



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
24.08.2011 Bulletin 2011/34

(51) Int Cl.:
F01D 9/04 (2006.01)

(21) Application number: **11154455.7**

(22) Date of filing: **15.02.2011**

(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

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(30) Priority: **16.02.2010 US 706198**

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(54) **Steam turbine nozzle segment having arcuate interface**

(57) Steam turbine nozzle segments with conical interfaces are disclosed. In one embodiment a steam turbine static nozzle blade (110) includes: an airfoil (112); an inner sidewall (114) integral with a first side of the airfoil (112); and an outer sidewall (116) integral with a second side of the airfoil (112); the inner sidewall (114)

and the outer sidewall (116) each including: a pressure side (124) having an arcuate concave surface (134) extending substantially an entire length of the sidewall (L); and a suction side (126) having an arcuate convex surface (136) extending substantially the entire length of the sidewall (L).

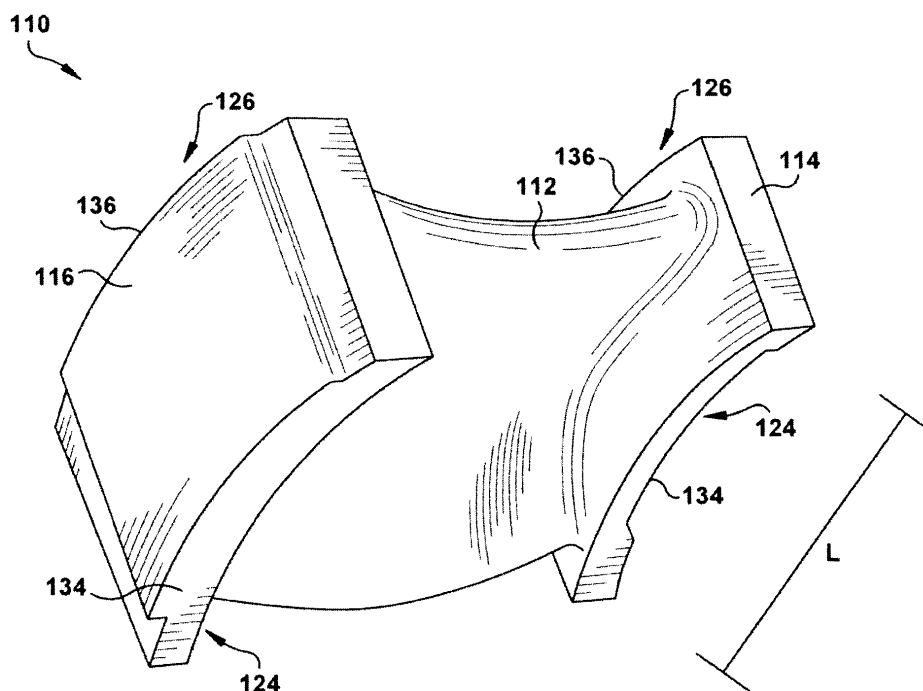


FIG. 4

Description

BACKGROUND OF THE INVENTION

[0001] The subject matter disclosed herein relates to a steam turbine nozzle assembly, or diaphragm stage. Specifically, the subject matter disclosed herein relates to a steam turbine nozzle assembly including a plurality of nozzle segments with arcuate or "conical" (e.g., arced concave, arced convex) interfaces.

[0002] Steam turbines include static nozzle (or "airfoil") segments that direct flow of a working fluid into turbine buckets connected to a rotating rotor. A complete assembly of nozzle segments is commonly referred to as a diaphragm stage of the steam turbine. One method of constructing the diaphragm stage is to weld (or alternatively, braze) a plurality of single airfoils with integrated sidewalls ("static nozzle blades", or "singlets") to inner and outer rings. Each of these singlets have interfaces to which adjacent singlets are welded or brazed (in the inner and outer ring). These interfaces include an axial leading edge section (or "pressure-side" section) oriented parallel to the steam turbine's axis, and an angled trailing edge section (or "suction-side" section). While the current singlet design including angled interface sections allows for a tight fit between individual segments, the angled interfaces make removal and repair of individual segments nearly impossible.

BRIEF DESCRIPTION OF THE INVENTION

[0003] Steam turbine nozzle segments with conical interfaces are disclosed. In one embodiment a steam turbine static nozzle blade includes: an airfoil; an inner sidewall integral with a first side of the airfoil; and an outer sidewall integral with a second side of the airfoil; the inner sidewall and the outer sidewall each including: a pressure side having an arcuate concave surface extending substantially an entire length of the sidewall; and a suction side having an arcuate convex surface extending substantially the entire length of the sidewall.

[0004] A first aspect of the invention includes a steam turbine static nozzle blade comprising: an airfoil; an inner sidewall integral with a first side of the airfoil; and an outer sidewall integral with a second side of the airfoil; the inner sidewall and the outer sidewall each including: a pressure side having an arcuate concave surface extending substantially an entire length of the sidewall; and a suction side having an arcuate convex surface extending substantially the entire length of the sidewall.

[0005] A second aspect of the invention includes a steam turbine diaphragm assembly comprising: an outer diaphragm ring; an inner diaphragm ring; and an annulus of static nozzle blades between the inner diaphragm ring and the outer diaphragm ring, each static nozzle blade comprising: an airfoil; an inner sidewall integral with a first side of the airfoil; and an outer sidewall integral with a second side of the airfoil; the inner sidewall and the

outer sidewall each including: a pressure side having an arcuate concave surface extending substantially an entire length of the sidewall; and a suction side having an arcuate convex surface extending substantially the entire length of the sidewall; wherein at least one of the static nozzle blades is demountably attached to a second one of the static nozzle blades.

[0006] A third aspect of the invention includes a steam turbine diaphragm assembly comprising: an outer diaphragm ring; an inner diaphragm ring; and an annulus of static nozzle blades between the inner diaphragm ring and the outer diaphragm ring, each static nozzle blade comprising: an airfoil; an inner sidewall integral with a first side of the airfoil; and an outer sidewall integral with a second side of the airfoil; the inner sidewall and the outer sidewall each including: a pressure side having an arcuate concave surface extending substantially an entire length of the sidewall; and a suction side having an arcuate convex surface extending substantially the entire length of the sidewall, wherein at least one of the static nozzle blades is demountably attached to a second one of the static nozzle blades in an axial direction; and a plurality of removable weld joints, each removable weld joint substantially removably affixing one of the static nozzle blades to one of the outer diaphragm ring or the inner diaphragm ring.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] These and other features of this invention will be more readily understood from the following detailed description of the various aspects of the invention taken in conjunction with the accompanying drawings that depict various embodiments of the invention, in which:

FIG. 1 shows a plan view of a top of a steam turbine nozzle assembly.

FIGS. 2 shows a three-dimensional perspective views of a steam turbine nozzle assembly.

FIG. 3 shows a partial three-dimensional perspective view of a steam turbine diaphragm assembly.

FIG. 4 shows a three-dimensional perspective view of a steam turbine static nozzle blade according to an embodiment.

FIGS. 5-6 show three-dimensional perspective views of a plurality of steam turbine static nozzle blades according to embodiments.

FIG. 7 shows a partial three-dimensional perspective view of a steam turbine diaphragm assembly according to an embodiment.

[0008] It is noted that the drawings of the invention are not to scale. The drawings are intended to depict only

typical aspects of the invention, and therefore should not be considered as limiting the scope of the invention. In the drawings, like numbering represents like elements between the drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0009] As indicated above, aspects of the invention provide for a steam turbine nozzle segment having a conical interface. Specifically, aspects of the invention provide for a steam turbine nozzle assembly including a plurality of nozzle segments with arcuate or "conical" (e.g., arced concave, arced convex) interfaces. These arced interfaces may allow for removal and/or repair of individual nozzle segments while substantially maintaining the structural integrity of the nozzle assembly.

[0010] Referring to the drawings, FIGS. 1-2 show a nozzle assembly 100 for a steam turbine (not shown). FIG. 1 shows a plan view of nozzle assembly 100, while FIG. 2 shows a three-dimensional schematic of nozzle assembly 100. Nozzle assembly 100 includes a static nozzle blade 10 including at least one airfoil 12 having an inner sidewall 14 and an outer sidewall 16. Nozzle assembly 100 further includes an inner ring 18 and an outer ring 20. Inner and outer, as used herein, refer to a radial position relative to a rotor (not shown) to which an inner end of airfoil 12 is coupled via inner ring 18. Inner ring 18 and inner sidewall 14 (and similarly, outer ring 20 and outer sidewall 16) are coupled together at an interface 80, which is understood to refer to the entire area where the rings and sidewall are adjacent and coupled. Inner ring 18 and inner sidewall 14 (and similarly, outer ring 20 and outer sidewall 16) are welded (or alternatively, brazed) together at several points at interface 80 (FIG. 1). It is understood that as described herein, brazing may be performed as an alternative to welding. As is understood in the art, welding and brazing may be used to join metals together. As is further understood in the art, welding may be performed by melting and fusing metals together, usually by adding a filler material. Brazing, by contrast, usually does not involve melting the base metals being joined, and is usually performed at lower temperatures than welding. While metal joints are described herein as "weld joints", it is understood that these metal joints may alternatively be described as "brazed joints."

[0011] Returning to FIG. 1, the multiple welded areas of interfaces 80, on both an entrance (front) side of airfoil 12 and an exit (back) side of airfoil 12, that are welded together are shown generally as weld joints 90 in FIGS. 1 and 2. Interfaces 80 between rings 18, 20 and sidewalls 14, 16 may each include a mechanical radial stop 19 which maintains airfoil 12 in the correct radial position during welding and prevents weld shrinkage. Interfaces 80 each may further include a mechanical axial stop 17 which maintains airfoil 12 in the correct axial position and controls the weld length depth. These mechanical stops 17, 19 comprise an interconnection of a series of male steps which engage in corresponding female steps of the

complementary part as described in more detail herein.

[0012] Turning to FIG. 3, the nozzle assembly 100 of FIG. 2 is shown, further including a plurality of static nozzle blades 10 arranged in a portion of a diaphragm assembly (full assembly omitted for clarity). As shown, sidewalls 14, 16 of static nozzle blades 10 may include angled interfaces 34 (e.g., a "dogleg" interface including two surfaces oriented at obtuse angles). These angled interfaces 34 may allow for a plurality of static nozzle blades to be arranged substantially flush with one another in nozzle assembly 100. As shown, the plurality of static nozzle blades 10 are held within inner 18 and outer sidewalls 20 via the plurality of welds 90.

[0013] Turning to FIG. 4, a steam turbine static nozzle blade 110 is shown according to an embodiment. Static nozzle blade 110 may include an airfoil 112, an inner sidewall 114, and an outer sidewall 116. As shown, inner sidewall 114 may be integral with a first side of the airfoil 112 (e.g., via machining from a forging or block, welding, casting, brazing, etc.), and outer sidewall 116 may be integral with a second side of the airfoil 112 (e.g., via machining from a forging or block, welding, casting, brazing, etc.). The inner sidewall 114 and the outer sidewall 116 may each include a pressure side 124 and a suction side 126. The terms "pressure side" and "suction side" correspond to the pressure side and suction side of airfoil 112, respectively. As is known in the art, the pressure side of airfoil 112 is the high-pressure side designed to guide the flow of a working fluid through the static nozzle blade 110. As is further known in the art, the suction side of airfoil 112 is the lower-pressure side substantially opposing the pressure side. Each pressure side 124 may have an arcuate concave surface 134, and each suction side 126 may have an arcuate convex surface 136. In one embodiment, the arcuate concave surface 134 may extend substantially an entire length L of the sidewall 114, 116, respectively, and the arcuate convex surface 136 may extend substantially the entire length L of the sidewall 114, 116, respectively. In one embodiment, the arcuate concave surface 134 of the inner sidewall 114 has a substantially equal arc radius to the arcuate convex surface 136 of the inner sidewall 114. Further, in this embodiment, the arcuate concave surface 134 of the outer sidewall 116 and the arcuate convex surface 136 of the outer sidewall 116 may have a substantially equal arc radius. Additionally, in this embodiment, the arcuate concave surfaces 134 of the inner sidewall 114 and outer sidewall 116, respectively, may have substantially equal arc lengths as the arcuate convex surfaces 136 of the inner sidewall 114 and outer sidewall 116, respectively.

[0014] With continuing reference to FIG. 4, in one embodiment, the arcuate concave surface 134 of the inner sidewall 114 and the arcuate concave surface 134 of the outer sidewall 116 complement the arcuate convex surface 136 of the inner sidewall 114 and the arcuate convex surface 136 of the outer sidewall 116, respectively. That is, in an arrangement including more than one steam turbine static nozzle blade 110 (FIGS. 5-7), the arcuate

convex surface 136 of an inner sidewall 114 of a first steam turbine static nozzle blade 110 complements the arcuate concave surface 134 of an inner sidewall 114 on a second similar steam turbine static nozzle blade 110. Likewise, the arcuate convex surface 136 of an outer sidewall 116 of a first steam turbine static nozzle blade 110 complements the arcuate concave surface 134 of an outer sidewall 116 on a second similar steam turbine static nozzle blade 110. It is understood that as used herein, the term "complement(s)" refers to a relationship between surfaces in which portions of those surfaces may be arranged substantially flush with one another. For example, in one embodiment, pressure-side (arcuate concave) surfaces and suction-side (arcuate convex) surfaces may be arranged in a steam turbine diaphragm assembly (FIG. 7) such that each of the respective (inner, outer) arcuate concave surfaces of a first steam turbine static nozzle blade 110 are substantially flush with the respective (inner, outer) arcuate convex surfaces of a second steam turbine static nozzle blade 110. The relationship between pressure-side surfaces and suction-side surfaces is further explained with reference to FIGS. 5-7.

[0015] Turning to FIGS. 5 and 6, arrangements including a plurality of substantially similar steam turbine static nozzle blades 110 are shown. In these arrangements, steam turbine static nozzle blades 110 may be arranged such that their complementary surfaces (arcuate concave surfaces 134 and arcuate convex surfaces 136, respectively) are substantially flush with one another. This may allow for, among other things, efficient feeding of steam across airfoils 112 and mechanical stability. FIG. 5 shows an arrangement including the plurality of steam turbine static nozzle blades 110 of FIG. 5, along with additional substantially similar blades, forming part of a steam turbine diaphragm assembly (diaphragm rings omitted). As described with respect to FIG. 5, and shown more clearly in FIG. 6, part of a steam turbine diaphragm assembly may be formed by arranging complementary conical surfaces of steam turbine static nozzle blades 110 flush with one another. As will be described with reference to FIG. 7, in a more complete diaphragm assembly, the plurality of steam turbine static nozzle blades 110 may be demountably attached to one another in an axial direction (denoted by "A"). This demountable attachment may allow for axial removal of one or more steam turbine static nozzle blades 110 from the assembly without substantially disturbing the structural integrity (e.g., weld joints 190) of the remainder of the assembly.

[0016] Turning to FIG. 7, a portion of a steam turbine diaphragm assembly 200 is shown according to an embodiment. Portion of steam turbine diaphragm assembly 200 may include a plurality of steam turbine static nozzle blades 110 arranged with substantially flush complementary surfaces as described with reference to FIGS. 5-6. Further, portion of steam turbine diaphragm assembly 200 may include an inner diaphragm ring 118 and an outer diaphragm ring 120, which may be substantially

similar to those inner and outer rings (18 and 20) shown and described with reference to FIGS. 1-3. In a complete diaphragm assembly (not shown for purposes of clarity), the plurality of steam turbine static nozzle blades 110 may form an annulus between the inner diaphragm ring 118 and the outer diaphragm ring 120. In this arrangement, plurality of steam turbine static nozzle blades 110 may be demountably attached to one another. Further, the plurality of steam turbine static nozzle blades 110 may be substantially removably affixed to at least one of the inner diaphragm ring 118 and outer diaphragm ring 120 via the plurality of removable weld joints 190. That is, where a steam turbine static nozzle blade 110 is not affixed to at least one of the inner diaphragm ring 118 and outer diaphragm ring 120, that steam turbine static nozzle blade 110 may be removed from the steam turbine diaphragm assembly 200 without removing weld joints 190 of one or more adjacent steam turbine static nozzle blades 110.

[0017] In the nozzle assembly 100 of FIG. 3, when a complete annulus of static nozzle blades 10 is assembled and welded (or alternatively, brazed), individual static nozzle blades 10 cannot be removed from the assembly 100 without removal of a plurality of the nozzle blades 10 (and their corresponding weld joints 90, or braze joints). This is because the angled interfaces 34 (FIG. 3) of the plurality of blades 10 obstruct movement of adjacent blades 10, even when a weld joint 90 is removed. Specifically, as shown in FIG. 3, the angled interfaces 34 of the plurality of blades 10 obstruct movement of those blades in an axial direction ("A"). In contrast, the plurality of steam turbine static nozzle blades 110 of an embodiment (e.g., FIG. 7) are demountably attached to one another. That is, each steam turbine static nozzle blade 110 that is not welded to one of the inner diaphragm ring 118 and outer diaphragm ring 120 may be removed or inserted between two fixed (e.g., welded) steam turbine static nozzle blades 110 in the axial direction (A). Phrased differently, in the steam turbine diaphragm assembly 200, each steam turbine static nozzle blade 110 may be demountably attached to an adjacent steam turbine static nozzle blade 110 in an axial direction. Further, in one embodiment each steam turbine static nozzle blade 110 is substantially removably affixed to at least one of the inner diaphragm ring 118 and outer diaphragm ring 120 by only the plurality of removable weld joints 190 (or alternatively, braze joints).

[0018] The steam turbine static nozzle blades 110 including conical (arcuate concave, arcuate convex) interfaces as described herein may allow for removal of individual blades 110 from an assembly (e.g., steam turbine diaphragm assembly 200) by removing (e.g., by grinding, machining and/or heating) only those removable weld joints 190 (or braze joints) associated with the individual blade being removed. This may allow for, among other things, faster and more efficient repair, replacement, and/or enhancement of individual steam turbine static nozzle blades 110.

[0019] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0020] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

[0021] For completeness, various aspects of the invention are now set out in the following numbered clauses:

1. A steam turbine static nozzle blade comprising:

an airfoil;

an inner sidewall integral with a first side of the airfoil; and

an outer sidewall integral with a second side of the airfoil;

the inner sidewall and the outer sidewall each including:

a pressure side having an arcuate concave surface extending substantially an entire length of the sidewall; and

a suction side having an arcuate convex surface extending substantially the entire length of the sidewall.

2. The static nozzle blade of clause 1, wherein the arcuate concave surface of the inner sidewall and the arcuate convex surface of the inner sidewall have a substantially equal arc radius.

3. The static nozzle blade of clause 2, wherein the arcuate concave surface of the outer sidewall and the arcuate convex surface of the outer sidewall have

a substantially equal arc radius.

4. The static nozzle blade of clause 3, wherein the arcuate concave surface of the inner sidewall and the arcuate concave surface of the outer sidewall complement the arcuate convex surface of the inner sidewall and the arcuate convex surface of the outer sidewall, respectively.

5. The static nozzle blade of clause 1, wherein the arcuate concave surface of the inner sidewall and the arcuate convex surface of the inner sidewall have a substantially equal arc length.

6. The static nozzle blade of clause 1, wherein the arcuate concave surface of the outer sidewall and the arcuate convex surface of the outer sidewall have a substantially equal arc length.

7. A steam turbine diaphragm assembly comprising:

an outer diaphragm ring;

an inner diaphragm ring;

an annulus of static nozzle blades between the inner diaphragm ring and the outer diaphragm ring, each static nozzle blade comprising:

an airfoil;

an inner sidewall integral with a first side of the airfoil; and

an outer sidewall integral with a second side of the airfoil;

the inner sidewall and the outer sidewall each including:

a pressure side having an arcuate concave surface extending substantially an entire length of the sidewall; and

a trailing surface having an arcuate convex surface extending substantially the entire length of the sidewall;

wherein at least one of the static nozzle blades is demountably attached to a second one of the static nozzle blades.

8. The steam turbine diaphragm assembly of clause 7, wherein the arcuate concave surface of the inner sidewall and the arcuate convex surface of the inner sidewall have a substantially equal arc radius.

9. The turbine diaphragm assembly of clause 8,

wherein the arcuate concave surface of the outer sidewall and the arcuate convex surface of the outer sidewall have a substantially equal arc radius.

10. The steam turbine diaphragm assembly of clause 9, wherein the arcuate concave surface of the inner sidewall and the arcuate concave surface of the outer sidewall of a first one of the static nozzle blades complement the arcuate convex surface of the inner sidewall and the arcuate convex surface of the outer sidewall, respectively, of a second one of the static nozzle blades.

11. The steam turbine diaphragm assembly of clause 10, further comprising a plurality of removable weld joints, each removable weld joint substantially removably affixing one of the static nozzle blades to one of the outer diaphragm ring or the inner diaphragm ring.

12. The steam turbine diaphragm assembly of clause 11, wherein the at least one of the static nozzle blades is demountably attached to the second one of the static nozzle blades by at least one of the removable weld joints.

13. The steam turbine diaphragm assembly of clause 12, wherein the at least one of the removable weld joints demountably attaches the at least one of the static nozzle blades to the second one of the static nozzle blades in an axial direction.

14. A steam turbine diaphragm assembly comprising:

an outer diaphragm ring;

an inner diaphragm ring;

an annulus of static nozzle blades between the inner diaphragm ring and the outer diaphragm ring, each static nozzle blade comprising:

an airfoil;

an inner sidewall integral with a first side of the airfoil; and

an outer sidewall integral with a second side of the airfoil;

the inner sidewall and the outer sidewall each including:

a pressure side having an arcuate concave surface extending substantially an entire length of the sidewall; and

a suction side having an arcuate convex surface extending substantially the entire length of the sidewall, wherein at least one of the static nozzle blades is demountably attached to a second one of the static nozzle blades in an axial direction; and

a plurality of pairs of removable weld joints, each pair of removable weld joints substantially removably affixing one of the static nozzle blades to one of the outer diaphragm ring or the inner diaphragm ring.

15. The steam turbine diaphragm assembly of clause 14, wherein the arcuate concave surface of the inner sidewall and the arcuate convex surface of the inner sidewall have a substantially equal arc radius.

16. The steam turbine diaphragm assembly of clause 15, wherein the arcuate concave surface of the outer sidewall and the arcuate convex surface of the outer sidewall have a substantially equal arc radius.

17. The steam turbine diaphragm assembly of clause 15, wherein the arcuate concave surface of the inner sidewall and the arcuate concave surface of the outer sidewall of a first one of the static nozzle blades complement the arcuate convex surface of the inner sidewall and the arcuate convex surface of the outer sidewall, respectively, of a second one of the static nozzle blades.

18. The steam turbine diaphragm assembly of clause 14, wherein each pair of removable weld joints substantially maintains an axial position of the removably affixed static nozzle blade.

19. The steam turbine diaphragm assembly of clause 14, wherein the arcuate concave surface of the inner sidewall and the arcuate convex surface of the inner sidewall have a substantially equal arc length; and wherein the arcuate concave surface of the outer sidewall and the arcuate convex surface of the outer sidewall have a substantially equal arc length.

20. The steam turbine diaphragm assembly of clause 14, wherein the removably affixed static nozzle blade is substantially affixed to the turbine diaphragm assembly by only the pair of removable weld joints.

Claims

1. A steam turbine static nozzle blade (110) comprising:

an airfoil (112);

an inner sidewall (114) integral with a first side of the airfoil (112); and

an outer sidewall (116) integral with a second side of the airfoil (112);
the inner sidewall (114) and the outer sidewall (116) each including:

a pressure side (124) having an arcuate concave surface (134) extending substantially an entire length of the sidewall (L); and
a suction side (126) having an arcuate convex surface (136) extending substantially the entire length of the sidewall (L).

2. The static nozzle blade (110) of claim 1, wherein the arcuate concave surface (134) of the inner sidewall (114) and the arcuate convex surface (136) of the inner sidewall (114) have a substantially equal arc radius.
3. The static nozzle blade of claim 2, wherein the arcuate concave surface (134) of the outer sidewall (116) and the arcuate convex surface (136) of the outer sidewall (116) have a substantially equal arc radius.
4. The static nozzle blade (110) of claim 3, wherein the arcuate concave surface (134) of the inner sidewall (114) and the arcuate concave surface (134) of the outer sidewall (116) complement the arcuate convex surface (136) of the inner sidewall (114) and the arcuate convex surface (136) of the outer sidewall (116), respectively.
5. The static nozzle blade (110) of claim 1, wherein the arcuate concave surface (134) of the inner sidewall (114) and the arcuate convex surface (136) of the inner sidewall (114) have a substantially equal arc length.
6. The static nozzle blade (110) of claim 1, wherein the arcuate concave surface (134) of the outer sidewall (116) and the arcuate convex surface (136) of the outer sidewall (116) have a substantially equal arc length.

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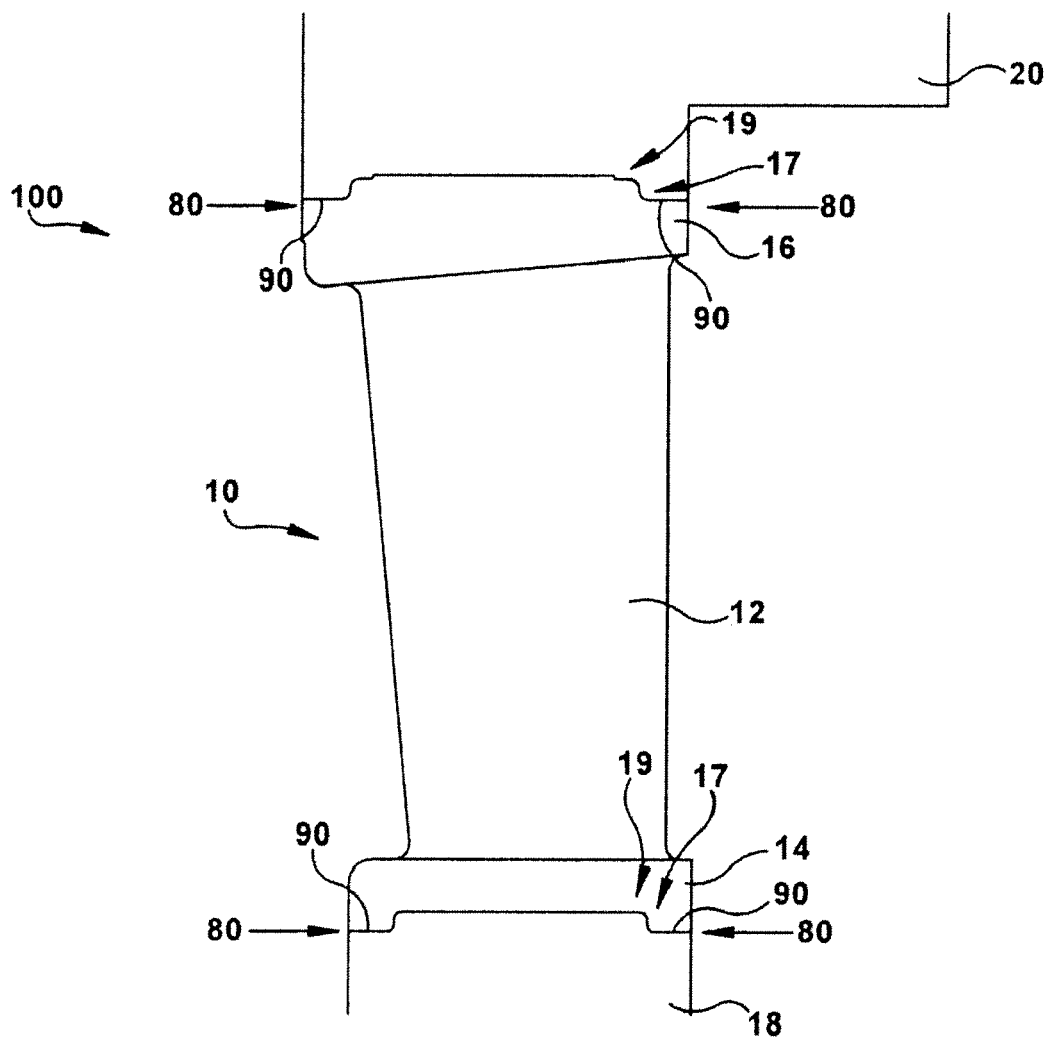


FIG. 1

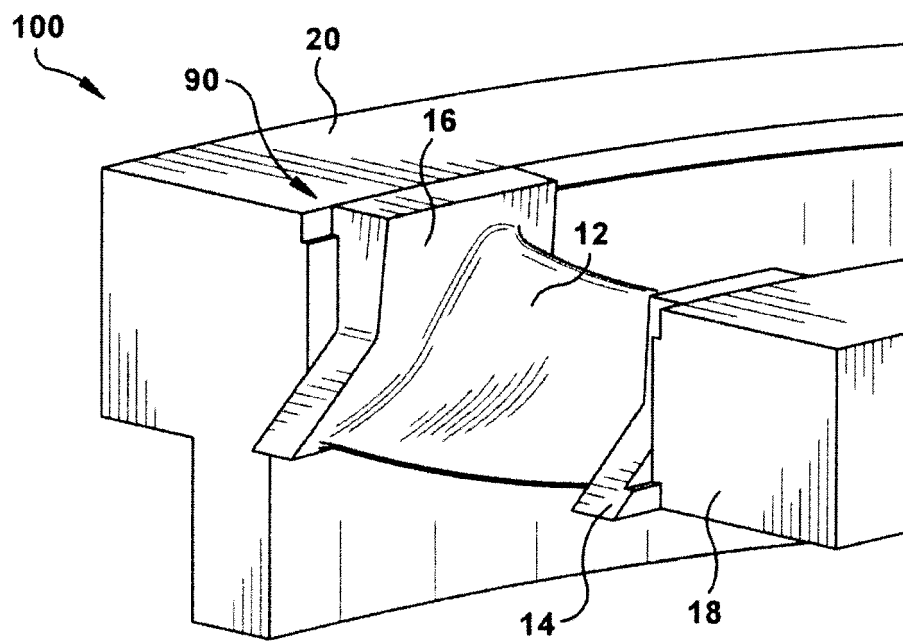


FIG. 2

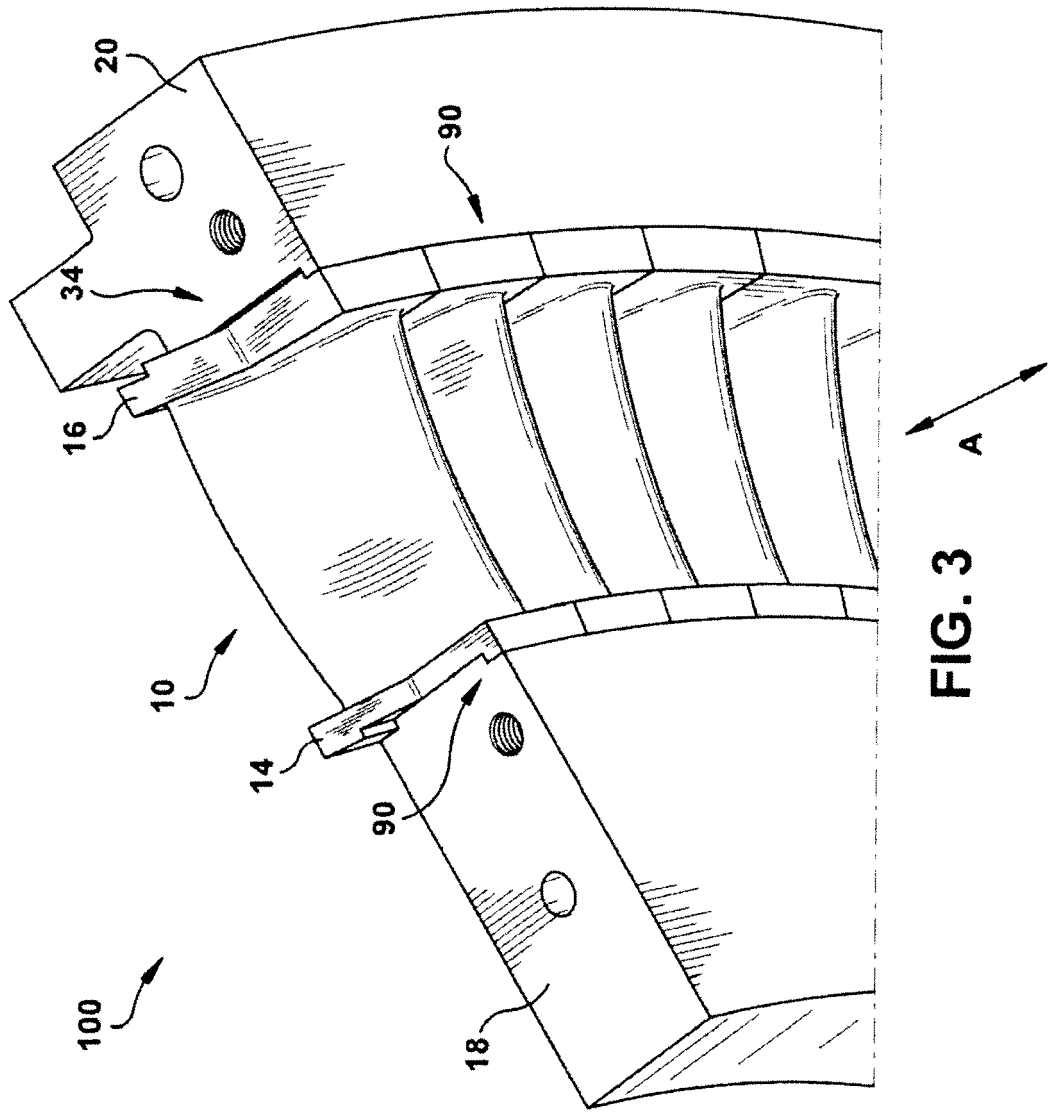


FIG. 3

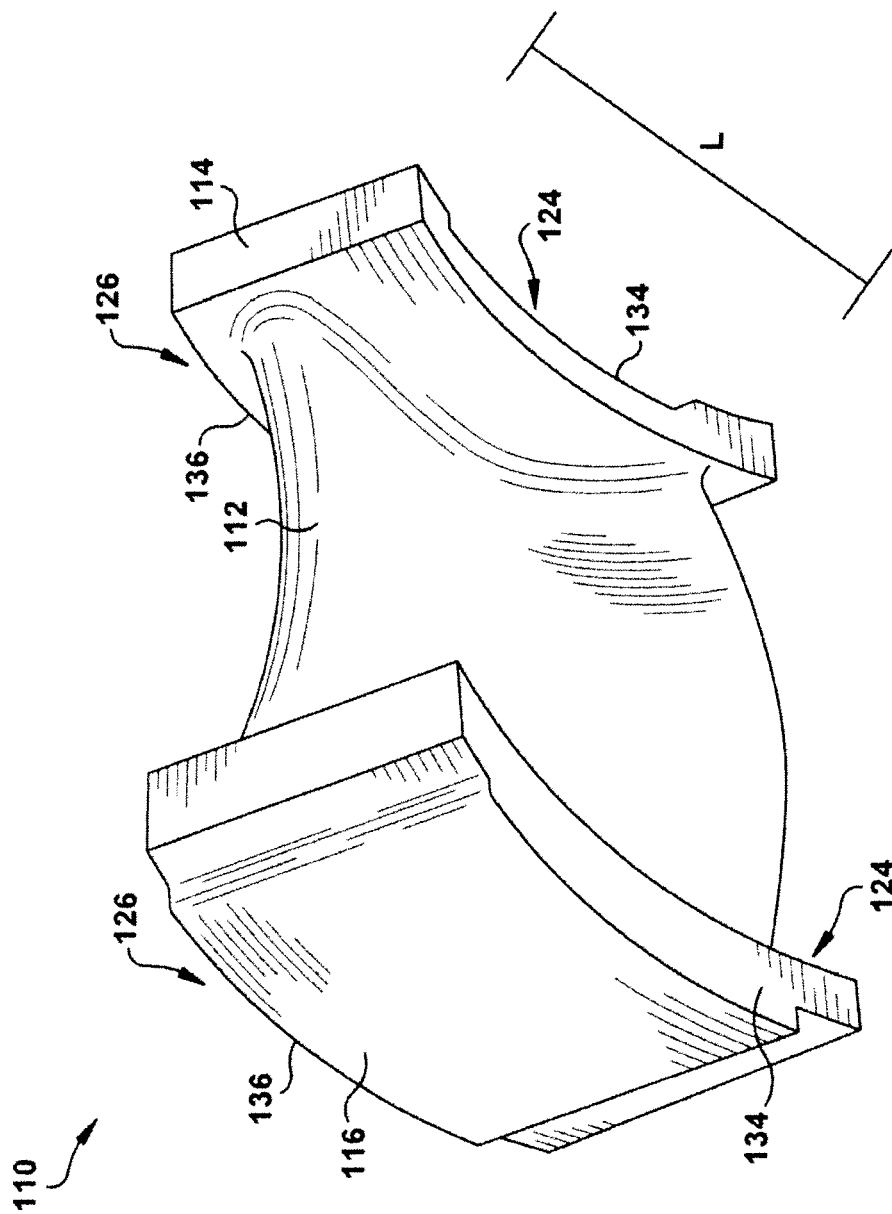


FIG. 4

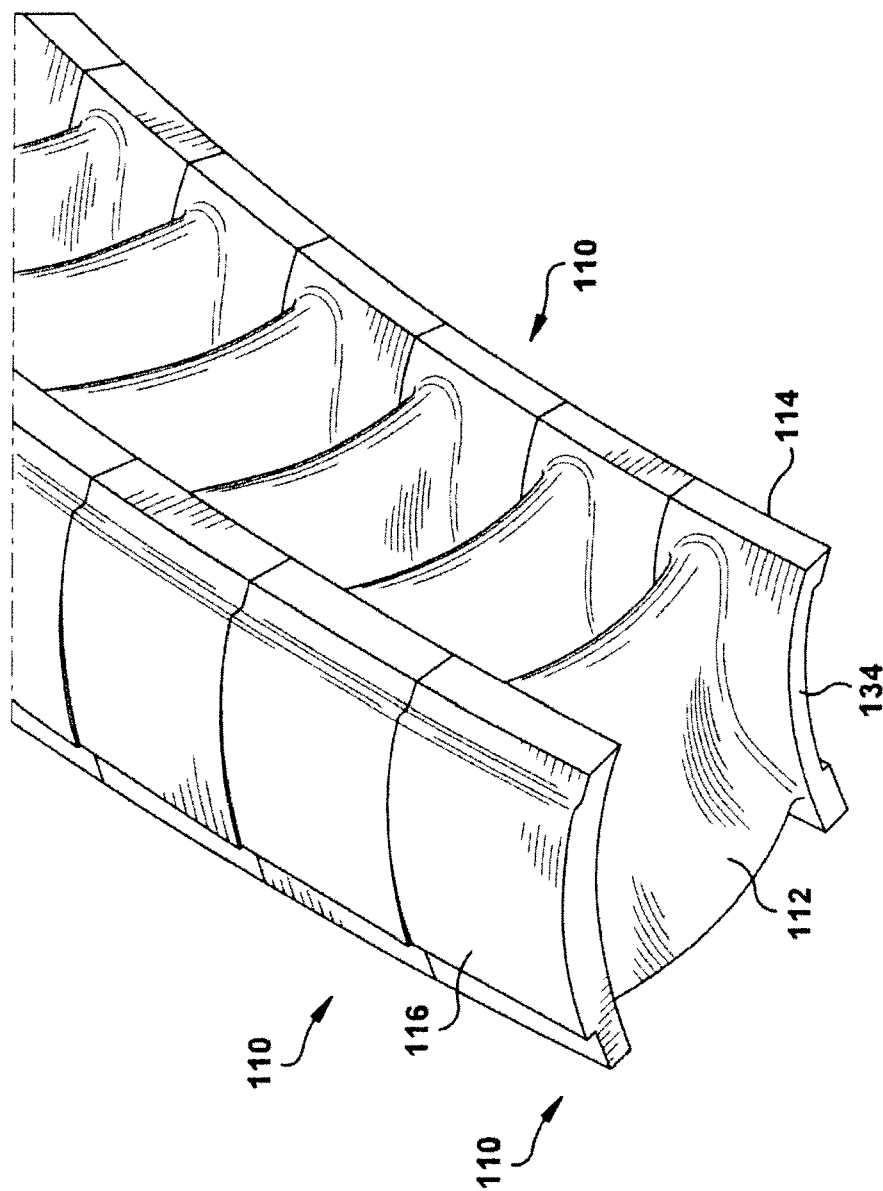


FIG. 5

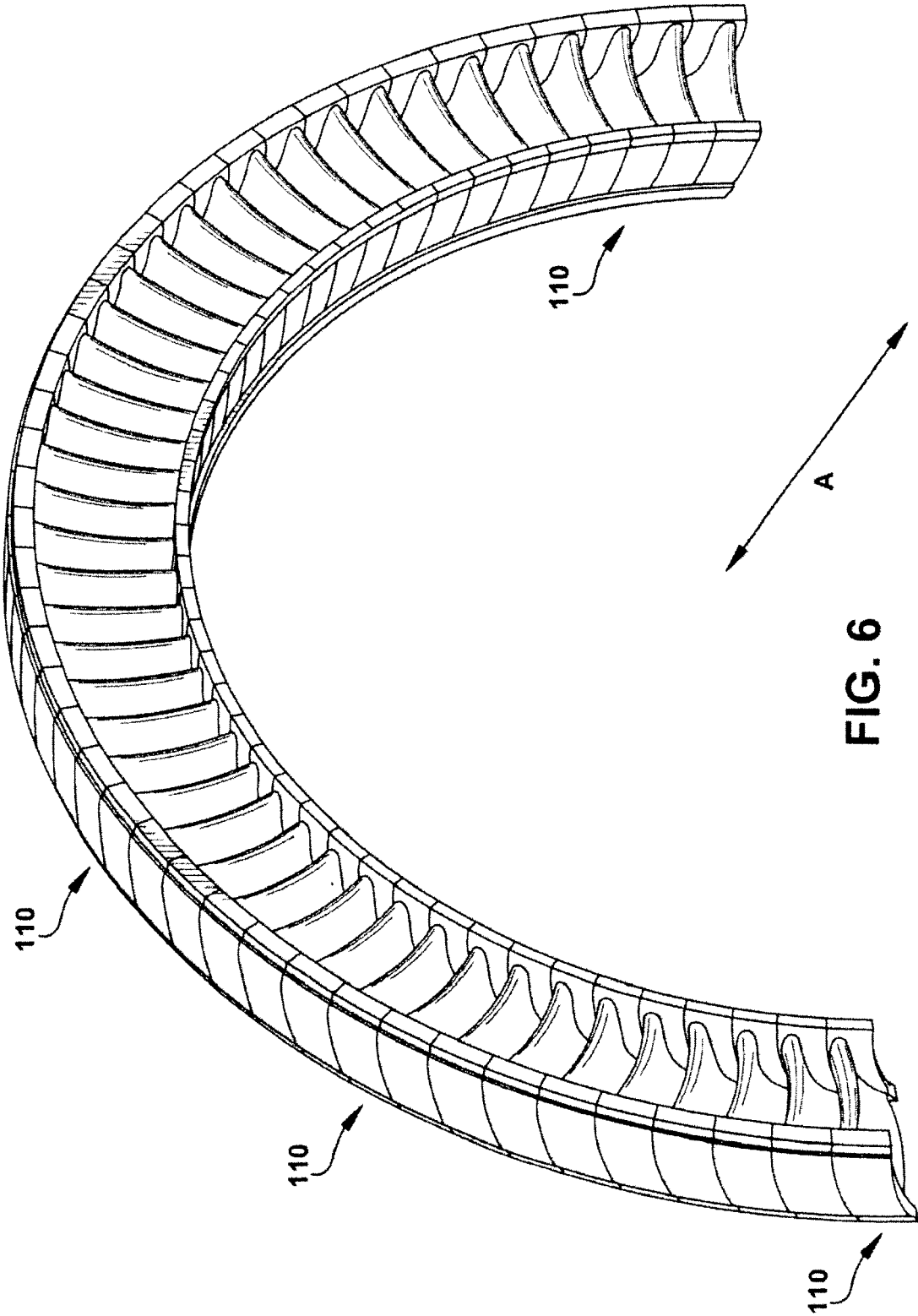


FIG. 6

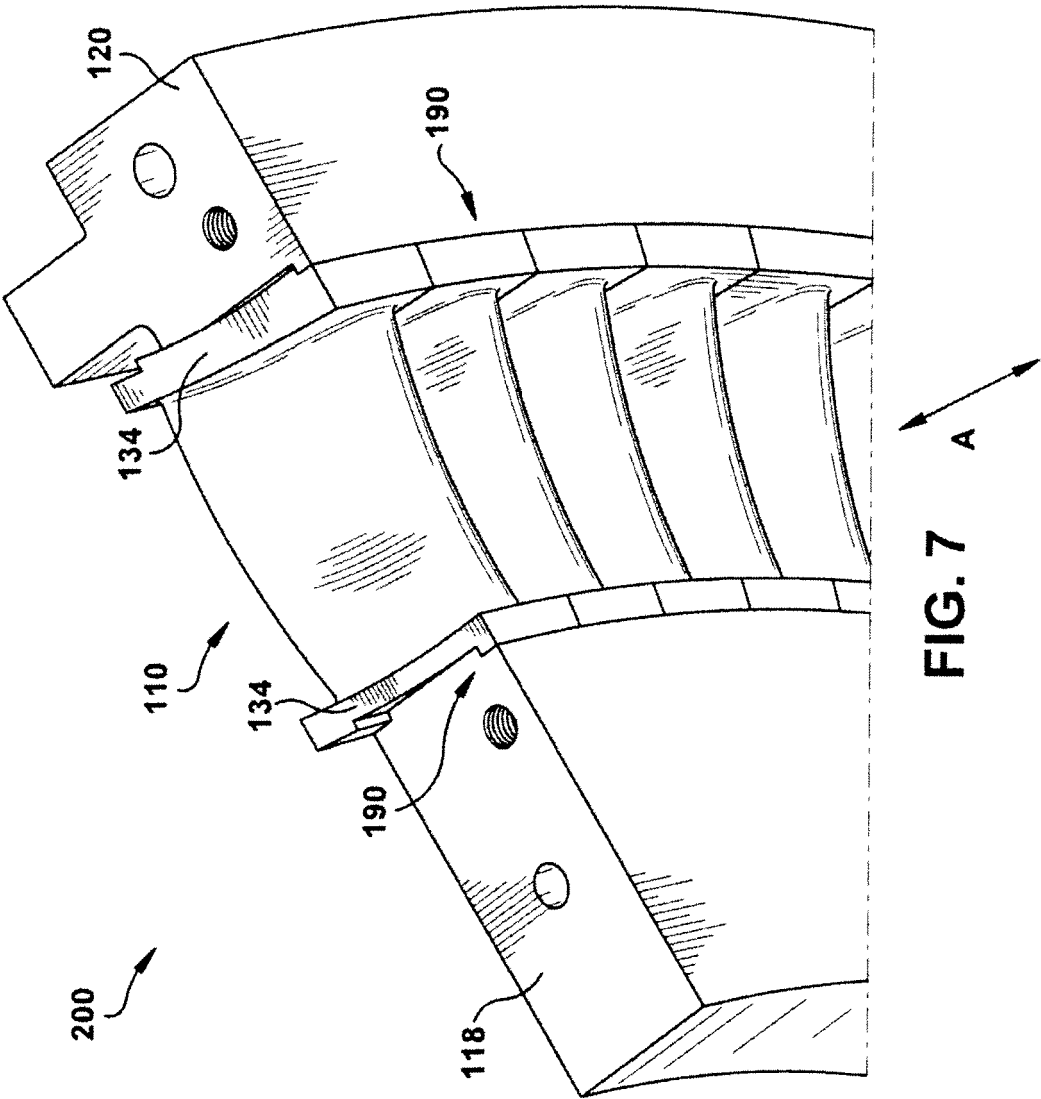


FIG. 7