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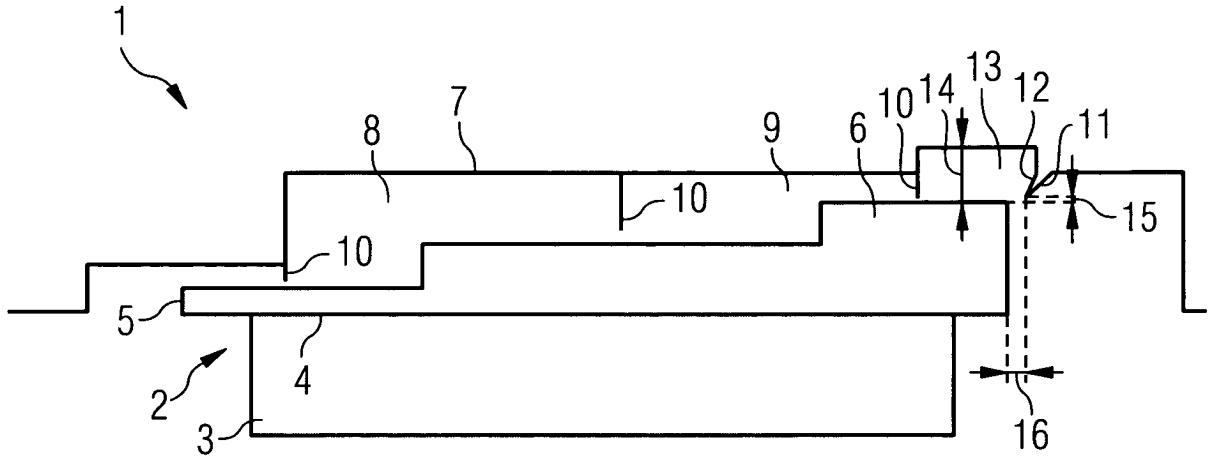
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(54) Axial flow turbine with low shroud leakage losses

(57) An axial flow turbine (1) comprises a turbine casing (7) and a blade ring (2) having a shroud (5) being spaced apart from the casing thereby forming a radial tip clearance (8), through which a leakage flow is passing during operation of the turbine, wherein the casing (7) comprises a deflector (11) arranged outside the tip clearance and adapted to alter the cavity flow such that the leakage flow is turned from axial direction to radial direction and/or such that a downstream part of the cavity (8) is aerodynamically blocked by the deflector.

FIG 1



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Description

[0001] The invention relates to an axial flow turbine with low shroud leakage losses.

[0002] An axial flow turbine, for example a steam turbine, comprises a casing and a rotor which is rotably supported within the casing. The rotor comprises a shaft and a plurality of rotor blade rings which are attached behind one another to the shaft. During operation of the steam turbine steam is expanded progressively by the blade rings to bring about driving the shaft.

[0003] Each rotor blade ring is formed by a plurality of rotor blades being circumferentially arranged, wherein two adjacent rotor blades form a blade passage. The rotor blades are aerodynamically profiled such that, when the steam flow passes the blade passages, the stream flow is turned and thereby a circumferential force on the rotor blades is generated. The circumferential forces on each blade of the rotor blade ring effect turning the rotor thereby generating shaft power.

[0004] The rotor blades are fixed to the shaft and extend therefrom to the casing. The lateral ends of the rotor blades at the casing are formed into blade tips, wherein at the blade tips the rotor blade ring is shrouded by a shroud. The shroud is fixed to the blade tips and spaced apart from the casing thereby forming a tip clearance. The height of the tip clearance is dimensioned such that during operation of the steam turbine it is prevented that the shroud scrubs at the casing. Due to the fact that static pressure of the steam flow upstream of the rotor blade ring is higher than static pressure of the steam flow downstream of the rotor blade ring, during operation of the steam turbine a leakage flow passes the tip clearance.

[0005] The main steam flow passes the blade passages for shaft power generation, whereas the leakage flow bypasses the rotor blade ring via the tip clearance. Therefore, the leakage flow does not participate to the shaft power generation and is lost. Further, the leakage flow after reentrained into the main flow path interferes with the main steam flow. Therefore, the main steam flow is locally inhomogeneous resulting to a mismatched flow. Furthermore, the tip clearance flow mixes with the main steam flow and generates disadvantageous dissipation. As consequence of this, the presence of the tip clearance flow affects the turbine efficiency.

[0006] In particular in high pressure turbines with low aspect ratio blades, the loss caused by the tip clearance flow is significantly high compared with the total losses of the steam turbine.

[0007] A remedy to reduce this negative effect of the tip clearance flow on the aerodynamic efficiency of the steam turbine is to take measurements reducing the tip clearance flow. A measurement, for example, is to provide a labyrinth seal on the outer circumference of the shroud within the tip clearance in order to reduce the mass flow of the tip clearance flow. As an alternative, a sealing element is fixed at the casing in the tip clearance. For fixing the sealing element to the casing, in the casing a circumferential groove is provided into which the sealing element is mortised.

[0008] It is an object of the invention to provide an axial flow turbine with reduced aerodynamic losses associated with shroud leakage flows.

[0009] According to the invention, the axial flow turbine comprises a turbine casing and a blade ring having a shroud being spaced apart from the casing thereby forming a radial tip clearance, through which a leakage flow is passing during operation of the turbine, wherein the casing comprises a deflector arranged outside the tip clearance and adapted to alter the cavity flow such that the leakage flow is turned from axial direction to radial direction and/or such that a downstream part of the cavity is aerodynamically blocked by the deflector.

[0010] At the discharge of the tip clearance, where the leakage flow discharges the tip clearance, the leakage flow mixes with the main flow. The mixing is accompanied by a vortex system generating dissipation and therefore loses. By turning the leakage flow from axial direction to radial direction toward the inward of the casing, when the leakage flow has discharged the tip clearance and before the leakage flow has been mixed with the main flow in the turbine, the vortex system is advantageously affected by means of the deflector. Therefore, the loss production caused by the leakage flow is reduced. At the same time the radial deflector is acting as an extra sealing element reducing the leakage mass flow fraction.

[0011] The deflector is arranged outside the tip clearance; hence the deflector has no influence on the geometry of the tip clearance. Therefore, known measurements for reducing the tip clearance flow, for example a labyrinth seal or a sealing element, can be provided in the tip clearance, although the deflector protrusion is arranged.

[0012] It is preferred that the deflector is arranged downstream of the rotor blade ring in the vicinity thereof.

[0013] Therefore, the radial deflector advantageously turns the leakage flow from axial direction to radial direction toward the inward of the casing before the leakage flow has been mixed with the main flow in the turbine downstream of the rotor blade ring. Further, since the deflector is arranged immediately downstream of the shroud, no additional space for the deflector has to be provided.

[0014] Preferably the deflector extends in radial direction towards the inward of the casing at most to the outer radius level of the shroud at the downstream edge. Further, the deflector is preferably formed into a ring protrusion.

[0015] Therefore, the deflector advantageously can be formed into a uniform geometry device.

[0016] Preferred is that a ring cavity is provided in the casing upstream of the deflector and adjacent thereto.

[0017] The ring cavity upstream the deflector provides additional radial space compared with the tip clearance. Therefore, upstream the deflector in the ring cavity a turning vortex can be generated for effectively turning the

leakage flow. Further, it is preferred that the deflector is integrally formed with the casing.

[0018] Therefore, the deflector can be manufactured in line with the manufacturing of the casing. This is the reason why the provision of the deflector in the casing is related to no significant additional costs. Enhanced recirculating flow in the ring cavity dissipates the momentum of leakage flow reducing its mass flow fraction.

[0019] Preferably the deflector comprises a deflection face upstream facing the leakage flow.

[0020] Therefore, the deflector works effectively like a vertical vane being formed into a circumferential strip.

[0021] It is preferred that the deflection face is bent opposite to the main flow direction.

[0022] Furthermore, the casing preferably comprises a plurality of turning vanes forming a turning vane ring being arranged within the tip clearance upstream of the deflector in order to reduce the circumferential component of the leakage flow. By means of the turning vanes the momentum of the leakage flow is advantageously changed. In particular, the combination of the deflector and the turning vanes modifies the leakage re-entry angle, reduces its circumferential velocity component and reduces the leakage mass flow fraction.

[0023] It is preferred that the turning vanes are arranged to be inclined toward axial direction to achieve a favourable direction of the leakage flow at re-entry into the main flow.

[0024] Further, it is preferred that the turning vanes are supported by the deflector or that the turning vanes and deflector are manufactured integrally.

[0025] In the following the invention is explained on the basis of a preferred embodiment with reference to the drawings. In the drawings:

Figure 1 shows a cross section of a first embodiment of a tip clearance area in the axial flow turbine according to the invention, and

Figure 2 shows a cross section of a second embodiment of a tip clearance area in the axial flow turbine according to the invention.

[0026] Figures 1 and 2 shows a tip clearance area of an axial flow turbine 1. The axial flow turbine 1 comprises a casing 7 and a rotor blade ring 2 formed by rotor blades 3. The blade 3 extends in radial direction of the casing 7 and has a longitudinal end formed into a blade tip 4 facing the casing 7.

[0027] During operation of the axial flow turbine 1 a main flow passes the tip clearance areas in Figures 1 and 2 from left to right.

[0028] The blade tip 4 is shrouded by a shroud 5 having an outer surface facing the casing 7. The outer surface of the shroud 5 comprises three shroud steps, wherein the shroud step 6 is located downstream and has the largest outer radius compared with the other two shroud steps.

[0029] In the area of the shroud 5 and the blade tip 4, respectively, the casing 7 comprises a clearance cavity 8. The outer surface of the shroud 5 is spaced apart from the bottom wall of the clearance cavity 8 thereby forming a tip clearance 9.

[0030] In order to reduce the shroud leakage flow (within clearance 9) three sealing elements 10 are provided. Each sealing element 10 is arranged and dimensioned for cooperating with one attributed shroud step. The sealing elements 10 are arranged in the way to allow for restricted axial movement of the rotor relative to the casing for all operating conditions.

[0031] Further, the casing 7 comprises a deflector 11 arranged outside the downstream the shroud edge 9 and downstream in the vicinity of the shroud step 6. The deflector 11 extends in radial direction towards the inward of the casing 7 such that the deflector 11 is still spaced in radial direction from the outer radius level of the shroud step 6. Furthermore, the gap between deflector and shroud as a result of mutual radial and axial displacements between rotor and casing is formed into a circumferential ring protrusion. The deflector 11 is integrally formed with the casing 7.

[0032] According to the embodiment shown in Figure 1, the height 14 of the ring cavity 13 is 6 mm, the axial distance 16 between the shroud 5 and the deflector 11 is 16 mm, and the radial distance 15 between the shroud step 6 and the deflector 11 is 15 mm.

[0033] In the clearance cavity 8 the casing 7 further comprises a ring cavity 13 being provided upstream of the deflector 11 and adjacent thereto. Further, the deflector 11 comprises a deflection face 12 upstream facing the leakage flow. According to the embodiment shown in Figure 1, the deflection face 12 is curved opposite to the main flow direction. Alternatively, according to the embodiment shown in Figure 2, the deflection face 12 is in line with the radial direction.

[0034] As can be seen in Figure 2, the casing 7 further comprises a plurality of turning vanes 17 forming a turning vane ring being arranged within the ring cavity 13 upstream of the deflector 11 and adjacent thereto. The turning vanes 17 are arranged in a way to reduce leakage flow circumferential velocity component. Further, the turning vanes 17 are abutting against the deflection face 12 thereby being supported by the deflector 11.

Claims

1. Axial flow turbine comprising a turbine casing (7) and a blade ring (2) having a shroud (5) being spaced apart from the casing (7) thereby forming a radial tip clearance (9), through which a leakage flow is passing during operation of the turbine (1),
   wherein the casing (7) comprises a deflector (11) arranged outside the tip clearance (9) and adapted to alter the cavity flow such that the leakage flow is turned from axial direction to radial direction and/or

such that a downstream part of the cavity is aerodynamically blocked by the deflector.

2. Axial flow turbine according to claim 1, wherein the deflector (11) is arranged downstream of the blade ring (2) in the vicinity thereof.

3. Axial flow turbine according to claim 2, wherein the deflector (11) extends in radial direction towards the inward of the casing (7) at most to the outer radius level (6) of the shroud (5) at the downstream edge.

4. Axial flow turbine according to claim 3, wherein the deflector (11) is formed into a ring protrusion.

5. Axial flow turbine according to claim 4, wherein a ring cavity (13) is provided in the casing (7) upstream of the deflector (11) and adjacent thereto.

6. Axial flow turbine according to any of claims 1 to 5, wherein the deflector (11) is integrally formed with the casing (7).

7. Axial flow turbine according to any of claims 1 to 6, wherein the deflector (11) comprises a deflection face (12) upstream facing the leakage flow.

8. Axial flow turbine according to any of claims 1 to 7, wherein the deflection face (12) is curved opposite to the main flow direction.

9. Axial flow turbine according to any of claims 1 to 8, wherein the casing (7) comprises a plurality of turning vanes (17) forming a turning vane ring being arranged within the tip clearance (9) upstream of the deflector (11) and adjacent thereto and being adapted to turn the leakage flow in circumferential direction of the casing (7).

10. Axial flow turbine according claim 9, wherein the turning vanes (17) are arranged to be inclined toward the leakage flow.

11. Axial flow turbine according to claim 9 or 10, wherein the turning vanes (17) are supported at the deflector (11).

FIG 1

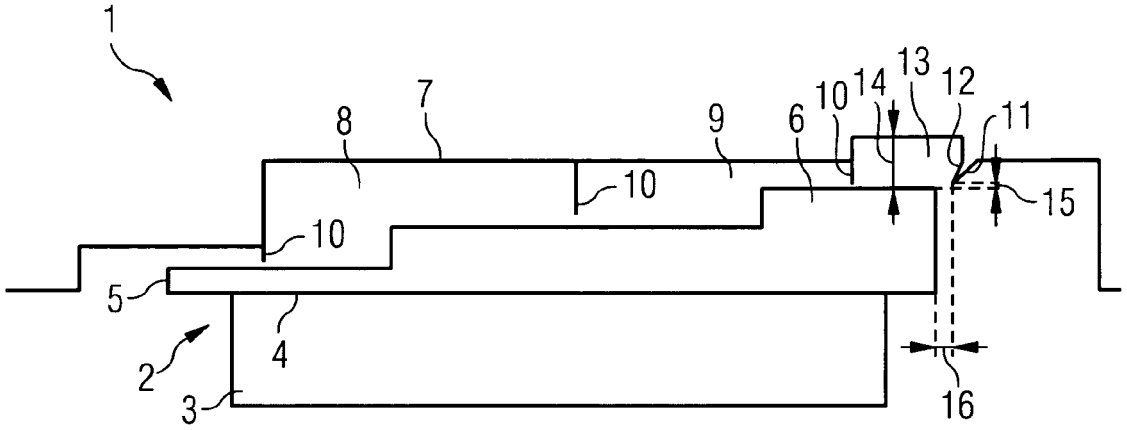
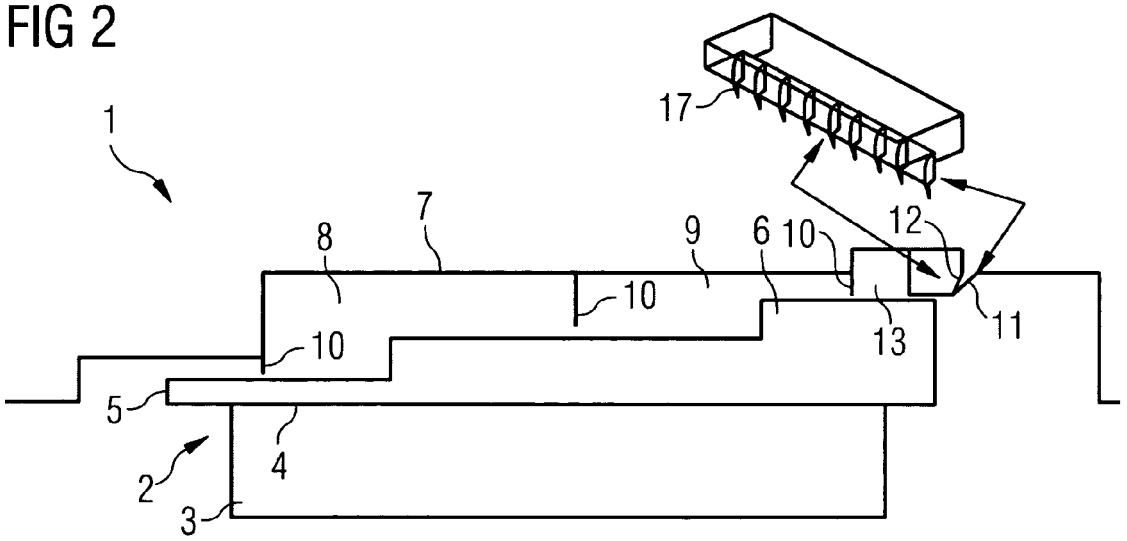

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FIG 2


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EUROPEAN SEARCH REPORT

Application Number
EP 08 00 3488

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Place of search	Date of completion of the search	Examiner
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