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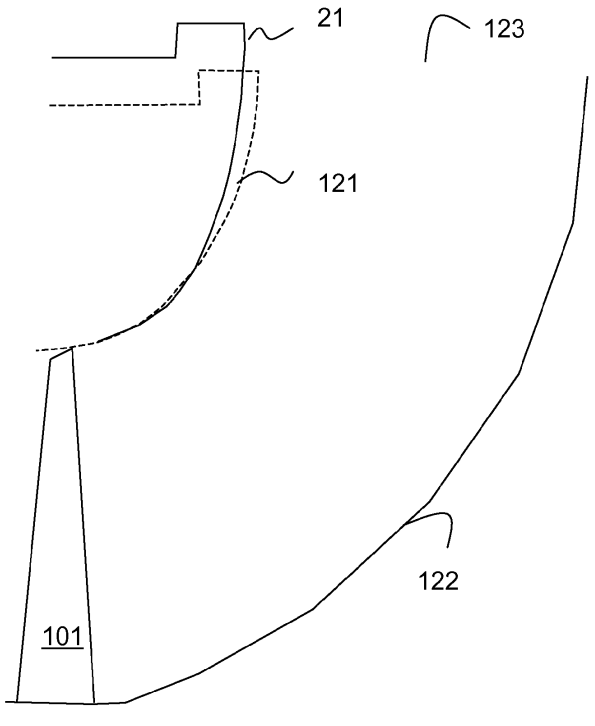
(54) Diffuser for turbomachines

(57) A diffuser is described with an entry section close to the last stage of a turbine having an outer wall including several subsequent straight wall parts at an angle to each other followed by a curved wall part with the curved wall part connecting the straight wall parts to a diffuser lip or exit and having as vertical cross-section a non-circular 2nd order curve, preferably part of an elliptic curve.

FIG. 2



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Description

Field of the Invention

[0001] The present invention relates to improvements to a diffuser for a turbomachine. It is particularly, but not exclusively, relevant to the diffuser following the last stage of a low pressure (LP) steam turbine.

Background of the Invention

[0002] Diffusers as found in large steam turbines are used for example to guide the steam from the last stage of the turbine to a condenser. Such a diffuser has two or more essentially concentric walls arranged at least initially with an axial orientation around the rotor axis of the turbine.

[0003] As described for example in the United States patent no. 6,602,046 the diffuser following the last stage has tasks of decelerating the flowing medium, increasing the usable pressure or enthalpy drop across the turbines, converting a proportion of the kinetic energy to pressure energy and reducing flow losses at the diffuser outlet toward the condenser groups. It is hence clear that the design of the diffuser contributes to the overall efficiency of a turbine machine and for that reason many efforts have been made to optimize the diffuser layout.

[0004] In a document published at the GT2011, Proceedings of ASME Turbo Expo 2011, June 6-10 2011 in Vancouver BC, Ca. by Ch. Musch, H, Stuer and G. Hermle entitled "OPTIMIZATION STRATEGY FOR A COUPLED DESIGN OF THE LAST STAGE AND THE SUCCESSIVE DIFFUSER IN A LOW PRESSURE ENVIRONMENT, the authors present a diffuser design with outer wall cross-section consisting of two straight lines at an angle followed by an arc and another straight section at an outlet in radial directions.

[0005] As described in the '046 patent, the straight lines can be formed as a sequence of kinks in the wall of the diffuser to deliberately cause flow separation from the wall. The configuration allows shock boundary layer pulsations to be suppressed. However, the measure may be associated with a considerable reduction in the diffuser efficiency.

[0006] In view of the existing prior art it can be seen as an object of the present to further optimize the existing diffuser designs and thus increase the efficiency of the turbomachines, particularly low pressure modules or turbines of a steam driven power plant.

Summary of the Invention

[0007] According to an aspect of the present invention, there is provided a diffuser having an outer wall having an entry section close to the last stage of a turbine including several subsequent straight sections at an angle to each other followed by a curved section with the curved section having as vertical cross-section a 2nd order curve, preferable a segment of an ellipse but excluding circle segments.

[0008] A 2nd order curve excluding circles can be described for example as an algebraic equation of Cartesian coordinates in the form:

$$[1] \qquad a_{11}x^2 + a_{12}xy + a_{22}y^2 + 2a_{13}x + 2a_{23}y + a_{33} = 0$$

with at least one mixed coefficient being <> 0.

[0009] It is found that using an elliptical shaped diffuser lip, a better diffuser design in terms of aerodynamics and performance is made possible. Particularly it is possible to have a higher curvature at the in-flow direction at the first part of the curved section and a reduced curvature towards the diffuser outlet. It is further possible to optimize the flare (or opening) angle of the diffuser and area ratio much closer to an ideal value than with an arc as due to the tip jet of the last stage blade, more turning of the flow in the diffuser can be done within the first angled straight sections or kinks.

[0010] These and further aspects of the invention will be apparent from the following detailed description and drawings as listed below.

Brief Description of the Drawings

[0011] Exemplary embodiments of the invention will now be described, with reference to the accompanying drawings, in which:

FIG. 1 shows a schematic vertical cross-section of a diffuser for a low pressure steam turbine stage as known with

potential optimization parameters;

FIG. 2 shows a schematic vertical cross-section of a diffuser in accordance with an example of the invention overlaid over the known diffuser of FIG. 1; and

FIG. 3 is a plot of slice diffuser recovery illustrating the potential efficiency gains of diffusers in accordance with the present invention over known diffusers.

Detailed Description of the Invention

[0012] Aspects and details of examples of the present invention are described in further details in the following description using the example of a diffuser for the a low pressure steam turbine.

[0013] In FIG. 1 there is shown a schematic vertical cross-section of a diffuser for a low pressure steam turbine stage as proposed in the GT2011 publication as referenced above. The figure shows a cross-section of the upper half of an essentially rotationally symmetrical diffuser. It also shows a part of the rotor **10** and of the inner casing **11.** Between the rotor and the casing and attached to one, respectively, are rotating blades and stator blades. The last stage of the turbine includes a circumferential arrangement of stator blades **111** attached to the casing **11** and a circumferential arrangement of rotating blades **101** attached to the rotor **10.**

[0014] Following the last stage **111,101** is the diffuser **12.** It has an outer wall **121** and an inner wall **122,** which together form an annular conduit guiding the steam to a condenser (not shown). The enlarged detail of FIG. 1 shows a part of the outer wall **121** of the diffuser and illustrates the parameters which can be used to optimize the diffuser for a given turbine and steam flow. Following the direction of the steam flow, the wall has first straight part of length **l1** followed by a second straight part of length **l2.** The second straight part forms an angle δ**1** with respect to a horizontal line, i.e. in axial direction. The two straight parts are followed by a curved part. The curved part has an angle δ**2** with respect to a horizontal line at its entry and a radius of **R** and an angle δ**3** with respect to a horizontal line at its exit. The arc is followed by another essentially straight section with the length **l3** in direction of the exit **123.** As described in the GT2011 reference all the parameters shown can be altered in order to configure an optimized diffuser **12.**

[0015] In FIG. 2 a modified diffuser in accordance with an example of the invention is shown overlaid over the diffuser of FIG. 1 (shown as dashed lines **121**). The new diffuser has a higher number of straight parts (3 over 4) and a higher order curve **21** following the straight parts. The curve **21** is essentially an elliptical curve.

[0016] As shown in FIG. 2, the elliptical shape **21** has a higher curvature at the beginning or entry and flares out into a flatter part towards the exit **123** compared to the circular curve **121** (dashed). Other numerals in FIG. 2 are the same as in FIG. 1. when denoting identical or similar elements.

[0017] A comparison of the efficiency of the two designs of FIG. 2 is shown in FIG. 3 illustrating the slice diffuser recovery. The graph is a plot of the recovery Chi between the diffuser inlet (last stage blade exit) and the diffuser exit (2R plane)over the medium speed in axial direction $C_{z\omega}$ in m/s at the diffuser inlet. The upper line illustrates the recovery of the new diffuser. This recovery is at least 3 per cent above the line of a known diffuser as shown in FIG. 1. From this comparison it becomes clear that hybrid diffusers in accordance with the invention have the potential to improve diffuser recovery in a significant manner. The hybrid diffuser with 4 or more straight parts followed by an elliptical can be regarded as the one with a better improvement potential than the prior art diffuser of FIG. 1.

[0018] Similar improvements can be demonstrated when comparing the new diffuser with a design using multiple straight parts, e.g. seven or more, for the outer wall while omitting any curved part.

[0019] A diffuser with a higher number of straight parts and their respective lengths angles between them followed by a curve of the general shape

$$[1] \qquad a_{11}x^2 + a_{12}xy + a_{22}y^2 + 2a_{13}x + 2a_{23}y + a_{33} = 0$$

with at least one mixed coefficient not being zero has a higher potential of being further improved than the more limited designs following the prior art. Such optimisation can be made using any of the known tools such as ANSYS CFX or other methods as described in the above referenced GT2011 publication.

[0020] The present invention has been described above purely by way of example, and modifications can be made within the scope of the invention. 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. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments.

[0021] 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.

[0022] 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.

LIST OF REFERENCE SIGNS AND NUMERALS

[0023]

rotor **10**
inner casing **11**
stator blades **111**
rotating blades **101** diffuser **12**
length of straight part **l1**
length of straight part **l2**
length of straight part **l3**
angles δ**2,** δ**3**
radius of circle segment **R**
exit **123**
curve **21**

Claims

1. A diffuser close to the last stage of a turbine having an outer wall with an entry section including several subsequent straight wall parts at an angle to each other followed by a curved wall part with the curved section connecting the straight parts to a diffuser lip or exit and having as its vertical cross-section a 2nd order curve.

2. The diffuser of claim 1, wherein the 2nd order curve is not a circle segment.

3. The diffuser of claim 1, wherein the 2nd order curve is a segment of an elliptical curve.

4. The diffuser of claim 1, wherein the number of straight parts is four or more.

5. The diffuser of claim 1, wherein the 2nd order curve is replaced by a larger number of straight parts.

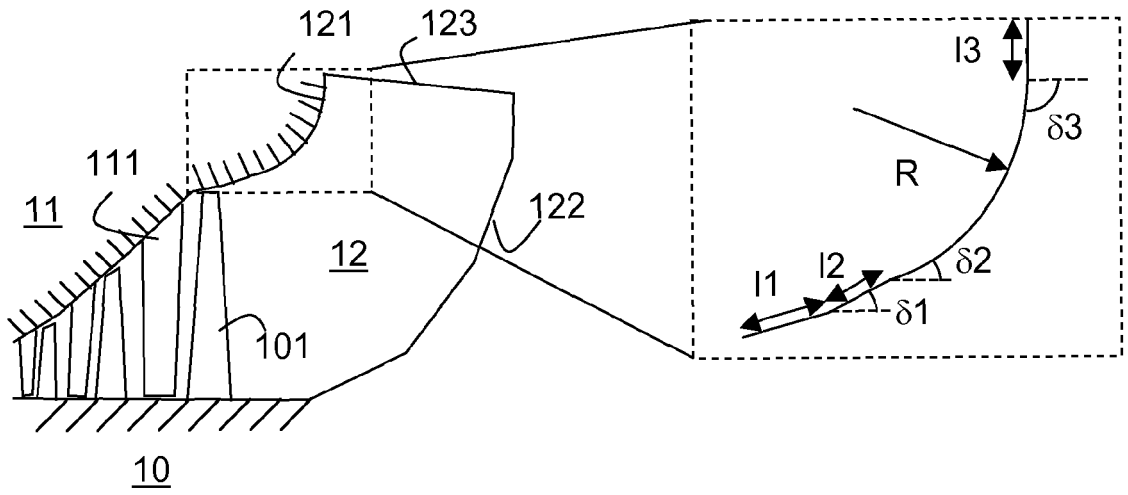


FIG. 1(Prior Art)

FIG. 2

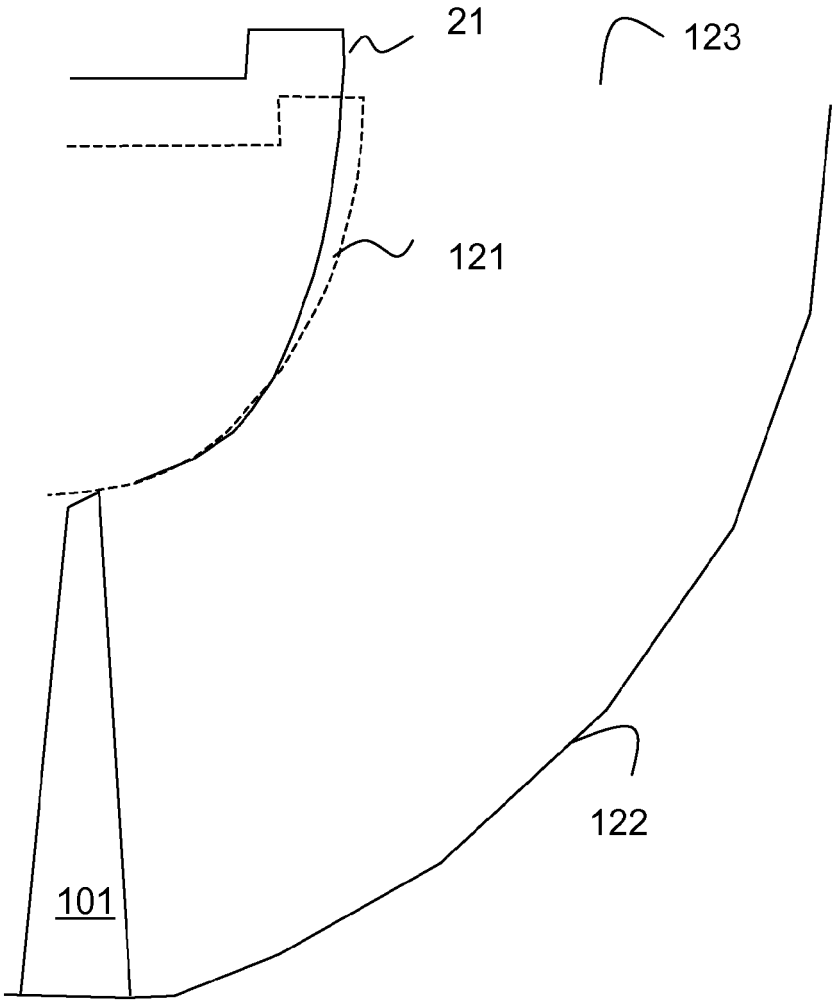
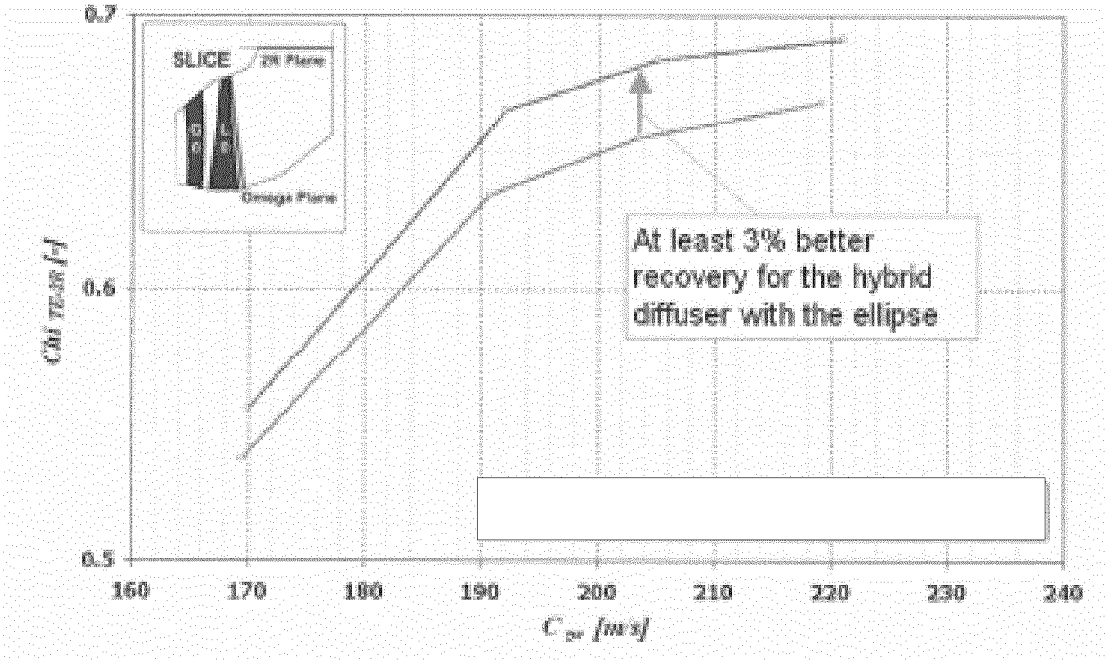


FIG. 3


0.7
0.6
0.5
160
170
180
190
200
210
220
230
240
SLICE
2N Plane
Omega Plane
At least 3% better recovery for the hybrid diffuser with the ellipse

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EUROPEAN SEARCH REPORT

Application Number
EP 12 17 2393

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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X Y	FR 2 569 766 A1 (PROIZV OB TUR [SU]) 7 March 1986 (1986-03-07) * figure 1 * -----	1,2,4 5	
Y	US 3 802 187 A (TITUS D) 9 April 1974 (1974-04-09) * figure 1 * * column 2, line 13 - line 22 * -----	5	
Y	EP 0 087 643 A1 (KRAFTWERK UNION AG [DE]) 7 September 1983 (1983-09-07) * figures 1,4 * * page 3, line 10 - line 19 * * page 4, line 15 - line 24 * -----	5	
			TECHNICAL FIELDS SEARCHED (IPC) F01D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	19 October 2012	Klados, Iason

CATEGORY OF CITED DOCUMENTS

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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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Patent documents cited in the description

- US 6602046 B **[0003]**

Non-patent literature cited in the description

- **CH. MUSCH ; H, STUER ; G. HERMLE.** OPTIMIZATION STRATEGY FOR A COUPLED DESIGN OF THE LAST STAGE AND THE SUCCESSIVE DIFFUSER IN A LOW PRESSURE ENVIRONMENT. *GT2011, Proceedings of ASME Turbo Expo,* 06 June 2011 **[0004]**