion of a propeller assembly according to an embodiment of the invention.

Figure 3 is a cross-sectional view of a portion of the propeller assembly of Figure 2.

Figure 4 is a partially exploded view of a portion of the propeller assembly of Figure 2 with the secondary preload system partially installed.

- 10 Figure 5 is a cross-sectional view of the propeller assembly of Figure 4 with the secondary preload system partially installed.

Figure 6 is a cross-sectional view of the propeller assembly of Figure 4 with the secondary preload system partially installed.

- 15 Figure 7 is a perspective view of the propeller assembly of Figure 4 with the secondary preload system installed and secured.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

- Figure 1 illustrates an aircraft 8 having multiple blade assemblies or propeller assemblies 10 each having a hub 12 and multiple blades 14. While one example of an aircraft has been illustrated, it will be understood that any suitable structure or craft, to which a propeller, turbine or fan having one or more blades is fitted, may utilize
20 embodiments of the invention described herein. More specifically, a blade assembly may include any suitable type of blade assembly including a propeller, turbine, and fan. Figure 2 illustrates a portion of an exemplary propeller assembly 10 including the hub 12 and illustrating only a portion of a single blade 14 therein. While a
25 plurality of circumferentially spaced blades 14 may be supported within the hub 12 as

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illustrated in Figure 1, only a portion of one blade 14 is illustrated in the remaining figures for clarity purposes.

Referring to Figure 2, the hub 12 has a generally cylindrical shape that rotates about the propeller axis and provides a means to secure multiple blades 14. The hub 12 may be formed from any suitable material including metal or composite materials. The hub 12 may be formed in any suitable manner and may secure any number of blades 14. More specifically, the hub 12 may include blade openings 16 and a portion of the blade 14, for example an outer sleeve 18, may be received within one of the blade openings 16.

The outer sleeve 18 of the blade 14 may be, for example, a metallic outer root sleeve. Typically, the body of the blade 14 is formed in a twisted airfoil shape and may be composed of any suitable material, such as metal or composite materials. The blade 14 converts rotary motion into a propulsive force. The blade 14 may be line-removable to provide cost and maintenance advantages. Line-removable blades may be externally mounted outboard of the hub 12 and must be restrained adequately during their rotation. The term line-removable indicates that the blade 14 may be removed and replaced in the field.

A pitch control unit (not shown) may be used to vary the blade pitch of the blades 14 by rotating the blade 14 to turn the angle of attack of the blade 14 as illustrated by the arrows 19. A bearing assembly 20 may be included between the hub 12 and the blade 14 to enable the blade 14 to rotate within the hub 12, which aid in the rotation of the blade 14 during pitch adjustment.

Figure 3 illustrates the bearing assembly 20 having an inboard bearing assembly 22 having a seating ring 24, balls 26, and a ball plug 28 and an outboard bearing assembly 30 having an inner bearing track 31 spaced from an outer bearing track 32 with a roller assembly 34 located there between. While the outboard bearing assembly 30 has been illustrated as a parallel roller bearing assembly, it will be understood that the bearing assembly 20 may include any suitable type of bearings including that the outboard bearing assembly 30 may be a ball bearing assembly or a taper roller bearing assembly. Regardless of its type, the outboard bearing assembly

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30 may be considered to be a preloaded bearing assembly provided between the outer sleeve 18 and the hub 12 and where the outboard bearing assembly 30 is preloaded and allows the blade 14 to rotate within the hub 12, as illustrated by the arrows 19, and is subject to the effects of rotational centrifugal force acting on the blade 14, as
5 illustrated with arrow 35.

In the illustrated example, the outboard bearing assembly 30 is fitted onto the outer sleeve 18. During operation, the bearing assembly 20 is subject to the effects of the rotational centrifugal force acting on the blade 14. In particular, there may be a tendency for the centrifugal force on the blade 14, as illustrated with arrow 35, which
10 acts to increase the length of the blade 14, to reduce preload of the outboard bearing assembly 30. The effect of this also reduces the expanded diameter of the outer bearing track 32 of the outboard bearing assembly 30 and where it is being used as a means of reducing installation clearances, the outboard bearing assembly 30 can become loose in the hub 12. This can result in relative movement and premature wear
15 of the hub 12 and damage the inner bearing track 31 and outer bearing track 32, which are inadequately supported.

Embodiments of the invention include a method and apparatus for supporting a bearing assembly such as the outboard bearing assembly 30 including preloading the outboard bearing assembly 30 for blade retention purposes including allowing the
20 blade 14 to rotate within the hub 12 and radially preloading a portion of the outboard bearing assembly 30 against the hub 12 such that centrifugal loading on the outboard bearing assembly 30 has no effect on the radial preload between the outboard bearing assembly 30 and the hub 12. For example, radially preloading the portion of the outboard bearing assembly 30 against the hub 12 may include removing installation
25 clearances between the portion of the outboard bearing assembly 30 and the hub 12 such that the outboard bearing assembly 30 is not used as the means for reducing such installation clearances.

In the illustrated exemplary embodiment, a secondary preload system 60 is operably coupled to the outboard bearing assembly 30 and radially preloads the outboard
30 bearing assembly 30 against the hub 12. More specifically, the secondary preload

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system 60 is illustrated as wedge assembly having an inner part 62 with a wedge surface 64 and an outer part 66 having a wedge surface 68, with the wedge surfaces 64 and 68 contacting each other. A side of the inner part 62 of the wedge assembly forming the secondary preload system 60 opposite the wedge surface 64 is designed as a press fit onto the outer bearing track 32. The radial stiffness of the inner part 62 of the secondary preload system 60 is designed such that compressive forces transmitted onto the outer bearing track 32 are minimized during the preload process.

As more clearly illustrated in Figure 4, a portion of the inner part 62 of the secondary preload system 60 comprises a thread 70 upon which the outer part 66 may be received. Further, the outer part 66 of the wedge assembly has been illustrated as a collet 72, which may be sized so that it may be threaded onto the thread 70 of the inner part 62 of the wedge assembly. The collet 72 has been illustrated as a multi-split collet. While the inner part 62 of the wedge assembly is shown with a preloading thread 70, the thread could alternatively be applied to the outer part 66 or a double threaded nut arrangement could be used.

The wedge preload is applied once the blade 14 is fully installed. That is, the collet 72 may be left out of position during blade installation for optimised clearance. The collet 72 may then be loaded into the hub 12 as shown in Figure 5. During installation, at least one nut 80 may be attached to the inner part 62 of the wedge assembly. In the illustrated example, the at least one nut 80 is a ring nut Figure 6 illustrates the nut 80 as having been tightened upon the thread 70. When the nut 80 is tightened, the inner part 62 of the wedge assembly is urged axially through the collet 72 and the collet 72 expands around the wedge surface 64. In such a state, the secondary preload system 60 is configured to remove all radial clearance between the outboard bearing assembly 30 and the hub 12. Once the nut 80 has been tightened, the secondary preload system 60 is fully installed and may be secured as in Figure 7. More specifically, the nut 80 may be secured with a lock piece 90 and several bolts 92 and the collet 72 may be retained with a number of bolts 94. The secondary preload system 60 divorces the radial preloading of the outboard bearing assembly 30 against the hub 12 from the effects of the centrifugal force such that during operation

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centrifugal loading on the outboard bearing assembly 30 has no effect on the radial preloading between the outboard bearing assembly 30 against the hub 12.

The embodiments described above provide for a variety of benefits including that the fit of the outboard bearing in the hub is not subsequently influenced by the centrifugal force effects on the outboard bearing, which would otherwise tend to offload the bearing and allow the outer track to lose radial preload against the hub wall. The above-described embodiments may remove installation clearances and are independent of the preload of the bearing. This results in improvements in service reliability as premature bearing wear and hub wear are reduced. Further, the above-described embodiments allow the blade to continue to be line replaceable and do not require any specialized tooling to replace the blade.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

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CLAIMS:

1. A blade assembly (10), comprising:
 - a hub (12) having at least one blade opening (16);
 - a blade (14) having an outer sleeve (18) received within the blade opening (16);
 - a bearing assembly (30) preloaded and provided between the outer sleeve (18) and the hub (12) and where the bearing assembly (30) allows the blade (14) to rotate within the hub (12) and at least a portion of the bearing assembly (30) is subject to the effects of rotational centrifugal force acting on the blade (14); and
 - a secondary preload system (60) operably coupled to the bearing assembly (30) and radially preloading the bearing assembly (30) against the hub (12);wherein the secondary preload system (60) divorces radial preloading of the bearing assembly (30) against the hub (12) from the effects of the centrifugal force such that centrifugal loading on the bearing assembly (30) has no effect on the radial preloading between the bearing assembly (30) against the hub (12).
2. The blade assembly (10) of claim 1, wherein the secondary preload system (60) comprises a wedge assembly having an inner part (62) and an outer part (66) each having a wedge surface (64, 68) in contact with the other.
3. The blade assembly (10) of claim 2, wherein the inner part (62) of the wedge assembly comprises a thread (70) upon which the outer part (66) may be received.
4. The blade assembly (10) of either of claim 2 or 3, wherein the outer part (66) of the wedge assembly comprises a collet (72) sized to interface with the inner part (62) of the wedge assembly.
5. The blade assembly (10) of any of claims 2 to 4, further comprising at least one nut (80) operably coupled to the inner part (62) of the wedge assembly.

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6. The blade assembly (10) of claim 5, wherein when the nut (80) is tightened the inner part (62) of the wedge assembly is urged axially through the collet (72).
7. The blade assembly (10) of any preceding claim, wherein the secondary preload system (60) is configured to remove all radial clearance between the bearing assembly (30) and the hub (12).
8. The blade assembly (10) of any preceding claim, wherein the bearing assembly (30) comprises a parallel roller bearing assembly (30), a ball bearing assembly (30), or a taper roller bearing assembly (30).
9. The blade assembly (10) of any preceding claim, where the bearing assembly (30) comprises an inner bearing track (31) spaced from an outer bearing track (32) with a roller assembly (34) located there between.
10. The blade assembly (10) of claim 9, wherein the secondary preload system (60) comprises a wedge assembly having an inner part (62) and an outer part (66) each having a wedge surface (64) in contact with the other.
11. The blade assembly (10) of claim 10, wherein a side of the inner part (62) of the wedge assembly opposite the wedge surface (64) is designed as a press fit onto the outer bearing track (32).
12. The blade assembly (10) of either of claim 10 or 11, wherein the inner part (62) of the wedge assembly comprises a radial stiffness that minimizes compressive force transmitted onto the outer bearing track (32) during the preload process.
13. A method for supporting a bearing assembly (30) in a blade assembly (10) where the bearing assembly (30) enables a blade (14) of the blade assembly (10) to rotate within a hub (12) and is subject to the effects of rotational centrifugal force acting on the blade (14), comprising:

preloading the bearing assembly (30) for blade retention purposes; and

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radially preloading a portion of the bearing assembly (30) against the hub (12) such that centrifugal loading on the bearing assembly (30) has no effect on the radial preload between the bearing assembly (30) and the hub (12).

14. The method of claim 13 wherein radially preloading the portion of the bearing assembly (30) against the hub (12) comprises removing installation clearances between the portion of the bearing assembly (30) and the hub (12).

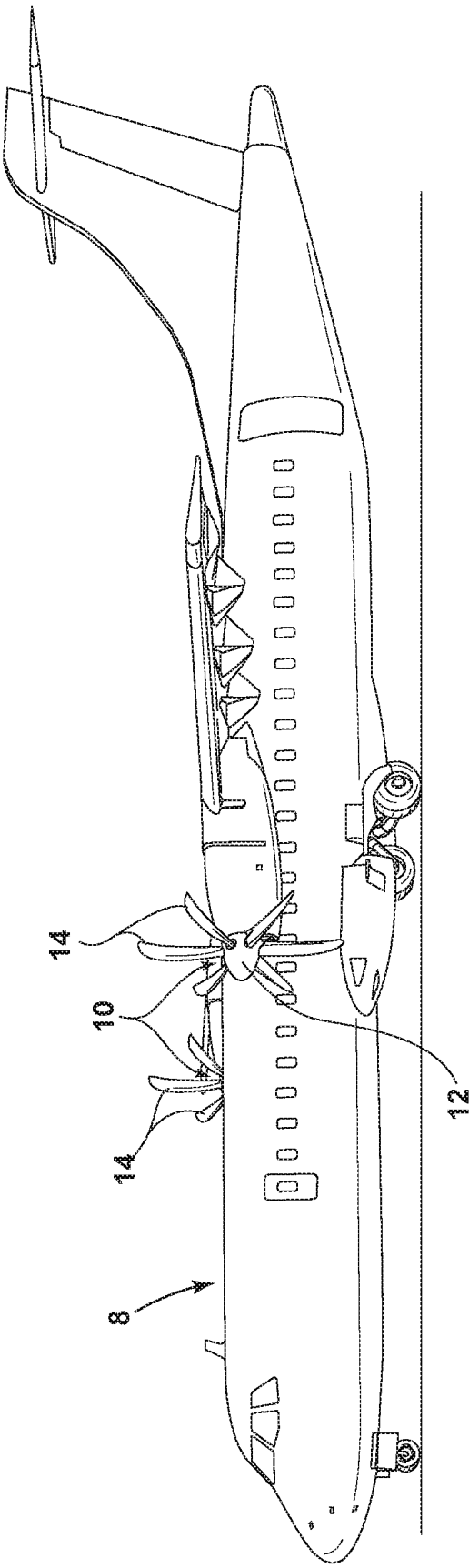


FIG. 1

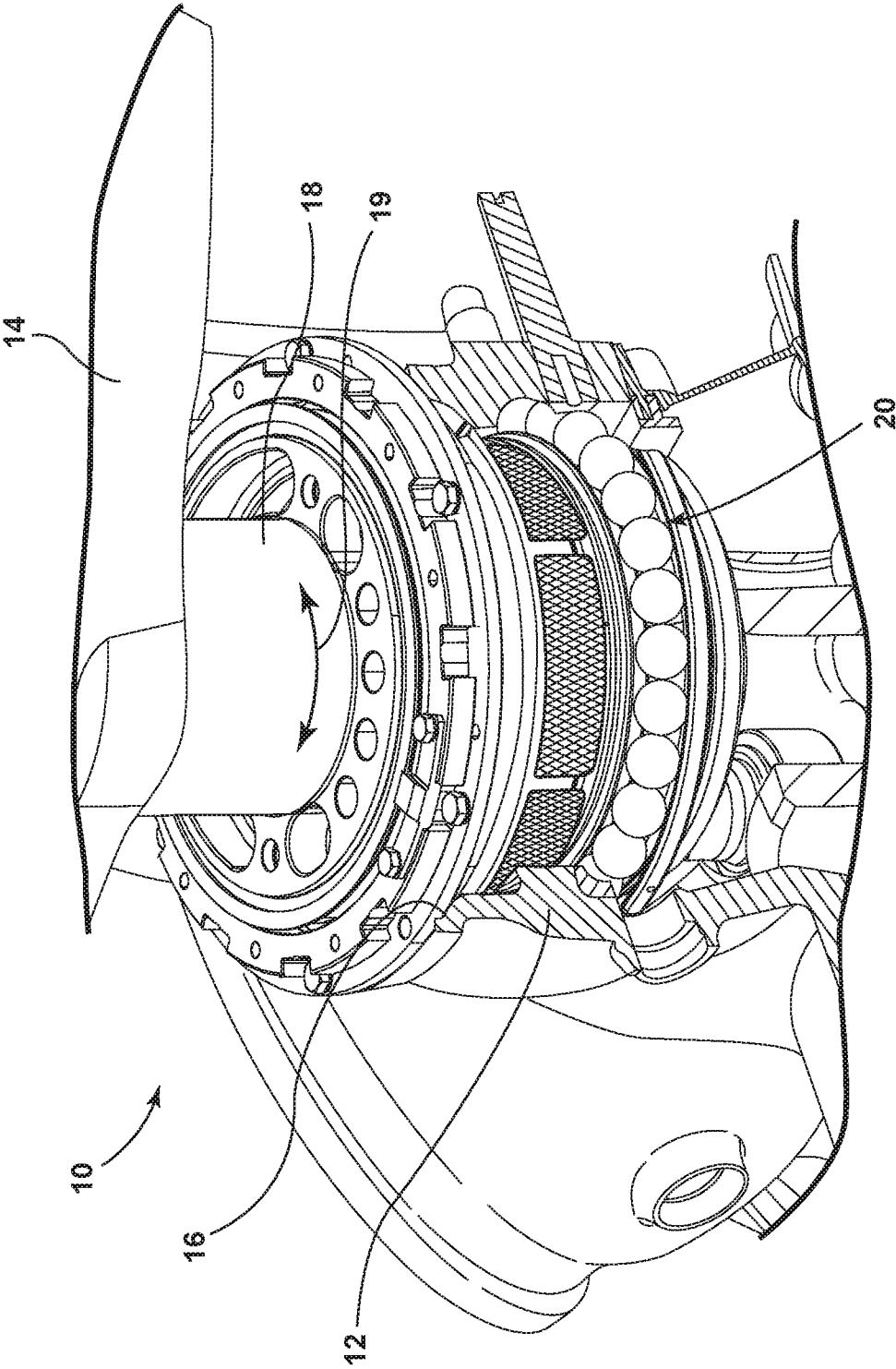
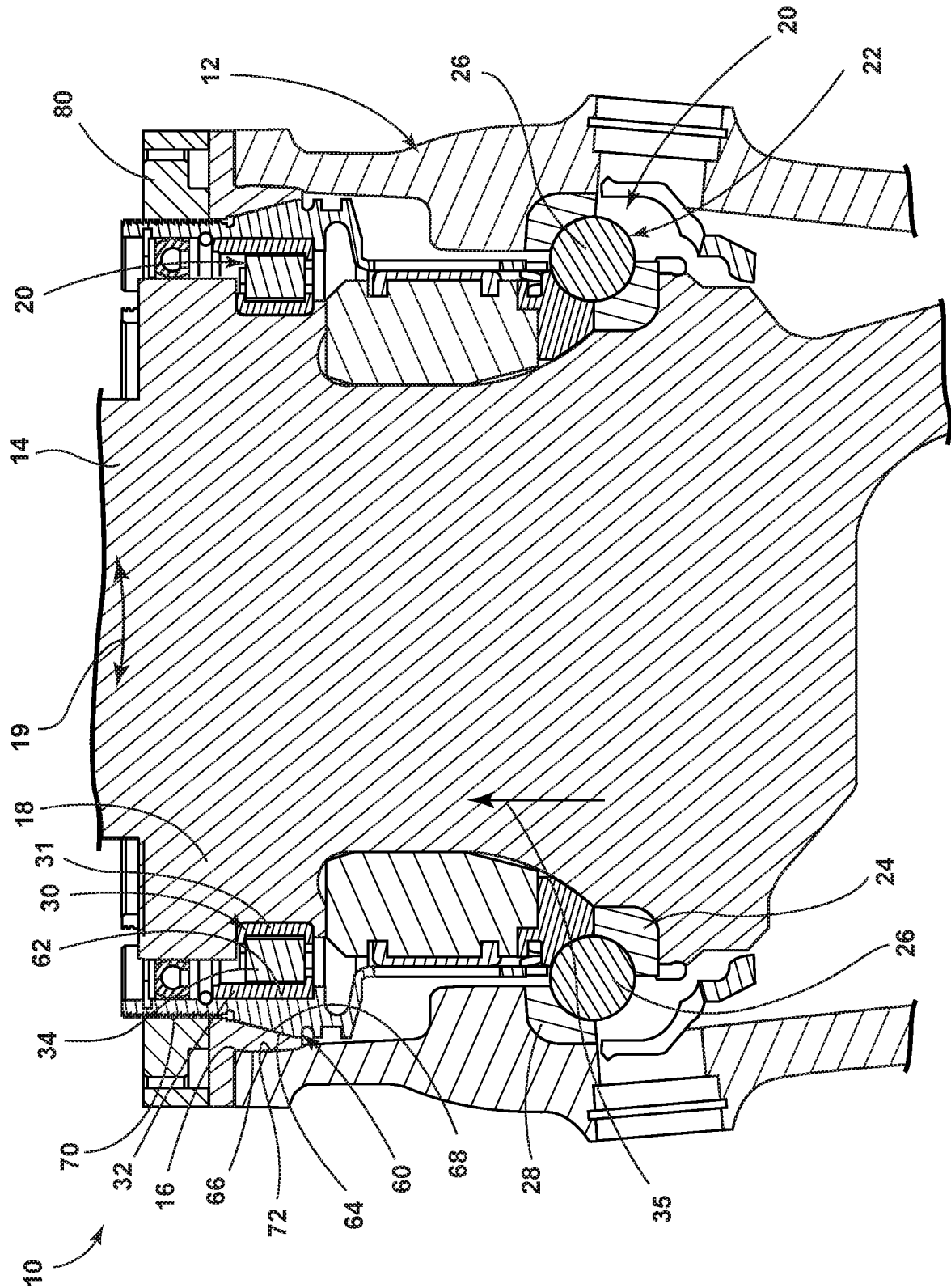


FIG. 2



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11

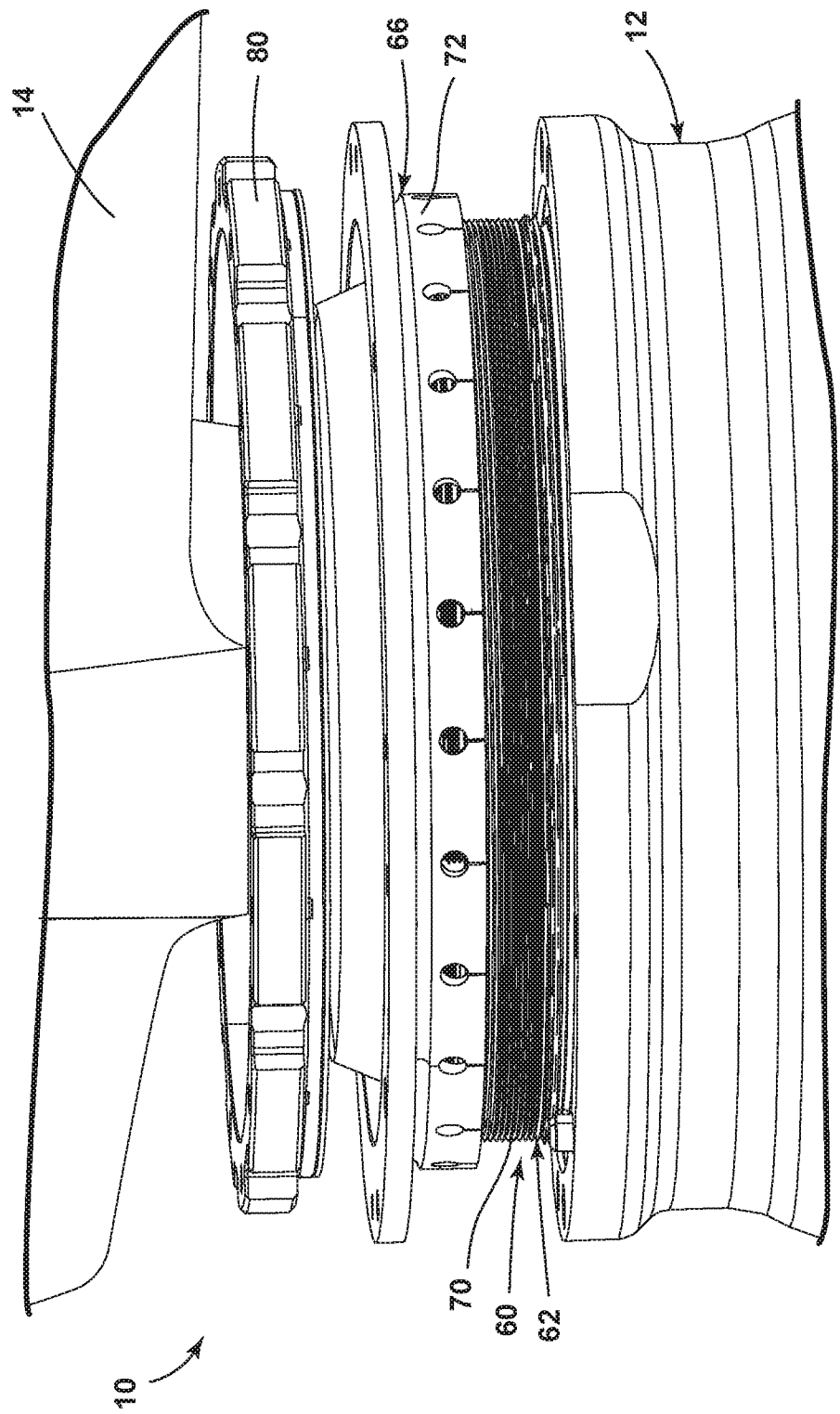
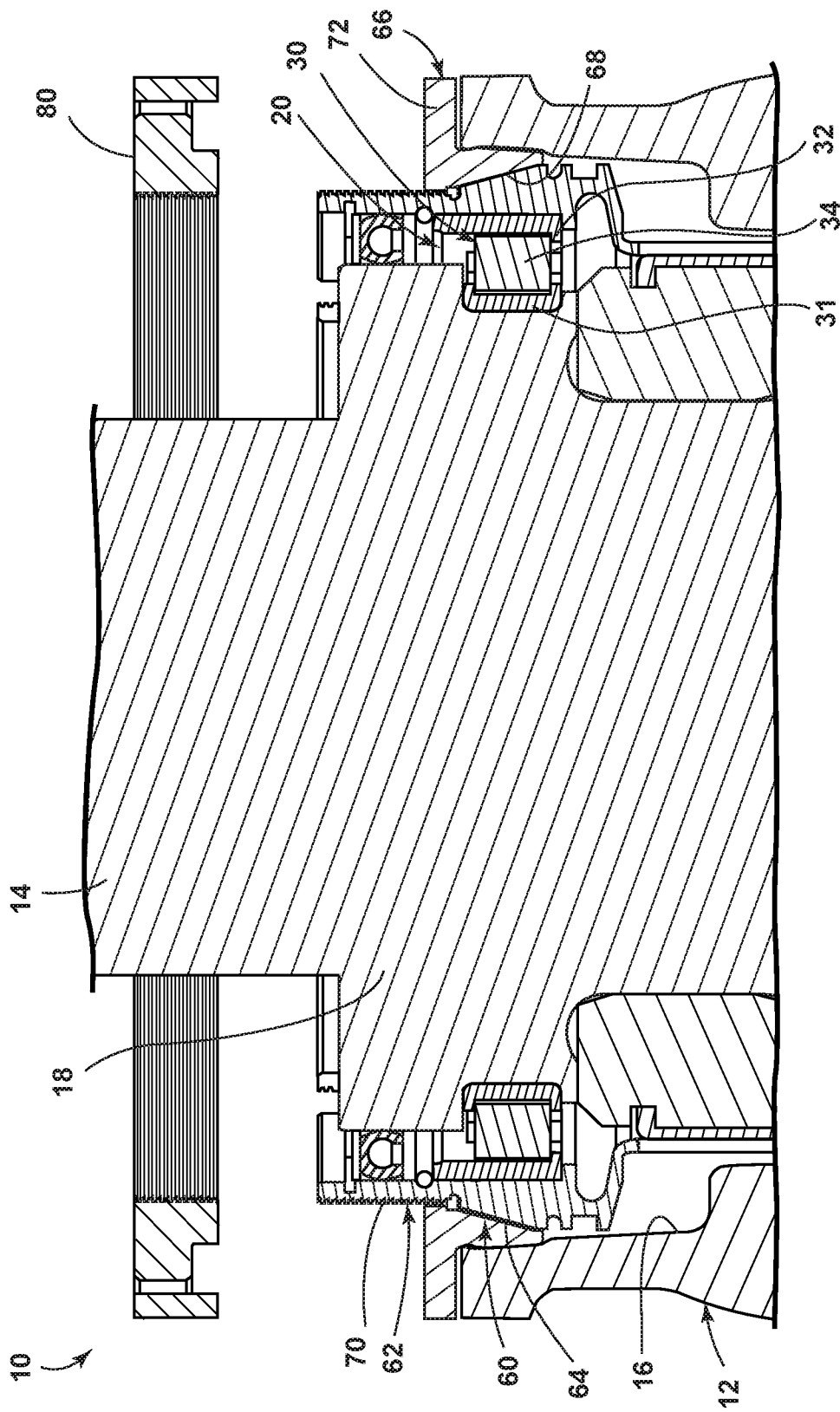


FIG. 4



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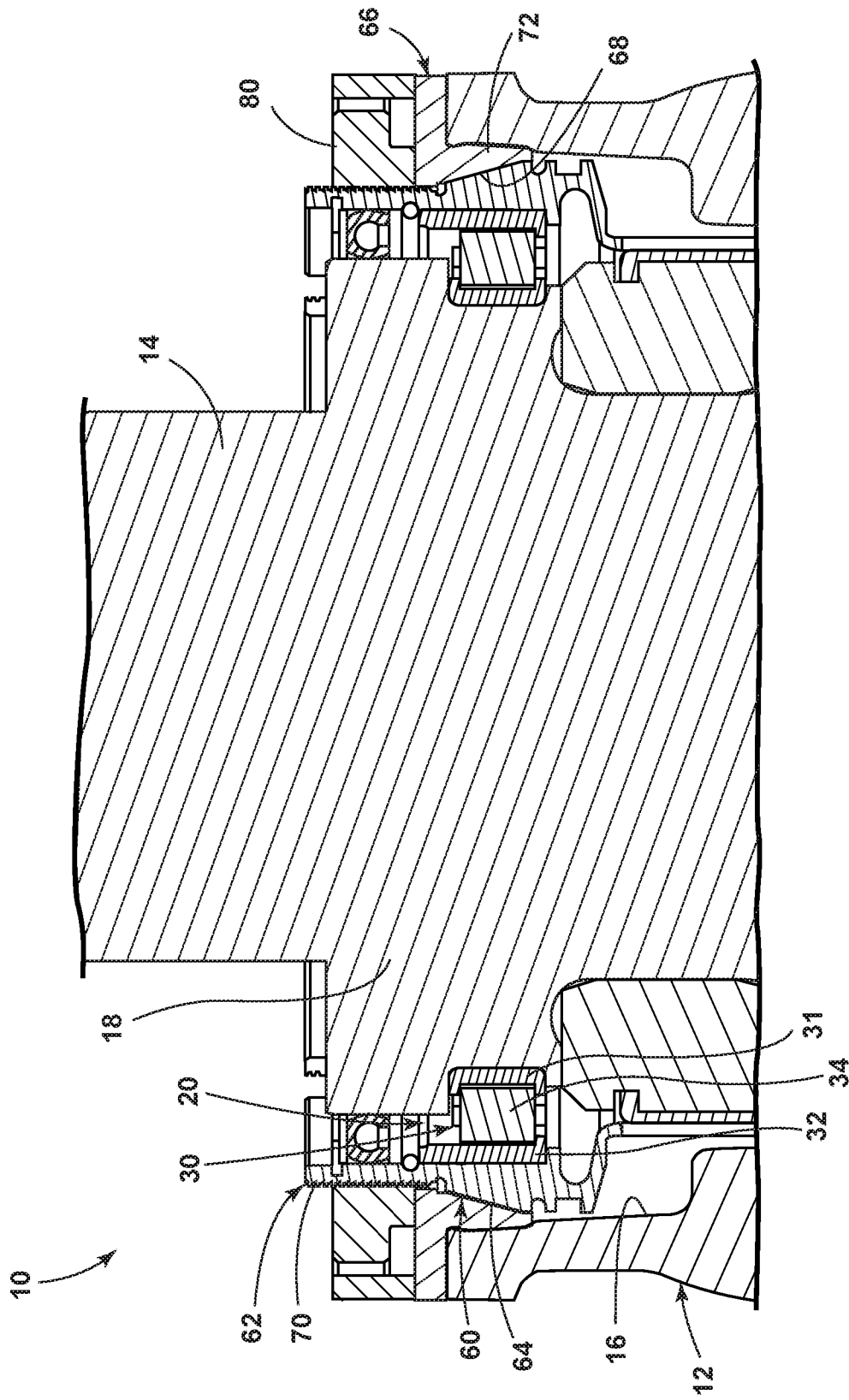


FIG. 6

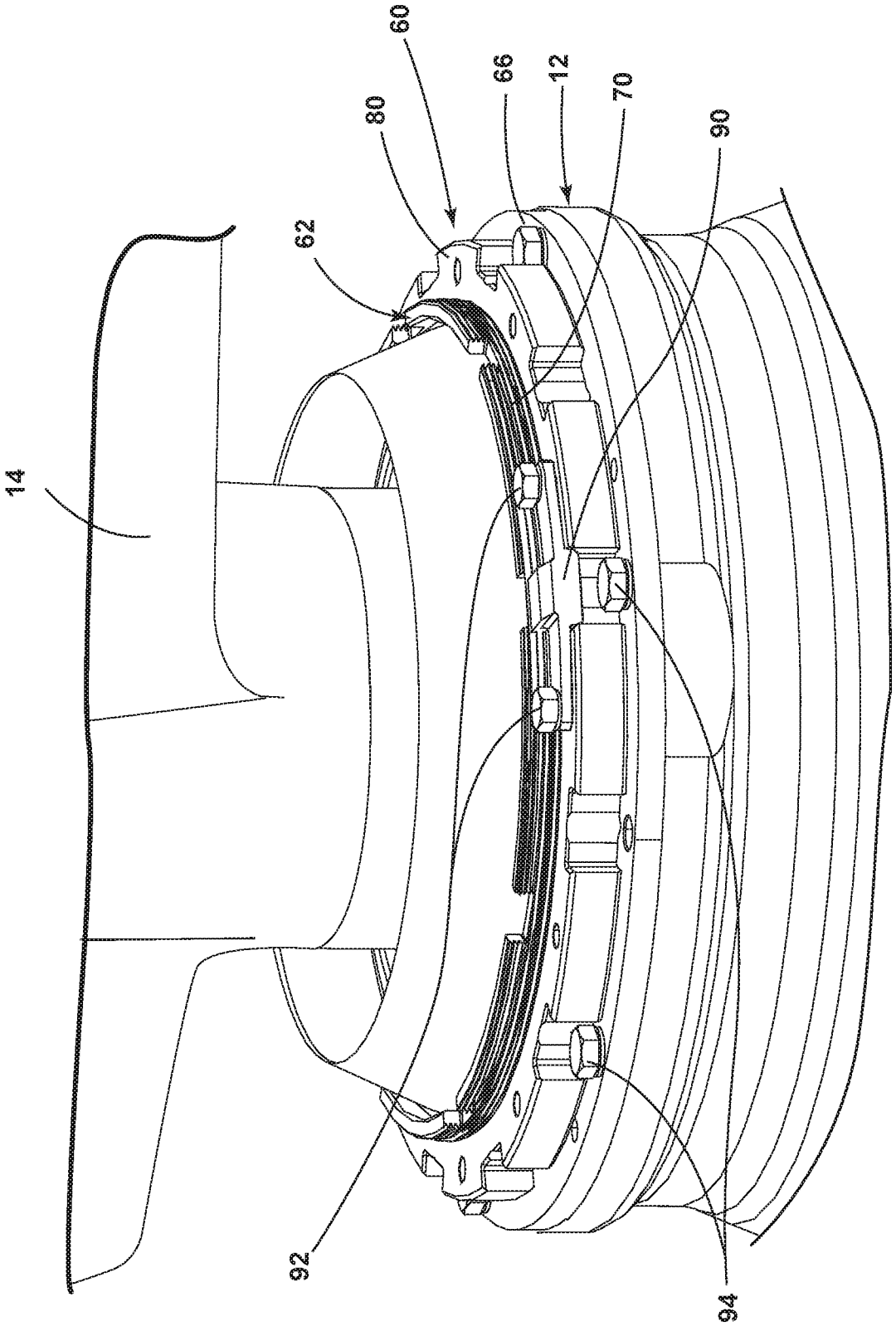


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2014/052056

A. CLASSIFICATION OF SUBJECT MATTER
INV. B64C11/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B64C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 628 688 A (DIEFENDERFER WILLIAM E) 17 February 1953 (1953-02-17) column 2, line 34 - column 3, line 27; figure 2 -----	1,2,4-14
X	US 6 213 719 B1 (VIOLETTE JOHN A [US] ET AL) 10 April 2001 (2001-04-10) column 4, line 6 - line 60; figure 2 -----	1-10, 12-14
X	GB 543 990 A (LEONARD GASKELL FAIRHURST) 23 March 1942 (1942-03-23) page 2, line 93 - page 3, line 5; figure 1 -----	1,2, 4-10, 12-14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2014/052056

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2628688	A	17-02-1953	NONE	

US 6213719	B1	10-04-2001	NONE	

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