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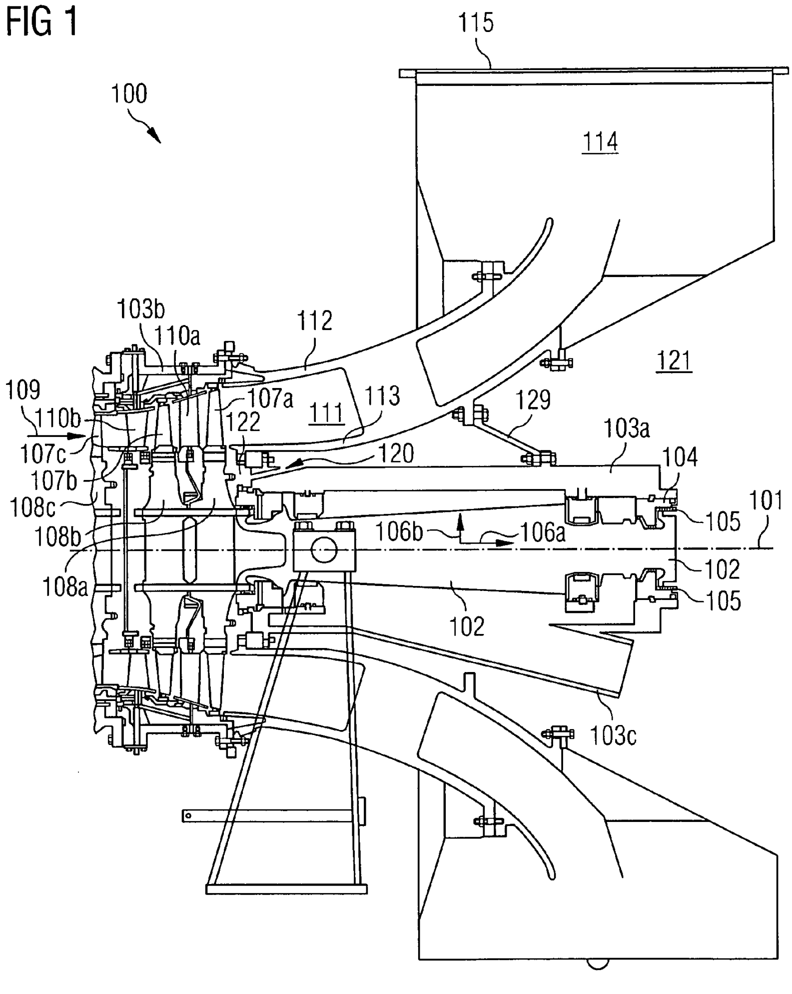
(71) Applicant: **Siemens Aktiengesellschaft**
80333 München (DE)

(72) Inventor: **James, Richard**
Middle Rasen
LN8 3LG Lincolnshire (GB)

(54) Turbine and method for operating the same

(57) The present invention provides a turbine for converting energy from a fluid flowing downstream, wherein the turbine comprises a housing 103; a rotor shaft 102 supported in the housing; and at least one rotor blade holder 108a connected to the rotor shaft, wherein the housing comprises at least one opening having 120 an entry 123 and an exit 124 for supplying cooling gas from outside 121 the housing to a downstream surface 126' of the at least one rotor blade holder 108a. Further, the present invention provides a method and a system for converting energy from a flowing fluid.

FIG 1



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Description

Field of invention

[0001] The present invention relates to a turbine for converting energy from a fluid flowing downstream, to a method for converting energy from a fluid flowing downstream and to a system for converting energy from a fluid flowing downstream, wherein the system comprises a turbine.

[0002] From the state-of-the-art a turbine is known which can convert energy from a flowing fluid. Potential energy (pressure head) and kinetic energy (velocity head) may be extracted from a flowing fluid using a turbine and may be converted to mechanical energy, such as rotational energy. In particular, this rotational energy may be used to drive a generator to generate electric energy.

[0003] There are a number of types of turbines known in the art. A steam turbine extracts energy from a flowing steam and is often used for the generation of electricity in thermal power plants. The steam may thereby be generated using coal or fuel oil or nuclear power. Gas turbines comprise upstream a compressor and a combustion chamber, where fuel is burned, wherein the burned fuel is used to drive the turbine, in particular the compressor.

[0004] In general a turbine comprises a rotor shaft which is rotatably supported by a bearing. Plural rotor blades are connected to the rotor shaft extending radially outwardly from the rotor shaft. The rotor blades are connected via rotor blade holders to the rotor shaft. A row of rotor blade holder may also be called a disk.

[0005] The rotor blades have a particularly defined surface profile such as to convert energy of a flowing fluid into a mechanical movement of the rotor blade. In a typical turbine plural rotor blades are arranged in a so-called rotor blade row substantially forming a row perpendicular to a rotation axis of the rotor shaft. Typically, a turbine may comprise several rotor blade rows arranged spaced apart in an axial direction from each other. In between each pair of rotor blade row a row of guide vanes is arranged that are connected to a stator part of the turbine. The stator part also comprises the bearing for the rotor shaft. Thus, the rotor blade rows may rotate relative to the static guide vane rows.

[0006] A flowing fluid containing potential energy (pressure head) and kinetic energy (velocity head) is supplied in an axial direction with respect to the rotor shaft. The flowing fluid impinges onto a most upstream row of guide vanes which deflects the flowing fluid such that the flowing fluid is directed to the row of rotor blades arranged downstream of the first guide vane row. The flowing fluid impinges onto the rotor blades and transfers a part of its energy to the rotor blade such that the rotor blades move into a certain direction. For this purpose, the rotor blades are shaped in a particular shape to optimally convert the energy of the impacting flowing fluid into mechanical movement. Since the rotor blades are connected to the rotor shaft via the rotor blade holder this causes the rotor shaft to rotate.

[0007] Having deposited a part of its energy to a row of rotor blades the flowing fluid reaches a downstream row of guide vanes which in turn directs the flowing fluid to a rotor blade row even further downstream. This further rotor blade row also extracts some energy from the flowing fluid and converts it to mechanical, rotational energy. Eventually, the flowing fluid lost most of its energy and exits from the last rotor blade row to an exhaust duct which may lead the flowing fluid to the environment.

[0008] Whatever type of turbine is concerned the flowing fluid used to drive the turbine often has a high temperature, a high pressure and a high velocity. Therefore, the rotor blades, the rotor blade holders as well as the guide vanes must be constructed and designed to withstand the impact of the hot, high pressure, high velocity fluid. In particular, upon impinging onto the rotor blades the flowing fluid not only transfers energy in form of mechanical energy but also in form of heat energy. Thereby, the rotor blades and rotor blade holders are heated up. The heating of the rotor blades and the rotor blade holders may cause them to fail due to material fatigue which may lead to problems, for example since the failing parts may collide with other components of the turbine, in particular with components of the stator, such as the guide vanes or support structures of the guide vanes.

[0009] In order to control the temperature of the rotor blade holder it has been proposed to cool the rotor blade holder by pressurized air. The cooling air serves two purposes. The first purpose is to prevent a part of the hot expanding gas being ingested to the region below the blade. The second purpose is to extract the heat being conducted from the blades to the blade holder and absorb the friction losses of the cooling flow moving with a lower velocity than the blade holder.

[0010] However, it has been observed that the operation of a turbine is often not satisfactory in particular regarding its efficiency and use of cooling fluid.

[0011] It is therefore an object of the present invention to provide a turbine for converting energy from a fluid which exhibits an improved efficiency and which has at the same time a simple construction. Further, it is an object of the present invention to improve a method for operating a turbine in particular regarding efficiency.

[0012] This objective is achieved by the independent claims. The dependent claims describe advantageous developments and modifications of the invention.

[0013] According to an aspect of the present invention a turbine for converting energy from a fluid flowing downstream is provided, wherein the turbine comprises: a housing; a rotor shaft supported in the housing; and at least one rotor blade holder connected to the rotor shaft, wherein the housing comprises at least one opening having an entry and an exit for supplying cooling gas from outside the housing to a downstream surface of the at least one rotor blade holder.

[0014] The turbine as defined before may be specifically a turbine section of a gas turbine engine, a steam turbine engine or the like. The turbine may also be the gas turbine engine or the steam turbine engine itself.

[0015] A gas turbine engine may comprise means for compressing air, mixing the compressed air with a fuel and burning the mixture of the compressed air and the fuel to generate mechanical energy within the turbine section. In case of a gas turbine the fluid flowing downstream may represent the burned mixture of the compressed air and the fuel.

[0016] In case of a steam turbine the fluid flowing downstream may represent water steam supplied by an external facility providing high energy water steam.

[0017] In particular, the fluid may be a gas which contains energy in form of potential energy (pressure head) and/or kinetic energy (velocity head) and/or heat energy. Further, the turbine may comprise a supply duct for supplying the flowing fluid to the turbine, in particular for supplying the flowing fluid to a rotor blade connected to a rotor blade holder comprised in the turbine.

[0018] The turbine comprises a housing which may accommodate a number of components of the turbine including wall structures and frame structures being static relative to the rotor shaft. The rotor shaft is supported in the housing. According to an embodiment, the rotor shaft may at least partly be accommodated in the housing. However, the rotor shaft and/or bearing means do not need to be entirely accommodated in the housing. In particular, the rotor shaft may be rotatably supported in the housing using additional bearing means, such as pad bearings or fluid bearings. In particular, the rotor shaft may freely rotate relative to the housing. Thus, the housing may be a component of the stator part of the turbine. The housing may comprise a frame structure and/or wall elements assembled from a number of separate parts which are fixedly connected to each other. The housing may delimit the turbine from an outside region which may be an atmospheric environment. The housing may comprise wall structures, such as metal walls, flanges and fixing means, such as screws or bolts for fixing the components to each other. The housing may also delimit a working space where the flowing fluid transfers its energy to a rotor blade. In particular, a portion of the housing, such as a wall portion or a sheet portion, may delimit the working space downstream of the at least one rotor blade holder.

[0019] Downstream of the at least one rotor blade holder there may or there may not be any bearing present.

[0020] The at least one rotor blade holder may be directly or indirectly connected to the rotor shaft. In particular, the at least one rotor blade holder may extend in a radial direction (with respect to a rotation axis of the rotor shaft) from the rotor shaft. Within the context of the present application, a radial direction refers to a direction perpendicular to a rotation axis of the rotor shaft. In the context of the present application an axial direction refers to a direction parallel to the rotation axis of the rotor shaft. In the context of the present application the flowing fluid supplied to the turbine defines a flowing direction flowing from upstream to downstream. An upstream side of a component refers to a side of the component to which the flow of the flowing fluid is directed to during operation. A downstream side of a component refers to a side of the component from which the flow of the flowing fluid is directed away.

[0021] The at least one opening in the housing for supplying cooling gas from outside the housing to a downstream surface of the at least one rotor blade holder may provide a gas communication between the outside of the housing and a working space of the turbine, where the flowing fluid transfers a part of its energy to a rotor blade connected to the at least one rotor blade holder. The opening may be a through-hole, a slit, a bore hole or the like. The at least one opening may penetrate a wall comprised in the housing. The opening may have different cross-sectional shapes, such as circular, oval, rectangular, square, triangle and the like. The at least one opening may have a shape such as a tube which may also be curved. An extension of the at least one opening in its cross-section may amount to 1 mm to 50 mm, in particular to 5 mm to 20 mm. A longitudinal extension of the at least one opening from the entry to the exit may amount to 1 cm to 30 cm, in particular to 2 cm to 15 cm, but may be greater of smaller depending on the application and overall size of the turbine.

[0022] The entry of the at least one opening in the housing may be in gas communication with the external atmospheric environment. The gas may be air taken from external atmospheric environment.

[0023] The entry of the at least one opening may also be in gas communication with a working space of the turbine, where the flowing fluid transfers part of its energy to a rotor blade connected to the at least one rotor blade holder. The gas then may be gas or air supplied from a compressor - typically called compressor bleed -, particularly with reduced pressure, and/or again air substantially taken from external atmospheric environment.

[0024] The downstream surface of the at least one rotor blade holder is the surface of the at least one rotor blade holder arranged at the downstream side of the at least one rotor blade holder. For transferring its energy to a rotor blade connected to the at least one rotor blade the flowing fluid impinges at an upstream surface of the rotor blade opposite to the downstream surface of the rotor blade. The downstream surface of the at least one rotor blade holder may be considered as a back surface of the at least one rotor blade holder.

[0025] The flowing fluid impinges onto an upstream surface of a rotor blade connected to the rotor blade holder for transferring part of its energy to the rotor blade.

[0026] The cooling gas may be air or a particular cooling gas which is taken from outside the housing and which may be pre-cooled if necessary. The pressure of the cooling gas may particularly be atmospheric pressure. The at least one opening in the housing advantageously allows supplying the cooling gas to the downstream surface of the at least one rotor blade holder to cool the downstream surface of the at least one rotor blade holder. At least 70%, in particular at least 90%, of the cooling gas impinging at the at least one rotor blade holder may first impinge at the downstream surface of the at least one rotor blade holder before impinging at other rotating parts of the turbine.

[0027] In particular, a cooling gas flow from outside the housing to the downstream surface of the at least one rotor blade holder may be caused by a pressure difference between the outside of the housing and a space around the downstream surface of the at least one rotor blade holder. In particular, the space around the downstream surface of the at least one rotor blade may comprise a part of a space of an exhaust duct, wherein the pressure may be below atmospheric pressure, such as below 1 bar, for example around 0.9 bar. Outside the housing substantially atmospheric pressure may prevail, such as around 1 bar. 1 bar is equal to 100,000 Pa (Pascal).

[0028] The pressure difference may result from the rotation of the blade holder disk.

[0029] Due to the pressure difference between the outside of the housing and the space around the downstream surface of the at least one rotor blade cooling gas from outside may be sucked via the entry of the opening into the opening, may pass through the opening and may exit via the exit of the opening towards the space around downstream surface of the at least one rotor blade.

[0030] Then, the cooling gas may contact or sweep over at least a part of the downstream surface of the at least one rotor blade holder to absorb at least a part of the heat energy contained in the at least one rotor blade holder. The flowing cooling gas may carry away the absorbed heat energy to cause a cooling effect of the at least one rotor blade holder and/or a rotor blade connected to the rotor blade holder. The cooling gas having absorbed at least a part of the heat energy comprised in the at least one rotor blade holder and/or rotor blade may be guided into and exhausted via an exhaust duct used for exhausting the flowing fluid or may be lead away along another duct.

[0031] According to an embodiment of the present invention the exit of the at least one opening is arranged downstream of the downstream surface of the at least one rotor blade holder. In particular, the exit of the at least one opening may be arranged downstream of a last disk of rotor blades holders in the turbine. Arranging the exit of the at least one opening downstream of the downstream surface of the at least one rotor blade holder may be advantageous for effectively supplying the cooling gas to the downstream surface of the at least one rotor blade holder. In particular, at the downstream side of the downstream surface of the at least one rotor blade holder a portion of the housing may be located which allows the provision of at least one opening for gas communication to the outside of the housing.

[0032] According to a further embodiment of the present invention the exit of the at least one opening is arranged radially (i.e. in a radial direction) closer to a rotation axis of the rotor shaft than the entry of the at least one opening. This provision may have advantageous effects for the flow of the cooling gas towards the downstream surface of the at least one rotor blade holder. In particular, the cooling gas may flow from a base portion of the at least one rotor blade holder close to the rotation axis of the rotor shaft to a radially outer portion of the at least one rotor blade holder farther away from the rotation axis of the rotor shaft, i.e. the cooling gas may at least partly flow radially outwards.

[0033] According to a further embodiment of the present invention the exit of the at least one opening is arranged axially closer to the surface of the at least one rotor blade holder than the entry. It is thus enabled to lead the cooling gas from a location axially far away from the downstream surface of the at least one rotor blade holder to a location axially closer to the surface of the at least one rotor blade holder. Thus, the cooling gas may be more precisely directed to the downstream surface of the at least one rotor blade holder.

[0034] According to a further embodiment of the present invention the turbine further comprises a bearing, wherein the housing at least partly houses the bearing and wherein the bearing supports the rotor shaft. The bearing may help to rotatably support the rotor shaft such that it may rotate with diminished friction. The bearing may comprise at least one rolling element bearing, pad bearing and/or fluid bearing for bearing the rotor shaft at several locations spaced apart in an axial direction. In particular, the bearing may be a component of the stator of the turbine. In particular, the at least one opening in the housing may be located within a portion of the housing which at least partly houses the bearing. In other embodiments the at least one opening is located within a portion of the housing not comprising or not enclosing the bearing.

[0035] According to a further embodiment of the present invention the at least one opening in the housing is delimited by an inner surface at least party having a cylindrical shape. Thereby, a simple manufacture of the at least one opening in the housing is enabled. For example, the at least one opening in the housing may be achieved by drilling a hole through the housing. In other embodiments of the present invention the opening may have a circular shape but may be not straight in a longitudinal section but may be bent.

[0036] According to a further embodiment of the present invention the at least one opening has a symmetry axis which includes an angle with a rotation axis of the rotor shaft between 5° and 75°, in particular between 10° and 40°, more in particular between 15° and 30°. By this provision the cooling gas may be directed towards the downstream surface of the at least one rotor blade holder according to a particular impingement direction which may be advantageous for effectively cooling the rotor blade holder and/or a connected rotor blade.

[0037] According to a further embodiment of the present invention the turbine comprises an inner exhaust duct wall and an outer exhaust duct wall for delimiting an exhaust duct for exhausting the fluid, wherein the inner exhaust duct wall is arranged radially closer to the rotor shaft than the outer exhaust duct wall and is mechanically connected to the housing. The inner exhaust duct wall and the outer exhaust duct wall may be arranged downstream the rotor blade holder and in particular downstream a last (i.e. most downstream) disk of rotor blade holders in the turbine. When the flowing fluid reaches the exhaust duct it has transferred a substantial part of its energy to the rotor blades connected to the rotor blade holder and thus to the rotor shaft. Thus, it has only low energy which means that it has a pressure and temperature each lower than further upstream.

[0038] According to a further embodiment of the present invention the entry of the at least one opening in the housing is arranged opposite to a portion of the inner exhaust duct wall. In particular, the portion of the inner exhaust duct wall may be a portion close to the at least one rotor blade holder. Arranging the entry of the at least one opening close to the at least one rotor blade holder avoids the requirement of an opening having an extended longitudinal length.

[0039] According to a further embodiment of the present invention the turbine further comprises at least one rotor blade connected to the rotor blade holder, wherein the at least one rotor blade holder is arranged between the rotor shaft and the at least one rotor blade for connecting the rotor blade to the rotor shaft, wherein the exit of the at least one opening is arranged closer to the at least one rotor blade holder than to the at least one rotor blade.

[0040] The at least one rotor blade holder may be considered as an adaptor connecting the rotor shaft to the at least one rotor blade. The at least one rotor blade holder may not be involved in the transfer of energy from the flowing fluid to the rotor shaft, as it does not provide a surface shape being suitable for transferring the energy of an impinging flowing fluid into mechanical energy. The at least one rotor blade holder may merely mediate the torque experienced by the rotor blade due to the impinging flowing fluid to the rotor shaft. The at least one rotor blade holder may be manufactured from a less expensive material than the at least one rotor blade. In other embodiments of the invention the material of the blade and blade holder (or the disk) is typically of a similar material as the rotor blades, although is not necessarily identical.

[0041] According to a further embodiment of the present invention the turbine is adapted such that cooling gas after exiting from the exit of the at least one opening flows radially outwards through a gap formed between (a) the at least one rotor blade holder and/or the at least one rotor blade and (b) an upstream edge of the inner exhaust duct wall. This flow path of the cooling gas may be advantageous for effectively cooling an inner (radially closer to the rotor shaft) part of the at least one rotor blade holder which may only ineffectively be cooled by supplying cooling gas from a periphery (radial periphery) of the at least one rotor blade.

[0042] According to a further embodiment of the present invention the turbine further comprises at least one further opening formed in the housing spaced apart in a circumferential direction (with respect to the rotor shaft) from the at least one opening. Thereby, a cooling effect may even be enhanced. In particular, plural openings may be arranged spaced apart in a circumferential direction, in particular spaced apart in a circumferential direction by same amounts. For example, plural drills may be provided through the housing without deteriorating the stability of the housing.

[0043] According to a further embodiment of the present invention the at least one rotor blade holder is a rotatable component of the turbine closest, in an axial direction with respect to the rotor shaft, to an upstream edge of the inner exhaust duct wall. Thus, a last (i.e. arranged most downstream) disk of rotor blade holders and/or rotor blades may be cooled using cooling gas supplied through the at least one opening.

[0044] Further, the turbine may comprise at least one further rotor blade arranged spaced apart from the at least one rotor blade in an axial direction with respect to the rotor shaft, wherein the at least one rotor blade is arranged downstream from the at least one further rotor blade. This provision enables a construction of a multistage turbine, in particular comprising plural rotor blade rotor disks arranged spaced apart in an axial direction. In particular, the most downstream rotor blade holder, respectively rotor blade holder disk, is subjected to a cooling due to the cooling gas supplied through the at least one opening in the housing. In particular rotor blade holders not arranged in the most downstream rotor blade holder disk may not be substantially cooled by the cooling gas supplied by the at least one opening in the housing.

[0045] According to a further aspect of the present invention a method for converting energy from a fluid flowing downstream is provided, wherein the method comprises: driving, by the flowing fluid, at least one rotor blade holder connected to a rotor shaft; and supplying cooling gas through at least one opening formed in a housing from outside the housing to a downstream surface of the at least one rotor blade holder, the housing supporting the rotor shaft, the at least one opening having an entry and an exit.

[0046] Thereby, an effective operation of the turbine may be provided, since the cooling of the at least one rotor blade holder is effectively performed by a flow of cooling gas through the at least one opening in the housing. For this kind of cooling no extra energy is required, as the flow of the cooling gas automatically establishes due to a pressure difference between the outside of the turbine and a space around the at least one rotor blade holder or by a centrifugal force caused by the rotating rotor blade and/or the rotor blade holder. Thereby, the efficiency of the turbine is improved.

[0047] According to a further aspect of the present invention a system for converting energy from a fluid flowing downstream is provided, wherein the system comprises a turbine according to an aspect of the present invention and a container, wherein the turbine is arranged in an inner space of the container, the inner space being held at a pressure slightly greater than atmospheric pressure, and wherein the entry of the at least one opening is in communication with the inner space of the container. The pressure difference may partly assist to drive the cooling gas to cool the rotor blade holder. However, the main pressure difference for driving the cooling gas may be generated by the flow of the streaming fluid through the turbine. The higher the load the higher may be the volume flow and therefore also the higher the velocity, which may result in a lower static pressure at the exit of the at least one opening for the cooling gas. At low load the cooling need of the rotor blade holder may be reduced.

[0048] Embodiments of the present invention will now be described with reference to the accompanying drawings.

Brief description of the drawings

[0049]

Fig. 1 schematically illustrates a sectional view of a portion of a turbine according to an embodiment of the present invention; and

Fig. 2 schematically illustrates a detailed view of the portion of the turbine illustrated in Fig. 1.

Fig. 1 schematically illustrates a portion of a turbine 100 - particularly a turbine section of a gas turbine engine - according to an embodiment of the present invention. The turbine 100 comprises a housing 103, which comprises several housing portions such as portion 103a, 103b, and 103c. These housing portions are directly or indirectly connected to each other and belong to the stator components of the turbine 100. That means, the housing components 103a, 103b, 103c are fixed and do not move, while the turbine 100 is operating.

[0050] The turbine 100 further comprises a rotor shaft 102 which is supported in the housing part 103a. In particular, the rotor shaft 102 is supported by a bearing 104. The bearing 104 is fixedly connected to the housing component 103a which in this embodiment represents a bearing housing. The bearing 104 comprises plural pad bearings 105 which support the rotor shaft 102 such that it can freely rotate around a rotation axis 101. The arrow labelled 106a indicates an axial direction and the arrow labelled 106b indicates a radial direction. The bearing housing 103a comprises an elongated cylindrical metal tube to support the rotor shaft 102 by plural bearing portions 104 and plural roller bearings 105 along the axial direction.

[0051] Connected to the rotor shaft 102 are plural rotor blade holders 108a, 108b, 108c from which the rotor blade holder 108c is only partly illustrated in Fig. 1. Mechanically connected to the rotor blade holders 108a, 108b and 108c are rotor blades 107a, 107b and 107c, respectively. The rotor blades 107a, 107b and 107c have particularly shaped upstream surfaces for converting energy of an impinging flowing fluid along the direction labelled with reference number 109 into a mechanical movement in a particular direction and thus for converting this energy into mechanical energy. Thereby, the flowing fluid flowing in a direction 109 alternatingly passes a rotor blade 107c, a guide vane 110b, a rotor blade 107b, a guide vane 110a and a rotor blade 107a. Thereby, the guide vanes 110b and 110a direct the flowing fluid to the rotor blades 107b and 107a, respectively which are arranged downstream to the respective guide vanes.

[0052] The guide vanes are fixedly connected to the housing portion 103b and belong to the stator part of the turbine 100. Thus, they stand still, while the rotor blades 107a, 107b and 107c move relative to the guide vanes 110a, 110b. The flowing fluid supplied to the turbine 100 along the flowing direction 109 deposits a part of its energy to the rotor blades such that a torque is generated and mediated via the rotor blade holders 108a, 108b and 108c to the rotor shaft 102 such that the rotor shaft 102 is caused to rotate around its rotation axis 101.

[0053] Having deposited part of its energy to the rotor shaft 102 the flowing fluid reaches an exhaust duct 111 located downstream to the last rotor blade 107a. The exhaust duct 111 is delimited by an outer exhaust duct wall 112 and an inner exhaust duct wall 113. In a portion of the exhaust duct 111 close to the rotor blade holder 108a and rotor blade 107a the pressure may be pretty low, such as below 1 bar, in particular around 0.9 bar. The flowing fluid passes through the exhaust duct and reaches an exhaust collector 114, from where it is exhausted into the environment outside the turbine through a silencer 115.

[0054] Opposite to the inner exhaust duct wall 113 close to the rotor blade holder 108a and rotor blade 107a the bearing housing 103a comprises an opening 120 for supplying cooling gas from a region 121 outside the housing to a region 122 close to the rotor blade holder 108a arranged most downstream. The structure and function of the opening 120 will be described in more detail referring to Fig. 2.

[0055] In other embodiments the opening 120 may be located in a housing portion not housing a bearing for supporting the rotor shaft. In particular, the opening may be located in a housing portion downstream of which no bearing means is arranged.

[0056] Fig. 2 schematically illustrates an enlarged sectional view of a portion of the turbine 100 illustrated in Fig. 1. The opening 120 is formed in the bearing housing

103a by drilling through the wall of the bearing housing 103a. Thereby, an entry 123 is formed which is arranged opposite to a portion of the inner exhaust conduct wall 113. The opening 120 has a shape of a tube, in particular a cylindrical shape, and may represent a bore hole. A symmetry axis of the cylinder is inclined relative to the axial direction such that the symmetry axis includes an angle of around 20° with the rotation axis 101 of the rotor shaft 102.

[0057] Further, an exit 124 of the opening 120 is formed towards the space 122 close to the rotor blade holder 108a. In particular, the exit 124 is located closer to the rotor blade holder 108a than to the rotor blade 107a.

[0058] The opening 120 provides a gas communication between the external region 121 and the region 122 close to the rotor blade holder 108a. Since in the region 122 close to the rotor blade holder 108a and/or in the exhaust conduct 111 a lower pressure prevails than in the external region 121 cooling gas, such as external air may flow along a path labelled by an arrow 125 through the opening 120 into the region 122 close to the rotor blade 107a. Thus, the pressure differential may be a driving force for the cooling gas to pass through the opening 120.

[0059] Another driving force may be a centrifugal force, which results during spinning of the rotor blade 107a. The cooling gas is introduced via the opening 120 at the exit 124 thereof at a small radius and moves radially upwards. Thereby, it impinges onto the rotor blade holder 108a, in particular onto a downstream surface 126' of the rotor blade holder 108a, from where it is pumped by the spinning rotor blade holder 108a radially outwards, involving a centrifugal force.

[0060] In particular, the exit 124 is arranged downstream of the downstream surface 126' of the rotor blade holder 108a. Further, the exit 124 is arranged axially closer to the downstream surface 126' of the rotor blade holder 108a than the entry 123 of the opening 120. Further, the exit 124 of the opening 120 is arranged radially closer to the rotation axis 101 than the entry 123 of the opening 120.

[0061] Having flown into the region 122 the cooling gas is directed to the downstream surface 126' of the rotor blade holder 108a. The cooling gas at least partially contacts the downstream surface 126' of the rotor blade holder 108a to at least partly absorb heat energy stored in the rotor blade holder 108a. The cooling gas having absorbed a part of the heat energy comprised in the rotor blade holder 108a carries away the absorbed heat energy.

[0062] The cooling gas flows radially outwards towards the downstream surface 126 of the rotor blade 107a. To reach this downstream surface 126 the cooling gas passes along the rotor blade holder 108a, passes a gap 127 formed between an edge 128 of the inner exhaust duct wall 113, the edge 128 being a most upstream portion of the exhaust duct wall 113, and a protrusion 129 of the rotor blade 107a attached to the rotor blade holder 108a. This gap may have a width d which may amount to 1 mm to 5 mm, in particular around 3 mm.

[0063] Having passed the gap 127 the cooling gas at least partially contacts the inner exhaust duct wall 113 of the exhaust duct 111 on its way through the exhaust. The cooling gas having absorbed a part of the heat energy comprised in the rotor blade holder 108a and rotor blade 107a carries away the absorbed heat energy and is exhausted via the exhaust duct 111 together with the flowing fluid from which a part of its energy has been converted into mechanical energy.

[0064] The inner exhaust duct wall 113 is further mechanically connected to the bearing housing 103a by struts 129.

[0065] The present invention provides a simple and effective way of cooling a rotor blade holder or a disk of a turbine. The windage effect caused by friction against a rotating rotor blade disk requires a small supply of air which can be continuously vented away after being heated by the disk. At the downstream side of the last power turbine disk the pressure is normally low which means that according to the prior art the cooling air supplied from the compressor usually would have a much higher pressure than needed due to the location of the compressor bleed. Throttling the air to the would required pressure as proposed by the prior art generates losses as well as reduces the capacity of the compressor and the performance of the gas turbine.

[0066] According to an embodiment by providing apertures in the wall between the back surface of the power turbine disk and exterior of the gas turbine air will be ingested simply by the rotating disk and pumped out into the exhaust diffuser entry, where the pressure is slightly lower than outside the gas turbine during operation provided that the gas turbine does not have any downstream heat recovery system. Thereby, the apertures may be provided in a housing.

[0067] The advantage of the present invention is that the cooling system is self-propelled and self-controlled. The cooling air which is non-pressurised, is provided at the correct pressure automatically - e.g. equal to the atmospheric pressure -, without effecting the performance or capacity of the gas turbine. The flow of the cooling air is generated only by the rotation of the disk and due to the little pressure difference between the inflowing cooling air and the pressure in the area near the rotating disk. The pressure difference is merely resulting by "normal" operation and no specific means to increase or decrease the pressure is needed.

[0068] The present invention is not restricted to the disclosed embodiments.

Claims

1. Turbine for converting energy from a fluid flowing downstream, the turbine comprising:

- a housing (103);
- a rotor shaft (102) supported in the housing; and
- at least one rotor blade holder (108a) connected to the
rotor shaft (102),
wherein the housing comprises at least one opening (120) having an entry (123) and an exit (124) for supplying cooling gas from outside the housing to a downstream surface (126') of the at least one rotor blade holder (108a).

2. Turbine according to claim 1, wherein the exit (124) of the at least one opening (120) is arranged downstream of the downstream surface (126') of the at least one rotor blade holder (108a).

3. Turbine according to claim 1 or 2, wherein the exit (124) of the at least one opening (120) is arranged radially closer to a rotation axis of the rotor shaft (102) than the entry of the at least one opening (120).

4. Turbine according to one of claims 1 to 3, wherein the exit (124) of the at least one opening (120) is arranged axially closer to the downstream surface (126') of the at least one rotor blade holder (108a) than the entry (123).

5. Turbine according to one of claims 1 to 4, further comprising

- a bearing (105),
wherein the housing (103a) at least partly houses the bearing (105) and wherein the bearing supports the rotor shaft (102).

6. Turbine according to one of claims 1 to 5, wherein the at least one opening (120) in the housing (103a) is delimited by an inner surface at least partly having a cylindrical shape.

7. Turbine according to claim 6, wherein the at least one opening (120) has a symmetry axis which includes an angle with a rotation axis (101) of the rotor shaft (102) between 5° and 75°, in particular between 10° and 40°, more in particular between 15° and 30°.

8. Turbine according to one of claims 1 to 7, further comprising

- an inner exhaust duct wall (113) and
- an outer exhaust duct wall (112)
for delimiting an exhaust duct for exhausting the fluid,
wherein the inner exhaust duct wall (113) is arranged radially closer to the rotor shaft (102) than the outer exhaust duct wall (112) and is mechanically connected to the housing (103a).

9. Turbine according to claim 8, wherein the entry (123) of the at least one opening (120) in the housing (103a) is arranged opposite to a portion of the inner exhaust duct wall (113).

10. Turbine according to one of claims 1 to 9, further comprising

- at least one rotor blade (107a) connected to the rotor blade holder (108a),
- wherein the at least one rotor blade holder (108a) is arranged between the rotor shaft (102) and the at least one rotor blade (107a) for connecting the rotor blade (107a) to the rotor shaft (102),
- wherein the exit (124) of the at least one opening (120) is arranged closer to the at least one rotor blade holder (108a) than to the at least one rotor blade (107a).

11. Turbine according to one of claims 1 to 10, which is adapted such that cooling gas after exiting from the exit (124) of the at least one opening (120) flows radially outwards through a gap (127) formed between (a) the at least one rotor blade holder (108a) and (b) an upstream edge (128) of the inner exhaust duct wall (113).

12. Turbine according to one of claims 1 to 11, further comprising

- at least one further opening
- formed in the housing spaced apart in a circumferential direction with respect to the rotor shaft (102) from the at least one opening (120).

13. Turbine according to one of claims 1 to 12 in combination with claim 8, wherein the at least one rotor blade holder (108a) is a rotatable component of the turbine closest, in an axial direction (101) with respect to the rotor shaft (102), to an upstream edge (128) of the inner exhaust duct wall (113).

14. Method for converting energy from a fluid flowing downstream, the method comprising:

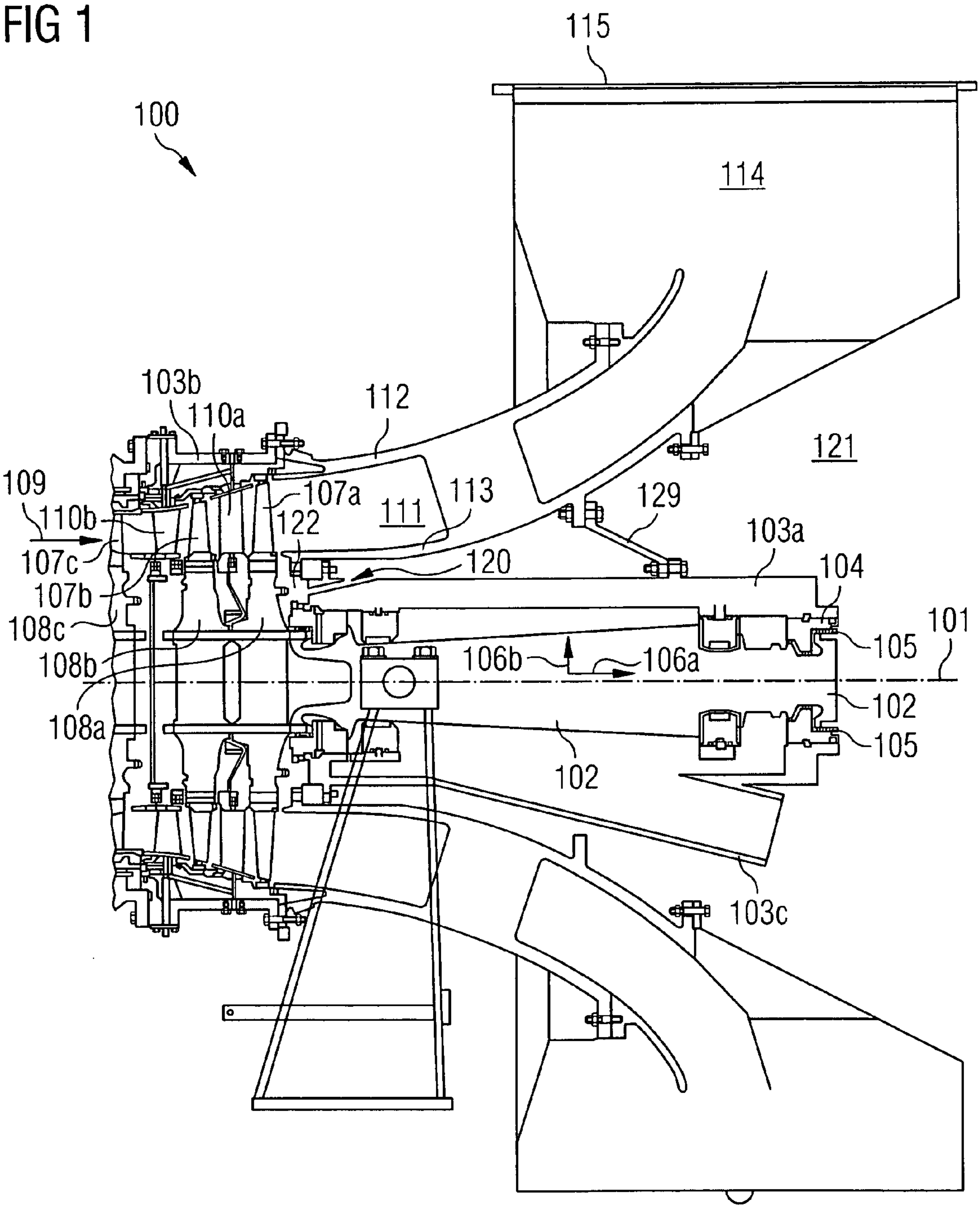
- driving, by the flowing fluid, at least one rotor blade holder (108a) connected to a rotor shaft (102); and
- supplying cooling gas through at least one opening (120) formed in a housing (103) from outside the housing (103) to a downstream surface of the at least one rotor blade holder (108a), the housing (103) supporting the rotor shaft (102), the at least one opening (120) having an entry (123) and an exit (124).

15. System for converting energy from a fluid flowing downstream, the system comprising:

- a turbine according to one of claims 1 to 13 and
- a container,

wherein the turbine is arranged in an inner space of the container, the inner space being held at a pressure greater than atmospheric pressure, and wherein the entry (123) of the at least one opening (120) is in communication with the inner space of the container.

FIG 1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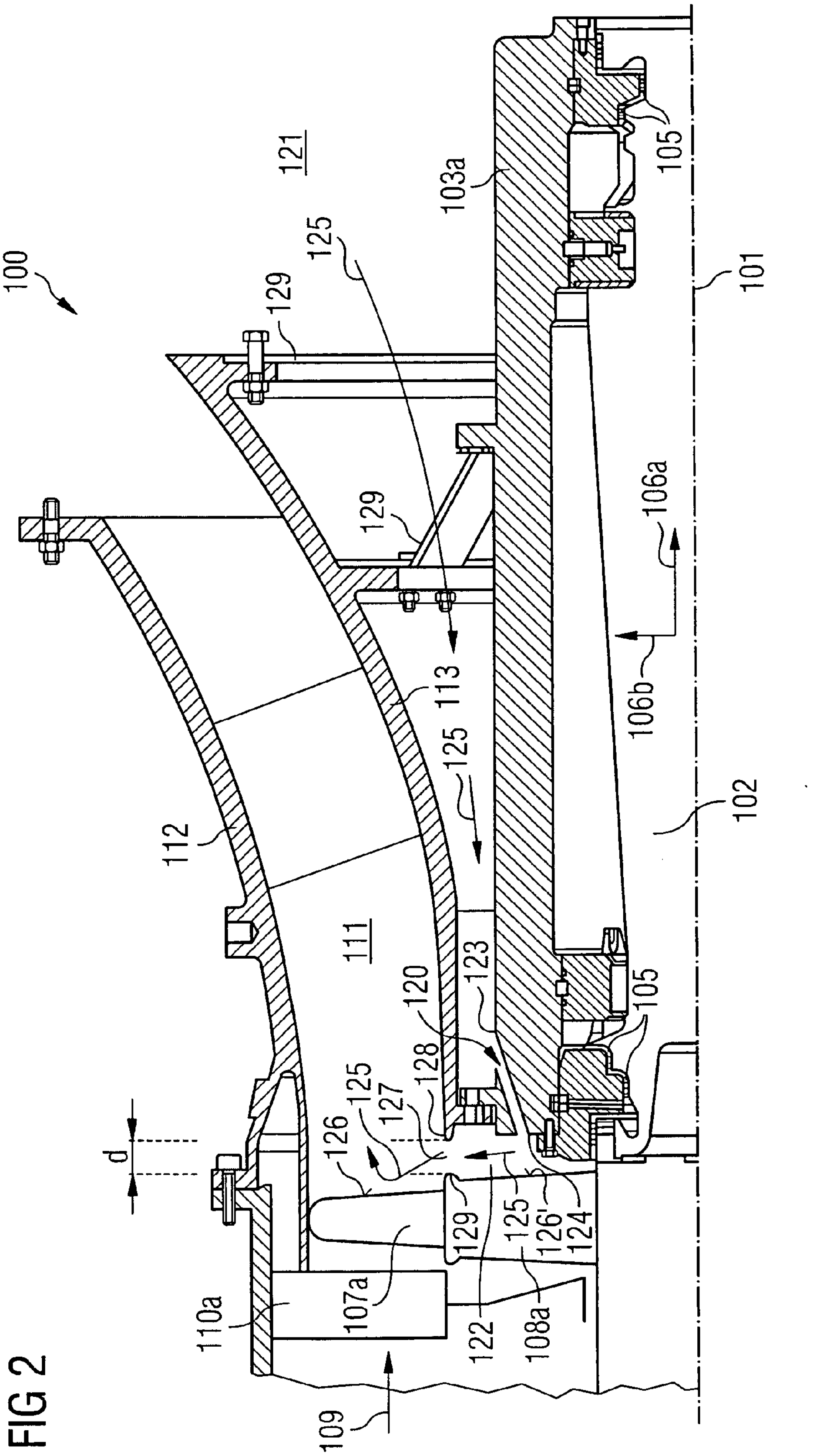
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FIG 2

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EUROPEAN SEARCH REPORT

Application Number
EP 09 01 5012

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	31 May 2010	Burattini, Paolo

CATEGORY OF CITED DOCUMENTS

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