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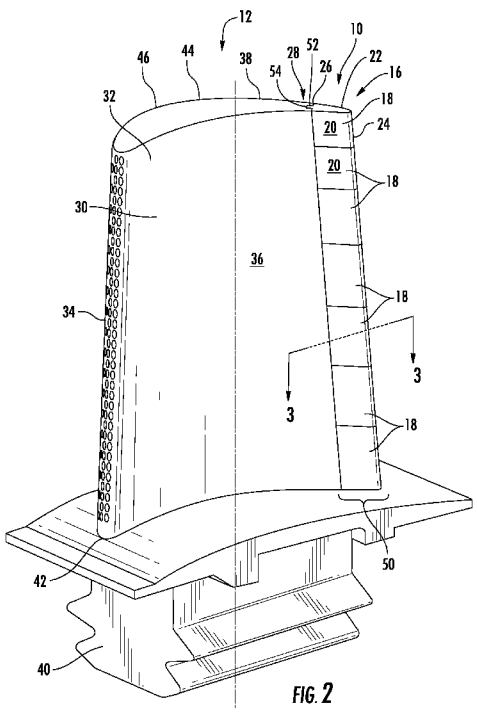


FIG. 2

(57) Abstract: A trailing edge insert (10) for a turbine airfoil (12) of a gas turbine engine (14) usable to increase the durability of the airfoil (12) and to reduce the thickness of the trailing edge, thereby reducing aerodynamic loss, increasing turbine efficiency, engine efficiency, and combined cycle efficiency is disclosed. The trailing edge insert (10) may be formed from a trailing edge body (16) formed from a plurality of trailing edge segments (18). Each trailing edge segment (18) may be formed from a pressure side (20), a suction side (22), a trailing edge (24) and an airfoil attachment side (26) and may include a trailing edge body connection system (28) enabling the trailing edge segments (18) to be attached to the generally elongated hollow airfoil (30). The trailing edge insert (10) may be formed from a different material than the material used to form the airfoil (30), such as, but not limited to ceramic matrix composite to increase the durability of the trailing edge.

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TRAILING EDGE INSERT FOR AN AIRFOIL WITHIN A GAS TURBINE ENGINE

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Development of this invention was supported in part by the United States Department of Energy, Advanced Turbine Development Program, Contract No. DE-FC26-05NT42644. Accordingly, the United States Government may have certain rights in this invention.

FIELD OF THE INVENTION

This invention is directed generally to airfoils usable in turbine engines, and more particularly to trailing edge inserts for airfoils usable in gas turbine engines.

BACKGROUND

Typically, gas turbine engines include a compressor for compressing air, a combustor for mixing the compressed air with fuel and igniting the mixture, and a turbine blade assembly for producing power. Combustors often operate at high temperatures that may exceed 2,500 degrees Fahrenheit. Typical turbine combustor configurations expose turbine vane and blade assemblies, to these high temperatures. As a result, turbine airfoils, such as turbine vanes and blades must be made of materials capable of withstanding such high temperatures. In addition, turbine airfoils often contain internal cooling systems for prolonging the life of the airfoils and reducing the likelihood of failure as a result of excessive temperatures.

Typically, turbine airfoils are ordinarily composed of a leading edge, a trailing edge, a suction side, and a pressure side. The inner aspects of most turbine airfoils typically contain an intricate maze of cooling circuits forming a cooling system. The cooling circuits in the airfoils receive air from the compressor of the turbine engine and pass the air through the ends of the airfoil. The cooling circuits often include multiple flow paths that are designed to remove heat from the turbine airfoil. At least some of the air passing through these cooling circuits is exhausted through orifices in the leading edge, trailing edge, suction side, and pressure side of the airfoil. While airfoils are cooled with intricate internal cooling systems, aspects of the airfoil are

susceptible to the formation of localized hot spots due to exposure within the hot gas path and insufficient cooling. Because of the high temperature environment in which the turbine airfoils are positioned, the trailing edges of the airfoils typically have a thick profile to prevent damage from thermal stress. However, the thick profile at the trailing edge negatively impacts aerodynamics of an airfoil, turbine efficiency, engine efficiency, and combined cycle efficiency. Thus, a need exists for an airfoil with enhanced thermal capacity to form a more durable airfoil with a more efficient trailing edge.

SUMMARY OF THE INVENTION

A trailing edge insert for a turbine airfoil of a gas turbine engine usable to increase the durability of the airfoil and to reduce the thickness of the trailing edge, thereby reducing aerodynamic loss, increasing turbine efficiency, engine efficiency, and combined cycle efficiency is disclosed. The trailing edge insert may be formed from a trailing edge body formed from a plurality of trailing edge segments. Each trailing edge segment may be formed from a pressure side, a suction side, a trailing edge and an airfoil attachment side and may include a trailing edge body connection system enabling the trailing edge segments to be attached to the generally elongated hollow airfoil. The trailing edge insert may be formed from a different material than the material used to form the airfoil, such as, but not limited to, a ceramic matrix composite (CMC), to increase the durability of the trailing edge. The use of trailing edge segments enables the trailing edge body to be used on curved trailing edges of turbine airfoils. The segmented trailing edge body prevents thermal mismatch from causing thermal stresses in the individual segments of the trailing edge body and in the turbine airfoil itself. The trailing edge insert may be formed from a material that will not melt or otherwise be compromised during use in a turbine engine, yet enable the trailing edge insert to be formed with a reduced thickness relative to conventional systems to reduce aerodynamic loss, increasing turbine efficiency, engine efficiency, and combined cycle efficiency.

In at least one embodiment, the turbine airfoil may be formed from a generally elongated hollow airfoil formed from an outer wall, and having a leading edge, a pressure side, a suction side, a root at a first end of the airfoil and a tip at a second

end opposite to the first end. The turbine airfoil may also include a cooling system positioned within interior aspects of the generally elongated hollow airfoil, wherein the generally elongated hollow airfoil is formed from a first material. The turbine airfoil may include a trailing edge body formed from a plurality of trailing edge segments, whereby each trailing edge segment is formed from a pressure side, a suction side, a trailing edge and an airfoil attachment side and includes a trailing edge body connection system enabling the trailing edge segments to be attached to the generally elongated hollow airfoil. The trailing edge body may be formed from a second material that differs from the first material and has higher heat tolerance than the first material. In at least one embodiment, the trailing edge body may be formed from, but is not limited to being, a ceramic matrix composite.

In at least one embodiment, the trailing edge body connection system attaching the airfoil attachment side of the trailing edge body to the trailing edge region of the generally elongated hollow airfoil may be formed from a key extending from the trailing edge body into a keyway within the trailing edge region of the generally elongated hollow airfoil. One or more restraining pins may extend from a portion of the generally elongated hollow airfoil forming the keyway into the key. The key of the trailing edge body connection system may extend an entire length of a width of the airfoil attachment side of the trailing edge body. The key of the trailing edge body connection system may have a thickness that is less than a thickness of the trailing edge body at the airfoil attachment side. The key may have a head that has a wider width than a base of the key forming a bulb shaped key, and the keyway may be formed from a chamber configured to receive the head, whereby the chamber has a larger width than an inlet throat of the keyway.

The airfoil may include one or more trailing edge discharge exhaust slots positioned within the trailing edge body and in communication with the cooling system within the generally elongated hollow airfoil. In at least one embodiment, the trailing edge discharge exhaust slot may be formed from a plurality of trailing edge discharge exhaust slots. The pressure and suction sides of the plurality of trailing edge segments may be aligned with each other. The pressure and suction sides of the plurality of trailing edge segments may have elliptically shaped outer surfaces. The pressure and suction sides of the plurality of trailing edge segments may be

flush with the pressure and suction sides of the generally elongated hollow airfoil. The pressure and suction sides of the plurality of trailing edge segments may be flush with outer surfaces of a thermal boundary coating on the pressure and suction sides of the generally elongated hollow airfoil.

During turbine engine operation, turbine airfoils are typically exposed to combustion gases great than about 1,600 degrees Celsius, which causes the turbine airfoils and related components to increase in temperature. The trailing edge segments may form the trailing edge of the turbine airfoil and may be capable of forming a curved shaped trailing edge. The trailing edge segments may also limit formation of stress within the turbine airfoil because the individual trailing edge segments are separated from each other, thereby preventing the transfer of thermal stresses between the trailing edge segments. The trailing edge segments may or may not be cooled by trailing edge discharge exhaust slots positioned within the trailing edge body.

An advantage of the trailing edge segments of the trailing edge body is that the trailing edge segments may be formed from CMC to better accommodate the hot gas path of gas turbine engines.

Another advantage of the trailing edge segments of the trailing edge body is that the trailing edge body may be formed from multiple segments, thereby eliminating thermal stresses within the airfoil from differences in temperatures between the trailing edge segments.

Yet another advantage of the trailing edge segments of the trailing edge body is that the segments formed from CMC are better able to accommodate localize hot spots without being susceptible to damage.

These and other embodiments are described in more detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate embodiments of the presently disclosed invention and, together with the description, disclose the principles of the invention.

Figure 1 is a perspective view of a turbine engine having airfoils with trailing edge bodies.

Figure 2 is a perspective view of a turbine airfoil having trailing edge bodies.

Figure 3 is a partial cross-sectional view of a trailing edge region of the airfoil taken along section line 3-3 in Figure 2.

Figure 4 is a partial cross-sectional view of a trailing edge region of another embodiment of the airfoil taken along section line 3-3 in Figure 2.

Figure 5 is a partial cross-sectional view of a trailing edge region of yet another embodiment of the airfoil taken along section line 3-3 in Figure 2.

Figure 6 is a partial cross-sectional, perspective view of a trailing edge region of another embodiment of the airfoil taken along section line 3-3 in Figure 2.

Figure 7 is a perspective view of a trailing edge segment of the trailing edge body.

DETAILED DESCRIPTION OF THE INVENTION

As shown in Figures 1-7, a trailing edge insert 10 for a turbine airfoil 12 of a gas turbine engine 14 usable to increase the durability of the airfoil 12 to reduce the thickness of the trailing edge insert 10, thereby reducing aerodynamic loss, increasing turbine efficiency, engine efficiency, and combined cycle efficiency is disclosed. The trailing edge insert 10 may be formed from a trailing edge body 16 formed from a plurality of trailing edge segments 18, as shown in Figures 2 and 6. Each trailing edge segment 18, as shown in Figures 2, 6 and 7, may be formed from a pressure side 20, a suction side 22, a trailing edge 24 and an airfoil attachment side 26 and may include a trailing edge body connection system 28 enabling the trailing edge segments 18 to be attached to the generally elongated hollow airfoil 30. The trailing edge insert 10 may be formed from a different material than the material used to form the airfoil 30, such as, but not limited to, a ceramic matrix composite to increase the durability of the trailing edge 24. The use of segments 18 enables the trailing edge body 16 to be used on curved trailing edges of turbine airfoils 12. The segmented trailing edge body 16 prevents thermal mismatch from causing thermal stresses in the individual segments 18 of the trailing edge body 16 and in the turbine airfoil 12. The trailing edge insert 10 may be formed from a material that will not melt or otherwise be compromised during use in a turbine engine 14, yet enable the trailing edge insert 10 to be formed with a reduced thickness relative to conventional

systems while maintaining its elliptical trailing edge shape, thereby reducing aerodynamic loss, increasing turbine efficiency, engine efficiency, and combined cycle efficiency

In at least one embodiment, as shown in Figure 2, the turbine airfoil 12 may be formed from a generally elongated hollow airfoil 30 formed from an outer wall 32, and having a leading edge 34, a pressure side 36, a suction side 38, a root 40 at a first end 42 of the airfoil 30 and a tip 44 at a second end 46 opposite to the first end 42. The turbine airfoil 12 may also include a cooling system 48 positioned within interior aspects of the generally elongated hollow airfoil 30. The generally elongated hollow airfoil 30 may be formed from a first material. The turbine airfoil 12 may also be formed from a trailing edge body 16 formed from a plurality of trailing edge segments 18. One or more of the trailing edge segments 18 may be formed from a pressure side 20, a suction side 22, a trailing edge 24 and an airfoil attachment side 24 and may include a trailing edge body connection system 28 enabling the trailing edge segments 18 to be attached to the generally elongated hollow airfoil 30. The trailing edge body 16 may be formed from a second material that differs from the first material and has higher heat tolerance than the first material. In at least one embodiment, the second material used to form the trailing edge body 16 may be, but is not limited to being, ceramic matrix composite (CMC). The trailing edge body 16 may be formed using any appropriate manufacturing process.

The trailing edge body connection system 28, as shown in Figures 2-7, may attach the airfoil attachment side 26 of the trailing edge body 16 to the trailing edge region 50 of the generally elongated hollow airfoil 30 is formed from a key 52 extending from the trailing edge body 16 into a keyway 54 within the trailing edge region 50 of the generally elongated hollow airfoil 30. The trailing edge body connection system 28 may also include one or more restraining pins 56, as shown in Figure 6, extending from a portion of the generally elongated hollow airfoil 30 forming the keyway 54 into the key 52. The restraining pin 56 may have any appropriate configuration and may be sized based upon the size of the orifices 58 in the generally elongated hollow airfoil 30 and the trailing edge body 16. In at least one embodiment, the key 52 of the trailing edge body connection system 28 may extend an entire length of a width of the airfoil attachment side 26 of the trailing edge body

16. The key 52 of the trailing edge body connection system 28 may have a thickness that is less than a thickness of the trailing edge body 16 at the airfoil attachment side 26. In at least one embodiment, as shown in Figures 3-5, the key 52 may have a head 60 that has a wider width than a base 62 of the key 52 forming a bulb shaped key, and the keyway 54 is formed from a chamber 64 configured to receive the head 60, whereby the chamber 64 has a larger width than an inlet throat 66 of the keyway 54.

In another embodiment, as shown in Figure 4, the cooling system 48 may include one or more trailing edge discharge exhaust slots 68 positioned within the trailing edge body 16 and in communication with the cooling system 48 within the generally elongated hollow airfoil 30. In at least one embodiment, the trailing edge discharge exhaust slot 68 may be formed from a plurality of trailing edge discharge exhaust slots 68. The trailing edge discharge exhaust slots 68 may be positioned adjacent to each other and may be positioned equidistant from each other, at random distances from each other or at another appropriate distance from each other. As shown in Figure 5, the trailing edge discharge exhaust slots 68 may extend through the pressure side 36 of the turbine airfoil 12. The trailing edge body 16 may form a trailing edge 24 on at an intersection between the suction side 38 of the airfoil 12 and the trailing edge 24 of the trailing edge body 16.

The pressure and suction sides 20, 22 of the plurality of trailing edge segments 18 may be aligned with each other. The pressure and suction sides 20, 22 of the plurality of trailing edge segments 18 may have elliptically shaped outer surfaces. In at least one embodiment, the pressure and suction sides 20, 22 of the plurality of trailing edge segments 18 may have a 0.5 mm trailing edge radius with a 1 mm trailing edge thickness. The pressure and suction sides 20, 22 of the plurality of trailing edge segments 18 may be flush with the pressure and suction sides 36, 38 of the generally elongated hollow airfoil 30. In at least one embodiment, as shown in Figures 4 and 5, the pressure and suction sides 36, 38 of the plurality of trailing edge segments 18 are flush with outer surfaces 70 of a thermal boundary coating 72 on the pressure and suction sides 36, 38 of the generally elongated hollow airfoil 30.

As shown in Figures 6 and 7, the side surfaces 74, 76 of each segment 18 may be generally planar. In at least one embodiment, the side surfaces 74, 76 of

one particular segment 18 may be aligned with each other and positioned on opposite sides of the segment 18 from each other. The side surfaces 74, 76 of each segment 18 may be positioned so that the side surfaces 74, 76 of each segment 18 are aligned with the side surfaces 74, 76 of adjacent segments 18.

During turbine engine operation, turbine airfoils 12 are typically exposed to combustion gases great than about 1,600 degrees Celsius, which causes the turbine airfoils 12 and related components to increase in temperature. The trailing edge segments 18 form the trailing edge of the turbine airfoil 12 and are capable of forming a curved shaped trailing edge. The trailing edge segments 18 may also limit formation in stress within the turbine airfoil because the individual trailing edge segments 18 are separated from each other, thereby preventing the transfer of thermal stresses between the trailing edge segments 18. The trailing edge segments 18 may or may not be cooled by trailing edge discharge exhaust slots 68 positioned within the trailing edge body 16.

The foregoing is provided for purposes of illustrating, explaining, and describing embodiments of this invention. Modifications and adaptations to these embodiments will be apparent to those skilled in the art and may be made without departing from the scope or spirit of this invention.

CLAIMS

We claim:

1. A turbine airfoil (12), characterized in that:

a generally elongated hollow airfoil (30) formed from an outer wall (32), and having a leading edge (34), a pressure side (36), a suction side (38), a root (40) at a first end (42) of the airfoil (30) and a tip (44) at a second end (46) opposite to the first end (42), and a cooling system (48) positioned within interior aspects of the generally elongated hollow airfoil (30), wherein the generally elongated hollow airfoil (30) is formed from a first material;

a trailing edge body (16) formed from a plurality of trailing edge segments (18), wherein each trailing edge segment (18) is formed from a pressure side (20), a suction side (22), a trailing edge (24) and an airfoil attachment side (26) and includes a trailing edge body connection system (28) enabling the trailing edge segments (18) to be attached to the generally elongated hollow airfoil (30); and

wherein the trailing edge body (16) is formed from a second material that differs from the first material and has higher heat tolerance than the first material.

2. The turbine airfoil (12) of claim 1, characterized in that the trailing edge body (16) is formed from ceramic matrix composite.

3. The turbine airfoil (12) of claim 1, characterized in that the trailing edge body connection system (28) attaching the airfoil attachment side (26) of the trailing edge body (16) to the trailing edge region (50) of the generally elongated hollow airfoil (30) is formed from a key (52) extending from the trailing edge body (16) into a keyway (54) within the trailing edge region (50) of the generally elongated hollow airfoil (30) and further comprising at least one restraining pin (56) extending from a portion of the generally elongated hollow airfoil (30) forming the keyway (54) into the key (52).

4. The turbine airfoil (12) of claim 3, characterized in that the key (52) of the trailing edge body connection system (28) extends an entire length of a width of the airfoil attachment side (26) of the trailing edge body (16).

5. The turbine airfoil (12) of claim 3, characterized in that the key (52) of the trailing edge body connection system (28) has a thickness that is less than a thickness of the trailing edge body (16) at the airfoil attachment side (26).

6. The turbine airfoil (12) of claim 1, characterized in that the key (52) has a head (60) that has a wider width than a base of the key (52) forming a bulb shaped key, and wherein the keyway (54) is formed from a chamber (64) configured to receive the head (60), whereby the chamber (64) has a larger width than an inlet throat of the keyway (54).

7. The turbine airfoil (12) of claim 1, further characterized in that at least one trailing edge discharge exhaust slot (68) positioned within the trailing edge body (16) and in communication with the cooling system (48) within the generally elongated hollow airfoil (30).

8. The turbine airfoil (12) of claim 7, characterized in that the at least one trailing edge discharge exhaust slot (68) is comprised of a plurality of trailing edge discharge exhaust slots (68).

9. The turbine airfoil (12) of claim 1, characterized in that the pressure and suction sides (20, 22) of the plurality of trailing edge segments (18) are aligned with each other.

10. The turbine airfoil (12) of claim 1, wherein the pressure and suction sides (20, 22) of the plurality of trailing edge segments (18) have elliptically shaped outer surfaces.

11. The turbine airfoil (12) of claim 1, characterized in that the pressure and suction sides (20, 22) of the plurality of trailing edge segments (18) are flush with the pressure and suction sides (36, 38) of the generally elongated hollow airfoil (30).

12. The turbine airfoil (12) of claim 1, characterized in that the pressure and suction sides (20, 22) of the plurality of trailing edge segments (18) are flush with outer surfaces (70) of a thermal boundary coating (72) on the pressure and suction sides (36, 38) of the generally elongated hollow airfoil (30).

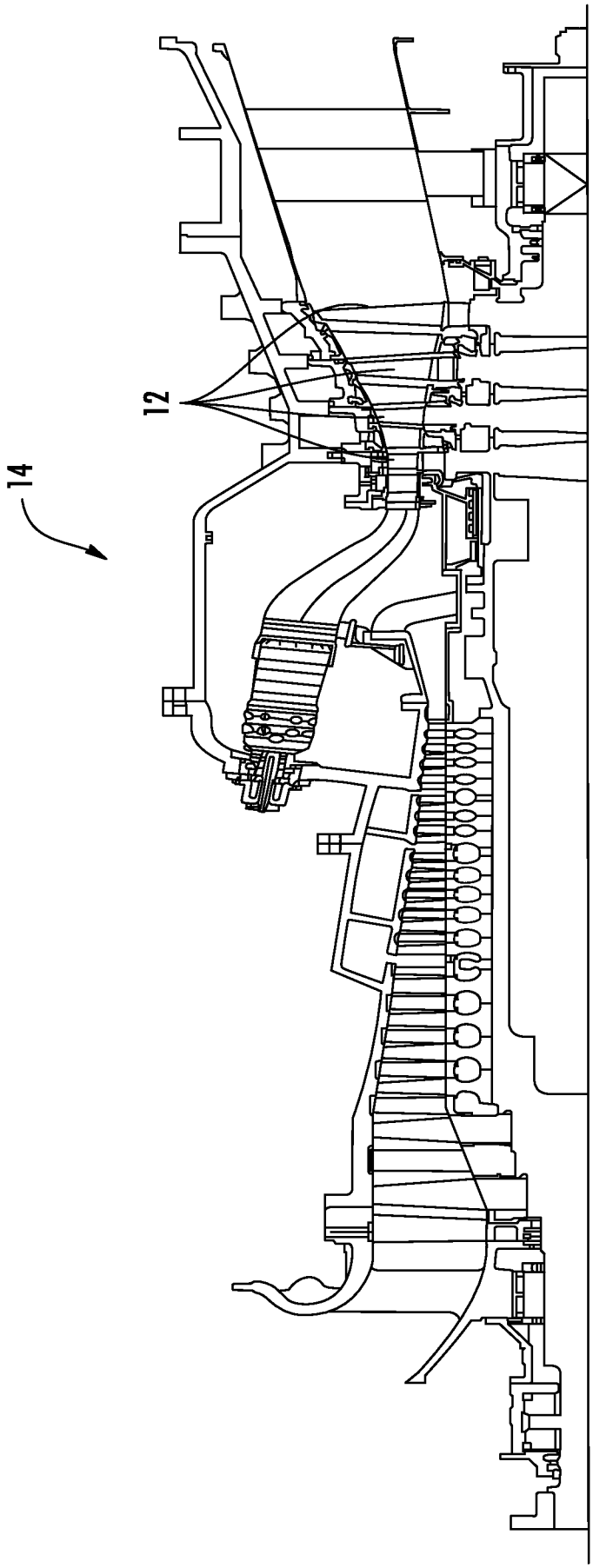


FIG. 1

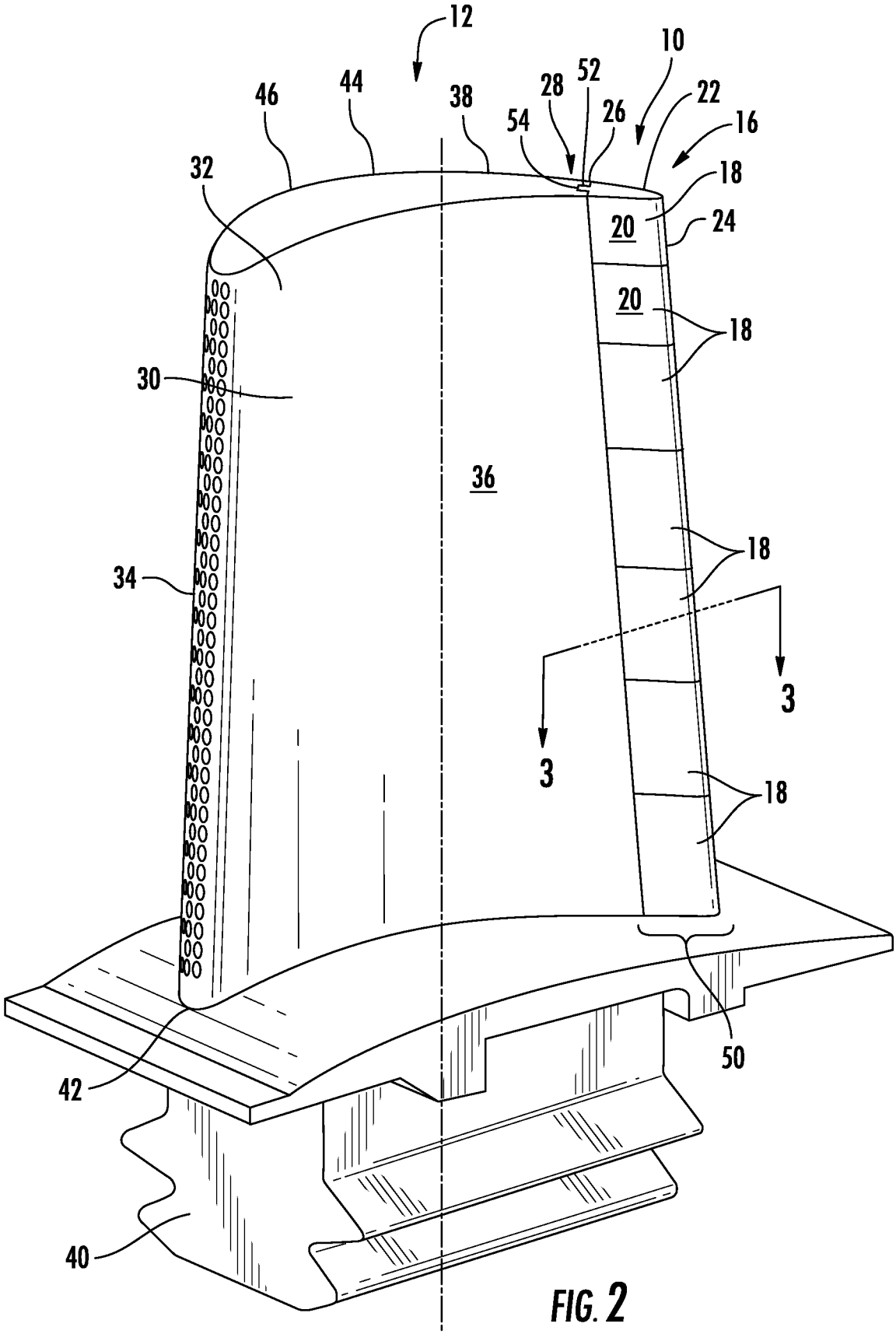

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FIG. 2

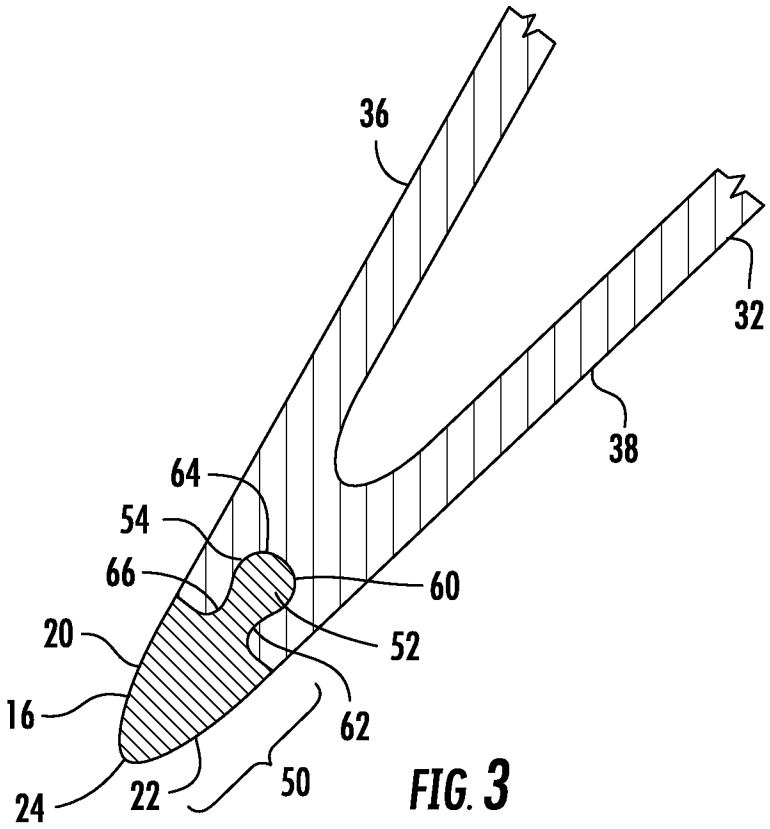

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FIG. 3

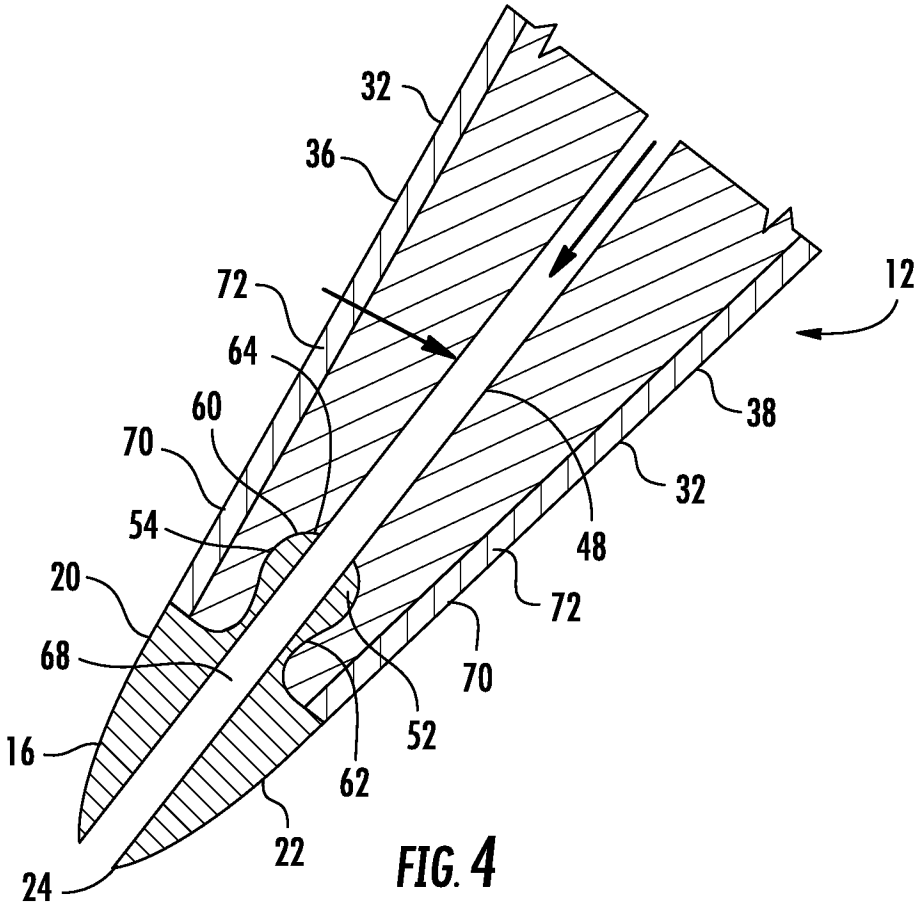

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FIG. 4

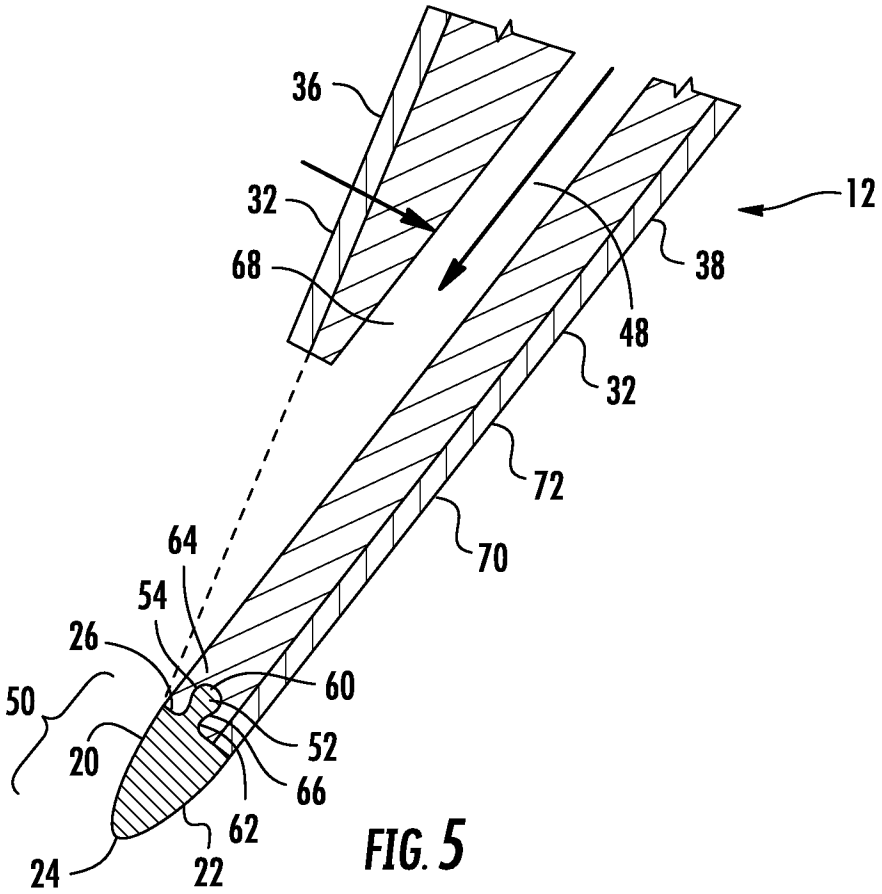


FIG. 5

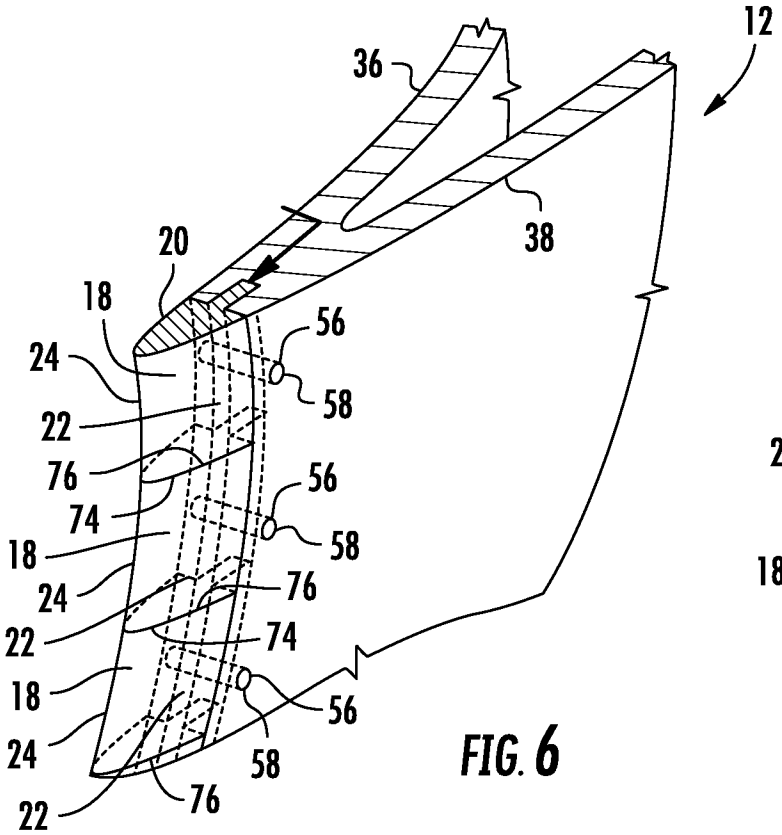


FIG. 6

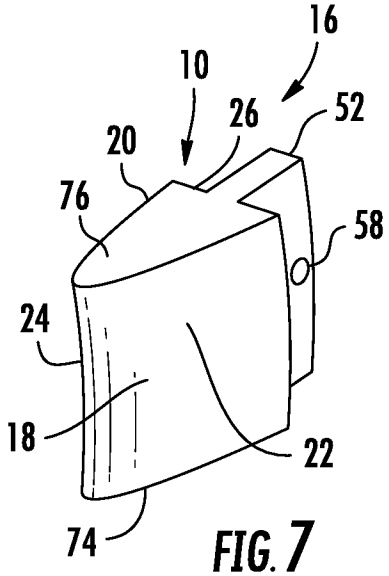


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/041655

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01D5/14 F01D5/28
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 38 21 005 A1 (MTU MUENCHEN GMBH [DE]) 28 December 1989 (1989-12-28) column 2, line 14 - column 6, line 39; claims 4,6,8; figures 3,5,6	1,4-12
X	EP 2 578 807 A2 (GEN ELECTRIC [US]) 10 April 2013 (2013-04-10)	1,2,4-12
Y	column 4, paragraph 20 - column 6, paragraph 31; figures 3,4	3
Y	US 2006/285973 A1 (KELLER DOUGLAS A [US]) 21 December 2006 (2006-12-21) page 2, paragraph 21; figures 1-3	3

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
29 January 2015	09/02/2015

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2014/041655

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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