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(54) **TURBOMACHINERY AND CORRESPONDING METHOD OF OPERATING**

(57) The invention relates to a turbomachinery, in particular a gas turbine, having a casing through which a working fluid flows during operation in a direction of flow (F), an axially displaceable rotor arranged in the casing and an annular seal (8). In order to minimize the leakage mass flows of the working fluid in the turbomachinery during operation, the annular seal (8) comprises an inner seal member (8a) having a plurality of axially spaced,

radially projecting seal elements (10), wherein the inner seal member (8a) is attached to a rotor component (2), and an outer seal member (8b) consisting of a plurality of seal segments (12), each seal segment (12) having a conical shape with a diameter increasing in the direction of flow (F), wherein the outer seal member (8b) is attached to a casing component (4).

FIG 2



Description

[0001] The present invention relates to a turbomachinery, having a casing through which a working fluid flows during operation in a direction of flow, an axially displaceable rotor arranged in the casing and an annular seal. The present invention relates also to a method of operating such turbomachinery.

[0002] The recent developments of gas turbines result into an increase of the operation conditions such as pressures and temperatures. High pressures and temperatures, on the other hand, lead to high pressure and temperature differences over individual parts of the gas turbine.

[0003] Clearances between moving parts of a gas turbine (e.g. between stationary and rotating parts) are required because of a particular design or because of transient thermal movement of the gas turbine parts.

[0004] High pressure differences across clearances and gaps lead to high leakage mass flows of the working fluid. Leakage mass flows are detrimental to the engine performance and therefore need to be minimized.

[0005] In order to minimize leakage mass flows seals are implemented on the rotor and/or the stator of the turbomachinery. In general, seals can be divided into seals with and without contact. Seals with contact are susceptible to wear and for this reason their performance decreases over time. As for noncontact seals, labyrinth seals are widely used.

[0006] The significant transient movement of parts in a gas turbine led to the need to adjust clearance over time in order to minimize leakage flows. Clearance adjustments can be performed with a variety of technical means and with open loop or closed loop control systems. The latter are typically simpler to install, less expensive and bear smaller operating risks while the former have the potential to reach tighter clearances.

[0007] PCT application WO 93/20335 A1 describes a method and a configuration for controlling a gap width between the blade tip of a rotor blade and a stator housing of a rotating machine with a turbine part and a compressor part. The control of the gap width takes place in such a way that, during the startup phase of the gas turbine, the shutting down of the gas turbine and load changes of the gas turbine, the gap width is larger than it is during continuous operation of the gas turbine. By this means, the danger of a turbine blade rubbing on the housing during starting, shutdown and load change is reduced. For this purpose, the rotors of the compressor and the turbine are permanently connected together so that they form a single rotor. The housings of the compressor and the turbine are separated from one another and the compressor housing is arranged so that it can be displaced relative to the turbine casing. Due to a displacement of the compressor casing, a displacement of the complete rotor and, therefore, a displacement between the turbine rotor blades and the turbine casing, take place simultaneously.

[0008] Displacing the rotor in order to optimize turbine clearances during steady state operation is also described in WO 00/28190 A1. The axial movement of the rotor is performed e.g. automatically by hydraulic pistons behind the compressor thrust bearing. Such clearance optimization upgrade is implemented after about one hour of warm-up period, i.e., when the different thermal expansions of rotor and casing components are aligned with each other. Should a loss of hydraulic pressure occur, the system is designed for the rotor to move back to its original position automatically in a "fail-safe" manner.

[0009] The benefit of this design is a better control the size of the clearance by displacing the rotor. Shifting the rotor upstream will increase the clearances while shifting the rotor downstream in the direction of flow of the working fluid will decrease the clearances. Large clearances are required e.g. during the start-up when parts change their shape due to large transient temperature gradients. When these differences have decayed, smaller clearances can be established by displacing of the rotor in the upstream direction.

[0010] It is an object of the present invention to minimize the leakage mass flows of the working fluid during operation of the turbomachinery.

[0011] The object of the invention is achieved by a turbomachinery in particular a gas turbine, having a casing through which a working fluid flows during operation in a direction of flow, an axially displaceable rotor arranged in the casing and an annular seal comprising:

- an inner seal member having a plurality of axially spaced, radially projecting seal elements, wherein the inner seal member is attached to a rotor component, and
- an outer seal member consisting of a plurality of seal segments, each seal segment having a conical shape with a diameter increasing in the direction of flow, wherein the outer seal member is attached to a casing component

[0012] The idea of the present invention is to provide an annular seal having an improved shape which results in an improved sealing quality when axially shifting the rotor after the transient movements have ceased. The result is achieved by dividing the outer seal member in two or more annular seal segments, in particular identical seal segments, and forming each seal segment as a cone having a diameter increasing in the direction of flow. When displacing the rotor upstream, the seal elements of the inner seal member are moved towards the outer seal member. Thus the projecting seal elements of the inner seal member are displaced axially from the wider part to the narrower part of the conical segments, so that the further the seal elements are shifted upstream, the smaller the gap between the seal elements on the rotor and the conical seal segments on the housing becomes. This way merely by shifting the inner seal member the gap can be closed without any radial shift of the inner or

outer seal members.

[0013] The inner seal member is hereby attached to a rotor component and the outer seal member is attached to a casing component. The rotor component is for example a turbine blade mounted on the rotor shaft. The rotor component can be also the rotor shaft so that the inner seal member is attached directly to the rotor. The same refers to the casing component, it can be a guide vane mounted on the casing or the casing itself.

[0014] The turbomachinery is preferably a gas turbine, an aircraft engine turbine, or a stationary gas turbine for the generation of electrical energy. A stationary gas turbine can then have an electrical output of more than 60 MW.

[0015] The turbomachinery preferably has at least two rows of rotor blades (blade rows) which are at an axial distance from one another, the casing and/or the blade tips being designed in such a way that an axial displacement of the rotor provides approximately the same radial gap for each blade row.

[0016] Preferably, the seal elements are knife edges. Knife edge seal assemblies are one variety of rotary seal employed in gas turbine engines. Also preferably, each of the seal segments of the outer seal member has a honeycomb structure. Such seal assemblies typically include a disk with an integral flange with one or more radial projections - the knife edges - and a honeycomb ring, here the outer seal member, attached e.g. to the casing or a guide vane. The disk and knife edge rotate with other components of the gas turbine, while the guide vane and honeycomb ring are stationary. The disk and knife edge rotate with other components of the gas turbine, while the guide vane and honeycomb ring are stationary. The knife edge and honeycomb ring are assembled relative to each other to leave a small radial gap between the top of the knife edge and the inner surface of the honeycomb ring before the knife edge begins rotating in the gas turbine. During operation of the turbomachinery the displacement of the rotor shaft and hence the displacement of the knife edges towards the honeycomb ring closes the gap between the knife edge and honeycomb ring and causes the knife edge to cut into the outer seal member with the honeycomb structure.

[0017] In another preferred embodiment of the invention the inner seal member is designed for displacement between 0.5 mm and 5 mm. This displacement is preferably provided in one direction so that the gap between the inner and the outer seal member and thus also the gap between the rotor and the casing of the turbomachinery is reduced during normal operation of the turbomachinery.

[0018] Furthermore, the object of the invention is achieved by a method of operating such turbomachinery as described above, in particularly a gas turbine, wherein the rotor is displaced relative to the casing when a steady state operation condition of the turbomachinery is reached. A displacement of the rotor and respectively of the inner seal member is only carried out when a steady

state operating condition of the turbomachinery has been reached with a completely steady-state temperature distribution of the individual components of the turbomachinery. The achievement of such operation condition, in particular the normal powered operation condition of the turbomachinery, can be determined by specifying a predetermined period, by the measurement of temperatures in the casing, by the measurement of temperature differences, by the measurement of the radial gap occurring as a consequence of the thermal expansions, and/or by relative displacement between the casing and the rotor. The axial shift of the rotor is performed e.g. automatically by hydraulic pistons behind the compressor thrust bearing. Such clearance optimization upgrade is implemented after e.g. about one hour of warm-up period, i.e. when the different thermal expansions of rotor and casing components are aligned with each other. Should a loss of hydraulic pressure occur, the system is designed for the rotor to move back to its original position automatically in a "fail-safe" manner.

[0019] Further features, properties, and advantages of the present invention will become clear from the following description of an embodiment of the invention in connection with the accompanying drawings:

FIG 1 is a partial sectional view of a rotor and a casing of a turbomachinery during transient condition, and

FIG 2 is a partial section view a rotor and a casing of a turbomachinery during steady state condition.

[0020] Referring now to the figures of the drawing in detail and first, particularly, to FIG 1 thereof, there is seen a partial sectional view of a rotor component 2 and a casing (or stator) component 4 of a turbomachinery, which is not shown in detail and which, in the present case, is a gas turbine. A gap 6 is formed between the rotor component 2 and the casing component 4. By means of the arrow F a flow direction of a hot gas being the working fluid is shown during the operation of the gas turbine. A radial direction is indicated by the arrow R.

[0021] In order to seal the gap 6 an annular seal 8 is provided in the gap 6. An inner seal member 8a of the annular seal 8 is attached to the rotor component 2, for example to a turbine blade. The inner seal member 8a has a plurality of axially spaced, radially projecting seal elements 10, which are designed as knife edges. An outer seal member 8b consists of a plurality of seal segments 12 having a honeycomb structure, each seal segment 12 having a conical shape with a diameter increasing in the direction of flow F. The outer seal member 8b, i.e. the single conical seal segments 12 are attached to the casing 4.

[0022] The gas turbine actually operates at transient condition for a considerable time. During the transient states the rotating shaft inertia, the thermodynamic parameters variations the heat transfer at the engine metallic parts, as well as the variations of engine dimensions

influence significantly the engine behavior. Such non-steady operation is set for example during start-up, stop and load changes of the gas turbine.

[0023] During continuous operation of the gas turbine in a steady state the rotor component 2 is shifted upstream against the flow direction F, so that the width of the gap 6 is smaller than it is during the transient conditions. This situation is shown in FIG 2. The tips of the knife edges 10 contact the honeycomb structure of the seal segments 8b and thus reduce the mass flow of the hot gases through the gap 6 in the direction of flow F.

Claims

1. A turbomachinery, in particular a gas turbine, having a casing through which a working fluid flows during operation in a direction of flow (F), an axially displaceable rotor arranged in the casing and an annular seal (8) comprising:
 - an inner seal member (8a) having a plurality of axially spaced, radially projecting seal elements (10), wherein the inner seal member (8a) is attached to a rotor component (2), and
 - an outer seal member (8b) consisting of a plurality of seal segments (12), each seal segment (12) having a conical shape with a diameter increasing in the direction of flow (F), wherein the outer seal member (8b) is attached to a casing component (4).
2. A turbomachinery according to claim 1, wherein the seal elements (10) are knife edges.
3. A turbomachinery according to any of the preceding claims, wherein the seal segments (12) of the outer seal member (8b) have a honeycomb structure.
4. A turbomachinery according to any of the preceding claims, wherein the inner seal member (8a) is designed for displacement between 0.5 mm and 5 mm.
5. Method of operating a turbomachinery, in particular gas turbine, according to one of the preceding claims, wherein the rotor is displaced relative to the casing when a steady state operation condition of the turbomachinery is reached.

FIG 1

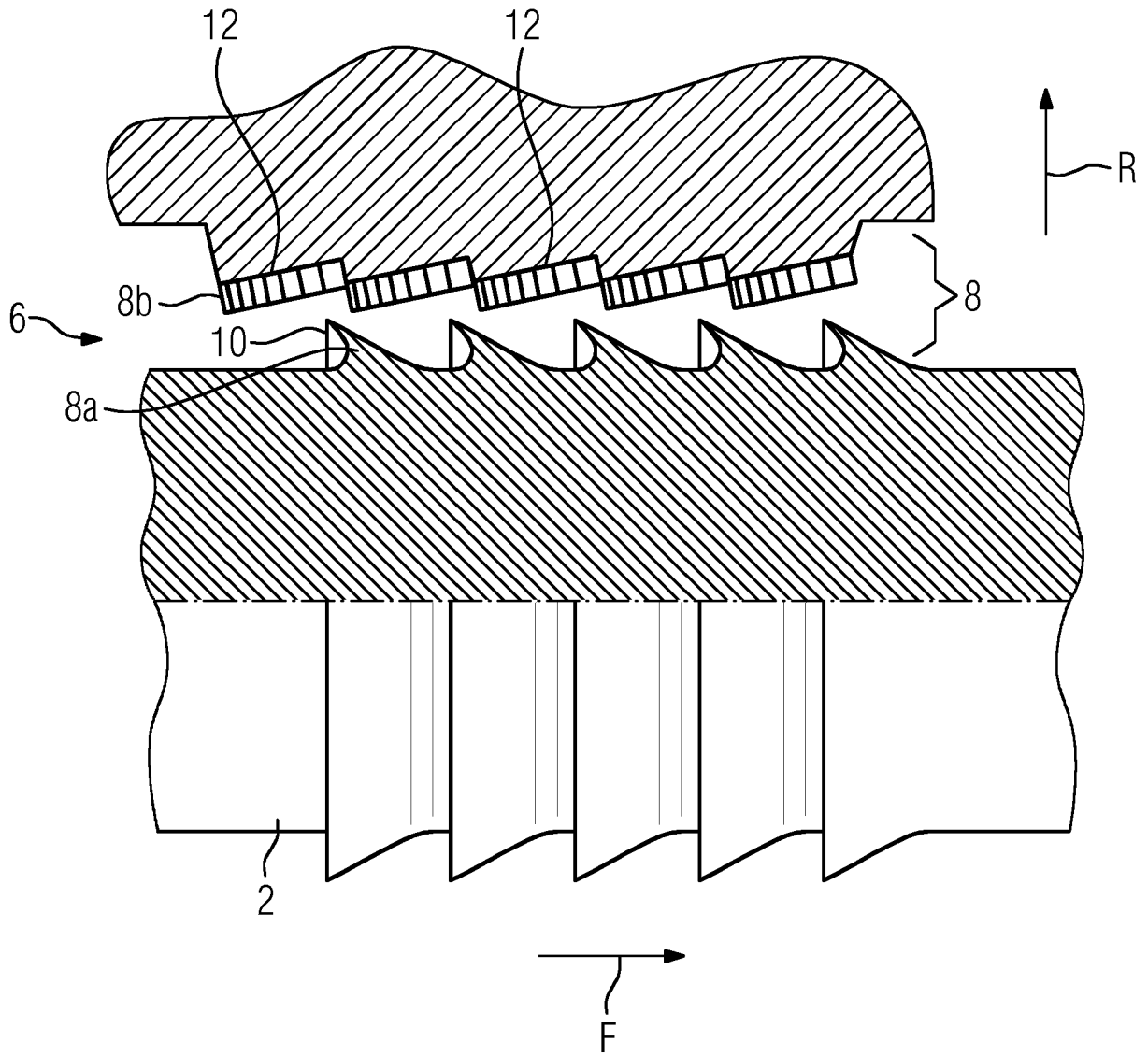
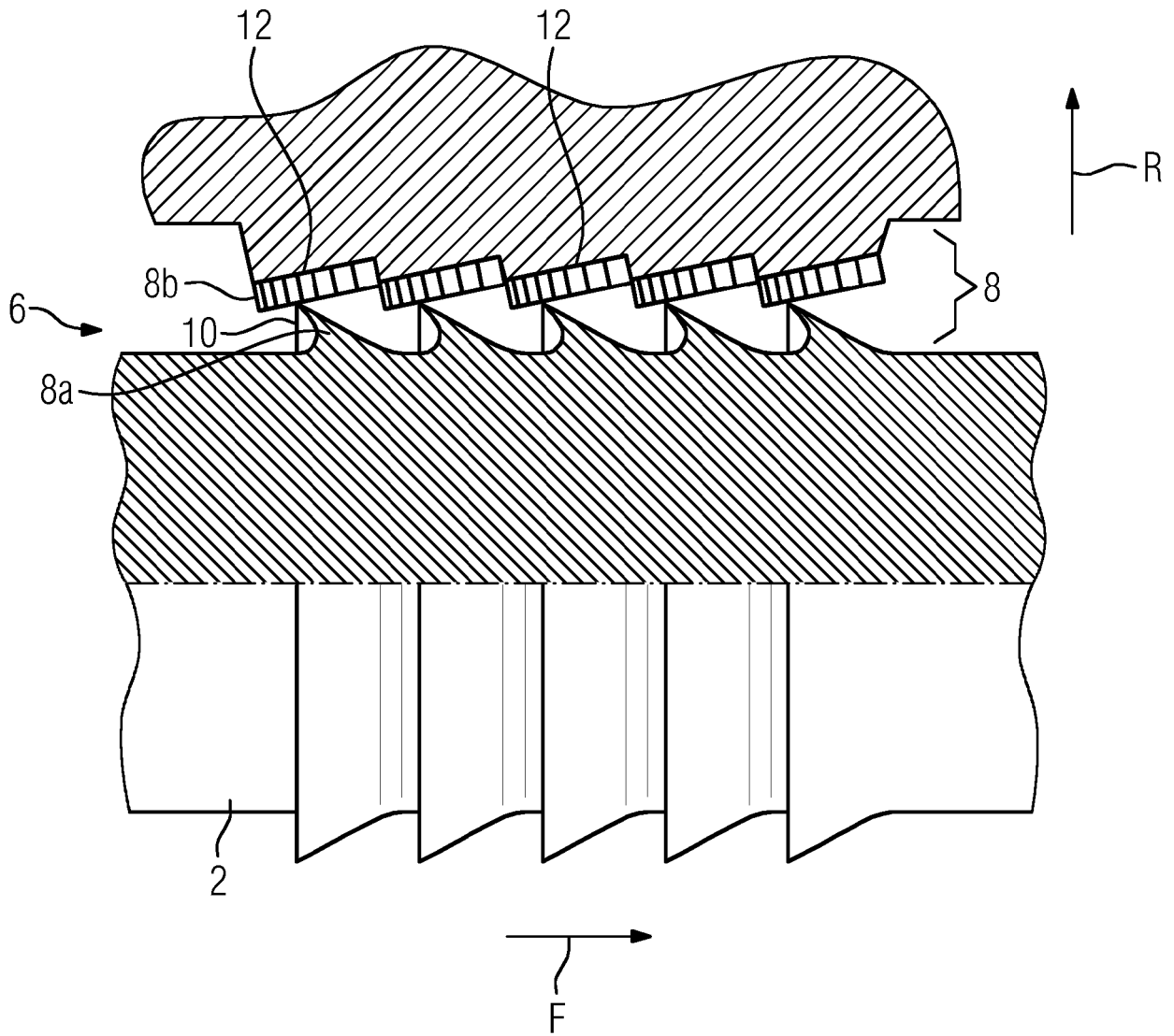


FIG 2





EUROPEAN SEARCH REPORT

Application Number
EP 17 16 8744

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			TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 16 October 2017	Examiner Ketelheun, Anja
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ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 17 16 8744

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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