(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) EP 2 998 506 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
23.03.2016 Bulletin 2016/12

(51) Int Cl.:
F01D 5/08 *(2006.01)* ***F01D 25/10*** *(2006.01)*

(21) Application number: **14185572.6**

(22) Date of filing: **19.09.2014**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(71) Applicant: **Siemens Aktiengesellschaft**
80333 München (DE)

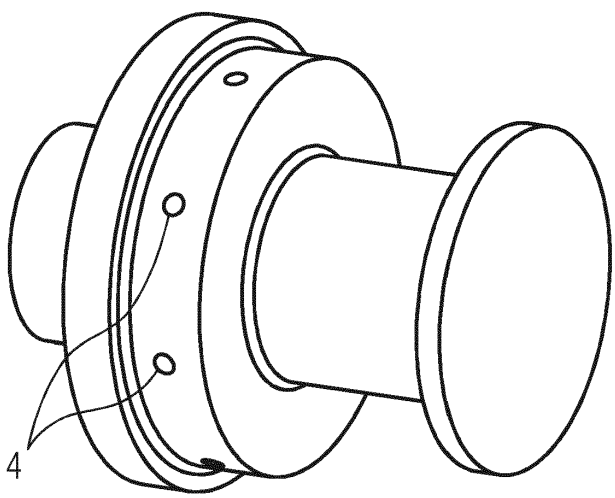
(72) Inventors:
- **Basu, Amitrajit**
  110078 New Delhi (IN)
- **Kumar, Gaurav**
  110019 New Delhi (IN)
- **Yadav, Anujkumar**
  110052 New Delhi (IN)

(74) Representative: **Patentanwaltskanzlei WILHELM & BECK**
Prinzenstraße 13
80639 München (DE)

(54) **System for reducing the start-up time of a steam turbine**

(57) A steam turbine includes a rotor core assembly (1), which includes a rotor core(2) extending in a longitudinal direction and one or more extended portions (3) coupled to the rotor core (2), extends the rotor core in a radial direction. The steam turbine further includes one or more thermal exchange channels (4) located on the one or more extended portions (3). The thermal exchange channel is capable of having thermal communication between the rotor core (2) and a steam surrounding the rotor core, thereby expediting the heating of the rotor core (2). In a variation of the invention, the one or more thermal exchange channels (4) may be interconnected through an interconnection channel (6) in order to drain accumulated moisture.

FIG 6A



EP 2 998 506 A1

Description

[0001] The method and system relates to reducing start-up time of a steam turbine, by enabling faster heating of the turbine rotor during start-up.

[0002] The rotor of the steam turbine is subjected to high temperature during operation. However, during start-up the rotor of the steam turbine will be at a much lower temperature than that of the steam. However, if such high temperature steam is introduced during the start-up of steam turbine, the rotor may experience a thermal shock, due to the temperature gradient existing between the outer surface (hot) and the inner core (cold) of rotor. Generally, the components such as rotor of the steam turbine are pre-heated to certain temperature before starting the normal operation of the turbine. The turbine is started up according to predefined start-up curves where the components such as rotors and valves are gradually preheated. Preheating of the rotor reduces the thermal stress experienced and increases the life of the rotor. But the pre-heating cycles are generally time consuming and non-productive.

[0003] Currently, various methods are used to preheat the rotor of the turbine during startup. For example, structural modifications are used to prevent the rotor from experiencing thermal shock. The rotor is designed to having a smaller cross section. In some cases, the rotor is rotated at a pre-defined low speed to uniformly pre-heat the rotor. In some instances, the rotor is kept warm during standstill by using heating means, which is very costly.

[0004] Further, the existing methods for preheating the rotor are either time consuming or economically unviable. The start-up time for a turbine is crucial for a customer as it is non-productive. The start-up time is critical for small turbines used in industrial or solar applications where daily start-up and shutdown is a norm. Therefore, the start-up time must be reduced for increasing the productivity of the turbine and decreasing the idle time.

[0005] Therefore, it is an object of the invention to reduce the start-up time for a turbine. It is also the object of the invention to provide a cost effective solution for minimizing the start-up time by expediting the heating of the rotor assembly.

[0006] The invention solves the object by providing a steam turbine comprising a rotor assembly having a rotor core extending in a longitudinal direction and one or more extended portions coupled to the rotor core and extending the rotor core in a radial direction. The steam turbine includes at least one thermal exchange channel located on the one or more extended portions, wherein the thermal exchange channel is capable of having thermal communication between the rotor core and a steam surrounding the rotor core. The rotor core is a solid metal part which extends longitudinally and has blades attached to it. The rotor core has protrusions or extensions at many places for structural reasons. The portions of the rotor core with protrusions require a relatively large amount of time to get heated during start-up cycle. The thermal exchange channels provide additional surface area for thermal exchange between the steam and the rotor core. During the preheating cycle, the thermal exchange channels exposes additional area to the surrounding steam for better heat exchange. Further, the preheating cycle or start-up cycle time is reduced by the aforementioned enhancement.

[0007] According to an embodiment of the invention, the rotor core has a first diameter and the one or more extended portions have a second diameter. The rotor core is cylindrical in shape and extends longitudinally. The rotor core has a first diameter along the longitudinal axis. The one or more extended portions along the longitudinal axis have a second diameter.

[0008] According to another embodiment of the invention, the second diameter (of the extended portions) is greater than the first diameter (of the rotor core). The extended portions at certain locations on the rotor core extend the rotor core in the radial direction. Therefore, the extended portions have a cross sectional diameter greater than that of the t rotor core.

[0009] According to yet another embodiment of the invention, the at least one thermal exchange channel is a tubular bore. The thermal exchange channel can be for example, straight or contoured. In some cases, the thermal exchange channel may be fabricated to have an 'L' shape or a 'U' shape, in the extended portions of the rotor core. Further, the thermal exchange channel may have any orientation and cross section in order to increase the thermal exchange.

[0010] In an embodiment of the invention, a plurality thermal exchange channel is interconnected. The thermal exchange channels are interconnected to form a network. For example, the thermal exchange channels can be fabricated to be connected to each other in the extended portion and not extending to the first diameter of the rotor core. The interconnection of thermal exchange channels enables efficient thermal communication between the surround steam and the rotor core.

[0011] In another embodiment, the interconnection of the plurality of thermal exchange channel provides a draining mechanism to drain condensed steam. The interconnection of the plurality of thermal exchange channel prevents the accumulation of water in the thermal exchange channel, thus preventing formation of rust.

[0012] In yet another embodiment, the draining mechanism includes at least one of a slanted thermal exchange channel. In this case, the thermal exchange channel is slanted to enable the accumulated water to drain from the rotor core.

[0013] In a further embodiment of the invention, the rotor core is enclosed by an outer casing. The steam may be released within the outer casing during start-up cycle. The steam released during the start-up cycle is at a relatively lower temperature than the steam used during normal operation of the turbine. The steam released during the start-up cycle is at a higher temperature than the rotor core thereby creating a thermal gradient.

[0014] The figures illustrate in a schematic manner further examples of the embodiments of the invention, in which:

FIG 1 illustrates an exemplary rotor core assembly of a turbine, according to a state of the art;

FIG 2A illustrates a perspective view of the rotor core assembly with thermal exchange channels, in accordance with the invention;

FIG 2B illustrates a cross sectional view of the rotor core assembly with thermal exchange channels, in accordance with the invention;

FIG 3A illustrates a perspective view of the rotor core assembly with 'L' shaped thermal exchange channels, in accordance with the invention;

FIG 3B illustrates a cross sectional view of the rotor core with 'L' shaped thermal exchange channels, in accordance with the invention;

FIG 4A illustrates a perspective view of the rotor core assembly with 'U' shaped thermal exchange channels, in accordance with the invention;

FIG 4B illustrates a cross sectional view of the rotor core with 'U' shaped thermal exchange channels 4, in accordance with the invention;

FIG 5A illustrates a perspective view of the rotor core assembly with slanted thermal exchange channels, in accordance with an embodiment of the invention;

FIG 5B illustrates a cross sectional view of the rotor core assembly with slanted thermal exchange channels 4, in accordance with an embodiment of the invention;

FIG 6A illustrates a perspective sectional view of the rotor core assembly with interconnected thermal exchange channels, in accordance with the invention; and

FIG 6B illustrates a cross sectional view of the rotor core with interconnected thermal exchange channels, in accordance with the invention.

[0015] Turbines are used in the industry mainly to generate power. The turbines may include, for example, a steam turbine and a steam turbine. The turbines normally include a rotor core to which blades are attached. During operation the rotor core rotates due to the impingement of pressurized fluids, thereby generating energy. FIG 1 illustrates an exemplary rotor core assembly 1 according to a state of the art. As shown in FIG 1, the rotor core 2 is cylindrical and extends longitudinally within an outer casing of the turbine (not shown in Figures). There rotor core may have a diameter d1. Along the rotor core 2, there may be one or more extended portions, such as extended portions 3, which radially extend the rotor core 2. The diameter at the extended portions 3 may be d2, where d2 is greater than the diameter d1 of the rotor core 2. The thickness of the metal increases at the regions on the rotor core where one or more extended portions, such as extended portions 3, are located. For example, regions such as balance pistons located on the rotor core. The rotor core 2 is generally made up of high strength alloys or super alloys such as nickel and ferrous based alloys. Before the turbine is operated at normal levels, the rotor assembly needs to be pre-heated to avoid thermal shock. When the turbine is to be operated, a start-up cycle is initiated wherein the rotor is rotated at a low speed and steam at a relatively lower temperature is introduced into the outer casing. The start-up cycle is performed to prevent the components of the turbine from experiencing thermal shock in case a high temperature steam is suddenly introduced into the casing. During start-up cycle, thermal exchange takes place between the rotor core and the steam. The rotor core which is at a lower temperature than the steam slowly begins to heat up. The time taken for the rotor core and the associated components to heat depends upon the capacity of the turbine. The time taken for the completion of the start-up cycle may range between 2-3 hours in some cases. The start-up cycle is unproductive and affects the customers who need to run the start-up cycle on a daily basis.

[0016] FIG 2A illustrates a perspective view of the rotor core assembly with thermal exchange channels, in accordance with the invention. The extended portions 3 of the rotor core assembly 1 are provided with one or more thermal exchange channels 4 for expediting the heating of the rotor core. The thermal exchange channels 4 exposes additional area for the steam for efficient thermal communication. The steam which is at a higher temperature than the rotor core interacts with the surface of the thermal exchange channels 4 and heats the rotor core. Therefore, the heating of the rotor core takes lesser time to heat up as compared with the heating time of the rotor core assembly 1 without the thermal exchange channels 4. The thermal exchange channels 4 can have varying depth and diameter based on the location on the rotor core. For example, the depth and diameter of the thermal exchange channels 4 are based on a location such as, axial sections, exhaust and balance piston. In general, bigger thermal exchange channels 4 are preferred for better thermal interaction, provided the sizes of the thermal exchange channels 4 meet other requirements such as, strength and rotor dynamics, which varies according to the design. FIG 2A illustrates the thermal exchange channels 4 which are generated by boring the extended portions 3 of the rotor core assembly 1. The thermal exchange channels 4 in FIG 2A are horizontal in orientation and a spaced apart on the periphery of the extended portion 2. FIG 2B illustrates a cross sectional view of the rotor core assembly with the thermal exchange channels, in accordance with the invention. In fig 2B, we can see that the thermal exchange channels 4 extend into the extended portion 3 of the rotor core assembly but do not penetrate completely. The thermal exchange channels 4 allow the steam, released during the start-up cycle to interact with the rotor core and expedite the heating up of the rotor core assembly 1.

[0017] FIG 3A illustrates a perspective view of the rotor core assembly with 'L' shaped thermal exchange channels, in accordance with the invention. In this embodiment, the thermal exchange channels are longer and extend deeper into the rotor core. In this case, the steam enters into the thermal exchange channels 4 and heats the rotor core. FIG 3B illustrates a cross sectional view of the rotor core with 'L' shaped thermal exchange channels, in accordance with the invention. In FIG 2B, it can be seen that the thermal exchange channels 4 extend deep into the extended portion of the rotor core 2 and expedite the heating of the rotor core.

[0018] FIG 4A illustrates a perspective view of the rotor core assembly with 'U' shaped thermal exchange channels, in accordance with the invention. In this embodiment, the thermal exchange channels 4 are longer than the 'L' shaped thermal exchange channels, thereby exposing more area for thermal exchange. Thus, there is faster heat transfer between the surrounding steam and the rotor core 2, resulting in reduced start-up time. FIG 4B illustrates a cross sectional view of the rotor core with 'U' shaped thermal exchange channels 4, in accordance with the invention.

[0019] FIG 5A illustrates a perspective view of the rotor core assembly with slanted thermal exchange channels 4, in accordance with an embodiment of the invention. The slanted thermal exchange channels 4 facilitate in draining condensed steam which might get accumulated in the thermal exchange channels 4. FIG 5B illustrates a cross sectional view of the rotor core assembly with the slanted thermal exchange channels 4, in accordance with the invention. In FIG 5B, it can be observed that due to the slanted thermal exchange channels 4 any condensed steam accumulated in the thermal exchange channels 4 are drained.

[0020] FIG 6A illustrates a perspective view of the rotor core assembly with interconnected thermal exchange channels, in accordance with the invention. The thermal exchange channels 6 are parallel to the plane of the extended portion of the rotor core. FIG 6B illustrates a cross sectional view of the rotor core with interconnected thermal exchange channels, in accordance with the invention. The interconnection channel 6 connecting the thermal exchange channels 4 forms a draining mechanism to drain condensed steam. Further, the inner end of the thermal exchange channels 4 are connected to each other by an interconnection channel 6, as shown in FIG 6B. Such an arrangement facilitates in draining any condensed steam within the thermal exchange channels 4. The steam accumulated in the thermal exchange channels 4 may condense when the rotor core is decelerating. The steam condensed in the thermal exchange channels 4 at the upper half of the rotor core is drained through one of the thermal exchange channels 4 in the lower half of the rotor core 2. The thermal exchange channels 4 with interconnection thus prevent rusting of the metal in the rotor core assembly due to accumulation of moisture.

[0021] According to the foregoing embodiments, the thermal exchange channels reduce the start-up time of a turbine by expediting the pre-heating process. The thermal exchange channels expose additional surface of the rotor core to the surrounding steam in order to heat up the rotor core faster. The thermal exchange channels result in lesser downtime for the customers. Further, the thermal exchange channels can be used for rotor balancing. Balancing mass can be coupled to the thermal exchange channels to balance the rotor core assembly 1.

[0022] Though the invention has been described herein with reference to specific embodiments, this description is not meant to be construed in a limiting sense. Various examples of the disclosed embodiments, as well as alternate embodiments of the invention, will become apparent to persons skilled in the art upon reference to the description of the invention. It is therefore contemplated that such modifications can be made without departing from the embodiments of the invention as defined.

Claims

1. A steam turbine comprising a rotor core assembly (1), wherein the rotor core assembly (1) comprises:

    a rotor core (2) extending in a longitudinal direction and one or more extended portions (3) coupled to the rotor core (2) and extending the rotor core in a radial direction, **characterized in that**, at least one thermal exchange channel (4) located on the one or more extended portions (3), wherein the at least one thermal exchange channel (4) is capable of having thermal communication between the rotor core and a steam surrounding the rotor core.

2. The steam turbine according to claim 1, wherein the rotor core has a first diameter (d1) and the one or more extended portions have a second diameter (d2).

3. The steam turbine according to claim 2, wherein the second diameter (d2) is greater than the first diameter (d1).

4. The steam turbine according to claim 1, wherein the at least one thermal exchange channel (4) is a tubular bore.

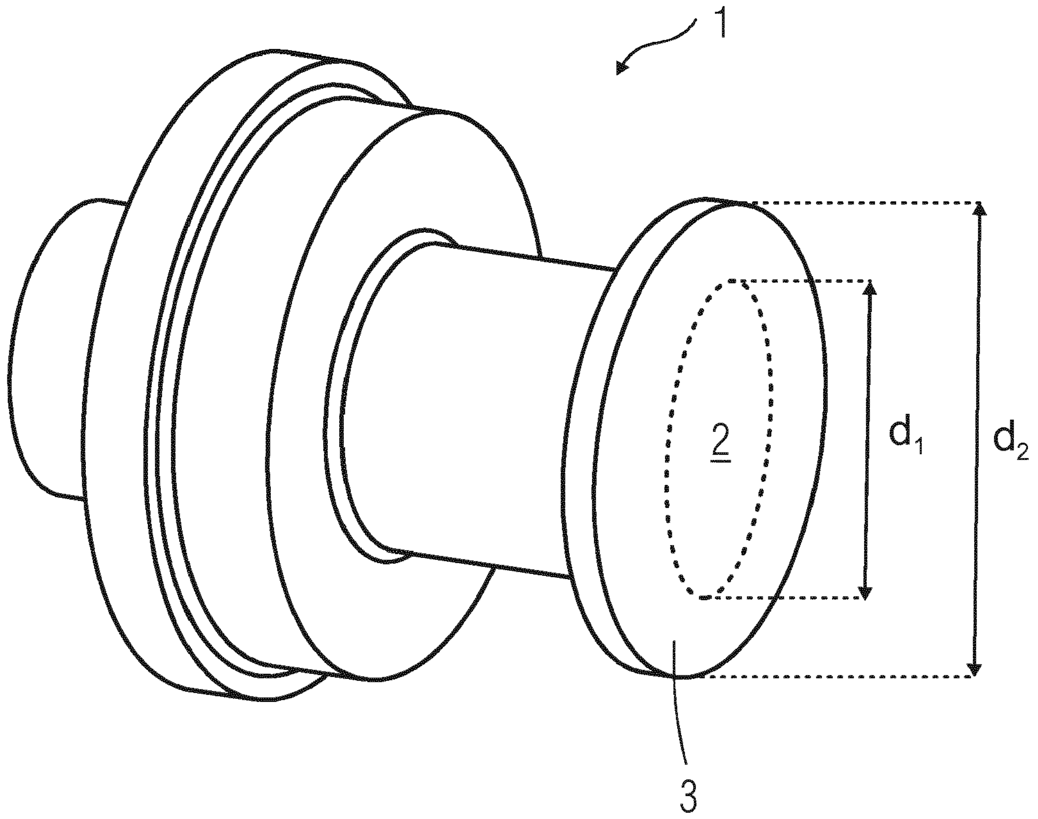
5. The steam turbine according to claim 1, wherein a plurality of thermal exchange channels (4) is interconnected.

6. The steam turbine according to claim 5, wherein the interconnection (6) of the plurality of thermal exchange channels (4) provides a draining mechanism to drain condensed steam.

7. The steam turbine according to claim 6, wherein the draining mechanism includes at least one of a slanted thermal exchange channel (4).

8. The steam turbine according any of the preceding claims, wherein the rotor core (2) is enclosed by an outer casing.

FIG 1



STATE OF THE ART

FIG 2A

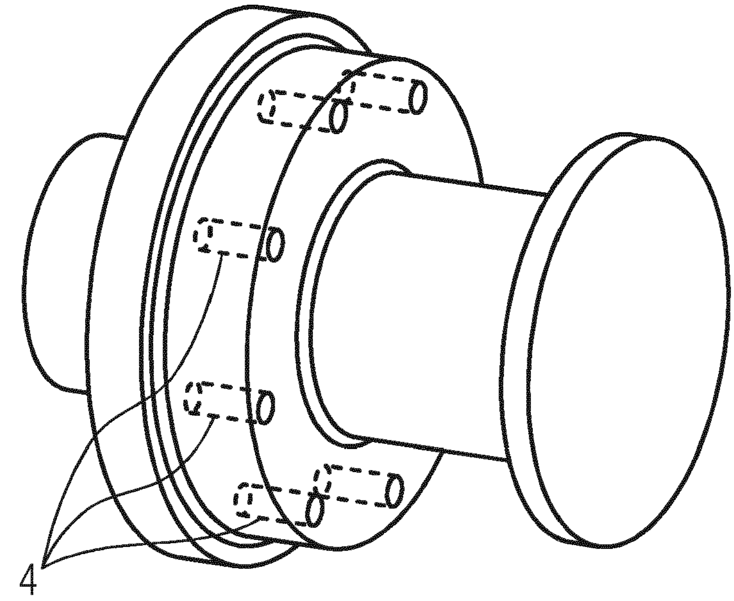


FIG 2B

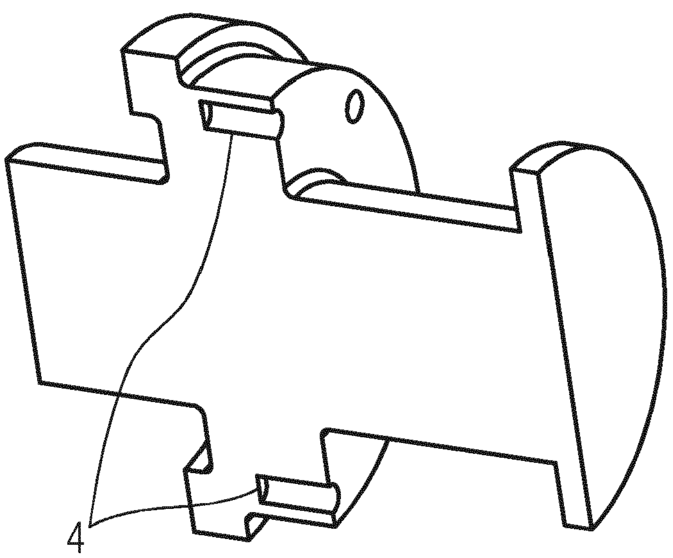


FIG 3A

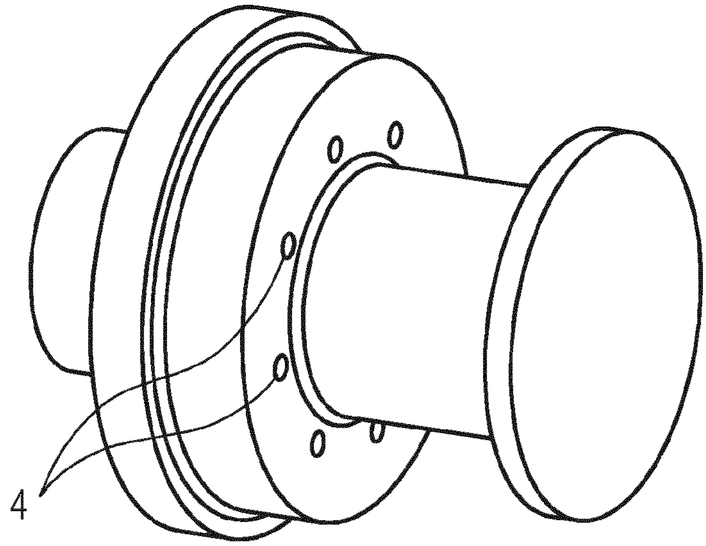


FIG 3B

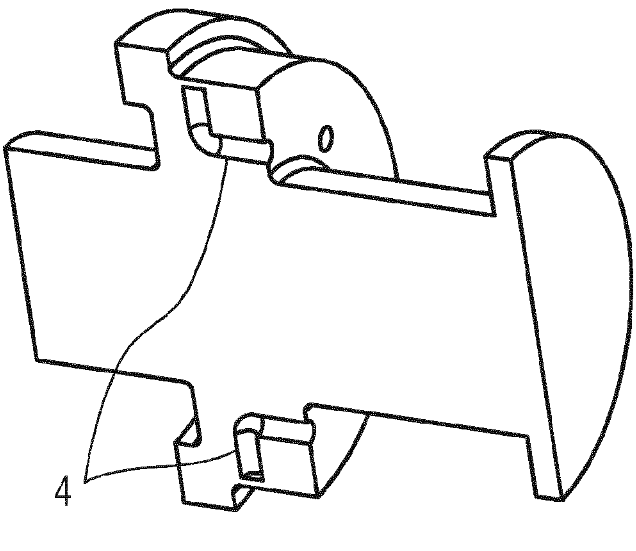


FIG 4A

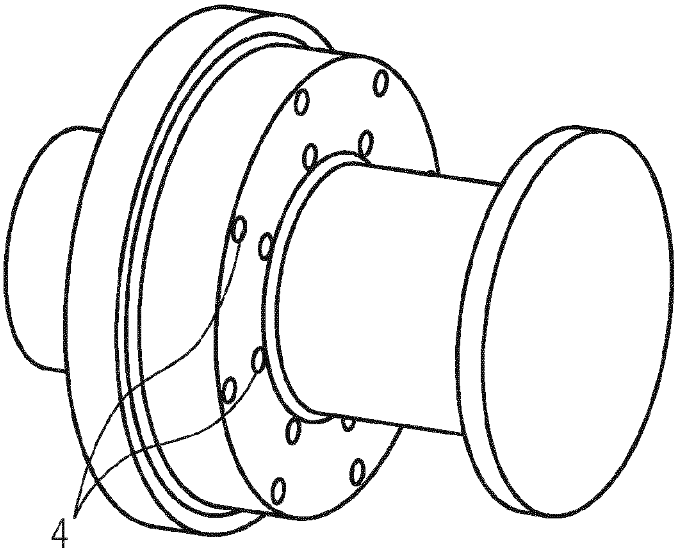


FIG 4B

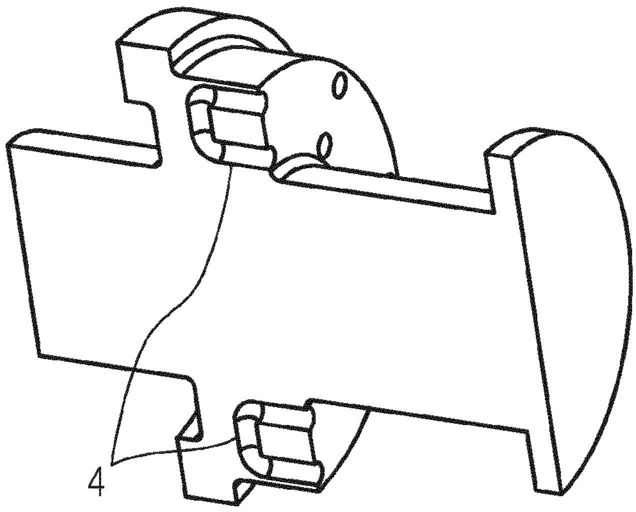


FIG 5A

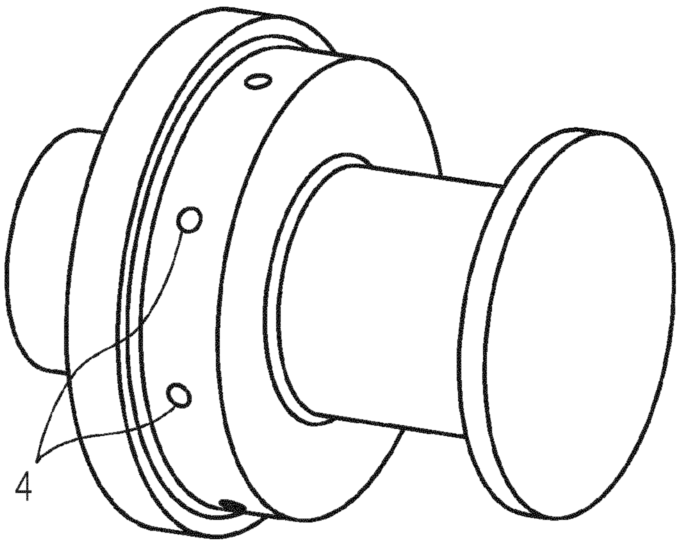


FIG 5B

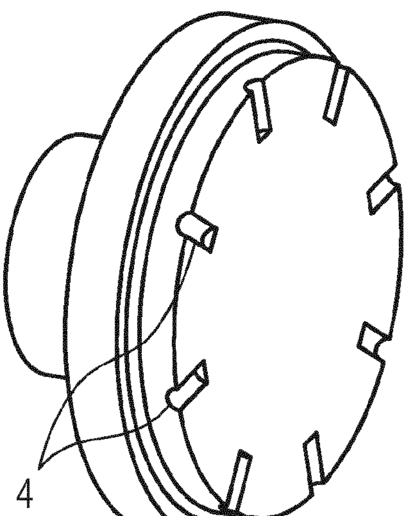


FIG 6A

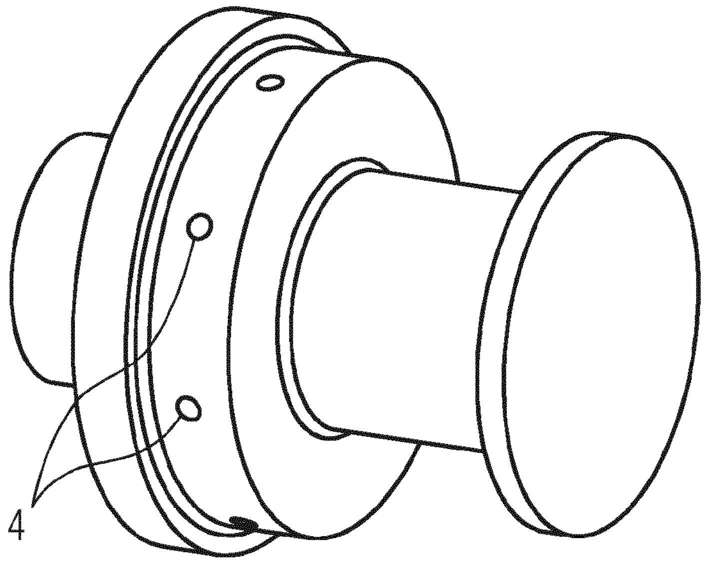
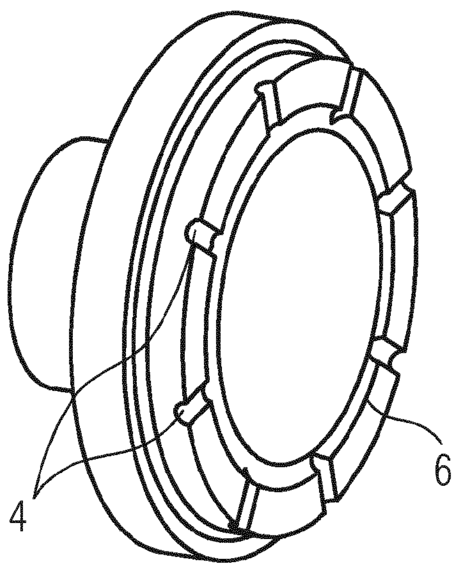


FIG 6B



Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 14 18 5572

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 911 933 A1 (SIEMENS AG [DE]) 16 April 2008 (2008-04-16) * column 2, paragraph 5 - column 2, paragraph 11 * * column 6, paragraph 35 - paragraph 36; figure 2 * -----	1-5,8	INV. F01D5/08 F01D25/10
X	EP 1 780 376 A1 (SIEMENS AG [DE]) 2 May 2007 (2007-05-02) * column 8, paragraph 43 - column 9, paragraph 56; figures 3-6 * -----	1-5,8	
X	EP 1 536 102 A2 (ALSTOM TECHNOLOGY LTD [CH]) 1 June 2005 (2005-06-01) * column 6, paragraph 23 - column 11, paragraph 41; figures 1-9 * -----	1-8	

TECHNICAL FIELDS SEARCHED (IPC)
F01D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	24 March 2015	Rau, Guido

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 14 18 5572

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-03-2015

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1911933 A1	16-04-2008	AT 458125 T	15-03-2010
		EP 1911933 A1	16-04-2008
		EP 2078137 A1	15-07-2009
		JP 4990365 B2	01-08-2012
		JP 2010506080 A	25-02-2010
		WO 2008043663 A1	17-04-2008
EP 1780376 A1	02-05-2007	AT 450693 T	15-12-2009
		CN 101300405 A	05-11-2008
		EP 1780376 A1	02-05-2007
		EP 1945911 A1	23-07-2008
		ES 2336610 T3	14-04-2010
		JP 4662570 B2	30-03-2011
		JP 2009513866 A	02-04-2009
		KR 20080068893 A	24-07-2008
		US 2009185895 A1	23-07-2009
		WO 2007051733 A1	10-05-2007
EP 1536102 A2	01-06-2005	DE 10355738 A1	16-06-2005
		EP 1536102 A2	01-06-2005
		US 2005118025 A1	02-06-2005

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82