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(54) Method of coupling two rotor sections and turbine rotor

(57) A method of coupling at least two sections of a rotor designed to carry the rotating parts of a turbine for the generation of electrical power for a public grid and a modified rotor is described with a coupling of increased diameter exceeding the nominal diameter of the rotor, with the step of removing mass from an volume lying exclusively within the interior of the sections when coupled such that the lateral critical speed of the coupling is moved away from the normal operating speed of the rotor

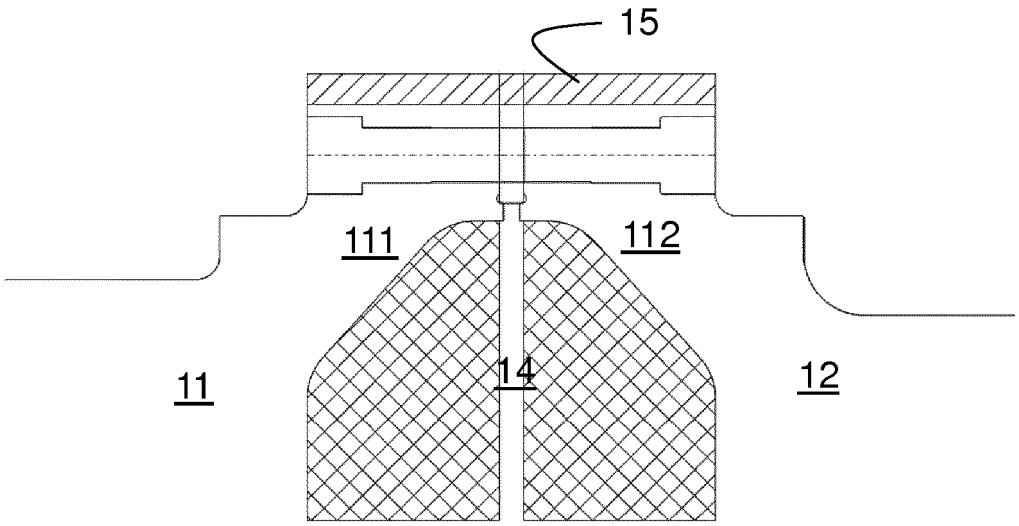

FIG. 3

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Description

[0001] This invention relates generally to a rotor assembly and method of refitting a large rotor, particularly for turbines such as low pressure steam turbines.

Background

[0002] As described for example in the United States patent no. 6,837,685, at least some known turbine rotor assemblies include a rotor wheel to which a plurality of blades are coupled. The rotor is typically assembled from several large cylindrical forgings or machined sections. The sections are either welded, bolted or connected through a heat shrinking process.

[0003] The rotor is supported at the ends or intermediate positions along its length by bearings. In the case of a large multi-stage steam turbine that includes high-pressure turbine, intermediate pressure turbines and low pressure turbines there are typically bearings to support the rotor at the end and between the stages.

[0004] It should be noted that rotors for large turbines weigh may weigh 155 tons or more and in spite of this considerable weight have to rotate at typically full or half-frequency of the power grid frequency, i.e. at 50 Hz or 60 Hz. In view of the high rotational speed, an unbalanced mass of the rotor causes the rotor to bend or buckle. As the speed of rotation increases the amplitude of such vibrations often passes through a maximum that is called a critical speed. Given the high tolerances to which modern turbines are manufactured, such out-of-position movement can cause damage and malfunction of the turbine.

[0005] It is therefore an object of the present invention to provide a rotor coupling and methods to couple rotor sections, for example as part of a repair or retrofit of the rotor. It is a particular object of the present invention to provide such rotor couplings and methods which are capable of reducing the risk of failure due to critical speeds.

Summary

[0006] According to an aspect of the present invention, there is provided a rotor to carry the rotating parts of a turbine for the generation of electrical power for a public grid with the rotor including at least two sections coupled with a coupling of increased diameter exceeding the nominal diameter of the rotor, wherein at least one of the rotor sections includes one or more cavities at the end of at least one rotor section and in the vicinity of the coupling such that the boundaries of the one or more cavities are all interior surfaces when the rotor sections are coupled.

[0007] In a preferred variant the one or more cavities at the end of the at least one rotor section and in the vicinity of the coupling extend from the wall of the rotor into a part of the coupling exceeding the nominal diameter of the rotor or are placed in a volume extending from the wall of the rotor into a part of the coupling exceeding the nominal diameter of the rotor.

[0008] In a preferred variant the at least one of the rotor sections carries the rotating parts of a low pressure steam turbine, such as the rotating blades or airfoils and their respective platforms.

[0009] According to another aspect of the present invention, there is provided a method of coupling at two sections of rotor to carry the rotating parts of a turbine for the generation of electrical power for a public grid with a coupling of increased diameter exceeding the nominal diameter of the rotor, the method including the step of removing mass from a volume lying exclusively within the interior of the sections when coupled.

[0010] In a preferred variant of the method, mass is removed to increase the critical lateral speed of the coupled rotor sections such that the difference between operational speed and the critical lateral speed is enlarged compared to coupled rotor sections with flat ends.

[0011] The above and further aspects of the invention will be apparent from the following detailed description and drawings as listed below.

Brief Description of the Drawings

[0012] Exemplary embodiments of the invention will now be described, with reference to the accompanying drawings, in which:

- FIG. 1 shows a coupling between two rotor sections after a modification according to known methods;
- FIG. 2 shows couplings between two rotor sections illustrating an example of the invention;
- FIG. 3 shows a couplings between two rotor sections illustrating examples of the invention; and
- FIG. 4 shows two plots of an excitation spectrum of rotor vibrations illustrating the effect of a modification in accordance with an example of the present invention.

Detailed Description

[0013] Aspects and details of examples of the present invention are described in further details in the following description. Exemplary embodiments of the present invention are described with references to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth to provide a thorough understanding of the invention. However, the present invention may be practiced without these specific details, and is not limited to the exemplary embodiments disclosed herein.

[0014] Fig. 1 shows a schematic diagram of two rotor sections **11, 12** linked by coupling **111, 112.** The rotor section can be, for example, two sections of a rotor for low pressure steam turbines. Such rotor sections are typ-

ically either solid or else have cylindrical shape with thick walls. At the coupling area **111, 112** the thickness of the wall and hence the outer radius of the rotor exceed the nominal outer radius of the rotor to provide openings for bolts or screws. The nominal radius can be regarded as the radius of the rotor in the coupling area derived by linearly extrapolating the radius of the rotor before the coupling section up to the end of the rotor section.

[0015] The rotor when provided may be optimized to provide, integrity at the lowest possible weight, lowest use of material, or else to ensure the interchangeability of components in order to minimize the number of spares. In a retrofit, however, the original rotor can be replaced by an improved rotor leaving some limited degrees of freedom to change the overall dimensions of the rotor.

[0016] In Fig. 1 it is assumed that coupling material **15** from the original coupling **111, 112** as outlined by the dashed lines can be removed to result in a smaller coupling **111a, 112a** outlined by solid lines. Normally such a reduction in mass is sufficient to move the lateral critical speed of the coupling or overhang modes far enough away from the normal operating speed.

[0017] In principle it is also possible to increase mass, to move the lateral critical speed of the overhang mode sufficiently below normal operating speed. However, this variant would be more expensive and might require costly and time-consuming modifications to coupling guards and/or the turbine casings. It can also be expected to have a greater sensitivity to unbalance; and might move the torsional natural frequencies of coupling modes, close to grid or twice grid frequency.

[0018] However the reduction of the coupling dimension may lead to an unacceptable loss of mechanical strength of the coupling. In such a case, or other cases where for example the outer rotor dimensions are fixed, removal of coupling material 15 from the couples is not possible.

[0019] Considering these problems, Fig. 2 shows an alternative way of shifting the lateral critical speed of the coupling or overhang modes far enough away from the normal operating speed.

[0020] In Fig. 2 there is shown a coupling with an original rotor section on the left side and an altered section on the right side thus illustrating the alterations as per an example of the invention. The coupling **111,112** of this example is shrunk onto the actual rotor. The original rotor section **12** has an essentially plane surface **13** facing the other section. The surface may have a very shallow indention (not shown) machined into it to restrict the contact areas with the other section. When modified in accordance with an example of the invention a cavity **14** is machined into the previously flat surface **13** by removing part of the wall of the rotor section **12.** In the example shown it extends further radially into the coupling area or volume outside the nominal radius of the rotor. The nominal radius is again defined as the radius of the rotor in the coupling area derived by linearly extrapolating the radius of the rotor before the coupling section up to the end of the rotor section.

[0021] It should be noted that when the sections are coupled, the cavity **14** is fully enclosed within the interior of the rotor. The walls of the cavity are thus not exposed to the air flow along the outside of the rotor. The cavity is rotationally symmetric to facilitate the balancing of the rotor.

[0022] Another example is shown in Fig. 3. The rotor has a forged solid coupling **111,112** on both ends of the rotor sections **11, 12.** A cavity **14** is machined into the walls of the rotor and part of the coupling. In addition, a ring of coupling material **15** is removed from the outside of the coupling.

[0023] The exact dimensions of the cavities shown are calculated using FE analysis to ensure that the mechanical integrity of the assembled rotor is not critically weakened. With the parameter in mind, it be regarded as beneficial to remove as much material as possible, thereby achieving a greater difference between the lateral critical speed of the coupling or overhang modes and the normal operating speed.

[0024] The plots of FIG. 4 show the shift of the vibrational spectrum of a rotor before (top plot) and after (bottom plot) creating a cavity at the coupling. The spectrum between the top and bottom plot is essentially identical but slightly shifted to the right. The cavity causes critical lateral speed to move away from the operational speed of the rotor. More precise measurements show a shift of the critical lateral speed from 1840 rpm to 1870 rpm, with a corresponding reduction in vibration amplitude at 1800 rpm (normal operating speed) of 20 μm peak to peak (from 45 μm to 35 μm zero-to-peak).

[0025] The present invention has been described above purely by way of example, and modifications can be made within the scope of the invention, particularly as relating to the desired geometry of the cavity **14** or the arrangement of cavities **14.** The invention may also comprise any individual features described or implicit herein or shown or implicit in the drawings or any combination of any such features or any generalization of any such features or combination, which extends to equivalents thereof. The breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments.

[0026] Each feature disclosed in the specification, including the drawings, may be replaced by alternative features serving the same, equivalent or similar purposes, unless expressly stated otherwise.

[0027] Unless explicitly stated herein, any discussion of the prior art throughout the specification is not an admission that such prior art is widely known or forms part of the common general knowledge in the field.

REFERENCE NUMBERS

[0028]

11,12	Rotor section

111,112	coupling
13	surface
14	cavity
15	coupling material

Claims

1. A method of coupling at least two rotor sections (11, 12) of a rotor designed to carry the rotating parts of a turbine for the generation of electrical power for a public grid with a coupling (111,112) of diameter exceeding the nominal diameter of the rotor sections (11, 12), the method including the step of removing mass from an volume lying exclusively within the interior of the rotor sections (11, 12) when coupled.

2. The method of claim 1 wherein the step of removing mass is designed to shift critical vibrational modes of the rotor further away from the normal operating speed of the rotor.

3. The method of claim 2 wherein the step of removing mass is designed to shift the lateral critical speed of the coupling further away from the normal operating speed of the rotor.

4. A rotor for carrying the rotating parts of a turbine for the generation of electrical power for a public grid with the rotor comprising at least two rotor sections (11,12) coupled with a coupling (111,112) of diameter exceeding the nominal diameter of the rotor sections (11,12), wherein at least one of the rotor sections includes one or more cavities at the end of the at least one rotor section (11,12) and in the vicinity of the coupling (111,112) such that the boundaries of the one or more cavities (14) are all interior surfaces when the rotor sections (111,112) are coupled.

5. The rotor of claim 4 wherein the one or more cavities (14) at the end of at least one rotor sections (11,12) and in the vicinity of the coupling (111,112) extend from the wall of the rotor into a part of the coupling (111,112) exceeding the nominal diameter of the rotor sections (11,12) or are placed in a volume extending from the wall of the rotor sections (11,12) into a part of the coupling (111,112) exceeding the nominal diameter of the rotor sections (11,12).

6. The rotor of claim 4 wherein the at least one of the rotor sections (11,12) carries the rotating parts of a low pressure steam turbine, such as the rotating blades or airfoils and their respective platforms.

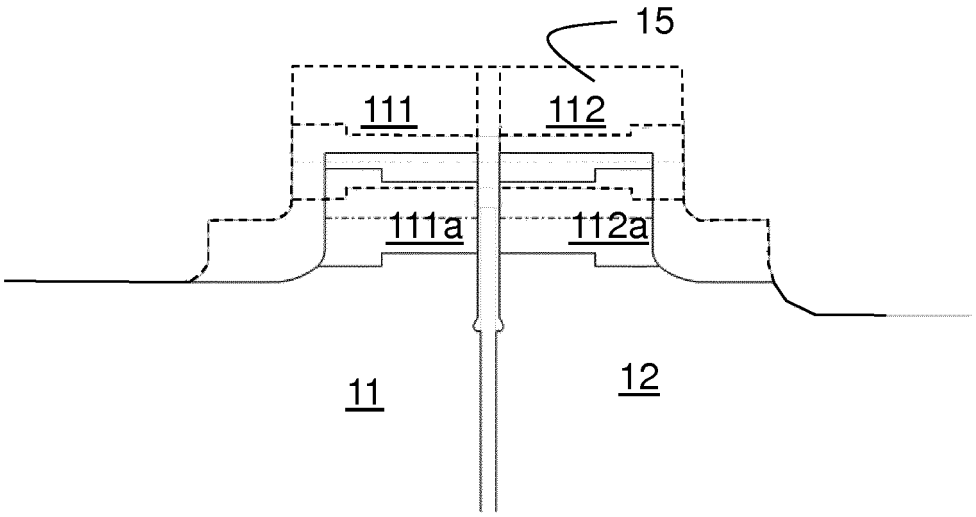


FIG. 1

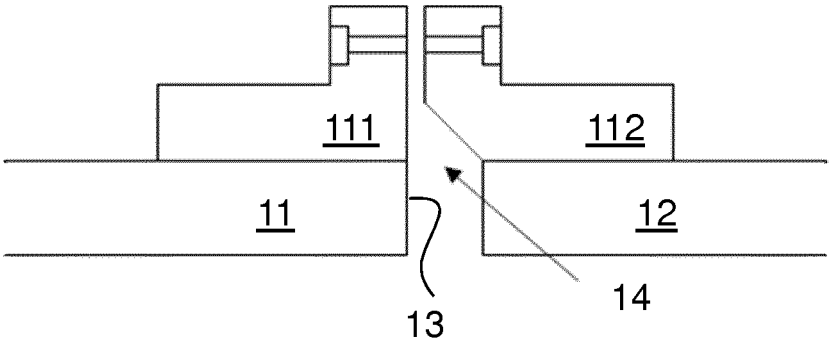


FIG. 2

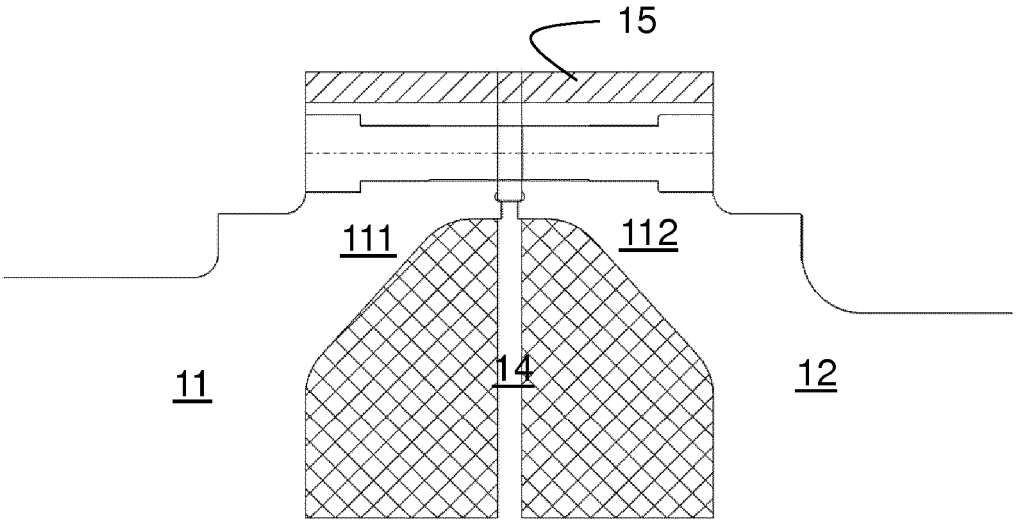
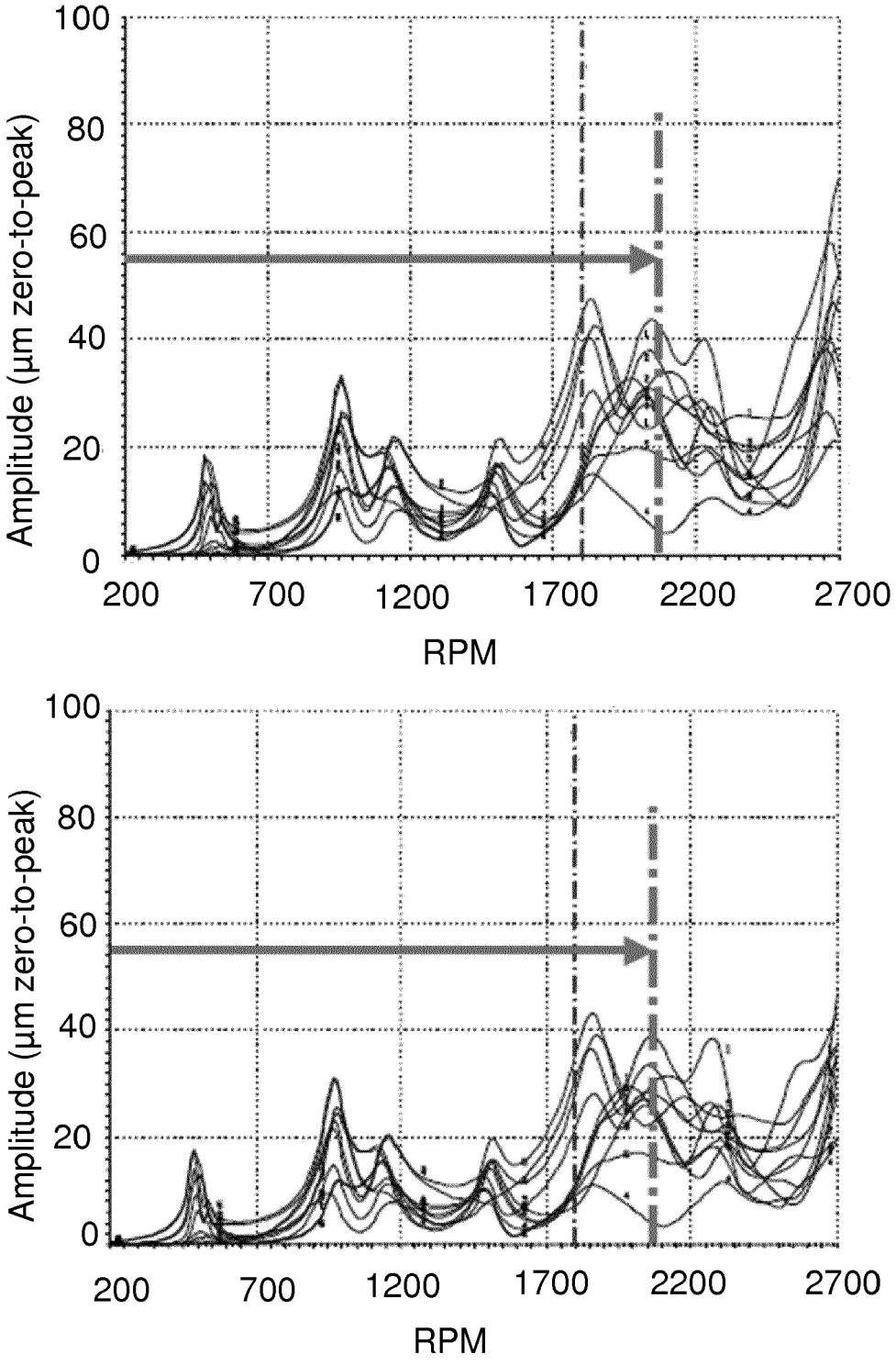


FIG. 3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80
60
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Amplitude (µm zero-to-peak)
200
700
1200
1700
2200
2700
RPM
100
80
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Amplitude (µm zero-to-peak)
200
700
1200
1700
2200
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RPM

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 12 18 4721

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Place of search	Date of completion of the search	Examiner
The Hague	19 February 2013	Steinhauser, Udo

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