(19) Europäisches Patentamt
European Patent Office
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(11) EP 2 639 404 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
18.09.2013 Bulletin 2013/38

(21) Application number: **13158914.5**

(22) Date of filing: **13.03.2013**

(51) Int Cl.:
F01D 5/14 (2006.01) ***F01D 5/22*** (2006.01)
F01D 25/30 (2006.01) ***F01D 9/02*** (2006.01)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **14.03.2012 US 201213419860**

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(54) **Exhaust diffuser for a turbine**

(57) An exhaust diffuser (2) for a turbine includes an inlet (18) configured to receive exhaust gas from a last stage bucket (14) of the turbine and an exhaust gas guide surface (4) configured to guide the exhaust gas. A curvature of the guide surface (4) comprises a first angle (B) with respect to an axis of the turbine and a ratio of a guide surface axial length (L) to the active length (AL) of the last stage bucket (14) which is between about 0.45 to 0.70. A method of diffusing exhaust of a turbine includes energizing a boundary layer along a curved exhaust flow guide surface (4) of an exhaust diffuser (2) with over tip leakage of a last stage bucket (14) of the turbine. The curved exhaust flow guide surface (4) is at a first angle (B) with respect to an axis of the turbine and a ratio of a guide surface axial length (L) to the active length (AL) of the last stage bucket (14) which is between about 0.45 to 0.70.

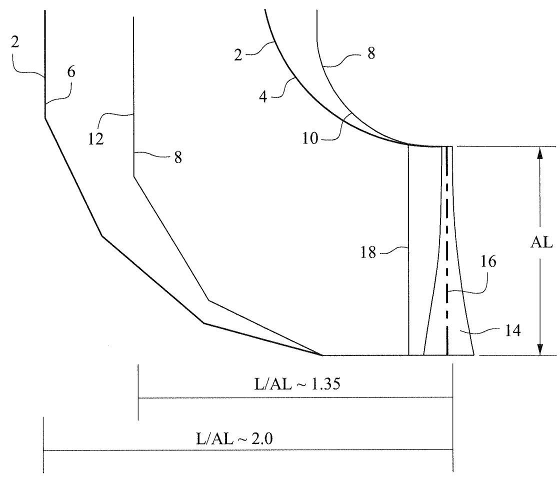

Fig. 1

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Description

[0001] The present invention relates to an exhaust diffuser for a turbine and to methods for reducing flow separation with over tip leakage flow with shrouded and unshrouded last stage buckets of the turbine.

[0002] In the discharge of exhaust steam from an axial flow turbine, for example discharge of this exhaust steam to a condenser, it is desirable to provide as smooth a flow of steam as possible and to minimize energy losses from accumulation of vortices, turbulences and non-uniformity in such flow. Usually the exhaust from the turbine is directed into an exhaust hood and from there through a discharge opening in the hood in a direction essentially normal to the axis of the turbine into a condenser. It is desirable to achieve a smooth transition from axial flow at the exhaust of the turbine to radial flow in the exhaust hood and thence a smooth flow at the discharge opening of this hood into the condenser.

[0003] In the constructing of an effective exhaust hood for use with such an axial flow turbine it is desirable to avoid acceleration losses within any guide means employed therein and to achieve a relatively uniform flow distribution at the discharge opening of the exhaust hood for the most efficient conversion of energy in the turbine and effective supplying of exhaust steam to the condenser to which it is connected.

[0004] It is also desirable to achieve optimum efficiency at the last stage buckets of the turbine prior to exhaust from the turbine by achieving a relatively uniform circumferential and radial pressure distribution in the exit plane of the last stage buckets. Usually, attempts have been made to accomplish these results while employing a hood having as short an axial length as possible, so as to limit the axial size of the turbine train.

[0005] Diffusers are commonly employed in steam turbines. Effective diffusers can improve turbine efficiency and output. Unfortunately, the complicated flow patterns existing in such turbines as well as the design problems caused by space limitations make fully effective diffusers almost impossible to design. A frequent result is flow separation that fully or partially destroys the ability of the diffuser to raise the static pressure as the steam velocity is reduced by increasing the flow area. For downward exhaust hoods used with axial steam turbines, the loss from the diffuser discharge to the exhaust hood discharge varies from top to bottom. At the top, much of the flow must be turned 180° to place it over the diffuser and inner casing, then turned downward. Pressure at the top is thus higher than at the sides, which are in turn higher than at the bottom.

[0006] According to a first aspect of the present invention, an exhaust diffuser for a turbine comprises an inlet configured to receive exhaust gas from a last stage bucket of the turbine; and an exhaust gas guide surface configured to guide the exhaust gas. A curvature of the guide surface comprises a first angle with respect to an axis of the turbine and a ratio of a guide surface axial length to the active length of the last stage bucket which is between about 0.45 to 0.70.

[0007] According to another aspect of the present invention, a method of diffusing exhaust of a turbine comprises energizing a boundary layer along a curved exhaust flow guide surface of an exhaust diffuser with over tip leakage of a last stage bucket of the turbine. The curved exhaust flow guide surface is at a first angle with respect to an axis of the turbine and a ratio of a guide surface axial length to the active length of the last stage bucket which is between about 0.45 to 0.70.

Fig. 1 schematically depicts first and second exhaust flow diffusers in relation to a last stage bucket of a turbine;

Fig. 2 schematically depicts the steam guide length of the second exhaust flow diffuser of Fig. 1 in relation to the last stage bucket;

Fig. 3 schematically depicts the angles of the steam guide surface of the second exhaust flow diffuser of Fig. 1;

Fig. 4 schematically depicts the angles of the steam guide surface in relation to an inclined shroud; and

Fig. 5 schematically depicts the last stage bucket and inclined shroud.

[0008] Referring to Fig. 1, a first exhaust flow diffuser 2 of a steam turbine low pressure section includes an inlet 18 that receives steam passing a last stage bucket 14 of the turbine. The exhaust flow diffuser 2 further includes a steam guide surface 4 that guides the steam flow passing from the last stage bucket 14, and a diffuser end wall 6. A ratio of the axial length L of the diffuser (as measured from a centerline 16 of the last stage bucket 14 to the diffuser end wall 6) to the active length AL of the last stage bucket 14 is approximately 2.0. The centerline 16 of the last stage bucket 14 is a radial line passing through the center of gravity of the bucket's root section.

[0009] Referring still to Fig. 1, a diffuser 8 of a second, different configuration from the diffuser 2 is also shown. The diffuser 8 has a ratio of axial length L (as measured from the centerline 16 to the diffuser end wall 12) to active length AL of the last stage bucket 14 of approximately 1.35. As shown in Fig. 1, the first diffuser 2 and the second diffuser 8 have the same diffuser area ratio which results in the second diffuser 8 having a sharper steam guide surface 10 curvature. Maintaining the diffuser area ratio of the second diffuser 8 the same as the first diffuser may lead to a flow separation from the steam guide surface 10 due to higher curvature.

[0010] The diffuser 8 uses over tip leakage from the last stage bucket 14 to energize a boundary layer along the steam guide surface 10 of the diffuser 8 to reduce, or prevent, separation of the steam from the steam guide surface 10. Reducing, or preventing, separation of the steam from the steam guide surface 10 improves the static pressure recovery.

[0011] The tip clearance of the last stage bucket 14 may be reduced, or minimized, to increase, or maximize, the work of the fluid (e.g., steam or hot gases) on the rotating blades of the turbine. Some amount of clearance may be provided to reduce the possibility of rub between the blades and the inner casing. The last stage bucket 14 may have a hot radial tip clearance that varies between, for example, about 125 to 200 mils and the leakage flow rate for example, about 0.5% to 2% of the annulus flow rate. It should be appreciated that the tip clearance of the last stage bucket 14 may be otherwise, for example between about 50 to 160 mils.

[0012] Referring to Fig. 2, the diffuser 8 having a L/AL ratio of approximately 1.5 has a ratio of the steam guide axial length SGL (as measured from the centerline 16 of the last stage bucket 14 to the end of the steam guide surface 10) to the active length AL of the last stage bucket 14 of approximately 0.45 to 0.70, for example approximately 0.55. Referring to Fig. 3, the last stage bucket 14 has a tip angle A of, for example, about 0° and the curvature of the steam guide surface 10 may have a first angle B that may correspond to a range of change in the angle over the previous 25% meridional length of the steam guide from the bucket tip slope, for example, 0° to 18°, for example about 2°, 11°, or 14°. The second angle C of curvature of the steam guide surface 10 at the 50% meridional distance may be, for example, a change of 14° to 32°, for example about 20°, 22°, or 28°. The third angle D of the curvature of the steam guide surface 10 at the 75% meridional distance may be, for example, a change of about 16° to 32°, for example about 24°, 26°, or 28°.

[0013] Referring to Figs. 4 and 5, the turbine may include an inclined shroud 20. The last stage bucket 14 has a tip angle A of, for example, about 25° and the curvature of the steam guide surface 10 may have a first angle B that may correspond to a range of change in the angle over the previous 25% meridional length of the steam guide from the bucket tip slope, for example, 0° to 18°, for example about 2°, 11°, or 14°. The second angle C of curvature of the steam guide surface 10 at the 50% meridional distance may be, for example, a change of 14° to 32°, for example about 20°, 22°, or 28°. The third angle D of the curvature of the steam guide surface 10 at the 75% meridional distance may be, for example, a change of about 16° to 32°, for example about 24°, 26°, or 28°.

[0014] Although the embodiments have been described with respect to a steam turbine, it should be appreciated that the diffuser may be used with gas turbines.

[0015] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

[0016] Various aspects and embodiments of the present invention are defined by the following numbered clauses:

1. A method of diffusing exhaust of a turbine, the method comprising:

   energizing a boundary layer along a curved exhaust flow guide surface of an exhaust diffuser with over tip leakage of a last stage bucket of the turbine, wherein the curved exhaust flow guide surface is at a first angle with respect to an axis of the turbine and a ratio of a guide surface axial length to the active length of the last stage bucket is between about 0.45 to 0.70.

2. A method according to clause 1, wherein a ratio of a guide surface axial length to the active length is about 0.55.

3. A method according to any preceding clause, wherein a ratio of an axial length of the exhaust diffuser to the active length is between about 1.35 and 2.0.

4. A method according to any preceding clause, wherein the curvature of the guide surface comprises a second angle and a third angle, and the first, second and third angles correspond to a range of change in the angle over the previous 25% meridional length of the steam guide at 25%, 50% and 75% meridional distances, respectively.

5. A method according to any preceding clause, wherein the first angle change is in the range of 0° to 18°, the second angle change is in the range of 14° to 32°, and the third angle change is in the range of 16° to 32°.

6. A method according to any preceding clause, wherein the second angle is larger than the first angle and the third angle is larger than the second angle.

7. A method according to any preceding clause, wherein the second angle and the third angle are approximately equal.

8. A method according to any preceding clause, wherein the first angle corresponds to a range of change in the angle at the 25% meridional distance from a shroud tip of the last stage bucket of the turbine.

9. A method according to any preceding clause, wherein a clearance between a tip of the last stage

bucket and an inner casing or shroud is between about 50 to 200 mils.

Claims

1. An exhaust diffuser (2) for a turbine, comprising:

    an inlet (18) configured to receive exhaust gas from a last stage bucket (14) of the turbine; and an exhaust gas guide surface (4) configured to guide the exhaust gas, wherein a curvature of the guide surface (4) comprises a first angle (B) with respect to an axis of the turbine and a ratio of a guide surface axial length (L) to the active length (AL) of the last stage bucket which is between about 0.45 to 0.70.

2. An exhaust diffuser according to claim 1, wherein a ratio of the guide surface axial length (L) to the active length (AL) is about 0.55.

3. An exhaust diffuser according to claim 1 or 2, wherein a ratio of an axial length (L) of the exhaust diffuser (2) to the active length (AL) is between about 1.35 and 2.0.

4. An exhaust diffuser according to any of claims 1 to 3, wherein the curvature of the guide surface (4) comprises a second angle (C) and a third angle (D), and the first, second and third angles (B,C,D) correspond to a range of change in the angle over the previous 25% meridional length of the steam guide (10) at 25%, 50% and 75% meridional distances, respectively.

5. An exhaust diffuser according to claim 4, wherein the first angle (B) change is in the range of 0° to 18°, the second angle (C) change is in the range of 14° to 32°, and the third angle (D) change is in the range of 16° to 32°.

6. An exhaust diffuser according to claim 4 or 5, wherein the second angle (C) is larger than the first angle (B) and the third angle (D) is larger than the second angle (C).

7. An exhaust diffuser according to claim 4 or 5, wherein the second angle (C) and the third angle (D) are approximately equal.

8. An exhaust diffuser according to any of claims 4 to 7, wherein the first angle (B) corresponds to a range of change in the angle at the 25% meridional distance from a shroud tip of the last stage bucket (14) of the turbine.

9. A turbine comprising a diffuser according to any preceding claim.

10. A turbine according to claim 9, wherein a clearance between a tip of the last stage bucket (14) and an inner casing or shroud is between about 50 to 200 mils.

11. A turbine according to claim 10, wherein the clearance is between about 125 to 160 mils.

12. A method of diffusing exhaust of a turbine, the method comprising:

    energizing a boundary layer along a curved exhaust flow guide surface (4) of an exhaust diffuser (2) with over tip leakage of a last stage bucket (14) of the turbine, wherein the curved exhaust flow guide surface (4) is at a first angle (B) with respect to an axis of the turbine and a ratio of a guide surface axial length (L) to the active length (AL) of the last stage bucket (14) is between about 0.45 to 0.70.

13. A method according to claim 12, wherein a ratio of a guide surface axial length (L) to the active length (AL) is about 0.55 and wherein a ratio of an axial length (L) of the exhaust diffuser to the active length (AL) is between about 1.35 and 2.0.

14. A method according to claim 12 or 13, wherein the curvature of the guide surface (4) comprises a second angle (C) and a third angle (D), and the first, second and third angles (B,C,D) correspond to a range of change in the angle over the previous 25% meridional length of the steam guide at 25%, 50% and 75% meridional distances, respectively.

15. A method according to claim 14, wherein the first angle (B) change is in the range of 0° to 18°, the second angle (C) change is in the range of 14° to 32°, and the third angle (D) change is in the range of 16° to 32°.

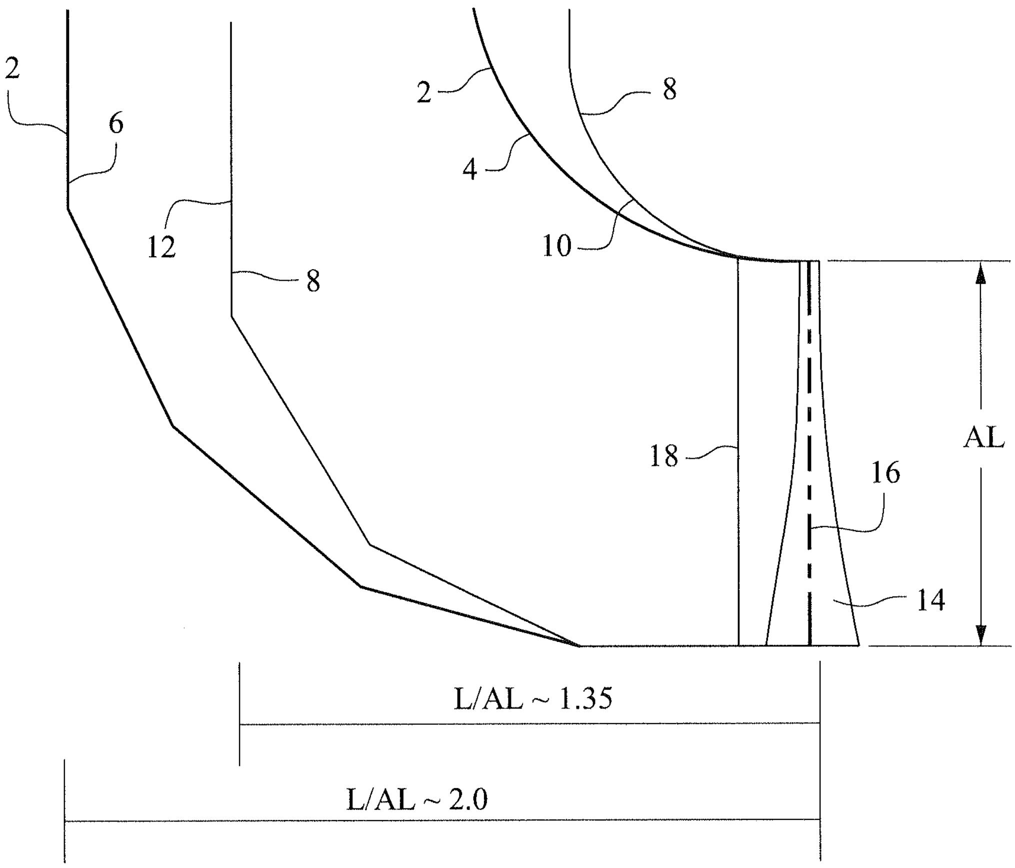

Fig. 1

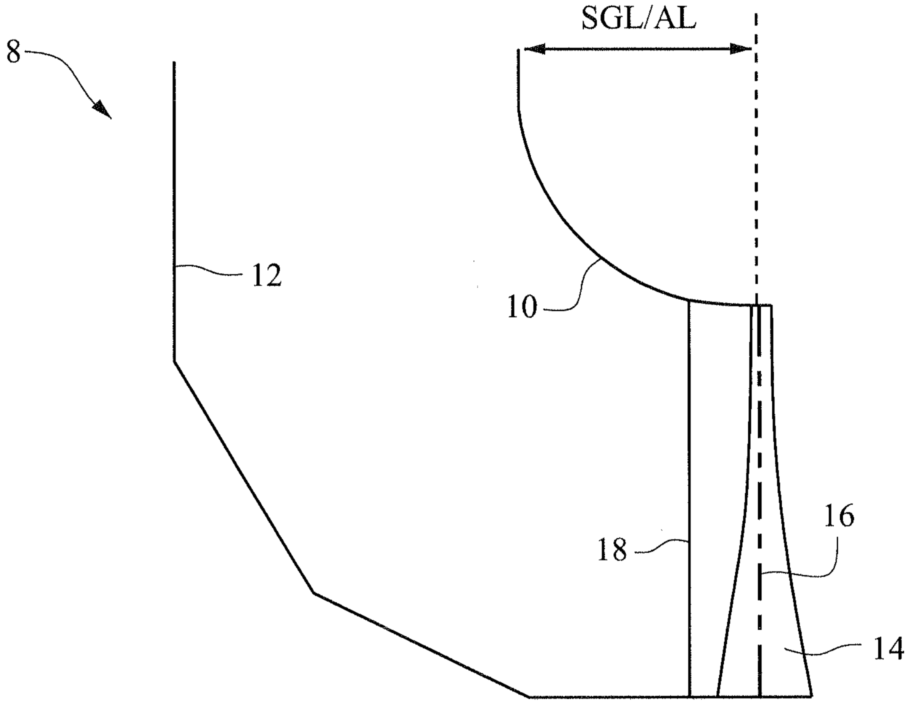

Fig. 2

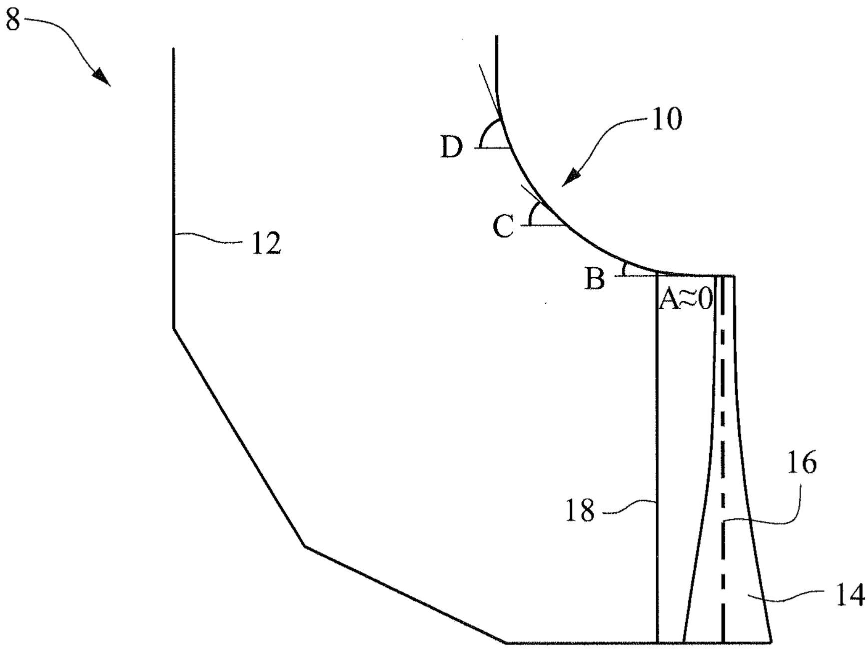

Fig. 3

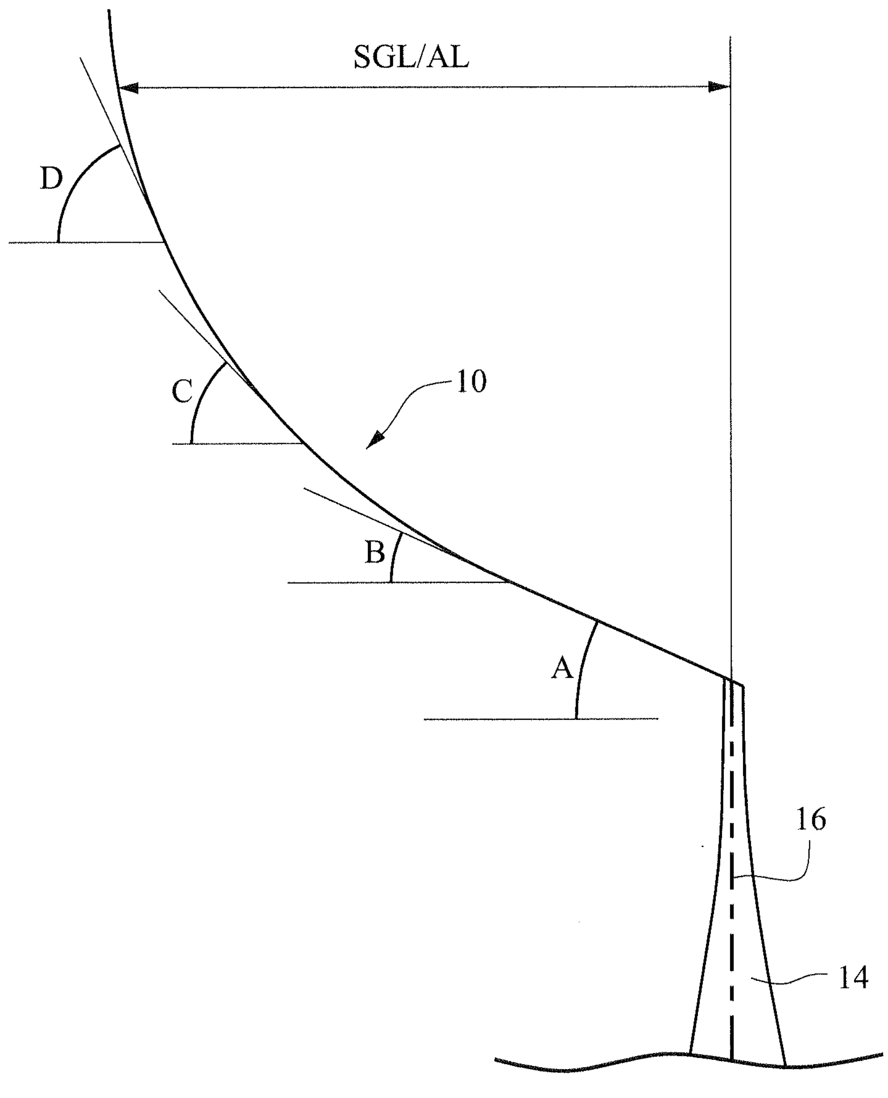

Fig. 4

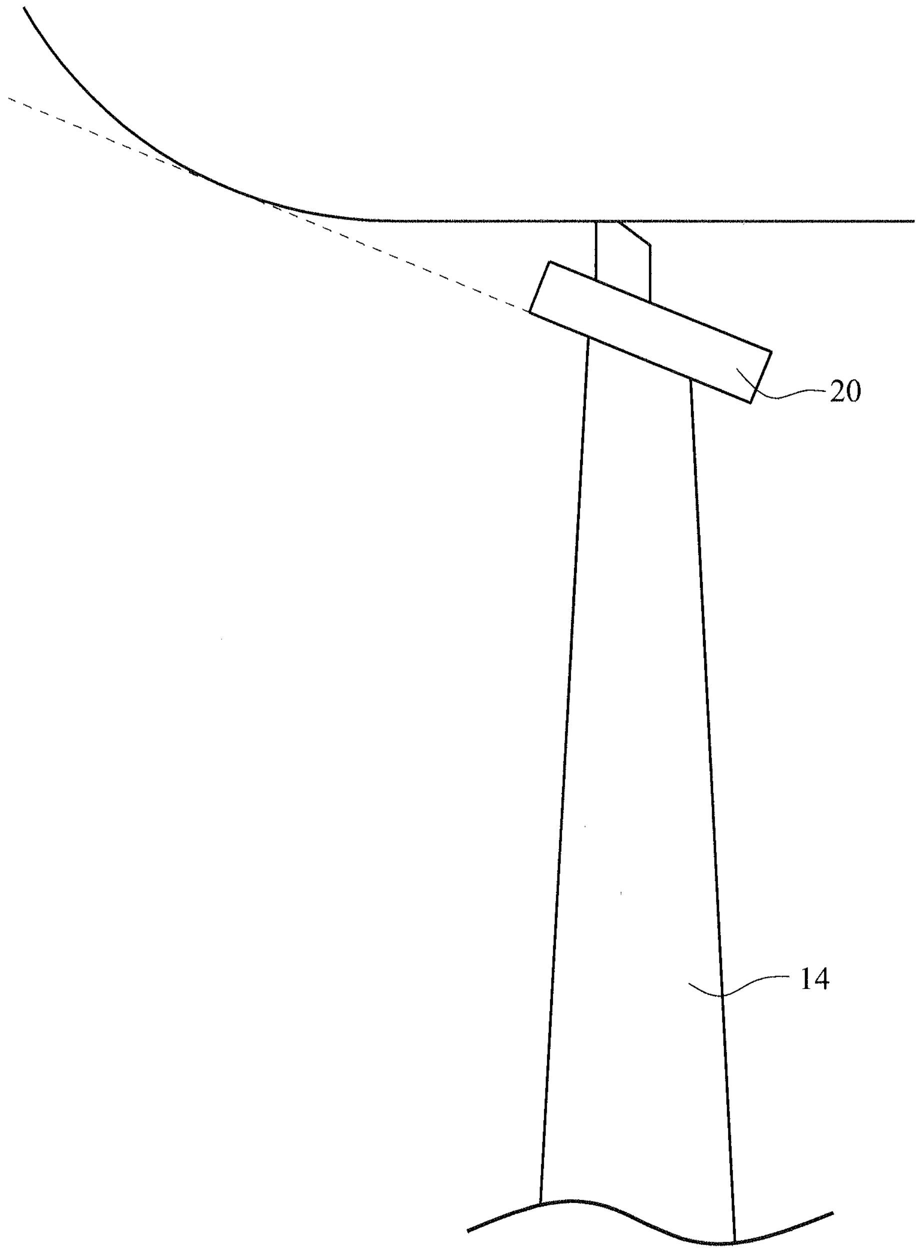

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 13 15 8914

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	EP 2 378 077 A2 (GEN ELECTRIC [US]) 19 October 2011 (2011-10-19) * paragraphs [0005], [0025], [0025]; figures 1,7 *	1-15	INV. F01D5/14 F01D5/22 F01D25/30 F01D9/02
X	US 4 214 452 A (FRANCONVILLE GERARD [FR] ET AL) 29 July 1980 (1980-07-29) * figure 1 *	1,3,9,12	
X	EP 1 178 183 A2 (ALSTOM SWITZERLAND LTD [CH] ALSTOM TECHNOLOGY LTD [CH]) 6 February 2002 (2002-02-06) * paragraphs [0040] - [0049]; figure 1 *	1-4,6,9, 12-14	

TECHNICAL FIELDS SEARCHED (IPC)
F01D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	27 May 2013	Pileri, Pierluigi

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27-05-2013

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2378077 A2	19-10-2011	EP 2378077 A2	19-10-2011
		JP 2011220336 A	04-11-2011
		RU 2011113994 A	20-10-2012
		US 2011250064 A1	13-10-2011
US 4214452 A	29-07-1980	BE 869473 A1	05-02-1979
		CH 622583 A5	15-04-1981
		DE 2836265 A1	01-03-1979
		FR 2401311 A1	23-03-1979
		GB 2003237 A	07-03-1979
		IT 1098119 B	07-09-1985
		JP S5444109 A	07-04-1979
		JP S6238523 B2	18-08-1987
		NL 7808709 A	27-02-1979
		US 4214452 A	29-07-1980
EP 1178183 A2	06-02-2002	DE 10037684 A1	14-02-2002
		EP 1178183 A2	06-02-2002
		JP 4791658 B2	12-10-2011
		JP 2002081301 A	22-03-2002
		US 2002127100 A1	12-09-2002

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