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(54) TURBINE ASSEMBLY, TURBINE INNER WALL ASSEMBLY AND TURBINE ASSEMBLY METHOD

(57) A turbine assembly 10 includes a rotary component 12 rotatable about an axis of a turbine, a plurality of inner wall segments 16 coupled to the rotary component 12 circumferentially around the rotary component 12 and rotatable with the rotary component 12, a non-rotary component circumferentially surrounding the rotary component 12, a plurality of outer wall segments 20 coupled to the non-rotary component and facing the rotary component 12, and a plurality of nozzles 18 extending from each of the outer wall segments 20, each nozzle having a tip distal from the outer wall segment such that the tips 34 form a seal with the inner wall segments 16 at an inner flow path of the turbine. An inner wall assembly and a turbine assembly method are also disclosed.

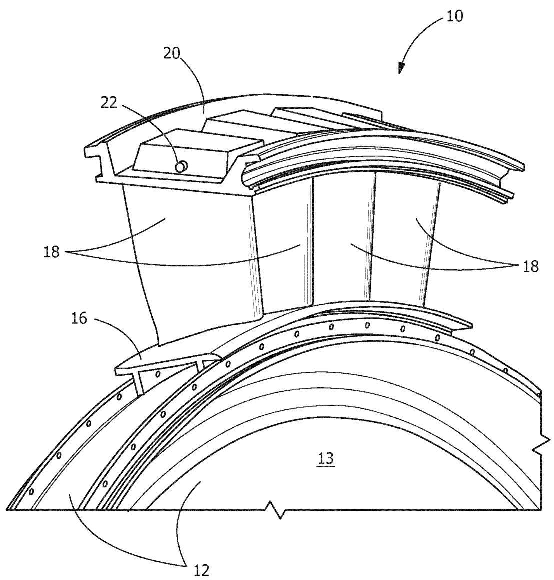

FIG. 1

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Description

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

[0001] This invention was made with Government support under contract number DE-FE0024006 awarded by the Department of Energy. The Government has certain rights in the invention.

FIELD OF THE INVENTION

[0002] The present embodiments are directed to turbine assemblies, turbine inner wall assemblies, and turbine assembly methods. More specifically, the present embodiments are directed to turbine inner wall assemblies with nozzles forming a seal with inner wall segments.

BACKGROUND OF THE INVENTION

[0003] A gas turbine generally includes a main flow path intended to confine a main working fluid therein, namely the hot combustion gases. Additionally, a cooling fluid that is independent of the main working fluid may be supplied to adjacent turbine rotor structural components. Sealing devices thus may be used to shield the rotor components from direct exposure to the main working fluid driving the turbine and to prevent the cooling fluid from escaping with the main working fluid. Typical sealing devices may reduce the efficiency and performance of a turbine due to leakage. For example, leakage in sealing devices, such as inter-stage seals, may require an increase in the amount of parasitic fluid needed for cooling purposes. The use of the parasitic cooling fluid decreases the overall performance and efficiency of a gas turbine engine.

[0004] A near-flow-path seal (NFPS) is a sealing device that is conventionally positioned about a nozzle and in between buckets of a turbine. A NFPS is typically intended to form an outer boundary for the flow of combustion gases, so as to prevent the flow of combustion gases from migrating therethrough.

[0005] Certain ceramic matrix composite (CMC) materials include compositions having a ceramic matrix reinforced with coated fibers. The composition provides strong, lightweight, and heat-resistant materials with possible applications in a variety of different systems.

[0006] The manufacture of a CMC part typically includes laying up pre-impregnated composite fibers having a matrix material already present (prepreg) to form the shape of the part (pre-form), autoclaving and burning out the pre-form, infiltrating the burned-out pre-form with the melting matrix material, and any machining or further treatments of the pre-form. Infiltrating the pre-form may include depositing the ceramic matrix out of a gas mixture, pyrolyzing a pre-ceramic polymer, chemically reacting elements, sintering, generally in the temperature range of 925 to 1650 °C (1700 to 3000 °F), or electrophoretically depositing a ceramic powder.

[0007] Examples of CMC materials include, but are not limited to, carbon-fiber-reinforced carbon (C/C), carbon-fiber-reinforced silicon carbide (C/SiC), silicon-carbide-fiber-reinforced silicon carbide (SiC/SiC), alumina-fiber-reinforced alumina (Al_2O_3/Al_2O_3), or combinations thereof. The CMC may have increased elongation, fracture toughness, thermal shock, dynamic load capability, and anisotropic properties as compared to a monolithic ceramic structure.

BRIEF DESCRIPTION OF THE INVENTION

[0008] In an embodiment, a turbine assembly includes a rotary component rotatable about an axis of a turbine, a plurality of inner wall segments coupled to the rotary component circumferentially around the rotary component and rotatable with the rotary component, a non-rotary component circumferentially surrounding the rotary component, a plurality of outer wall segments coupled to the non-rotary component and disposed to extend toward the rotary component, and a plurality of nozzles extending from each of the outer wall segments, each nozzle having a distal tip, the distal tips forming a seal with the inner wall segments at an inner flow path of the turbine.

[0009] In another embodiment, an inner wall assembly includes a rotary component rotatable about an axis of a turbine and a plurality of inner wall segments coupled to the rotary component circumferentially around the rotary component and rotatable with the rotary component.

[0010] In another embodiment, a turbine assembly method includes coupling a plurality of inner wall segments circumferentially to a rotary component and mounting a plurality of outer wall segments to a non-rotary component and disposed to extend toward the rotary component. A plurality of nozzles extend from each outer wall segment toward one of the plurality of inner wall segments. The nozzles form a seal with the inner wall segments at an inner flow path of the turbine.

[0011] Other features and advantages of the present invention will be apparent from the following more detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1 is a perspective view of a turbine assembly in an embodiment of the present disclosure.

FIG. 2 is a partial cross sectional perspective view of a turbine assembly in an embodiment of the present disclosure.

FIG. 3 is a partial cross sectional perspective view of the inner wall segment pinned to the rotary component of the turbine assembly of FIG. 1.

FIG. 4 is a partial cross sectional perspective view of an inner wall segment hooked to a near flow path seal segment of the rotary component of a turbine assembly in an embodiment of the present disclosure.

FIG. 5 is a partial cross sectional perspective view of an inner wall segment dovetailed to a near flow path seal segment of the rotary component of a turbine assembly in an embodiment of the present disclosure.

[0013] Wherever possible, the same reference numbers will be used throughout the drawings to represent the same parts.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Provided is a turbine assembly with composite turbine nozzles and integrated rotating end wall segments forming a seal with the nozzles.

[0015] Embodiments of the present disclosure, for example, in comparison to concepts failing to include one or more of the features disclosed herein, save cooling flow, increase efficiency, reduce loss due to gaps between a cantilevered airfoil, eliminate the need for separate near flow path seals (NFPSs), reduce the number of gaps at the inner flow path, reduce the amount of pull load, reduce the cooling flow needed, or combinations thereof.

[0016] FIG. 1 shows a turbine assembly 10 including a rotary component 12, an inner wall segment 16, a set of nozzles 18, and an outer wall segment 20. The rotary component 12 is rotatable about a central axis of the turbine. Although only one is shown in FIG. 1, the inner wall segments 16 are coupled circumferentially around and surround the rotary component 12 and are rotatable with the rotary component 12. Although only one is shown in FIG. 1, the outer wall segments 20 are mounted to a non-rotary component (not shown) circumferentially surrounding the rotary component and disposed to extend toward the rotary component 12. A set of nozzles 18 extend from the outer wall segment 20 toward the inner wall segment 16 and form a seal with the inner wall segment 16 at the inner flow path of the turbine. The nozzles 18 are attached by nozzle pins 22 to the outer wall segment 20 and extend in a cantilevered fashion therefrom. The rotary component 12 is a single piece that is a dedicated rotor wheel 13 that is free from physical attachment to either the upstream or the downstream bucket wheel.

[0017] FIG. 2 shows a turbine assembly 10 including a rotary component 12 including a rotor wheel 13 and a near flow path seal segment 14, an inner wall segment 16, a set of nozzles 18, and an outer wall segment 20. The rotary component 12 is rotatable about a central axis of the turbine. A plurality of the near flow path seal segments 14 are mounted circumferentially around the rotor wheel 13 and rotate with the rotor wheel 13. In some embodiments, the near flow path seal segments 14 are connected by a dovetail to the rotor wheel 13. The inner wall segments 16 are coupled to the near flow path seal segments 14 and are rotatable with the rotor wheel 13 and the near flow path seal segments 14. The outer wall segments 20 are mounted to a non-rotary component (not shown) circumferentially surrounding the rotary component and disposed to extend toward the rotary component 12. A set of nozzles 18 extend from each outer wall segment 20 toward the inner wall segment 16 and form a seal with the inner wall segment 16 at the inner flow path of the turbine. The nozzles 18 are attached by nozzle pins 22 to the outer wall segment 20 and extend in a cantilevered fashion. An end of a near flow path seal segment 14 is visible in FIG. 2.

[0018] Different attachment designs between the inner wall segments 16 defining the rotating flow path and the rotary component 12 may be used. FIG. 3 shows a perspective partial cross sectional view of the coupling of the inner wall segment 16 to the rotary component 12 of the embodiment of FIG. 1. The rotary component 12 includes a rotary coupler 30. In this embodiment, the rotary coupler 30 includes a pair of outwardly-extending mounting flanges. In addition to an upper surface 32 forming a seal with the tips 34 of the nozzles 18, the inner wall segment 16 includes an inner wall coupler 36 complementary to the rotary coupler 30. In this embodiment, the inner wall coupler 36 includes a pair of wall flanges extending from the lower surface of the inner wall segment 16 to sit adjacent to the outwardly-extending mounting flanges of the rotary component 12. The inner wall segments 16 are fastened to the rotary component 12 by way of wall pins 38 extending into holes in the outwardly-extending mounting flanges and holes in the wall flanges to mount the inner wall segments 16 to the rotary component 12.

[0019] FIG. 4 shows a coupling of the inner wall segment 16 to the near flow path seal segment 14 of the rotary component 12. The rotary coupler 30 includes a pair of axially-extending mounting flanges. The inner wall coupler 36 includes a pair of L-shaped flanges extending from the lower surface of the inner wall segment 16 to engage the axially-extending mounting flanges of the near flow path seal segment 14 of the rotary component 12 that serve as a hook to connect the near flow path seal segment 14 to the inner wall segment 16, thereby mounting the inner wall segment 16 to the near flow path seal segment 14 of the rotary component 12.

[0020] FIG. 5 shows another alternate coupling of the inner wall segment 16 to the near flow path seal segment 14 of the rotary component 12. The rotary coupler 30 includes an outwardly-extending tenon of a dovetail. The inner wall coupler 36 includes a mortise between two extensions from the lower surface of the inner wall segment 16 to engage the outwardly-extending tenon of the near flow path seal segment 14 of the rotary component 12, thereby mounting the inner wall segment 16 to the near flow path seal segment 14 of the rotary component 12. Alternatively, the tenon may be formed by the inner wall segment 16 and the mortise may be formed by the near flow path seal segment 14 of the rotary component 12 to achieve the dovetail coupling.

[0021] The pinning, hooking, and dovetailing couplings may be used with either a singular rotary component 12 or with a rotary component 12 including near flow path seal segments 14. In embodiments where pinning attaches the inner wall segments 16 to the rotary component 12, the rotary couplers 30 may continue around the entire circumference without a gap. In hooking or dovetailing embodiments, however, some sort of gap is needed to allow the inner wall couplers 36 to engage the rotary coupler 30. With either a single rotary component 12 or a rotary component 12 including near flow path seal segments 14, the gap may be included in the rotary coupler 30 at a location around the rotary component 12 permitting the inner wall coupler 36 to slidingly engage the rotary couplers 30, thereby coupling the inner wall segment 16 to the rotary component 12. In the case of a rotary component 12 including near flow path seal segments 14, however, the inner wall segments 16 may alternatively be coupled to the near flow path seal segments 14 without a gap in the rotary couplers 30 if the inner wall segments 16 are first coupled to the near flow path seal segments 14 and then the near flow path seal segments 14 are attached to the rotor wheel 13 and there is a gap allowing coupling of the near flow path seal segments 14 to the rotor wheel 13.

[0022] In some embodiments, the composite turbine nozzle assembly includes an outer wall segment 20 as a one-piece segment of an outer side wall to support multiple nozzles 18 as singlet cantilevered composite airfoils. The number of nozzles 18 supported by each one-piece outer wall segment 20 may be two, alternatively at least two, alternatively in the range of two to six, alternatively four, alternatively at least four, alternatively six, alternatively at least six, or any number, range, or sub-range therebetween. The airfoils are attached only to the outer wall segments 20, leaving a small gap between the tip 34 and the inner flow path defined by the upper surface 32 of the inner wall segment 16.

[0023] In some embodiments, the inner wall segments 16 have an arc length greater than the nozzle pitch of the nozzles 18. In some embodiments, the arc length of the inner wall segments 16 is similar to the arc length of the outer wall segments 20. The number of nozzles 18 sealing with each one-piece inner wall segment 16 may be two, alternatively at least two, alternatively in the range of two to six, alternatively four, alternatively at least four, alternatively six, alternatively at least six, or any number, range, or sub-range therebetween.

[0024] In some embodiments, the rotary component 12 is the rotating rotor wheel 13. In such embodiments, each inner wall segment 16 may be made as a one-piece inner flow path segment and may be attached to the rotor wheel 13 directly. In other embodiments, the rotary component 12 includes a plurality of near flow path seal segments 14 attached to the rotor wheel 13. In such embodiments, the inner wall segment 16 is indirectly attached to the rotor wheel 13, the inner wall segment 16 being attached to a near flow path seal segment 14, which is attached to the rotor wheel 13. In either case, the inner wall segments 16 are coupled to the rotary component 12. In some embodiments, the inner wall segment 16 is pinned to the rotary component 12. In other embodiments, the inner wall segment 16 is hooked to the rotary component 12. In other embodiments, the inner wall segment 16 is dovetailed to the rotary component 12.

[0025] Making the outer wall segments 20 and the inner wall segments 16 longer reduces the number of the intersegment seals needed, thereby saving the cooling flow.

[0026] A preferred design accommodates nozzles 18 that are high-temperature composite airfoils that tolerate higher temperatures with less cooling flow needed, thereby increasing the efficiency of the turbine.

[0027] The rotating inner flow path defined by the inner wall segment 16 eliminates the need for separate NFPSs, thereby saving cooling flow and increasing efficiency. The rotating inner flow path defined by the inner wall segment 16 also reduces the efficiency loss caused by a gap between the cantilevered airfoil and the inner flow path.

[0028] In some embodiments, the inner wall segments 16 defining the rotating inner flow path are made of lightweight high-temperature ceramic matrix composite (CMC) materials, thereby reducing the pull load and the cooling flow needed.

[0029] In some embodiments, the inner wall segments 16 are effectively pinned to the rotating rotary component 12 due to the relative light weight of the CMC material.

[0030] In some embodiments, the nozzles 18 are made of lightweight high-temperature ceramic matrix composite (CMC) materials, thereby reducing the cooling flow needed.

[0031] In some embodiments, the length of the inner wall segments 16 is greater than one nozzle 18 or blade pitch, which reduces the number of segment gaps to seal.

[0032] In some embodiments, the inner wall segments 16 defining the CMC inner flow path are attached to a dedicated rotor wheel 13, which is free from physical attachment to either the upstream or the downstream bucket wheel.

[0033] In some embodiments, a bayonet-style design includes a one-piece outer wall segment 20 and multiple cantilevered CMC airfoils for a stage-2 nozzle 18 of a turbine. An outer wall segment 20 accommodates two cantilevered CMC airfoils as nozzles 18, alternatively at least two cantilevered CMC airfoils, alternatively in the range of two to six cantilevered CMC airfoils, alternatively four cantilevered CMC airfoils, alternatively at least four cantilevered CMC airfoils, alternatively six cantilevered CMC airfoils, alternatively at least six cantilevered CMC airfoils, or any number, range, or sub-range therebetween.

[0034] In some embodiments, a lightweight, high-temperature CMC material of an inner wall segment 16 defining a rotating inner flow path minimizes the pull load and cooling flow needed. The lightweight material permits a pinned attachment of the inner wall segment 16 to the rotary component 12, which may be a rotating rotor wheel 13. The length of the inner wall segments 16 may be greater than one nozzle 18 or blade pitch, which reduces the number of segment gaps to seal. The inner wall segments 16 are preferably attached to a dedicated rotor wheel 13 and not to the upstream or downstream bucket wheels.

[0035] While the invention has been described with reference to one or more embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims. In addition, all numerical values identified in the detailed description shall be interpreted as though the precise and approximate values are both expressly identified.

[0036] Various aspects and embodiments of the present invention are defined by the following numbered clauses:

1. A turbine assembly comprising:

   a rotary component rotatable about an axis of a turbine;

   a plurality of inner wall segments coupled to the rotary component circumferentially around the rotary component and rotatable with the rotary component;

   a non-rotary component circumferentially surrounding the rotary component;

   a plurality of outer wall segments coupled to the non-rotary component and disposed to extend toward the rotary component; and

   a plurality of nozzles extending from each of the plurality of outer wall segments, each of the plurality of nozzles having a distal tip, the distal tips forming a seal with the plurality of inner wall segments at an inner flow path of the turbine.

2. The turbine assembly of clause 1, wherein the rotary component comprises a rotor wheel and a plurality of near flow path seal segments mounted circumferentially around the rotor wheel and rotatable with the rotor wheel, wherein the plurality of inner wall segments are coupled to the plurality of near flow path seal segments of the rotary component.

3. The turbine assembly of any preceding clause, further comprising a plurality of wall pins, wherein each of the plurality of wall pins extends into one of a plurality of pin holes on each of the plurality of inner wall segments and on the rotary component to couple each of the plurality of inner wall segments to the rotary component.

4. The turbine assembly of any preceding clause, wherein each of the plurality of inner wall segments is connected by a hook to the rotary component to couple each of the plurality of inner wall segments to the rotary component.

5. The turbine assembly of any preceding clause, wherein each of the plurality of inner wall segments is connected by a dovetail to the rotary component to couple each of the plurality of inner wall segments to the rotary component.

6. The turbine assembly of any preceding clause, wherein the rotary component comprises a dedicated rotor wheel free from physical attachment to an upstream bucket wheel or a downstream bucket wheel.

7. The turbine assembly of any preceding clause, wherein the plurality of inner wall segments and the plurality of nozzles comprise a ceramic matrix composite material.

8. The turbine assembly of any preceding clause, wherein each of the plurality of inner wall segments has a segment arc length greater than a nozzle pitch for the plurality of nozzles.

9. An inner wall assembly comprising:

   a rotary component rotatable about an axis of a turbine; and

   a plurality of inner wall segments coupled to the rotary component circumferentially around the rotary component and rotatable with the rotary component.

10. The inner wall assembly of any preceding clause, wherein the rotary component comprises a rotor wheel and a plurality of near flow path seal segments mounted circumferentially around the rotor wheel and rotatable with the rotor wheel, wherein the plu-

rality of inner wall segments are coupled to the plurality of near flow path seal segments of the rotary component.

11. The inner wall assembly of any preceding clause, further comprising a plurality of wall pins, wherein each of the plurality of wall pins extends into one of a plurality of pin holes on each of the plurality of inner wall segments and on the rotary component to couple each of the plurality of inner wall segments to the rotary component.

12. The inner wall assembly of any preceding clause, wherein each of the plurality of inner wall segments is connected by a hook to the rotary component to couple each of the plurality of inner wall segments to the rotary component.

13. The inner wall assembly of any preceding clause, wherein each of the plurality of inner wall segments is connected by a dovetail to the rotary component to couple each of the plurality of inner wall segments to the rotary component.

14. The inner wall assembly of any preceding clause, wherein the rotary component comprises a dedicated rotor wheel free from physical attachment to an upstream bucket wheel or a downstream bucket wheel.

15. The inner wall assembly of any preceding clause, wherein the plurality of inner wall segments comprise a ceramic matrix composite material.

16. A turbine assembly method comprising:

coupling a plurality of inner wall segments circumferentially to a rotary component; and

mounting a plurality of outer wall segments to a non-rotary component and disposed to extend toward the rotary component, wherein a plurality of nozzles extend from each of the plurality of outer wall segments toward one of the plurality of inner wall segments;

wherein the plurality of nozzles form a seal with the plurality of inner wall segments at an inner flow path of the turbine.

17. The method of any preceding clause, wherein coupling the plurality of inner wall segments to the rotary component comprises inserting each of a plurality of wall pins into one of a plurality of pin holes on each of the plurality of inner wall segments and on the rotary component.

18. The method of any preceding clause, wherein coupling the plurality of inner wall segments to the rotary component comprises connecting the plurality of inner wall segments to the rotary component by a hook.

19. The method of any preceding clause, wherein coupling the plurality of inner wall segments to the rotary component comprises connecting the plurality inner wall segments to the rotary component by a dovetail.

20. The method of any preceding clause, further comprising mounting a plurality of near flow path seal segments to a rotor wheel circumferentially around the rotor wheel to form the rotary component.

Claims

1. A turbine assembly (10) comprising:

a rotary component (12) rotatable about an axis of a turbine;
a plurality of inner wall segments (16) coupled to the rotary component (12) circumferentially around the rotary component (12) and rotatable with the rotary component (12);
a non-rotary component circumferentially surrounding the rotary component (12);
a plurality of outer wall segments (20) coupled to the non-rotary component and disposed to extend toward the rotary component (12); and
a plurality of nozzles (18) extending from each of the plurality of outer wall segments (20), each of the plurality of nozzles having a distal tip, the distal tips forming a seal with the plurality of inner wall segments (16) at an inner flow path of the turbine.

2. The turbine assembly (10) of claim 1, wherein the rotary component (12) comprises a rotor wheel (13) and a plurality of near flow path seal segments (14) mounted circumferentially around the rotor wheel (13) and rotatable with the rotor wheel (13), wherein the plurality of inner wall segments (16) are coupled to the plurality of near flow path seal segments (14) of the rotary component (12).

3. The turbine assembly (10) of claim 1, wherein the rotary component (12) comprises a dedicated rotor wheel (13) free from physical attachment to an upstream bucket wheel or a downstream bucket wheel.

4. The turbine assembly (10) of claim 1, 2 or 3, wherein the plurality of inner wall segments (16) and the plurality of nozzles (18) comprise a ceramic matrix composite material.

5. The turbine assembly (10) of any of claims 1 to 4, wherein each of the plurality of inner wall segments has a segment arc length greater than a nozzle pitch for the plurality of nozzles (18).

6. An inner wall assembly comprising:

a rotary component (12) rotatable about an axis of a turbine; and
a plurality of inner wall segments (16) coupled to the rotary component (12) circumferentially around the rotary component (12) and rotatable with the rotary component (12).

7. The inner wall assembly of claim 6 further comprising a plurality of wall pins (38), wherein each of the plurality of wall pins (38) extends into one of a plurality of pin holes on the plurality of inner wall segments (16) and on the rotary component (12) to couple each of the plurality of inner wall segments (16) to the rotary component (12).

8. The inner wall assembly of claim 6 or 7, wherein each of the plurality of inner wall segments (16) is connected by a hook to the rotary component (12) to couple each of the plurality of inner wall segments (16) to the rotary component (12).

9. The inner wall assembly of claim 6 or 7, wherein each of the plurality of inner wall segments (16) is connected by a dovetail to the rotary component (12) to couple each of the plurality of inner wall segments (16) to the rotary component (12).

10. A turbine assembly (10) method comprising:

coupling a plurality of inner wall segments (16) circumferentially to a rotary component (12); and
mounting a plurality of outer wall segments (20) to a non-rotary component and disposed to extend toward the rotary component (12), wherein a plurality of nozzles (18) extend from each of the plurality of outer wall segments toward one of the plurality of inner wall segments (16);
wherein the plurality of nozzles (18) form a seal with the plurality of inner wall segments (16) at an inner flow path of the turbine.

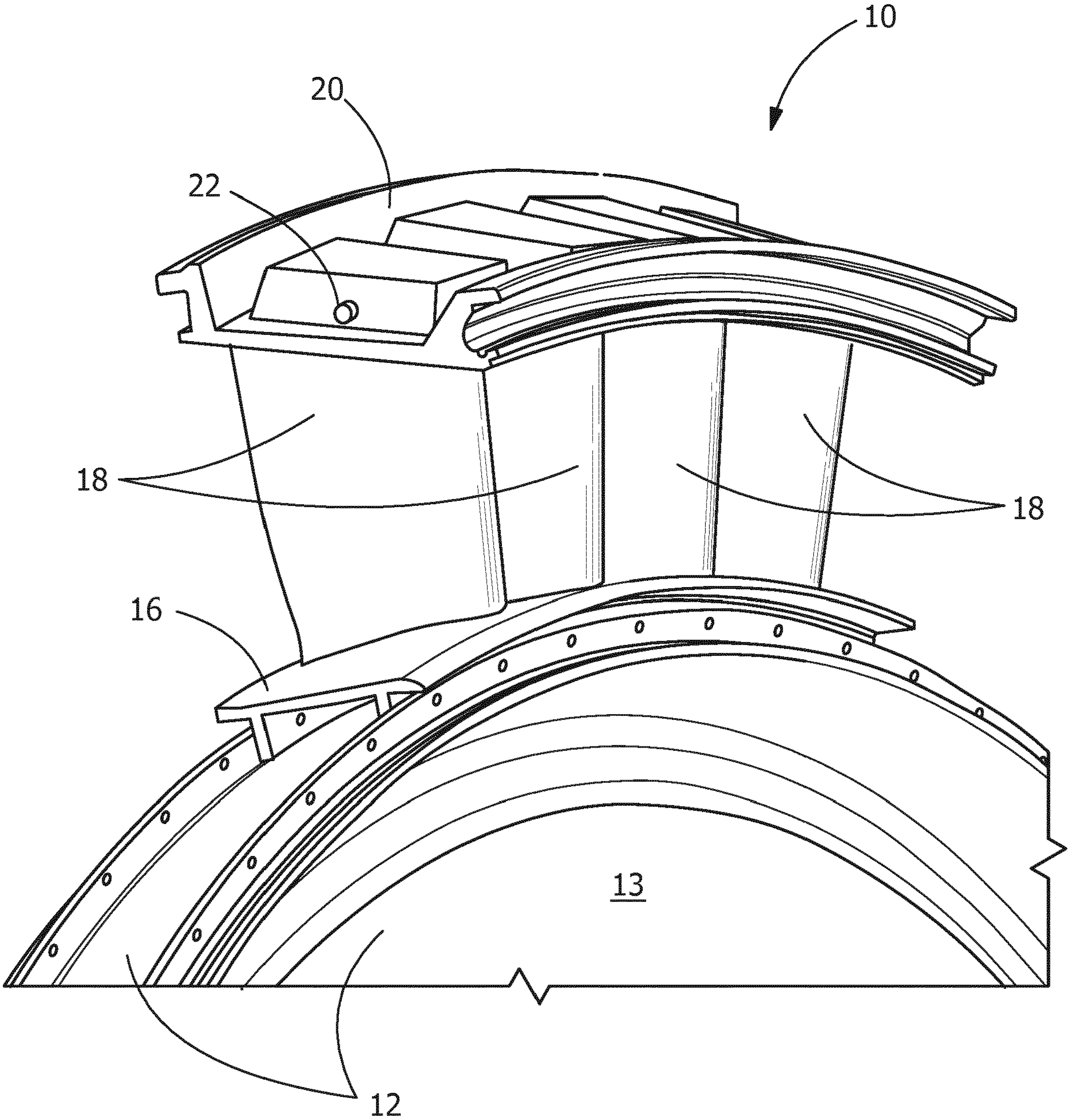

FIG. 1

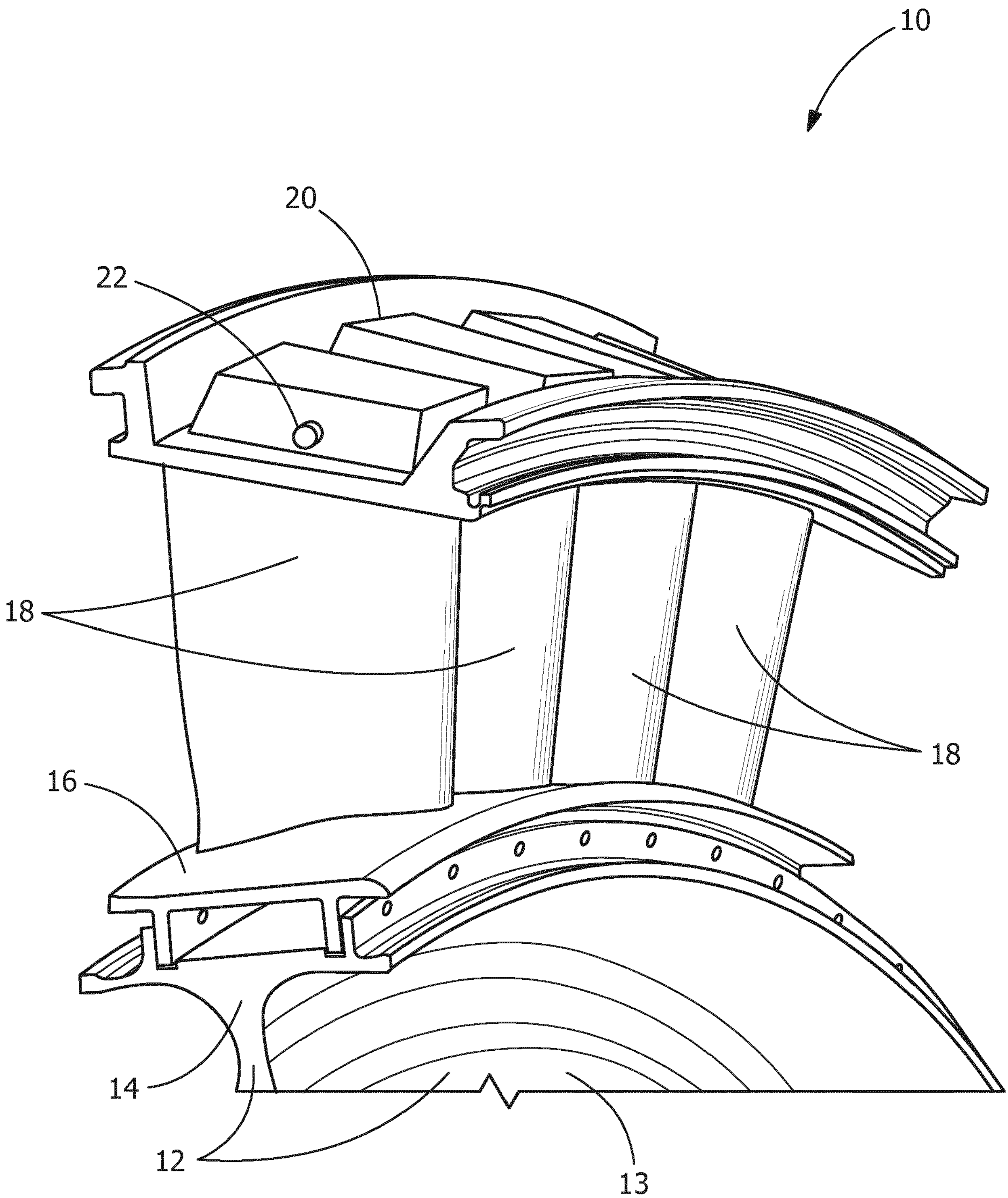

FIG. 2

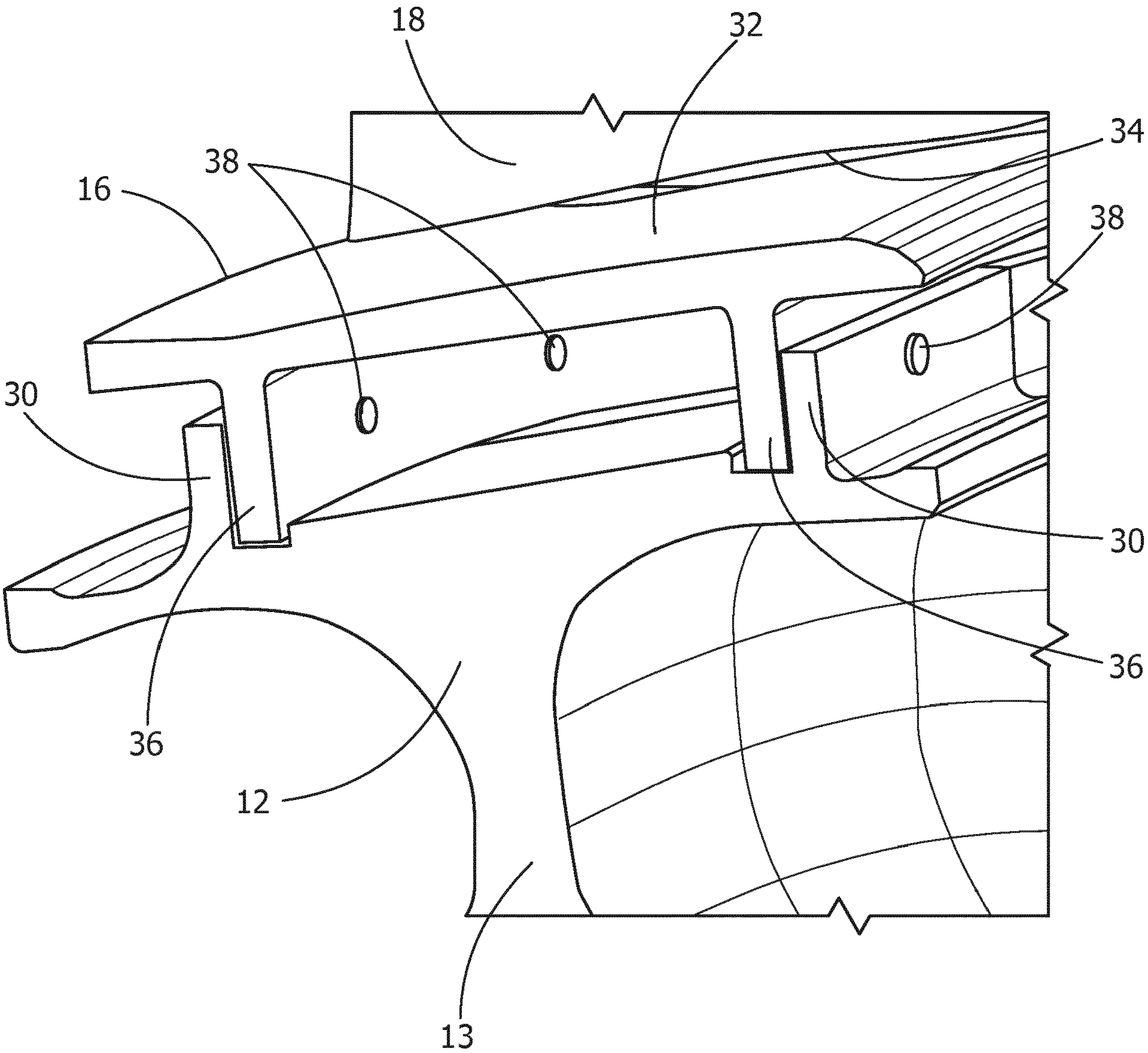

FIG. 3

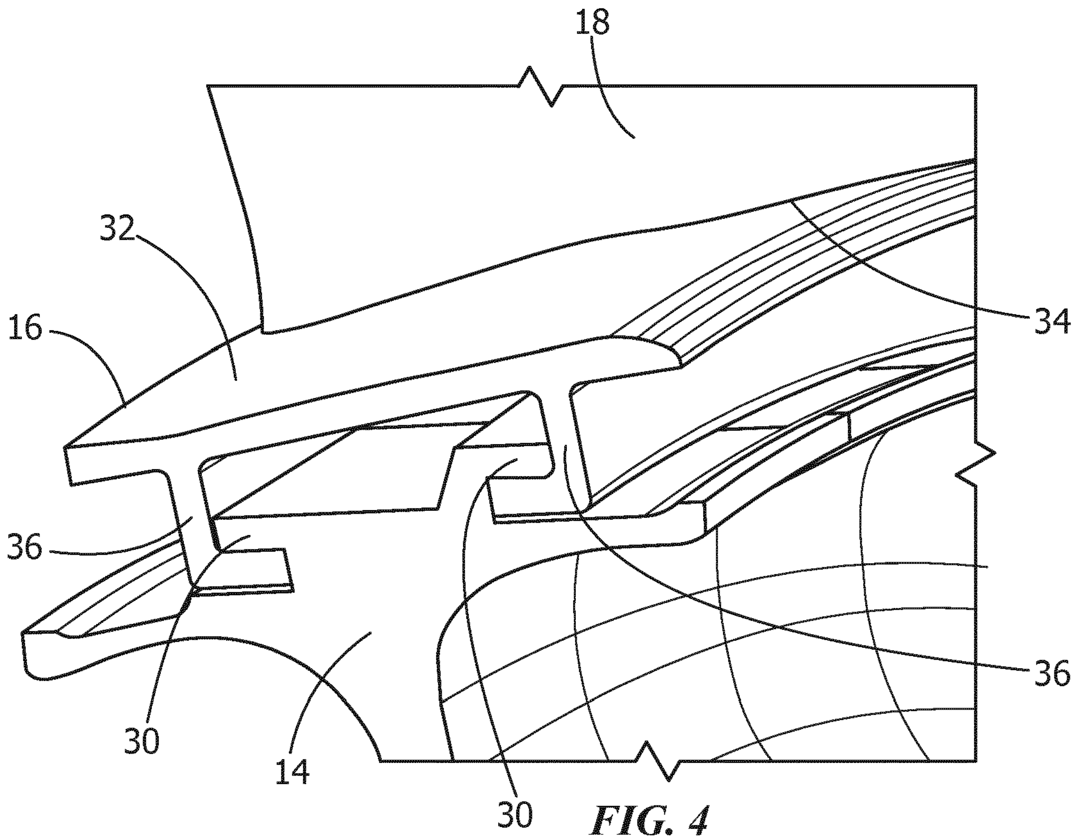

FIG. 4

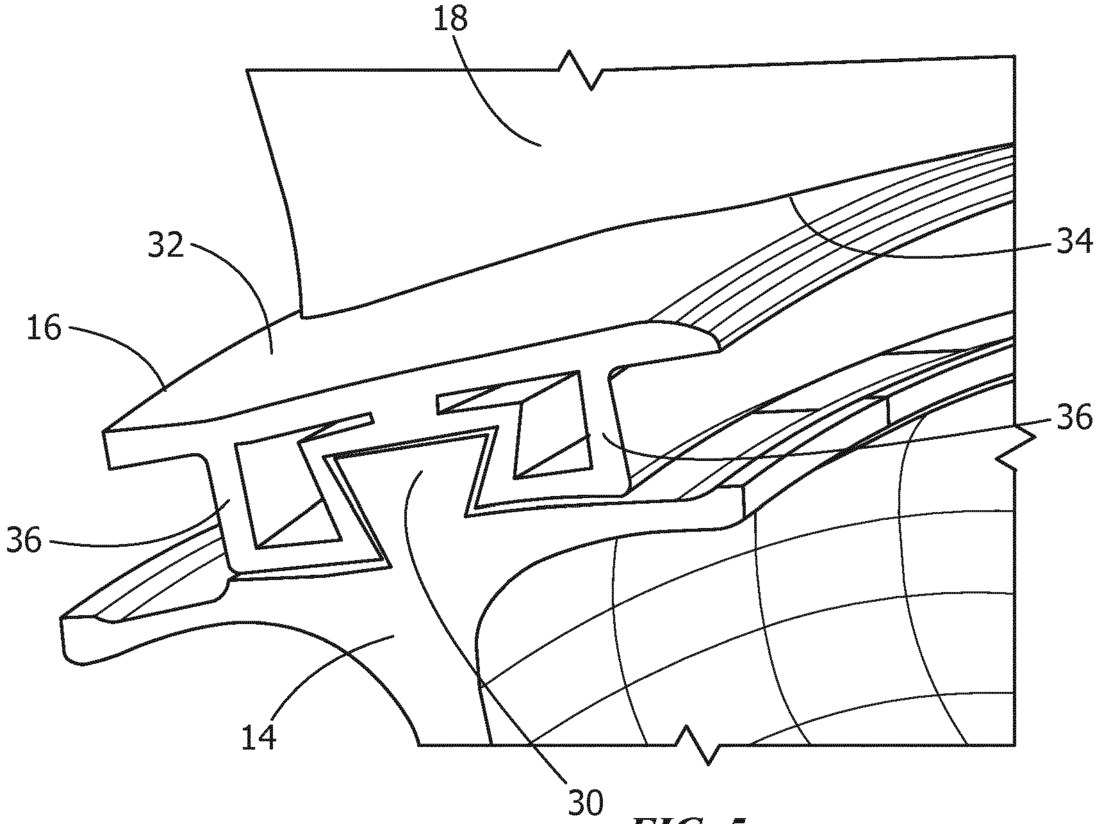

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 17 16 9742

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 Y	EP 2 208 860 A2 (GEN ELECTRIC [US]) 21 July 2010 (2010-07-21) * paragraphs [0017] - [0019]; figure 2 *	1-3,6,9, 10 4	INV. F01D11/00
Y	EP 2 784 269 A1 (ROLLS ROYCE PLC [GB]) 1 October 2014 (2014-10-01) * paragraphs [0034] - [0037]; figures 2-4 *	4	
Y	WO 2014/107217 A1 (GEN ELECTRIC [US]) 10 July 2014 (2014-07-10) * claim 5 *	4	
X	GB 706 730 A (VICKERS ELECTRICAL CO LTD) 7 April 1954 (1954-04-07) * page 2, lines 97-105; figures 1,2 *	1-3,6,9, 10	
X	EP 2 884 051 A1 (SIEMENS AG [DE]) 17 June 2015 (2015-06-17) * paragraphs [0047], [0048]; figures 3,4,6 *	1,2,5-7, 10	TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	10 October 2017	Teusch, Reinhold

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 16 9742

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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10-10-2017

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