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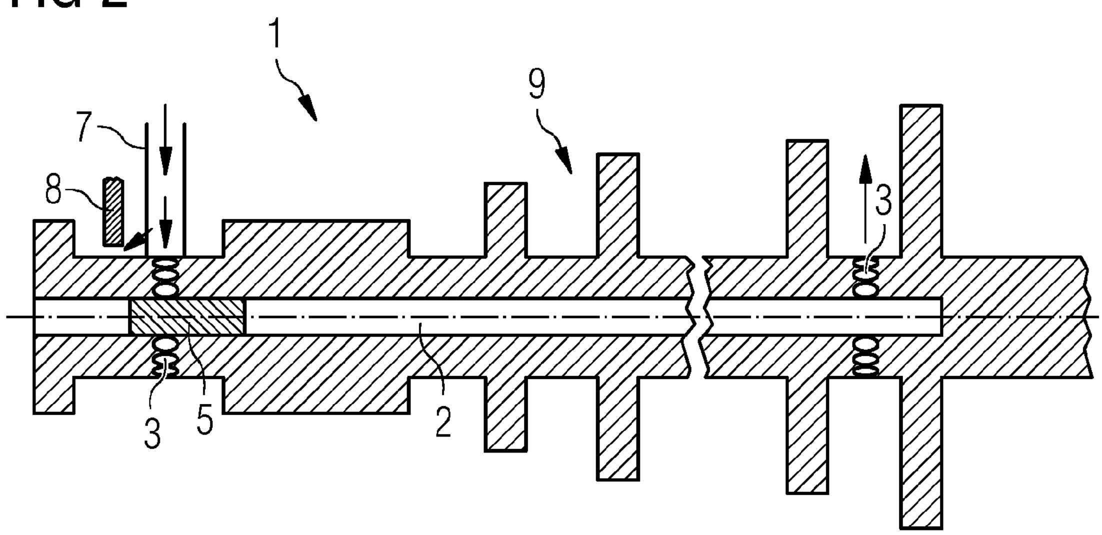
(54) **Rotor for a steam turbine**

(57) Rotor (1) for a steam turbine, especially for solar-thermal power plants. The rotor (1) is embodied such that steam flows through at least some areas of it. A steam turbine with such a rotor (1) and a method for operating such a steam turbine are also disclosed.

FIG 2



EP 2 573 317 A1

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Description

[0001] The invention relates to a rotor for a steam turbine, especially for solar-thermal power plants, in accordance with the preamble of independent claim 1. The invention further relates to a steam turbine with such a rotor and also to a method for operating a steam turbine.

[0002] Especially for steam turbines with frequent (daily) startup and shutdown cycles it is important, above all from a commercial perspective, to keep the startup times as short as possible. This applies especially to steam turbines which operate in the field of power generation by using concentrated solar radiation (solar-thermal technology). Since the period of solar radiation is limited however, optimum use must be made thereof. The long startup times previously needed are a result of the necessity for the rotor and housing, including internal components, to be heated as evenly as possible in order to avoid rubbing damage caused by the rotor and/or housing distortions. A similar situation obtains when the tur— bine is shut down. Here, long after the disconnection from the electrical power network the turbine must continue to be heated by inflowing steam in order to avoid rubbing damage due to the distortion of the rotor and/or housing as a result of uneven cooling.

[0003] Suitable measurement and calculation methods as well as a material mass to be heated that is as small as possible are the basis of current attempts to keep the startup times as short as possible. In addition voluminous housing parts are heated up from the outside in the critical operating phases (startup/shutdown cycles) by heating mats. The heating mats are however not capable of adequately heating the internal components and especially the rotor, so that an additional inflow of steam for heating up these components is needed which heats up the components by means of convective heat transfer. The applicant's as yet unpublished German patent application 10 2011 00 5122 proposes heating the components of the steam turbine by means of inductive heating. Inductive heating allows rapid and even heating of all components of the steam turbine. The disadvantages of inductive heating however are the high level of technical complexity and the associated high costs.

[0004] Based on the prior art, the object of the present invention is thus to provide a steam turbine rotor which can be heated up easily and quickly. A further object of the present invention is to provide a steam turbine having such a rotor. Finally the object of the present invention is to provide a method for operating such a steam turbine.

[0005] The object is achieved in respect of the rotor by the features of independent claim 1. In respect of the steam turbine the object is achieved by the features of claim 9 and in respect of the method the object is achieved by the features of independent claim 10.

[0006] Embodiments of the invention able to be used individually or in combination are the subject matter of the subclaims.

[0007] The inventive rotor for a steam turbine, especially for solar-thermal power plants, is characterized in that the rotor is embodied such that steam is able to flow through it at least in some areas. Having steam not only flowing around the outside of the rotor but also flowing through it at least in some areas results in greatly improved heat transfer from the steam to the rotor, enabling the latter to heat up much more quickly. The markedly quicker and more effective heating-up as a result of steam flowing through the rotor makes it possible to start up the steam turbine significantly more quickly. This allows the steam turbine to be coupled to the electrical network more quickly, whereby a greater efficiency and thus a more cost-effective operation of the steam turbine can be achieved.

When the steam turbine is shut down the throughflow of steam through the rotor enables a more even cooling of the rotor to be achieved, as a result of which rubbing damage and/or housing or rotor distortions can be largely excluded. The operational reliability of the rotor and of the entire steam tur— bine is greatly increased by this.

[0008] One embodiment of the invention makes provision for the rotor to have an axial hole through which steam is able to flow. The axial hole is able to be made in the rotor using simple means. In particular the axial hole can be produced in a simple manner during manufacturing of the rotor by drilling or turning. Only a few production steps are necessary for this. The costs of incorporating the axial hole are thus low.

[0009] A further embodiment of the invention makes provision for at least one radial hole to open out into the axial hole. The radial hole enables the steam to flow from outside into the axial hole in a simple manner. The inflow in this case can be via a single radial hole or radial holes can be made spaced evenly around the circumference of the rotor, which makes a more uniform inflow of steam possible during the rotation of the rotor. The axial holes in their turn are able to be made easily, by drilling into the rotor for example.

[0010] A further embodiment of the invention makes provision for regulation of the steam volume flow able to be fed to the rotor and/or removed from the rotor. The control of the inflow or outflow of the steam volume flow enables the heating of the rotor to be regulated. In this case the control should be undertaken in such a manner that the heat flow is sufficient to adequately heat the rotor, so that rotor distortion and thus rubbing damage during the operation of the steam turbine will be effectively prevented.

[0011] An embodiment of the invention makes provision for the steam volume flow to be able to be regulated by means of a valve or a closure element. The valve can be arranged in front of or behind the inflow to the rotor. Preferably the valve is controlled by means of an open-loop or closed-loop control unit. The closure element can for example be arranged movably within the rotor in the axial hole. The closure element can in this case be moved within the axial hole so that it can close off an inflow opening completely or partly and regulates the steam volume flow in this way. Preferably the closure element is controlled by means of an open-loop or closed-loop control unit.

[0012] A further embodiment of the invention makes provision for the steam which flows through the rotor at least in some areas to be sealing steam. The use of sealing steam offers the advantage that no additional steam is necessary to heat the rotor. The sealing steam is necessary for sealing the steam turbine from the environment and thus is already provided as a design element. By using the sealing steam additionally to heat up the rotor an especially more simple design of the rotor and thus of the overall steam turbine is thus ensured. An additional steam source is not necessary.

[0013] The inventive steam turbine comprising a rotor as claimed in one of the above-cited claims is characterized in that the rotor is embodied such that steam is able to flow through it at least in some areas of it. The flow of steam through the rotor results in a significantly shorter heatup time than if steam were merely to flow around the outside of the rotor. This enables the steam turbine to connect to the electrical network more quickly and thus work more effectively. Since the rotor is embodied in a simple manner the steam turbine is low-cost and fault-tolerant.

[0014] The inventive method for operating a steam turbine is characterized in that at least in defined operating states the rotor has steam flowing through it at least in some areas. The defined operating states can be the starting-up of the steam turbine for example. Because steam flows through the rotor during these operating states, i.e. during the startup of the steam turbine, rubbing damage due to rotor and/or housing distortions is effectively avoided. Further operating states can be the idle state and/or the shutdown of the steam tur— bine. Here too an even temperature distribution within the rotor is achieved and thereby rubbing damage and rotor and housing distortions effectively prevented.

[0015] The inventive rotor, the inventive steam turbine and the inventive method for operating a steam turbine are especially suitable for use in solar-thermal power plants in which the steam turbine is started up and shut down each day.

[0016] Exemplary embodiments and further advantages of the invention are explained below with reference to the drawings, in which:

Figure 1 shows a radial section through a first exemplary embodiment of an inventive steam turbine;

Figure 2 shows a radial section through a second exemplary embodiment of an inventive steam turbine.

[0017] The figures each show greatly simplified schematic diagrams, with only the components essential to the invention being shown in each case. The steam turbine is shown only in a rudimentary form in this case. Components that are the same or have the same function are provided with the same reference characters in all the figures.

[0018] Figure 1 shows a radial section through an inventive steam turbine. The steam turbine comprises a turbine housing 8 shown only in a rudimentary fashion and a rotor 1 rotatably mounted in the turbine housing 8. The rotor 1 comprises a number of rotor stages 9 which are likewise represented only schematically. In order to prevent ambient air being able to get into the turbine housing 8 between the turbine housing 8 and the rotor 1, sealing air is used which prevents ambient air from penetrating into the turbine housing 8.

[0019] In order to achieve a maximally rapid heating-up of the rotor 1, especially when the steam turbine is starting up, the rotor 1 is embodied so that steam can flow through it. For this purpose the rotor 1 has a number of radial holes 3 which are evenly distributed around the circumference of the rotor and open out into an axial hole 2. Steam, especially sealing steam, can flow through the radial holes 3 into the axial hole 2 and thus flow through the inside of the rotor. When steam flows through the rotor 1 the latter is heated up sig— nificantly more quickly than would be possible if steam were only to flow around the rotor 1. This means that the rotor 1 is at its operating temperature more quickly, which enables the steam turbine to be started up more quickly and thus able to join the electrical network more quickly. Rubbing damage caused by rotor distortion as a result of uneven heating of the rotor 1 is avoided. In exemplary embodiment 1 the steam flows through the rotor 1 largely completely. The steam vol— ume flow which flows through the rotor 1 can be controlled by way of a control valve 4. In the exemplary embodiment the control valve 4 is arranged at the rear end of the rotor. Arranging the valve in the supply line to the rotor 1 is also conceivable. So that the control valve 4 does not have to constantly rotate along with the rotor, a clutch 6 is provided which decouples the control valve 4 from the rotor 1. The control valve 4 is preferably connected to a regulating device which controls the control valve such that optimum heating of rotor 1 is guaranteed in each case.

[0020] As well as the rapid heating of the rotor during the startup of the steam turbine the rotor 1 also improves the behavior of the steam turbine when it is being shut down and during steam turbine downtimes, since no rotor distortion occurs as a result of uneven cooling-down of the rotor 1. This is because during shutdown of the turbine or when it is at a standstill an uneven cooling-off of the rotor underside and upper side normally occurs, which can result in rotor distortions.

[0021] Figure 2 shows a second exemplary embodiment of a steam tur— bine. The steam turbine in this case is embodied largely identically to the first exemplary embodiment, so that the reader is referred here to the description for exemplary embodiment 1. By contrast with the first exemplary embodiment, the axial hole 2 is em-

bodied not as a through-hole but as a blind hole. At the end of the blind hole further radial holes 3 are provided through which the steam can escape to the outside again after flowing through the rotor 1. Preferably in this case a number of radial holes 3 are provided which are distributed evenly over the circumference so that an even outflow of steam is ensured. The blind hole in this case is only made far enough into the rotor 1 as is necessary to achieve even heating-up and even cooling-down of the rotor. It is normally not necessary to drill a hole right through the rotor 1 in the axial direction since the temperature decreases with each rotor stage group and thus at the end on the turbine output side only a low rotor temperature is present and thus a small risk of rotor distortions no longer exists.
In exemplary embodiment 2 the steam volume flow is regulated by means of a closure element 5 which is arranged movably in the axial hole 2. Depending on the position of the closure element 5 a more or less large opening cross-section for the radial hole 3 is opened up or closed off for the flow, thereby enabling the steam volume flow to be regulated. The closure element 5 is preferably connected in its turn to a control device.

[0022] The rotor 1 preferably again has sealing steam flowing through it so that no additional steam supply is necessary.

[0023] The inventive method for operating a steam turbine is explained briefly below. The method is designed so that, upon defined operating states being reached, steam, preferably sealing steam, flows through at least areas of the rotor 1. The defined operating states in this case are at least the shutdown and/or the idle state and/or the starting-up of the steam turbine. During one of these defined operating states the rotor 1 has steam flowing through at least some areas of it. By this means the rotor 1 is brought quickly up to operating temperature and heats up very evenly during this process. The even heating of the rotor 1 effectively avoids a deflection of the rotor 1 and thus rubbing damage on the tur— bine housing 8 being able to occur. The rapid heating-up of the rotor 1 means that the other internal components of the steam turbine are heated up more quickly at the same time. The faster heating-up of the rotor and additional internal components of the steam turbine makes it possible to start the steam turbine more quickly. Especially when such a steam turbine is used for solar-thermal power plants, this achieves optimum utilization of the hours of sunshine, as a result of which a more cost-effective operation of such a solar-thermal power plant can be achieved.

[0024] Basically the inventive rotor and the inventive steam turbine are suitable for all steam turbines, with particular advantages being produced for steam turbines where there is frequent starting-up and shutting-down of the steam turbine, as is typically the case in solar-thermal power plants.

Claims

1. A rotor (1) for a steam turbine, especially for solar-thermal power plants,
characterized in that
the rotor (1) is embodied so that steam is able to flow through it at least in some areas.

2. The rotor (1) for a steam turbine as claimed in claim 1, **characterized in that**
the rotor (1) has an axial hole (2) through which steam can flow.

3. The rotor (1) for a steam turbine as claimed in claim 2, **characterized in that**
the axial hole (2) is embodied as a through-hole or as a blind hole.

4. The rotor (1) for a steam turbine as claimed in claim 2 or 3,
characterized in that
at least one radial hole (3) opens out into the axial hole (2) .

5. The rotor (1) for a steam turbine as claimed in claim 4, **characterized in that**
the axial hole (2) is able to have steam supplied to it and/or removed from it through the at least one radial hole (3).

6. The rotor (1) for a steam turbine as claimed in one of the preceding claims,
characterized in that
the steam volume inflow and/or outflow is able to be regulated.

7. The rotor (1) for a steam turbine as claimed in claim 6, **characterized in that**
the steam volume flow is able to be regulated by means of a valve (4) or a closure element (5).

8. The rotor (1) for a steam turbine as claimed in one of the preceding claims,
characterized in that
the steam which flows through at least some areas of the rotor (1) is sealing steam.

9. A steam turbine comprising a rotor (1),
characterized in that
the rotor (1) is a rotor (1) as claimed in one of claims 1 to 9.

10. A method for operating a steam turbine,
characterized in that
at least in defined operating states steam flows through at least some areas of the rotor (1).

11. The method for operating a steam turbine as claimed

in claim 10,
characterized in that
at least during the shutdown and/or the downtime and/or the startup of the steam turbine steam flows through at least some areas of the rotor (1),

FIG 1

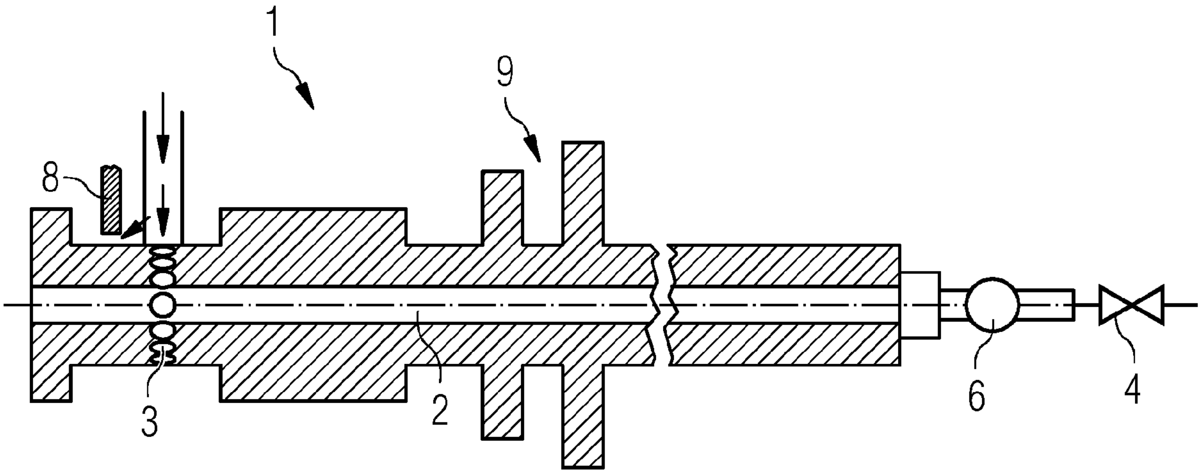
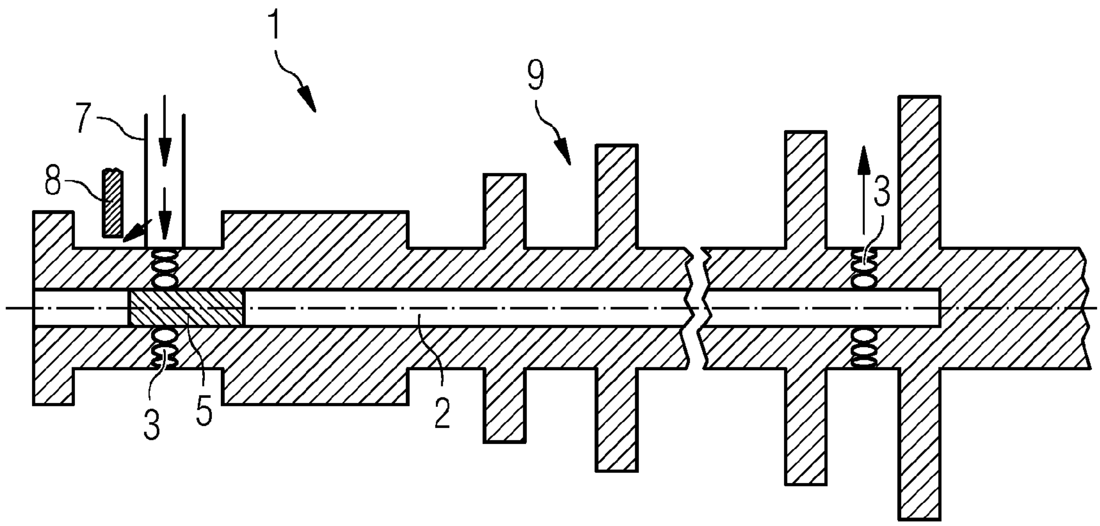


FIG 2



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EUROPEAN SEARCH REPORT

Application Number
EP 11 18 2186

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 6 162 018 A (BEECK ALEXANDER [DE] ET AL) 19 December 2000 (2000-12-19) * column 1, lines 4-5 * * column 3, lines 21-55 * * column 4, line 39 - column 5, line 23 * * column 6, lines 11-13; figures 1,3-6 * -----	1-11	INV. F01D5/08 F01D25/10
X	JP 9 177755 A (TOSHIBA CORP) 11 July 1997 (1997-07-11) * abstract * * paragraphs [0001] - [0003], [0022], [0033]; figure 8 * -----	1-11	
X	US 2005/118025 A1 (HIEGEMANN MICHAEL [CH] ET AL) 2 June 2005 (2005-06-02) * column 1, lines 6-9 * * column 2, lines 37-42 * * column 4, line 27 - column 5, line 36; figures 1,7 * -----	1-11	
X	EP 1 892 376 A1 (SIEMENS AG [DE]) 27 February 2008 (2008-02-27) * abstract * * paragraphs [0031] - [0033], [0043]; figure 1 * -----	1-11	TECHNICAL FIELDS SEARCHED (IPC) F01D
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	6 March 2012	Souris, Christophe

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EUROPEAN SEARCH REPORT

Application Number
EP 11 18 2186

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2010/149614 A2 (SIEMENS AG [DE]; BIRNBAUM JUERGEN [DE]; FICHTNER MARKUS [DE]; REISSIG) 29 December 2010 (2010-12-29) * abstract * * page 1, lines 5-8 * -----	1-11	

TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	6 March 2012	Souris, Christophe

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

REFERENCES CITED IN THE DESCRIPTION

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