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(54) **ROTOR BLADE FOR STEAM TURBINE**

(57) This application provides controlled flow runners (130) for use with steam turbines. Example controlled flow runners may include a tip, a blade (82) adjacent to the tip, the blade having a top width, a middle width, and

a bottom width, where the middle width is less than the top width and the bottom width, and a root adjacent to the blade.

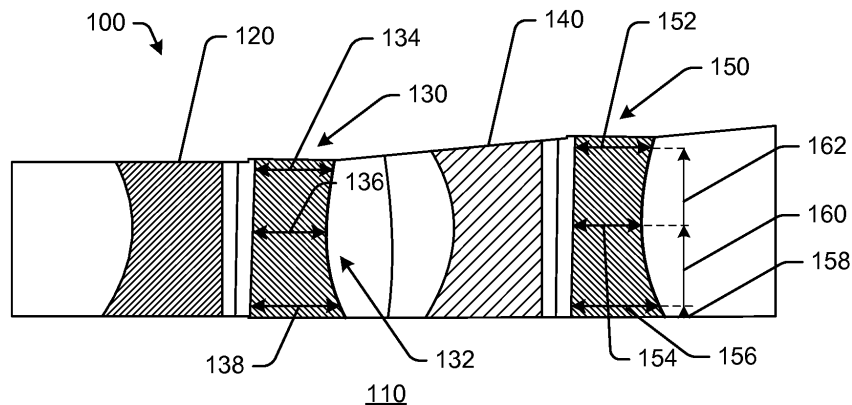


Fig. 4

Description

TECHNICAL FIELD

[0001] The present application and the resultant patent relate generally to axial flow turbines of any type and more particularly relate to controlled flow runners for steam turbines.

BACKGROUND OF THE INVENTION

[0002] Generally described, steam turbines and the like may have a defined steam path that includes a steam inlet, a turbine section, and a steam outlet. Steam leakage, either out of the steam path, or into the steam path from an area of higher pressure to an area of lower pressure, may adversely affect the operating efficiency of the steam turbine. For example, steam path leakage in the steam turbine between a rotating shaft and a circumferentially surrounding turbine casing may lower the overall efficiency of the steam turbine

[0003] Steam may generally flow through a number of turbine stages typically disposed in series through first-stage guides and blades (or nozzles and buckets) and subsequently through guides and blades of later stages of the turbine. In this manner, the guides may direct the steam toward the respective blades, causing the blades to rotate and drive a load, such as an electrical generator and the like. The steam may be contained by circumferential shrouds surrounding the blades, which also may aid in directing the steam or combustion gases along the path. In this manner, the turbine guides, blades, and shrouds may be subjected to high temperatures resulting from the steam, which may result in the formation of hot spots and high thermal stresses in these components. Because the efficiency of a steam turbine is dependent on its operating temperatures, there is an ongoing demand for components positioned along the steam or hot gas path to be capable of withstanding increasingly higher temperatures without failure or decrease in useful life.

[0004] Certain turbine blades may be formed with an airfoil geometry. The blades may be attached to tips and roots, where the roots are used to couple a blade to a disc or drum. The turbine blade geometry and dimensions may result in certain profile losses, secondary losses, leakage losses, mixing losses, etc. that may adversely affect efficiency and/or performance of a steam turbine.

SUMMARY OF THE INVENTION

[0005] This application and the resultant patent provide controlled flow runners for use with steam turbines. An example controlled flow runner may include a tip shroud, a blade adjacent to the tip shroud, the blade having a top width, a middle width, and a bottom width, where the middle width is less than the top width and the bottom width, and a root attachment below the blade.

[0006] This application and the resultant patent further

provide a method of using a controlled flow runner with a steam turbine. The method may include the steps of providing a root for a controlled flow runner, coupling a blade for a controlled flow runner to the root, where the blade may include a top width, a middle width, and a bottom width, wherein the middle width is less than the top width and the bottom width, and coupling a tip to the blade.

[0007] This application and the resultant patent further provide a steam turbine with a controlled flow runner. The steam turbine may include a disc, a first controlled flow guide mounted in the inner casing, and a first controlled flow runner coupled to the disc adjacent to the first controlled flow guide. The first controlled flow runner may include a first blade. The first blade may have a top width at a first radial distance from the disc, a middle width at a second radial distance from the disc, and a bottom width at a third radial distance from the disc. The middle width may be less than the top width and the bottom width, and the second radial distance may be greater than the first radial distance and less than the third radial distance.

[0008] These and other features and improvements of this application and the resultant patent will become apparent to one of ordinary skill in the art upon review of the following detailed description when taken in conjunction with the several drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1 is a schematic diagram of a steam turbine.

FIG. 2 is a schematic diagram of a portion of a turbine as may be used in the steam turbine of FIG. 1, showing a number of turbine stages.

FIG. 3 is a front plan view of a turbine blade as may be used in the turbine of FIG. 2.

FIG. 4 is a cross-sectional side view of a portion of a steam turbine with controlled flow runners as described herein.

FIG. 5 depicts various perspective and side views of a controlled flow runner as described herein.

FIG. 6 schematically depicts an example view of a portion of a turbine and a back surface deflection angle, according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0010] Referring now to the drawings, in which like numerals refer to like elements throughout the several views, FIG. 1 shows a schematic diagram of an example of a steam turbine 10. Generally described, the steam turbine 10 may include a high pressure section 15 and

an intermediate pressure section 20. Other pressures in other sections also may be used herein. An outer shell or casing 25 may be divided axially into an upper half section 30 and a lower half section 35. A central section 40 of the casing 25 may include a high pressure steam inlet 45 and an intermediate pressure steam inlet 50. Within the casing 25, the high pressure section 15 and the intermediate pressure section 20 may be arranged about a rotor or disc 55. The disc 55 may be supported by a number of bearings 60. A steam seal unit 65 may be located inboard of each of the bearings 60. An annular section divider 70 may extend radially inward from the central section 40 towards the disc. The divider 70 may include a number of packing casings 75. Other components and other configurations may be used.

[0011] During operation, the high pressure steam inlet 45 receives high pressure steam from a steam source. The steam may be routed through the high pressure section 15 such that work is extracted from the steam by rotation of the disc 55. The steam exits the high pressure section 15 and then may be returned to the steam source for reheating. The reheated steam then may be rerouted to the intermediate pressure section inlet 50. The steam may be returned to the intermediate pressure section 20 at a reduced pressure as compared to the steam entering the high pressure section 15 but at a temperature that is approximately equal to the temperature of the steam entering the high pressure section 15. Accordingly, an operating pressure within the high pressure section 15 may be higher than an operating pressure within the intermediate section 20 such that the steam within the high pressure section 15 tends to flow towards the intermediate section 20 through leakage paths that may develop between the high pressure 15 and the intermediate pressure section 20. One such leakage path may extend through the packing casing 75 about the disc shaft 55. Other leaks may develop across the steam seal unit 65 and elsewhere.

[0012] FIG. 2 shows a schematic diagram of a portion of the steam turbine turbine 10 including a number of stages 52 positioned in a steam or hot gas path 54 of the steam turbine 10. A first stage 56 may include a number of circumferentially-spaced first-stage guides 58 and a number of circumferentially-spaced first-stage blades 60. The first stage 56 also may include a first-stage shroud 62 extending circumferentially and surrounding the first-stage blades 60. The first-stage shroud 62 may include a number of shroud segments positioned adjacent one another in an annular arrangement. In a similar manner, a second stage 64 may include a number of second-stage guides 66, a number of second-stage blades 68, and a second-stage shroud 70 surrounding the second-stage blades 68. Any number of stages and corresponding guides and runners may be included. Other embodiments may have different configurations.

[0013] FIG. 3 depicts a turbine bucket 80 as may be used in one of the stages 52 of the turbine 10. For example, the bucket 80 may be used in the second stage

64 or a later stage of the turbine 10. Generally described, the turbine bucket 80 may include a blade 82, a dovetail or root 84, and a platform 86 disposed between the blade 82 and the root 84. As described above, a number of the blades or buckets 80 may be arranged in a circumferential array within the stage 52 of the turbine 10. In this manner, the blade 82 of each bucket 80 may extend radially with respect to a central axis of the turbine 10, while the platform 86 of each bucket 80 extends circumferentially with respect to the central axis of the turbine 10.

[0014] The blade 82 may extend radially outward from the root 84 to an optional tip shroud 88 positioned about a tip end 90 of the bucket 80. In some embodiments, the tip shroud 88 may be integrally formed with the blade 82. The root 84 may extend radially inward from the platform 86 to a root end 92 of the bucket 80, such that the platform 86 generally defines an interface between the blade 82 and the root 84. As is shown, the platform 86 may be formed so as to extend generally parallel to the central axis of the turbine 10 during operation thereof. The root 84 may be formed to define a root structure, such as a dovetail, configured to secure the bucket 80 to a turbine disc or drum of the turbine 10. During operation of the turbine 10, the flow of steam or combustion gases 35 travels along the steam or hot gas path 54 and over the platform 86, which along with an outer circumference of the turbine disc forms the radially inner boundary of the steam or hot gas path 54. Accordingly, the flow of steam or combustion gases 35 is directed against the blade 82 of the bucket 80, and thus the surfaces of the blade 82 are subjected to very high temperatures.

[0015] Referring to FIGS. 4 and 5, a steam turbine 100 with guides and runners as described herein is depicted in one embodiment. The steam turbine 100 may include a first controlled flow guide 120 for a first stage, and a first controlled flow runner 130 for the first stage. The first controlled flow runner 130 may be positioned adjacent to the first controlled flow guide 120. The first controlled flow guide 120 and the first controlled flow runner 130 may be coupled to a disc or drum 110. The guides of the steam turbine may be controlled flow guides and the runners may be controlled flow runners. The steam turbine 100 may include a second controlled flow guide 140 for a second stage, and a second controlled flow runner 150 for the second stage. The second controlled flow guide 140 may be a controlled flow guide and the second controlled flow runner 150 may be a controlled flow runner. Any number of stages and/or controlled flow guides and controlled flow runners may be included.

[0016] One or more of the controlled flow runners, specifically the first controlled flow runner 130 and the second controlled flow runner 150, may include a tip, a blade, and a root. The root may be configured to couple the runner to the disc 110. The blade may be positioned between the root and the tip. In some embodiments, a tip shroud may be coupled to the tip.

[0017] The blade of the first controlled flow runner 130 may have a bowed configuration 132. Specifically, the

blade of the first controlled flow runner 130 may have a reduced axial width about a midsection of the first controlled flow runner 130. As illustrated in FIG. 4, the blade of the first controlled flow runner 130 may include a top width 134, a middle width 136, and a bottom width 138. The widths may be axial widths. The top width 134 may be an axial width of a top portion of the first controlled flow runner 130. The top width 134 may be a width of a portion of the first controlled flow runner 130, or more specifically, the blade, that is radially outward from the disc 110. The middle width 136 may be an axial width of the first controlled flow runner 130 or the blade that is determined or measured about a middle portion of the blade of the first controlled flow runner 130. The bottom width 138 may be an axial width of the blade or the first controlled flow runner 130 at a bottom portion, which may be adjacent to the disc or drum 110.

[0018] The second controlled flow runner 150 may also have an axial width that varies at different distances measured from the root of the second controlled flow runner 150 or the turbine disc. For example, the second controlled flow runner 150 may have a top axial width 152, a middle axial width 154, and a bottom axial width 156. The bottom axial width 156 may be an axial width of the second controlled flow runner 150 that is measured a first radial distance 158 from the disc 110. The middle axial width 154 may be an axial width of the second controlled flow runner 150 that is measured a second radial distance 160 from the disc 110. The second radial distance 160 may be greater than the first radial distance 158. The top axial width 152 may be an axial width of the second controlled flow runner 150 that is measured a third radial distance 162 from the disc 110. The third radial distance 162 may be greater than the first radial distance 158 and the second radial distance 160. The middle axial width 154 of the second controlled flow runner 150 may be reduced relative to the top axial width 152 and the bottom axial width 156, so as to result in reduced profile losses. As shown in FIG. 4, the second controlled flow runner 150 may have a height that is greater than a height of the first controlled flow runner 130.

[0019] In some embodiments, the middle width of one or more, or all, of the runners in the steam turbine 100, such as the first controlled flow runner 130 and the second controlled flow runner 150 may be less than the respective top widths and the bottom widths. The runners may therefore have a bowed configuration. The middle widths of the runners in the steam turbine 100 may be dimensioned so as to reduce profile losses. For example, dimensioning the middle width to be less than the top and/or bottom widths may reduce profile losses in the steam turbine 100. In some embodiments, the bottom width of the respective runners may be greater than the top widths. The controlled flow runners may therefore be configured to accelerate guide wake and reduce mixing losses in the steam turbine 100. In some embodiments, steam turbines may include multiple stages with respective pairs of controlled flow guides and controlled flow

runners that correspond to respective turbine stages.

[0020] In FIG. 5, a blade portion 164 of a controlled flow runner as described herein is depicted in perspective view. The blade portion 164 may have an airfoil geometry 162, with a bowed configuration 160 at a trailing edge. A bottom portion 166 of the blade portion 164 may have a different center of gravity than top or middle portions of the blade portion 164.

[0021] The controlled flow runner may have a bowed stack configuration 160, where the tip, blade, and root are stacked with offset centers-of-gravity. Specifically, a first center of gravity of the tip of the runner may be offset from a second center of gravity of the blade. The second center of gravity of the blade may be offset from a third center of gravity of the root. The bowed trailing edge and/or the opening/pitch distribution of the blade may generate optimized controlled flow vortex distribution as gas passes over the controlled flow runner. FIG. 5 further illustrates the blade in a top perspective view 170, a front view 180, and a side view 190, which illustrates the bowed midsection 192 of the blade.

[0022] FIG. 6 schematically depicts one example embodiment of a portion of a turbine 200. The turbine 200 may include a number of blades 202 positioned adjacent to one another to form a stage. In some instances, the blades 202 may form the last stage of the turbine 200. Any number of blades 202 may be used herein to form any stage of the turbine 200. For example, the blades 202 may form a first stage, a last stage, or any stage there between. The blades 202 may be attached to a disc and circumferentially spaced apart from one another. Each of the blades 202 may include a leading edge 208, a trailing edge 210, a pressure side 212, and a suction side 214. A passage 216 may be formed between adjacent blades 202. The passage 216 may include a throat area 218. The throat area 218 is the shortest distance from the trailing edge 210 to the suction side 214 of adjacent blades 202. The blades may have an ultra-high back surface deflection. In some embodiments, the back surface deflection may be greater than a threshold value, such as about 10 degrees, or between about 5 degrees and about 25 degrees.

[0023] FIG. 6 further schematically illustrates mean section differences between a controlled flow runner as described herein, and another runner (shown in dashed lines). The differences in geometry are indicated by the change in position of the respective suction sides 220, 222 and pressure sides 228, 230, as well as the separation 226 between the leading edges and separation 224 between the trailing edges.

[0024] Tip section differences between a controlled flow runner as described herein, and another runner (shown in dashed lines) are also illustrated in FIG. 6. As shown, differences in positioning of the suction sides 240, 242, and 246, 248, as well as differences in separation (which may be minimal), may result in increased strength and reduced losses. FIG. 6 further illustrates an example back surface deflection, represented by δ , which may

indicate uncovered flow turning on the suction surface, and may be an angle between a tangent to the suction surface at the throat point and a tangent drawn at the suction surface trailing edge circle blend point.

[0025] A method of using the controlled flow runners described herein may include the steps of providing a root for a controlled flow runner in a steam turbine, coupling a blade for the controlled flow runner to the root, where the blade has a top width, a middle width, and a bottom width, and where the middle width is less than the top width and the bottom width. The method may include coupling a tip to the blade.

[0026] As a result of the controlled flow runners described herein, stage efficiency gains for steam turbines may be about 0.20%, with reduced profile loss at the controlled flow runner, reduced secondary loss, and improved positive incidence. Certain embodiments may be used to retrofit existing steam turbines. Certain embodiments may provide reduced weight runners with consistent mechanical reliability, while maintaining costs. The controlled flow runner may therefore improve stage efficiency, while maintaining or improving mechanical reliability and without increasing cost or complexity of the steam turbine. emissions may be reduced.

[0027] It should be apparent that the foregoing relates only to certain embodiments of this application and resultant patent. Numerous changes and modifications may be made herein by one of ordinary skill in the art without departing from the general spirit and scope of the invention as defined by the following claims and the equivalents thereof. For completeness, various aspects of the invention are set out in the following numbered clauses:

1. A controlled flow runner for use with a steam turbine comprising:

a tip; a blade adjacent to the tip, the blade comprising a top width, a middle width, and a bottom width, wherein the middle width is less than the top width and the bottom width; and a root adjacent to the blade.

2. The controlled flow runner of clause 1, wherein the blade comprises a bowed stack configuration.

3. The controlled flow runner of clause 1, wherein a first center of gravity of the blade is offset from a second center of gravity of the root.

4. The controlled flow runner of clause 3, wherein the first center of gravity is offset from a third center of gravity of the tip.

5. The controlled flow runner of clause 1, wherein the trailing edge of the blade comprises a bowed configuration.

6. The controlled flow runner of clause 5, wherein the opening/pitch distribution of the blade generates the optimized controlled flow vortex distribution.

7. The controlled flow runner of clause 1, wherein

the bottom width is greater than the top width.

8. The controlled flow runner of clause 1, wherein the Back Surface Deflection of the blade is greater than a threshold value.

9. The controlled flow runner of clause 1, further comprising a tip shroud coupled to the tip, and wherein the top width is adjacent to the tip shroud.

10. The controlled flow runner of clause 1, wherein the middle width is an axial width.

11. The controlled flow runner of clause 1, wherein the middle width is dimensioned to reduce profile losses.

12. The controlled flow runner of clause 1, wherein the root is coupled to a disc, and wherein the bottom width is adjacent to the root.

13. The controlled flow runner of clause 1, wherein the blade is positioned adjacent to a controlled flow guide.

14. The controlled flow runner of clause 1, wherein the controlled flow runner is configured to accelerate guide wake and reduce mixing losses.

15. A method comprising:

providing a root for a controlled flow runner in an inner casing of a steam turbine;
coupling a blade for the controlled flow runner to the root, wherein the blade comprises a top width, a middle width, and a bottom width, wherein the middle width is less than the top width and the bottom width; and
coupling a tip to the blade.

16. A steam turbine comprising:

a disc;
a casing;
a first controlled flow guide installed in the casing; and
a first controlled flow runner coupled to the disc adjacent to the first controlled flow guide, the first controlled flow runner comprising a first blade;

the first blade comprising a top width at a first radial distance from the disc, a middle width at a second radial distance from the disc, and a bottom width at a third radial distance from the disc;
wherein the middle width is less than the top width and the bottom width; and
wherein the second radial distance is greater than the third radial distance and less than the first radial distance.

17. The steam turbine of clause 16, further comprising:

a second controlled flow guide coupled to the

disc;

a second controlled flow runner coupled to the disc adjacent to the second controlled flow guide, the second controlled flow runner comprising a second blade, wherein the second blade has a height that is greater than a height of the first blade.

18. The steam turbine of clause 17, wherein a back surface deflection of the first blade is greater than a threshold value.

19. The steam turbine of clause 16, further comprising a plurality of controlled flow guides and a plurality of controlled flow runners.

20. The steam turbine of clause 16, wherein respective pairs of controlled flow guides and controlled flow runners correspond to respective turbine stages.

Claims

1. A controlled flow runner (130) for use with a steam turbine (010) comprising:

a tip;

a blade (82) adjacent to the tip, the blade comprising a top width, a middle width, and a bottom width, wherein the middle width is less than the top width and the bottom width; and

a root (84) adjacent to the blade.

2. The controlled flow runner of claim 1, wherein the blade comprises a bowed stack configuration (132).

3. The controlled flow runner of claim 1 or claim 2, wherein a first center of gravity of the blade is offset from a second center of gravity of the root.

4. The controlled flow runner of claim 3, wherein the first center of gravity is offset from a third center of gravity of the tip.

5. The controlled flow runner of any preceding claim, wherein the trailing edge (210) of the blade comprises a bowed configuration.

6. The controlled flow runner of claim 5, wherein the opening/pitch distribution of the blade generates the optimized controlled flow vortex distribution.

7. The controlled flow runner of any preceding claim, wherein the bottom width is greater than the top width.

8. The controlled flow runner of any preceding claim, wherein the back surface deflection of the blade is greater than a threshold value.

9. The controlled flow runner of any preceding claim, further comprising a tip shroud (88) coupled to the tip, and wherein the top width is adjacent to the tip shroud.

10. The controlled flow runner of any preceding claim, wherein the middle width is an axial width.

11. The controlled flow runner of any preceding claim, wherein the middle width is dimensioned to reduce profile losses.

12. The controlled flow runner of any preceding claim, wherein the root is coupled to a disc (110), and wherein the bottom width is adjacent to the root.

13. The controlled flow runner of any preceding claim, wherein the blade is positioned adjacent to a controlled flow guide or wherein the controlled flow runner is configured to accelerate guide wake and reduce mixing losses.

14. A method comprising:

providing a root for a controlled flow runner in an inner casing of a steam turbine;
coupling a blade for the controlled flow runner to the root, wherein the blade comprises a top width, a middle width, and a bottom width, wherein the middle width is less than the top width and the bottom width; and
coupling a tip to the blade.

15. A steam turbine (10) comprising:

a disc (110);
a casing;
a first controlled flow guide (120) installed in the casing; and
a first controlled flow runner (130) coupled to the disc adjacent to the first controlled flow guide, the first controlled flow runner comprising a first blade;
the first blade comprising a top width at a first radial distance from the disc, a middle width at a second radial distance from the disc, and a bottom width at a third radial distance from the disc;
wherein the middle width is less than the top width and the bottom width; and
wherein the second radial distance is greater than the third radial distance and less than the first radial distance.

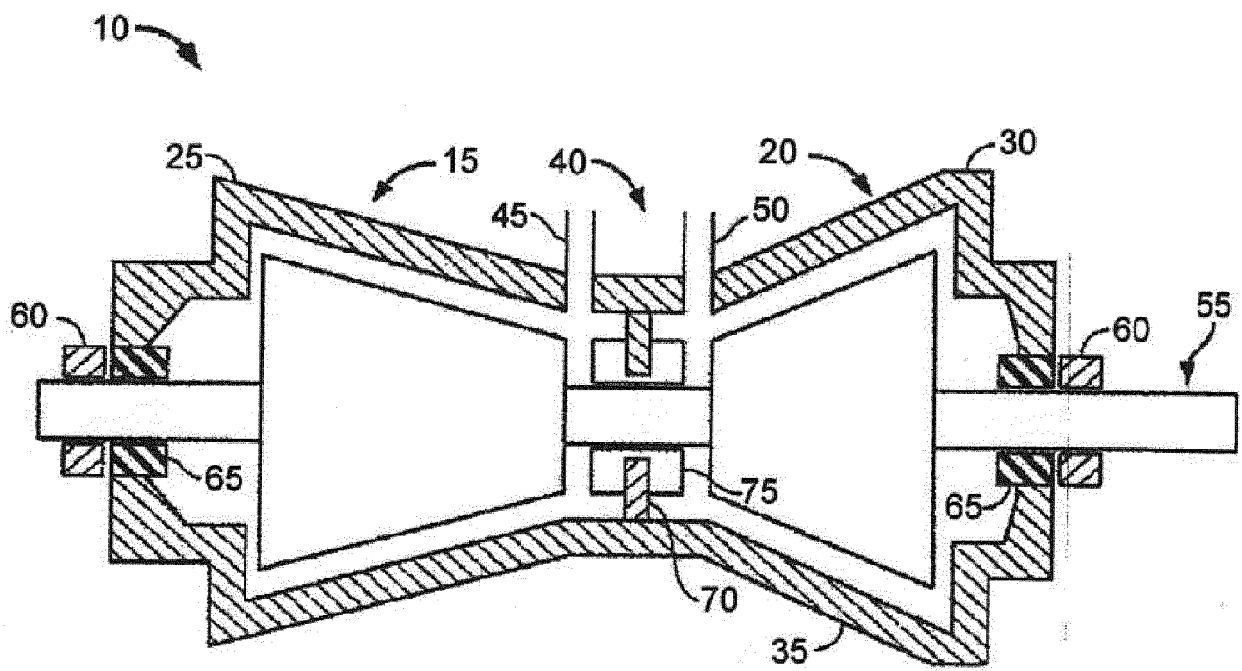


Fig. 1

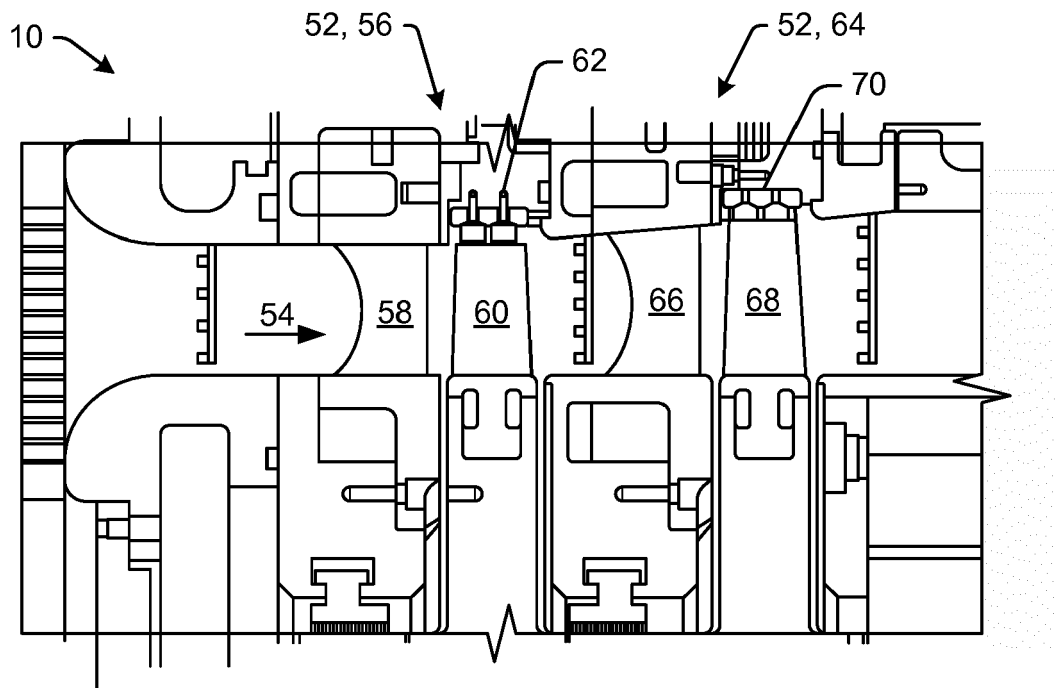


Fig. 2

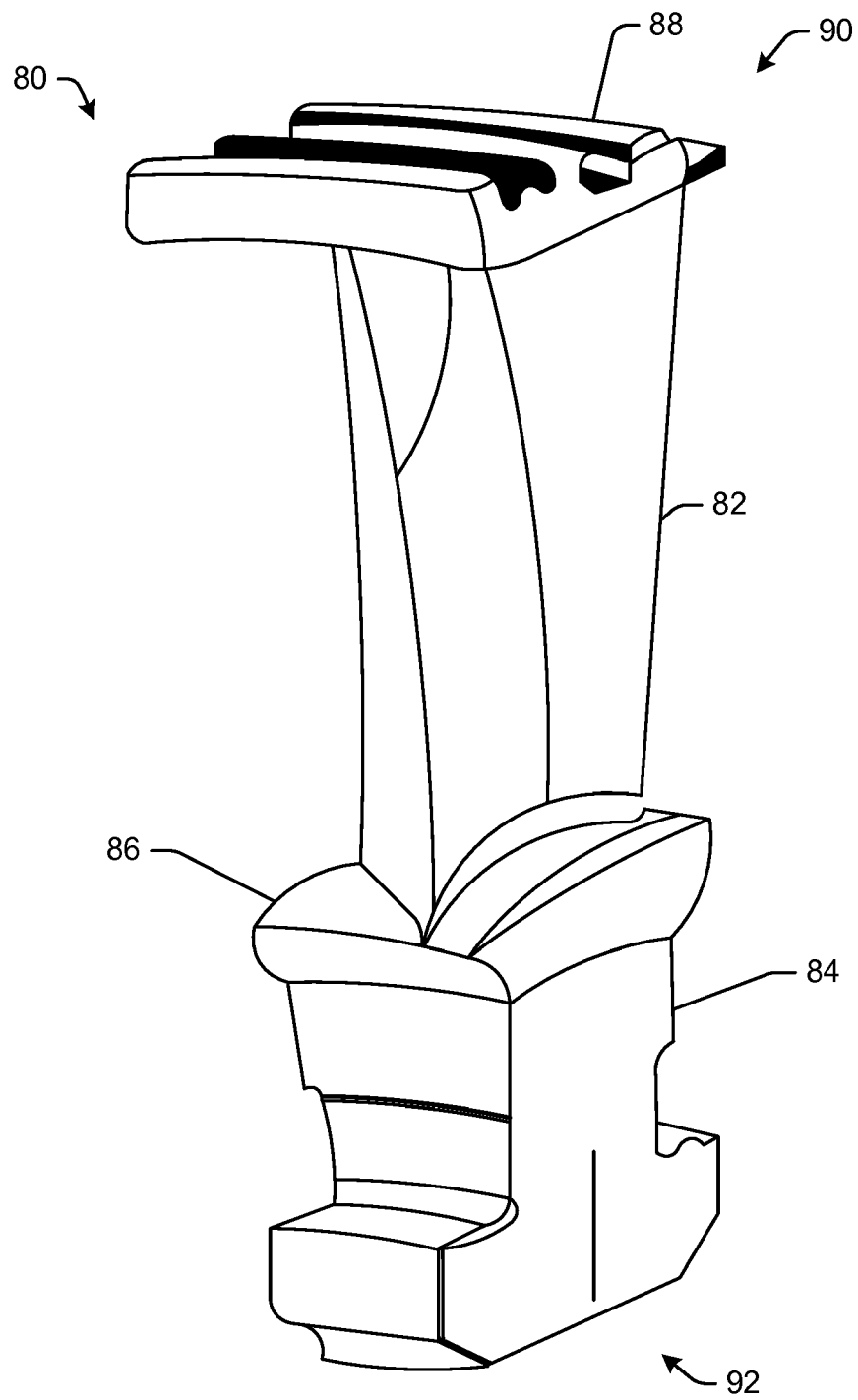


Fig. 3

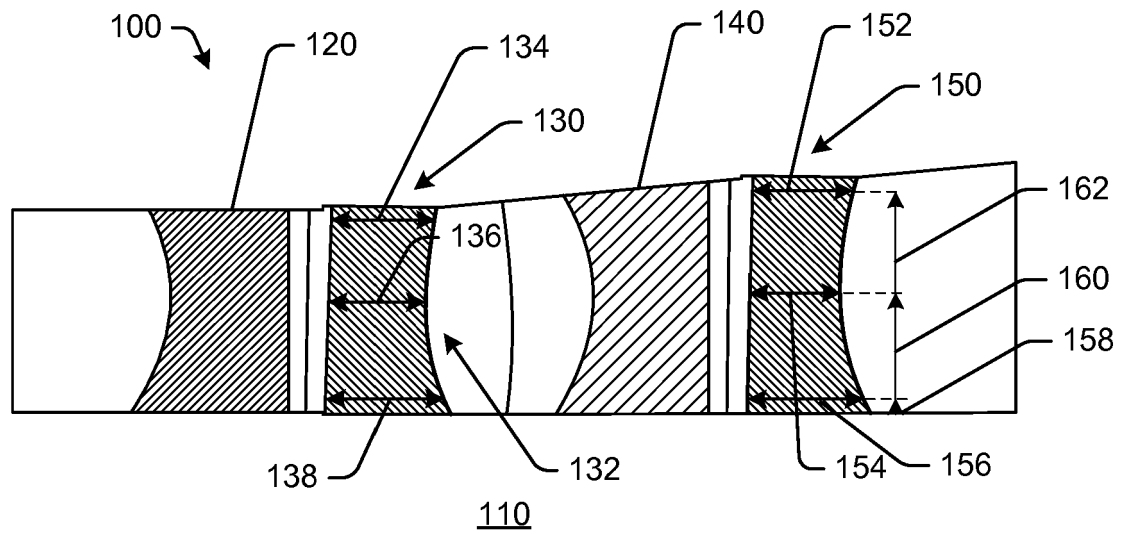


Fig. 4

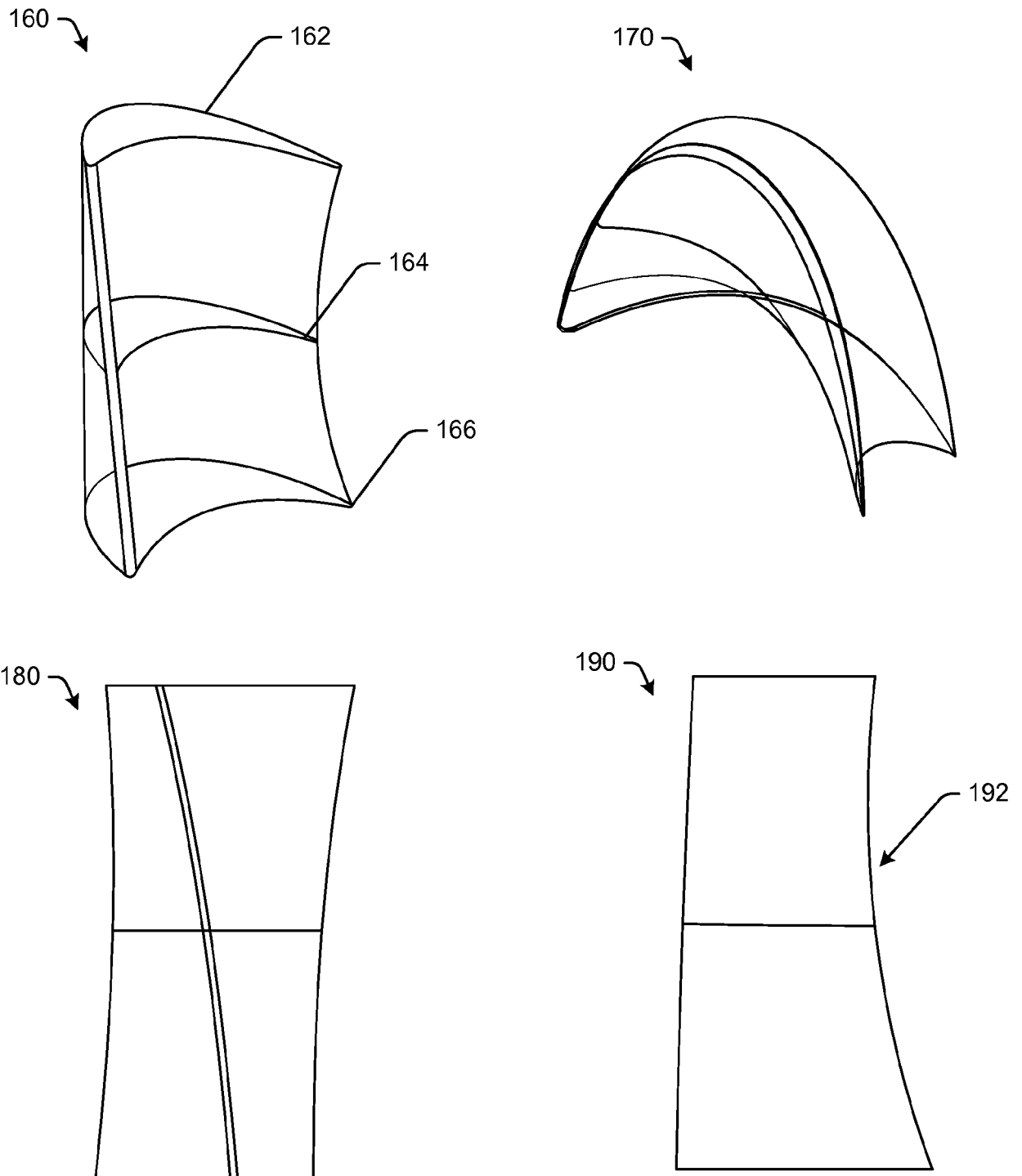
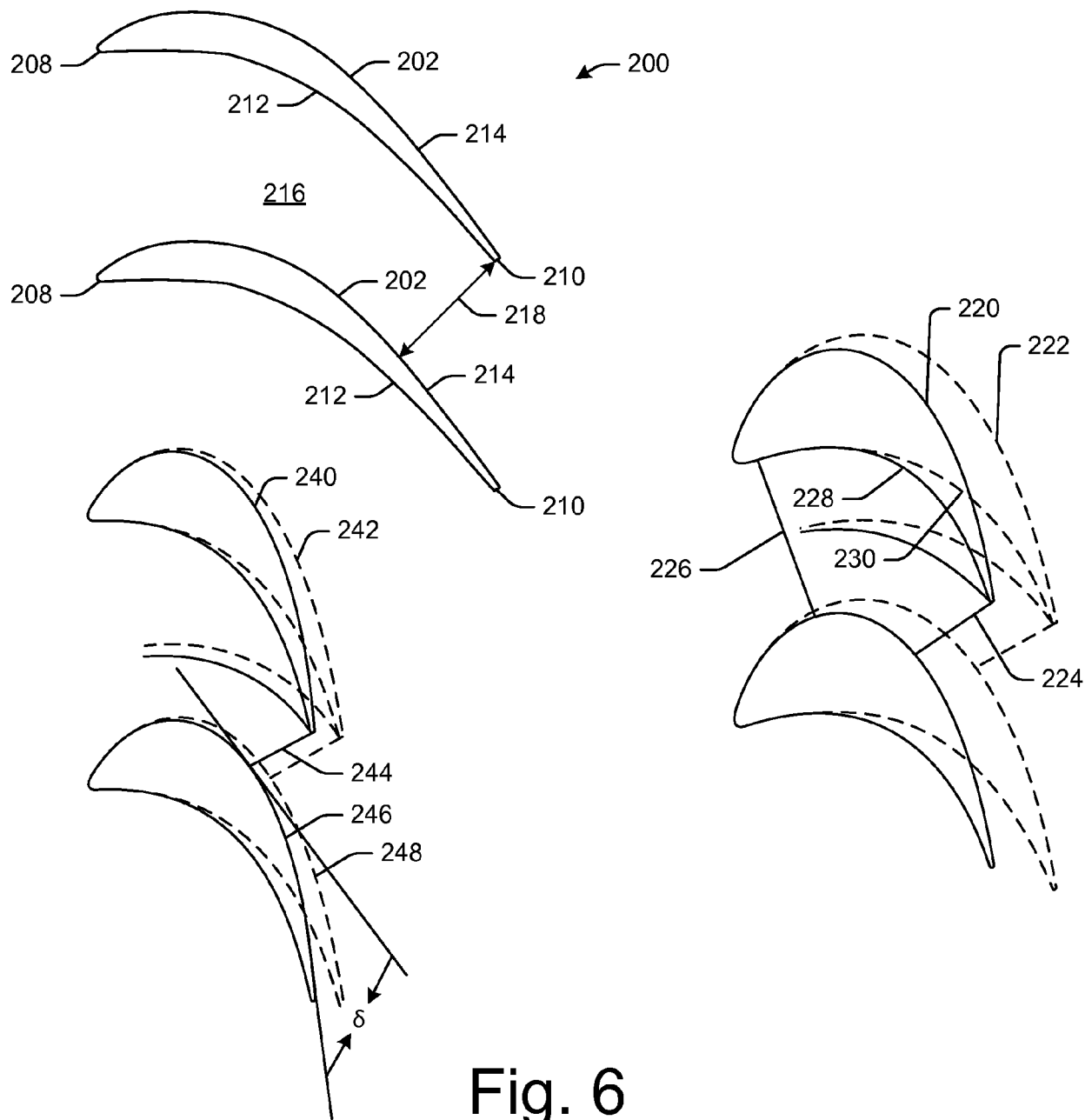


Fig. 5





EUROPEAN SEARCH REPORT

Application Number
EP 17 15 4386

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DOCUMENTS CONSIDERED TO BE RELEVANT			
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Y	* paragraphs [0001], [0028]; figures 2, 4 *	9	
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			TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 17 July 2017	Examiner Georgi, Jan
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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