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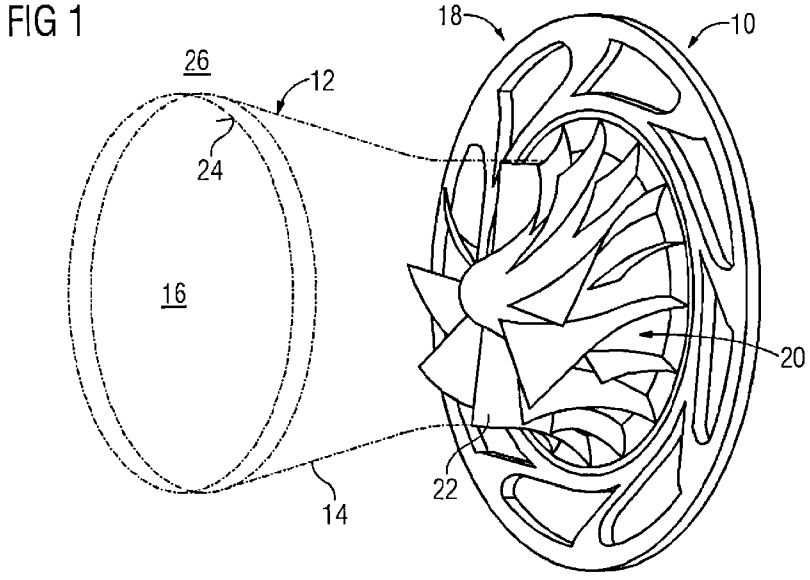
(54) Title: TURBO-MACHINE AND WASTE HEAT UTILIZATION DEVICE

FIG 1



(57) Abstract: The invention relates to a turbo-machine (10) comprising: at least one turbine stage (18); an outlet duct (16) arranged downstream of the turbine stage (18), the outlet duct (16(being bounded at least partly by at least one wall (14) of the turbo-machine (10) towards the outside (26) of the turbo-machine (10); and at least one flow element (28) for influencing the flow of a fluid flowing from the turbine stage (18) through the outlet duct (16), the flow element (28) being arranged in the outlet duct (16), wherein the flow element (28) is configured as a ring (28) having a profile in the form of an airfoil.

TURBO-MACHINE AND WASTE HEAT UTILIZATION DEVICE

DESCRIPTION

The invention relates to a turbo-machine according to the preamble of patent claim 1 as well as a waste heat utilization device.

Turbo-machines are well known from the general prior art. Such a turbo-machine can be configured as, for example, a steam turbine. Such a turbo-machine can also be used for a waste heat utilization device, the turbo-machine being an expansion device for expanding a working fluid utilized by the waste heat utilizing device. For example, the waste heat utilization device uses a thermodynamic cycle, for example, in the form of an organic ranking cycle (ORC), the working fluid being a working fluid for said thermodynamic cycle. The working fluid can be an organic fluid.

The turbo-machine comprises at least one turbine stage and an outlet duct arranged downstream of the turbine stage. The outlet duct is bounded at least partly by at least one wall of the turbo-machine towards the outside of the turbo-machine. Such an outlet duct can be found, for example, in US 5,462,088 A.

Having flowed through the turbine stage, the fluid which is expanded by the turbine stage flows from the turbine stage to the outlet duct and through the outlet duct. In other words, the outlet duct is used to guide the fluid away from the turbine stage.

The turbo-machine also comprises at least one flow element for influencing the flow of the fluid flowing from the turbine stage through the outlet duct. The flow element is arranged in the outlet duct.

Conventionally, plates or a set of plates are used as flow elements for influencing the flow of the fluid, the plates extending throughout the outlet duct in its radial direction. This means that the plates extend perpendicularly to the direction of flow of the fluid. It is also known to use vanes as flow elements for influencing the flow of the fluid. Said

vanes can be, for example, movable in relation to the wall. Alternatively, the vanes cannot be movable in relation to the wall. Adjustable or movable vanes are very complicated with regard to their design and with regard to supporting the movable vanes in the outlet duct. Hence, using adjustable or moveable vanes is very expensive. Vanes which cannot be moved in relation to the wall cannot be adapted to different mass flows of the fluid. Hence, vanes which cannot be moved in relation to the wall cannot be used for multimode devices since they can cause local separations of the flow of the fluid. Such separations affect the efficiency of the turbo-machine negatively.

It is therefore an object of the present invention to provide a turbo-machine of the previously mentioned kind as well as a waste heat utilization device which can be operated very efficiently and manufactured in a very cost-efficient way.

The object is solved by a turbo-machine having the features of patent claim 1 and a waste heat utilization device having the features of patent claim 10. Advantageous embodiments with expedient and non-trivial developments of the invention are indicated in the other patent claims.

A first aspect of the present invention relates to a turbo-machine, the turbo-machine comprising at least one turbine stage and an outlet duct arranged downstream of the turbine stage, the outlet duct being bounded at least partly by at least one wall of the turbo-machine towards the outside of the turbo-machine.

The turbo-machine also comprises at least one flow element for influencing the flow of a fluid flowing from the turbine stage through the outlet duct, the flow element being arranged in the outlet duct.

According to the present invention, the flow element is configured as a ring having a profile in the form of an airfoil. In other words, the ring has a cross-section having an outer contour in the form of an airfoil. Since a wing of an aircraft also has an airfoil, the ring is also referred to as ring wing. Said ring or ring wing is closed and extends completely in the circumferential direction of the outlet duct. By influencing the flow of

the fluid by means of the ring, separations of the flow of the fluid can be reduced. Hence, the flow field of the fluid in the outlet duct can be improved even in case of the turbo-machine being a multimode turbo-machine or a multimode turbo generator.

The ring is not necessarily movable in relation to the wall. In other words, advantageously, the ring is immobile in relation to the wall. By means of the ring, the flow field of the fluid can be influenced particularly positively and in a very easy way. Thus, the turbo-machine can be operated very efficiently. Moreover, the costs of the turbo-machine, in particular, for supporting or mounting the ring can be kept to a minimum.

The basic idea behind the ring and its use is that the ring can be placed in regions of probable flow separations so that the ring does not affect a core flow of the fluid. Moreover, the ring does not cause additional vortexes if the flow of the fluid is swirled. As a consequence, a multimode device can be operated more efficiently by using the ring comparing with flat plates or vanes as flow elements.

Advantageously, the ring, in particular, its airfoil is designed in such a way that the ring directs the separated or inclined to be separated flow of the fluid to the wall, thereby reducing or preventing separations and turbulences of the flow of the fluid.

In an advantageous embodiment of the invention the ring is mounted on an inner side of the wall, the inner side bounding the outlet duct. Thereby, the ring can be arranged and fixed in the outlet duct very easily and cost-efficiently. Moreover, influencing the core flow of the fluid can be prevented.

It has turned out to be particularly advantageous if the ring is mounted on the inner side of the wall in such a way that a flow of the fluid between the inner side and the ring is prevented. In other words, the fluid cannot flow through a space between the inner side and the ring. Thus, the flow of the fluid can be influenced by the ring very efficiently which allows for realizing a particularly efficient operation of the turbo-machine.

In order to keep the number of parts of the turbo-machine, the costs and the weight of the turbo-machine to a minimum, according to a further advantageous embodiment of the invention the ring contacts the inner side of the wall. Thereby, the fluid cannot flow between the inner side and the ring which leads to a very positive flow field of the fluid. Moreover, additional parts for mounting the ring on the wall can be avoided since the ring is mounted directly on the inner side of the wall.

In a further advantageous embodiment of the present invention the turbo-machine comprises at least one second ring for influencing the flow of the fluid, the second ring being arranged in the outlet duct, having a profile in the form of an airfoil, and being arranged at a distance from the first ring in the direction of flow of the fluid. The embodiments of the first ring described above can also be regarded as respective embodiments of the second ring and vice versa. The usage of at least two rings allows for realizing a particularly uniform velocity distribution and lower swirling of the flow of the fluid. Depending on the flow field of the fluid it is possible to use different combinations of rings which can have different diameters and/or various or different airfoils in order to obtain a desired flow pattern in the outlet duct.

Advantageously, the airfoils of the rings differ from each other. Thereby, the rings, in particular, their airfoils can be adapted to different conditions in different areas of the outlet duct thereby influencing the flow of the fluid in a particularly positive way.

In a further advantageous embodiment of the invention the first ring has a first diameter and the second ring has a second diameter, the diameters differing from each other. Hence, the flow of the fluid can be influenced in different ways by means of the different rings in order to realize a desired flow field leading to a particularly efficient operation of the turbo-machine.

In order to realize a particularly efficient operation of the turbo-machine, the outlet duct is configured as a diffuser.

In a further particularly advantageous embodiment of the invention the first turbine

stage has a radial turbine wheel. The fluid flows to an against the radial turbine wheel in its radial direction. Having entered a blade section of the turbine wheel, the fluid flows off the turbine wheel in the axial direction of the turbine wheel into the outlet duct. By using a radial turbine and a radial turbine wheel, the dimensions of the turbo-machine can be kept to a minimum.

A second aspect of the invention relates to a waste heat utilization device utilizing a thermodynamic cycle, in particular, an organic rankine cycle, the fluid being a working fluid, in particular, an organic working fluid. The waste heat utilization device comprises at least one turbo-machine according to the first aspect of the invention. Advantageous embodiments of the first aspect of the invention are to be regarded as advantageous embodiments of the second aspect of the invention and vice versa.

The turbo-machine is used as an expansion device for the waste heat utilization device, the turbo-machine, in particular, its turbine stage expanding the fluid in the form of the working fluid flowing through the turbo-machine.

The turbo-machine can comprise a shaft on which blades are mounted. The turbo-machine can comprise a turbine wheel, in particular, a radial turbine wheel having the blades and being coupled to the shaft. The working fluid flowing through the turbine stage and the turbine wheel drives the shaft about an axis of rotation the shaft is rotatable about. The shaft can be, for example, supported on at least one housing of the turbo-machine by means of a bearing device.

By driving the shaft, waste energy in the form of the waste heat contained in the working fluid can be transformed at least partly into mechanical energy provided by the shaft.

The turbo-machine can also comprise at least one generator coupled to the shaft. The generator is being capable of transforming the mechanical energy provided by the shaft into electric energy. Thereby, waste heat contained in the working fluid can be transformed at least partly into electric energy which can be, for example, stored in a

battery or guided to an electrical consumer in order to drive said electrical consumer.

By using the turbo-machine according to the present invention, the waste heat utilization device can be operated particularly efficiently in a very cost-efficient way. Thus, a very high amount of waste heat contained in the working fluid can be transformed into mechanical energy or electric energy respectively.

Further advantages, features, and details of the invention derive from the following description of preferred embodiments as well as from the drawing. The features and feature combinations previously mentioned in the description as well as the features and feature combinations mentioned in the following description of the figures and/or shown in the figures alone can be employed not only in the respective indicated combination but also in any other combination or taken alone without leaving the scope of the invention.

The drawing shows in:

FIG 1 a schematic and perspective view of a turbo-machine according to a first embodiment, the turbo-machine comprising exactly one flow element for influencing the flow of a fluid flowing through an outlet duct of the turbo-machine, the flow element being configured as a ring having a profile in the form of an airfoil;

FIG 2 a schematic and perspective view of the turbo-machine according to a second embodiment, the turbo-machine comprising two flow elements in the form of rings arranged in the outlet duct;

FIG 3 a schematic longitudinal sectional view of the turbo-machine according the first embodiment;

FIG 4 a schematic longitudinal sectional view of the turbo-machine according to the second embodiment;

FIG 5 a schematic front view of the turbo-machine according to the first embodiment; and

FIG 6 a schematic front view of the turbo-machine according to the second embodiment.

In the figures elements or elements having the same functions are equipped with the same reference.

FIG 1 shows a turbo-machine 10 which, for example, can be used for a waste heat utilization device. The waste heat utilization device utilizes a thermodynamic cycle in the form of an organic rankine cycle using a fluid in the form of an organic fluid as a working fluid. The turbo-machine 10 expands the working fluid thereby transforming waste energy in the form of waste heat contained in the working fluid into electric energy.

The turbo-machine 10 comprises a diffuser element 12 having at least one wall 14, the diffuser element 12 being illustrated transparently in FIG 1. The diffuser element 12 bounds an outlet duct 16 which is configured as a diffuser since the diameter of the outlet duct 16 gets larger with regard to the direction of flow of the working fluid flowing through the outlet duct 16 downstream of a turbine stage 18 of the turbo-machine 10. In other words, the turbo-machine 10 comprises the turbine stage 18 having a turbine wheel 20 which can be seen in FIG 1 since the diffuser element 12 is illustrated transparently.

The turbo-machine 10 also comprises a shaft not shown in FIG 1, the turbine wheel 20 being coupled to the shaft. The shaft is rotatably supported on a housing of the turbo-machine 10 about an axis of rotation. The turbine wheel 20 is configured as a radial turbine wheel and has a set of blades 22 via which the turbine wheel 20 and the shaft can be driven about the axis of rotation by the working fluid flowing through the turbine stage 18 and the turbine wheel 20. The working fluid flows against the turbine wheel 20 in its radial direction. The working fluid flows off the turbine wheel 20 in its axial

direction. The axial direction of the turbine wheel 20 coincides with the axis of rotation.

The outlet duct 16 is arranged downstream of the turbine wheel 20 with regard to the direction of flow of the working fluid through the turbine stage 18. Having flowed through the turbine wheel 20 the working fluid flows off the turbine wheel 20 and into the outlet duct 16, wherein the working fluid is expanded by the turbine stage 18.

Since the turbine wheel 20 and the shaft are driven by the working fluid, waste energy in the form of waste heat contained in the working fluid can be transformed into mechanical energy provided by the shaft. In order to transform the mechanical energy provided by the shaft into electric energy, the turbo-machine 10 can comprise a generator not shown in FIG 1. The generator is coupled to the shaft so that it can be driven by the shaft. Thereby, the waste heat contained in the working fluid can be transformed into electric energy at least partly.

As can be seen from FIG 1, the outlet duct 16 is bounded by an inner side 24 of the wall 14 towards the outside 26 of the turbo-machine 10 in the radial direction of the turbine wheel 20 and the outlet duct 16 respectively. In order to realize a particularly efficient operation in a particularly cost-efficient way, the turbo-machine 10 comprises exactly one flow element for influencing the flow of the working fluid flowing from the turbine stage 18 through the outlet duct 16, the flow element being arranged in the outlet duct 16.

The flow element is configured as a ring 28 which is also referred to as ring wing since the ring 28 has a profile in the form of an airfoil like a wing of, for example, an aircraft. The ring 28 is mounted on the inner side 24 of the wall 14, wherein the ring 28 contacts the inner side 24. Thereby, the fluid cannot flow between the ring 28 and the inner side 24. In other words, a flow of the fluid between the inner side 24 and the ring 28 is prevented.

By means of the ring 28 a very advantageous flow field of the working fluid can be realized. The basic idea behind using the ring 28 is that the flow field in the outlet duct

16 affects the efficiency of the turbo-machine 10 in the form of a turbo generator. The more separation of the flow of the working fluid flowing through the outlet duct 16 occurs the higher the turbulence of the flow is. The higher the turbulence is the lesser the efficiency of the turbo generator is. By using the ring 28 the outlet of the working fluid can be optimized so that flow separations can be avoided or reduced. This leads to a very high efficiency of the turbo-machine 10.

Moreover, by means of the ring 28 a particularly uniform flow pattern at the outlet of the turbine stage 18 can be realized so that the flow losses can be kept to a minimum. Furthermore, the ring 28 has a relatively simple design so that the ring 28 can be produced and mounted very easily and cost-efficiently. Beyond that, a complicated support for the ring 28 can be avoided since the ring 28 is immobile in relation to the wall 14.

FIG 2 shows the turbo-machine 10 according to a second embodiment. As can be seen from FIG 1, the turbo-machine 10 according to the second embodiment comprises the ring 28 as a first ring and a second ring 30. The second ring 30 is a flow element for influencing the flow of the working fluid flowing through the outlet duct 16, the second ring 30 being arranged in the outlet duct 16. The second ring 30 has a profile in the form of an airfoil like a wing of an aircraft, the second ring 30 being arranged at a distance from the first ring 28 in the direction of flow of the working fluid.

Since the diameter of the outlet duct 16 (diffuser) gets larger with regard to the direction of flow of the working fluid, the second ring 30 which also contacts the inner side 24 of the wall 14 has a larger diameter than the first ring 28.

In order to adapt the rings 28, 30 to different conditions prevailing in different areas in which the rings 28, 30 are arranged respectively, the airfoils of the rings 28, 30 can differ from each other. In other words, depending on the flow filed inside the outlet duct 16, it is possible to use a combination of the rings 28, 30 having different diameters and/or different airfoils in order to obtain a desired flow pattern at the outlet of the turbine stage 18. Hence, a particularly uniform velocity distribution and low swirling of the flow can be realized.

FIG 3 shows the turbo-machine 10 according to the first embodiment. As can be seen from FIG 3, flow separations in an area 32 inside the outlet duct 16 can be kept to a minimum.

From FIG 4 an area 32 of the outlet duct 16 of the turbo-machine 10 according to the second embodiment can be seen. Flow separations in the area 32 can be kept to a minimum, too.

FIG 5 shows border areas 34 of the outlet duct 16 according to the first embodiment. By means of the ring 28, flow separations especially in the border areas 34 can be kept to a minimum.

FIG 6 shows the outlet duct 16 according to the second embodiment. By means of the rings 28, 30, flow separations especially in the border areas 34 can be kept to a minimum.

CLAIMS

1. A turbo-machine (10) comprising:

- at least one turbine stage (18);
- an outlet duct (16) arranged downstream of the turbine stage (18), the outlet duct (16(being bounded at least partly by at least one wall (14) of the turbo-machine (10) towards the outside (26) of the turbo-machine (10); and
- at least one flow element (28) for influencing the flow of a fluid flowing from the turbine stage (18) through the outlet duct (16), the flow element (28) being arranged in the outlet duct (16),

characterized in that

the flow element (28) is configured as a ring (28) having a profile in the form of an airfoil.

2. The turbo-machine (10) according to claim 1,
characterized in that
the ring (28) is mounted on an inner side (24) of the wall (14), the inner side (24) bounding the outlet duct (16).

3. The turbo-machine (10) according to claim 2,
characterized in that
the ring (28) is mounted on the inner side (24) in such a way that a flow of the fluid between the inner side (24) and the ring (28) is prevented.

4. The turbo-machine (10) according to claim 3,
characterized in that
the ring contacts (28) the inner side (24) of the wall (14).

5. The turbo-machine (10) according to any one of the preceding claims,
characterized in that
the turbo-machine (10) comprises at least one second ring (30) for influencing the flow of the fluid, the second ring (30) being arranged in the outlet duct (16), having a profile

in the form of an airfoil, and being arranged at a distance from the first ring (28) in the direction of flow of the fluid.

6. The turbo-machine (10) according to claim 5,
characterized in that
the airfoils of the rings (28, 30) differ from each other.

7. The turbo-machine (10) according to any one of claim 5 or 6,
characterized in that
the first ring (28) has a first diameter and the second ring (30) has a second diameter, the diameters differing from each other.

8. The turbo-machine (10) according to any one of the preceding claims,
characterized in that
the outlet duct (16) is configured as a diffuser.

9. The turbo-machine (10) according to any one of the preceding claims,
characterized in that
the turbine stage (18) has a radial turbine wheel (20).

10. A waste heat utilization device utilizing a thermodynamic cycle and having at least one turbo-machine (10) according to any one of the preceding claims.

FIG 1

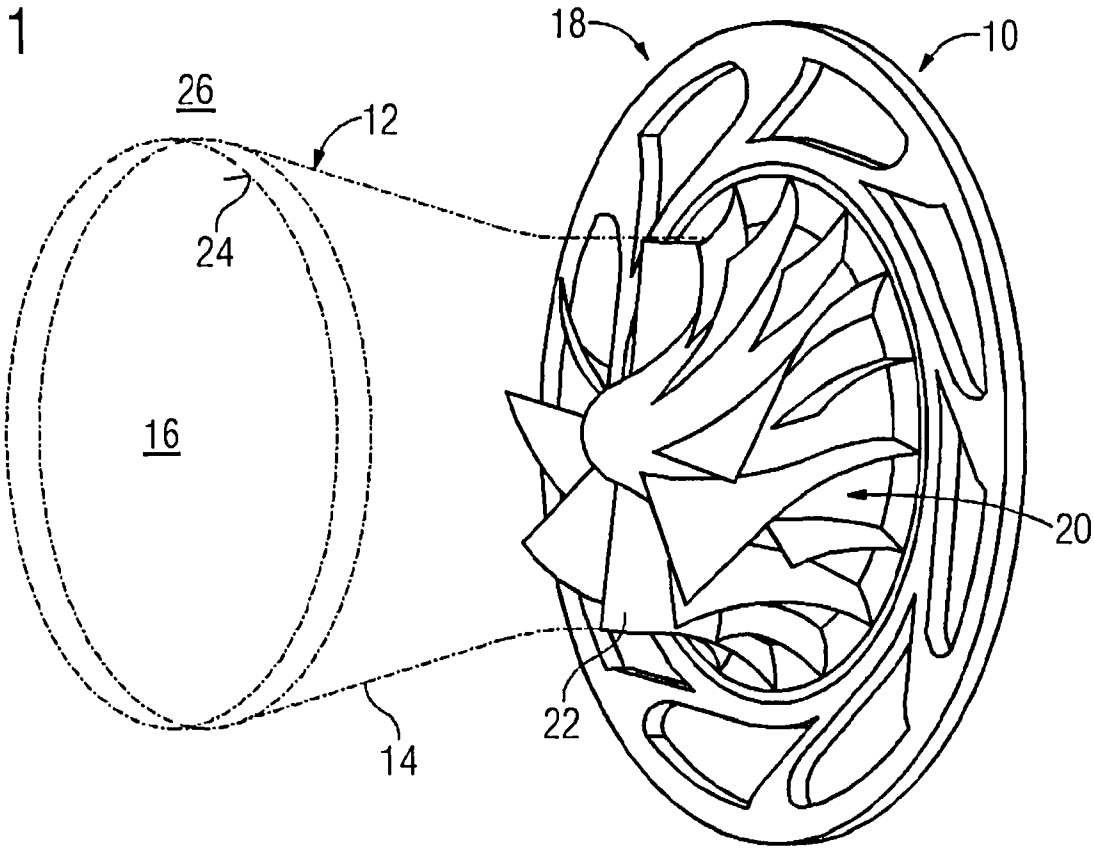


FIG 2

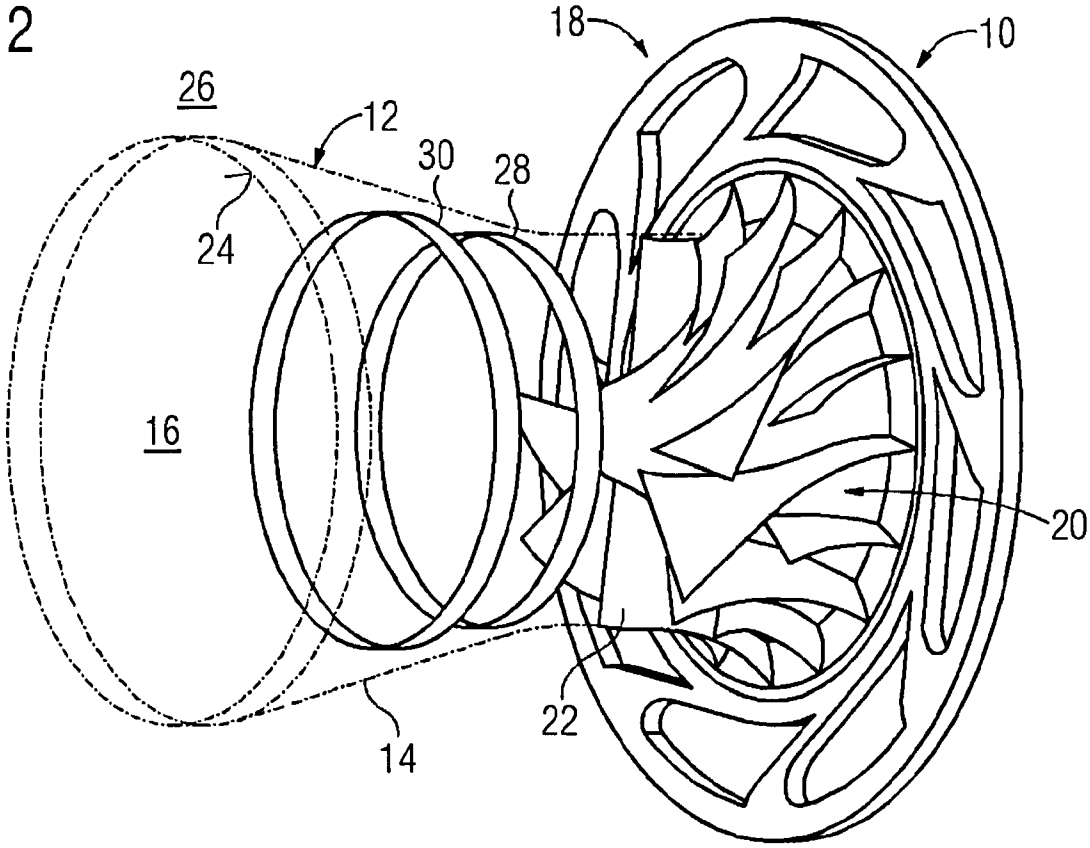


FIG 3

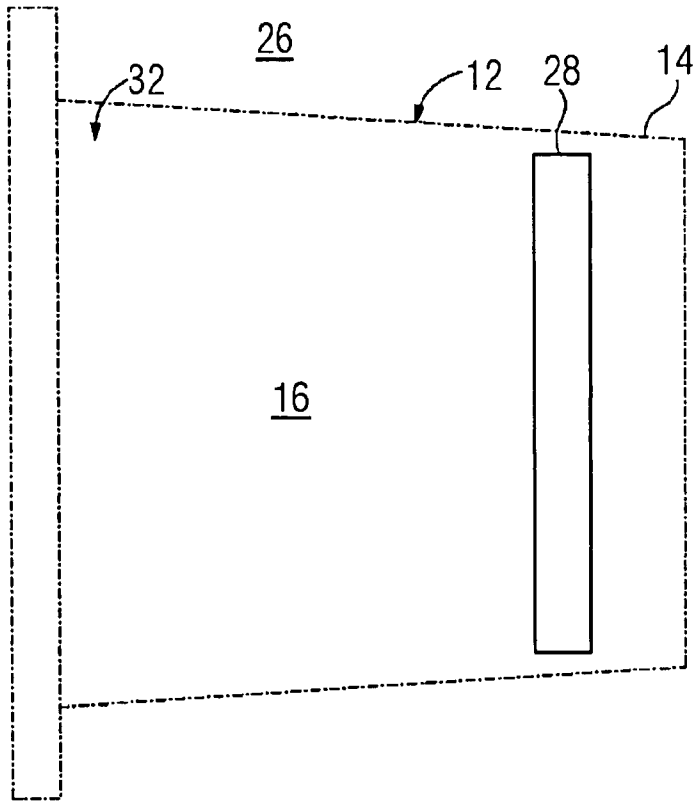


FIG 4

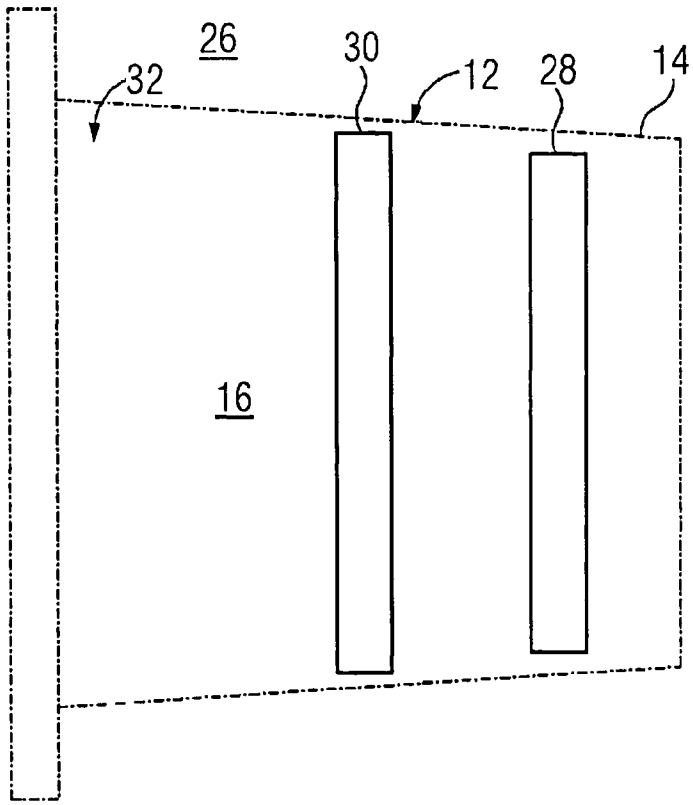


FIG 5

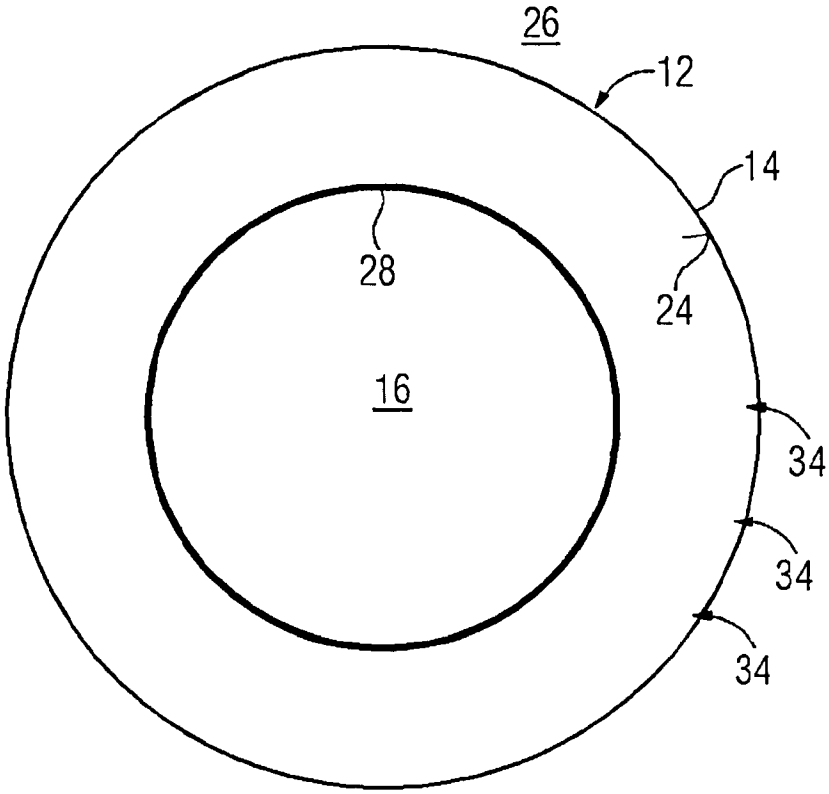
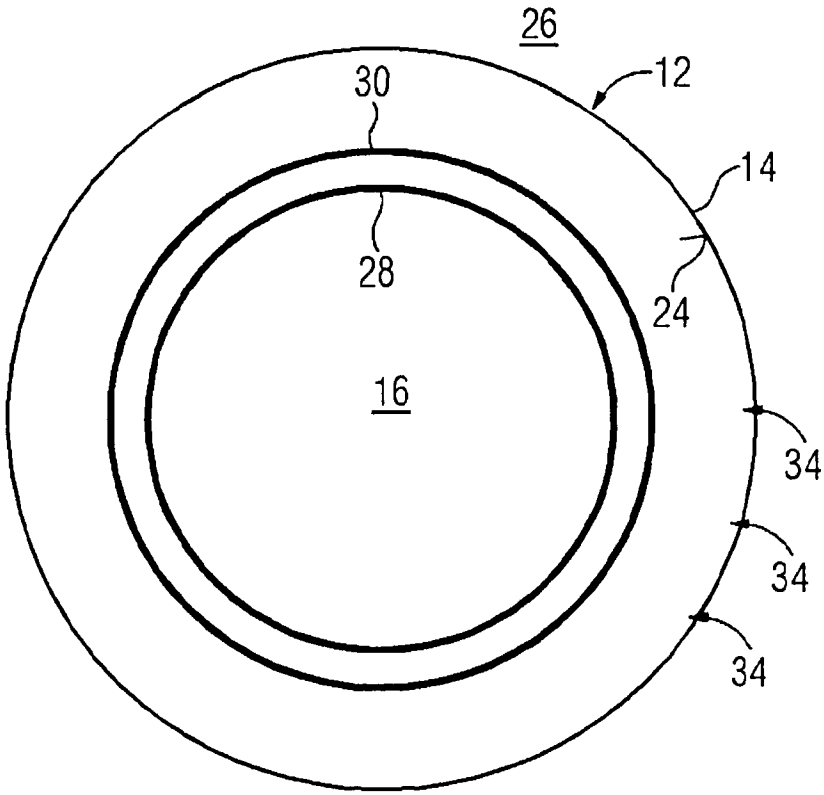


FIG 6



INTERNATIONAL SEARCH REPORT

International application No
PCT/RU2013/000362

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01D25/30
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)
F01D

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 Y	EP 1 970 539 A1 (SIEMENS AG [DE]) 17 September 2008 (2008-09-17) paragraph [0045] - paragraph [0061]; figures	1-9 10
Y	US 2010/064655 A1 (ZHANG HUA [US] ET AL) 18 March 2010 (2010-03-18) paragraph [0013] - paragraph [0015]; figures	10
X	DE 102 55 389 A1 (ALSTOM TECHNOLOGY LTD BADEN [CH]) 9 June 2004 (2004-06-09) paragraph [0027] - paragraph [0038]	1-9
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[X] Further documents are listed in the continuation of Box C.

[X] 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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Date of the actual completion of the international search	Date of mailing of the international search report
28 January 2014	05/02/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Teissier, Damien

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INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/063893 A1 (PRUTHI ROHIT [IN] ET AL) 15 March 2012 (2012-03-15) the whole document	1-9
X	EP 0 581 978 A1 (ASEA BROWN BOVERI [CH]) 9 February 1994 (1994-02-09) the whole document	1-9
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Information on patent family members

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