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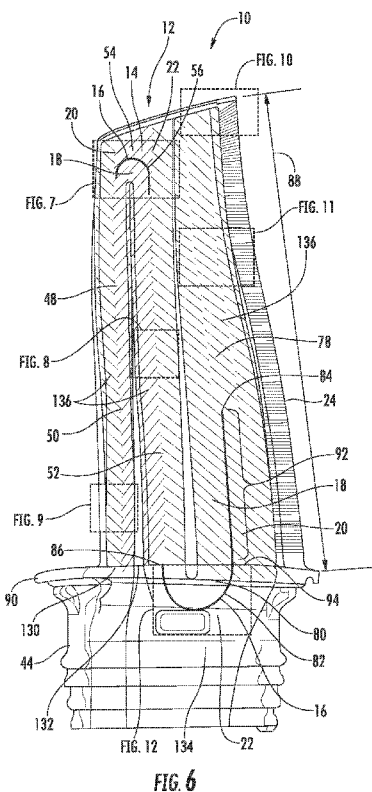
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(54) Title: TURBINE AIRFOIL WITH FLOW SPLITTER ENHANCED SERPENTINE CHANNEL COOLING SYSTEM



(57) Abstract: A turbine airfoil (10) with a cooling system (12) including a serpentine cooling channel (14) with at least one flow splitter (16) forming inner and outer cooling fluid flow paths (18, 20) in at least one turn (22) is disclosed. The inner and outer cooling fluid flow paths (18, 20) created in one or more turns (22) in the serpentine cooling channel (14) create better flow characteristics in the turns (22). The inner cooling fluid flow path (18) created by the flow splitter (16) may reduce the recirculation zone for better heat transfer in the serpentine cooling channel (14). The cooling system (12) may also include a flow splitter (16) in a turn immediately upstream from the trailing edge (24) that extends along a portion of the trailing edge (24) to prevent cooling fluids from being exhausted through the trailing edge (24) prematurely.



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TURBINE AIRFOIL WITH FLOW SPLITTER ENHANCED SERPENTINE CHANNEL COOLING SYSTEM

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

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

FIELD OF THE INVENTION

10 This invention is directed generally to turbine airfoils, and more particularly to cooling systems in hollow turbine airfoils.

BACKGROUND

15 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 blade assemblies to these high temperatures. As a result, turbine blades must be made of materials capable of withstanding such high
20 temperatures. In addition, turbine blades often contain cooling systems for prolonging the life of the blades and reducing the likelihood of failure as a result of excessive temperatures, as shown in Figures 1 and 2. Serpentine cooling channels sometimes suffer from regions of higher temperature and poor flow distribution in the turns, as shown in Figures 3 and 4. Often times, the flow of cooling fluid in the
25 channels immediately downstream of turns suffer from low speed fluid and, thus, increased temperatures near the inner corner of the turns. Thus, a need exists for a cooling channel in internal cooling systems of airfoils.

SUMMARY OF THE INVENTION

30 A turbine airfoil with a cooling system including a serpentine cooling channel with at least one flow splitter forming inner and outer cooling fluid flow paths in at

least one turn is disclosed. The inner and outer cooling fluid flow paths created in one or more turns in the serpentine cooling channel create better flow characteristics in the turns. The inner cooling fluid flow path created by the flow splitter may reduce the recirculation zone for better heat transfer in the serpentine cooling channel. The cooling system may also include a flow splitter in a turn immediately upstream from the trailing edge that extends along a portion of the trailing edge to prevent cooling fluids from being exhausted through the trailing edge prematurely.

In at least one embodiment, the serpentine cooling channel may be an improved serpentine cooling channel, such as, but not limited to being a three pass channel in a large turbine blade, such as, but not limited to, a Row 3 blade. The flow splitters may separate cooling fluid flow into inner and outer fluid flow paths upstream of the turn. The cooling fluid, such as, but not limited to air, in the inner fluid flow path may stay adjacent the inner rib and reduce the recirculation zone for better heat transfer. The flow splitter in the second turn, which may be near the root of the airfoil may extend radially outward to prevent cooling fluid from prematurely exiting through the exhaust orifices in the trailing edge. The flow splitter in the second turn is also configured to connect the inner ceramic core for the inner cooling fluid flow path with the outer ceramic core for the outer flow path during the casting process to have a better manufacturing yield by improving the ceramic core structural rigidity. The serpentine cooling channel with flow splitters provides improved cooling fluid flow patterns, improves heat transfer and reduces the maximum temperature within the airfoil.

In at least one embodiment, the turbine airfoil may include a generally elongated, hollow airfoil having a leading edge, a trailing edge, a pressure side, a suction side on an opposite side of the airfoil from the pressure side, a tip section at a first end, a root coupled to the airfoil at an end generally opposite the first end for supporting the airfoil and for coupling the airfoil to a disc, and a cooling system formed from at least one cavity in the elongated, hollow airfoil. The cooling system may include a serpentine cooling channel formed from one or more first legs in fluid communication with a downstream second leg via a first turn. The first leg and second leg may direct cooling fluid flow in generally opposite directions to each

other. One or more first turn flow splitters may be positioned in the first turn creating an inner cooling fluid flow path and an outer cooling fluid flow path in the first turn.

A trailing end of the first turn flow splitter may extend radially inward further than a leading end of the first turn flow splitter. A leading end linear portion of the
5 first turn flow splitter may be generally aligned with a trailing end linear portion of the first turn flow splitter. A distance between the trailing end linear portion of the first turn flow splitter and an inner surface of an inner rib defining a downstream portion of the inner cooling fluid flow path may be greater than a distance taken orthogonally
10 between an inner surface of the inner rib defining an upstream portion of the inner cooling fluid flow path and an axis aligned with the leading end linear portion of the first turn flow splitter.

The serpentine cooling channel of the cooling system may also include a third leg in fluid communication with the second leg via a second turn. The second leg and third leg may direct cooling fluid flow in generally opposite directions to each
15 other. One or more second turn flow splitters may be positioned in the second turn creating an inner cooling fluid flow path and an outer cooling fluid flow path in the second turn.

A trailing end of the second turn flow splitter may extend radially outward further than a leading end of the at least one second turn flow splitter. In at least one
20 embodiment, the trailing end of the second turn flow splitter may extend into the third leg a distance of at least 15 percent of a span height of the generally elongated, hollow airfoil. A trailing end linear portion of the second turn flow splitter may extend linearly radially outward from a chordwise extending axis aligned with the leading end of the second turn flow splitter. A leading end linear portion of the second turn
25 flow splitter may be generally aligned with a trailing end linear portion of the second turn flow splitter. A distance between the trailing end linear portion of the second turn flow splitter and an inner surface of an inner rib defining a downstream portion of the inner cooling fluid flow path in the second turn may be greater than a distance taken orthogonally between an inner surface of the inner rib defining an upstream
30 portion of the inner cooling fluid flow path of the second turn and the leading end linear portion of the second turn flow splitter. The distance between the trailing end linear portion of the second turn flow splitter and the inner surface of the inner rib

defining a downstream portion of the inner cooling fluid flow path in the second turn may be between 1.25 times and 2.5 times greater than a distance taken orthogonally between an inner surface of the inner rib defining an upstream portion of the inner cooling fluid flow path of the second turn and the leading end linear portion of the second turn flow splitter.

The second turn flow splitter may include one or more perforations placing the inner and outer cooling fluid flow paths in fluid communication through the second turn flow splitter. The second turn flow splitter may include a first perforation upstream of an axis aligned with an inner rib separating the second and third legs of the serpentine cooling channel, and may include a second perforation downstream of the axis aligned with the inner rib separating the second and third legs of the serpentine cooling channel.

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 cross-sectional filleted view of a conventional turbine airfoil with a conventional three channel cooling system.

Figure 2 is a cross-sectional filleted view of a conventional turbine airfoil with a conventional three pass serpentine channel cooling system.

Figure 3 is a diagram of the flow of cooling fluids through the conventional three pass serpentine channel cooling system in Figure 2 and displays the pockets of low speed cooling fluid and poor heat transfer on inner, downstream sides of the turns.

Figure 4 is a diagram of the heating load on the conventional three pass serpentine channel cooling system in Figure 2.

Figure 5 is a turbine airfoil including a cooling system with a serpentine channel including one or more flow splitters.

Figure 6 is a cross-sectional filleted view of the turbine airfoil of Figure 5 taken at section line 6-6.

Figure 7 is a detail cross-sectional filleted view of a first turn of the cooling system in the turbine airfoil shown in Figure 6 taken at detail 7-7.

Figure 8 is a detail cross-sectional filleted view of a second leg of the cooling system in the turbine airfoil shown in Figure 6 taken at detail 8-8.

5 Figure 9 is a detail cross-sectional filleted view of a first leg of the cooling system in the turbine airfoil shown in Figure 6 taken at detail 9-9.

Figure 10 is a detail cross-sectional filleted view of a third leg of the cooling system at a tip of the turbine airfoil shown in Figure 6 taken at detail 10-10.

10 Figure 11 is a detail cross-sectional filleted view of a third leg of the cooling system of the turbine airfoil shown in Figure 6 taken at detail 11-11.

Figure 12 is a detail cross-sectional filleted view of a second turn of the cooling system of the turbine airfoil shown in Figure 6 taken at detail 12-12.

15 Figure 13 is a diagram of the flow of cooling fluids through the serpentine channel cooling system in Figure 6 and displays the improved cooling fluid distribution.

Figure 14 is a diagram of the improved temperature distribution on the serpentine channel cooling system in Figure 6.

DETAILED DESCRIPTION OF THE INVENTION

20 As shown in Figures 5-14, a turbine airfoil 10 with a cooling system 12 including a serpentine cooling channel 14 with at least one flow splitter 16 forming inner and outer cooling fluid flow paths 18, 20 in at least one turn 22 is disclosed. The inner and outer cooling fluid flow paths 18, 20 created in one or more turns 22 in the serpentine cooling channel 14 create better flow characteristics in the turns 22.

25 The inner cooling fluid flow path 18 created by the flow splitter 16 may reduce the recirculation zone for better heat transfer in the serpentine cooling channel 14. The cooling system 12 may also include a flow splitter 16 in a turn 22 immediately upstream from a trailing edge 24 that extends along a portion of the trailing edge 24 to prevent cooling fluids from being exhausted through the trailing edge 24

30 prematurely.

In at least one embodiment, as shown in Figures 5 and 6, the turbine airfoil may include a turbine airfoil 10 formed from a generally elongated, hollow airfoil 30

having a leading edge 32, a trailing edge 24, a pressure side 36, a suction side 38 on an opposite side of the airfoil 30 from the pressure side 36, a tip section 40 at a first end 42, a root 44 coupled to the airfoil 30 at a second end 46 generally opposite the first end 42 for supporting the airfoil 30 and for coupling the airfoil 30 to a disc, and a cooling system 12 formed from at least one cavity 48 in the elongated, hollow airfoil 30. The cooling system 12 may include a serpentine cooling channel 14 formed from one or more first legs 50 in fluid communication with a downstream second leg 52 via a first turn 54. The first leg 50 and second leg 52 may direct cooling fluid flow in generally opposite directions to each other.

The cooling system 12 may include one or more first turn flow splitters 56 positioned in the first turn 54, as shown in Figures 6 and 7, creating an inner cooling fluid flow path 18 and an outer cooling fluid flow path 20 in the first turn 54. In at least one embodiment, a trailing end 58 of the first turn flow splitter 56 may extend radially inward further than a leading end 60 of the first turn flow splitter 56. A leading end linear portion 62 of the first turn flow splitter 56 may be generally aligned with a trailing end linear portion 64 of the first turn flow splitter 56. In at least one embodiment, the first turn flow splitter 56 may be configured such that a downstream portion 66 of the inner cooling fluid flow path 18 has a larger cross-sectional area than an upstream portion 68. In particular, a distance between the trailing end linear portion 64 of the first turn flow splitter 56 and an inner surface 70 of an inner rib 72 defining a downstream portion 66 of the inner cooling fluid flow path 18 may be greater than a distance taken orthogonally between an inner surface 74 of the inner rib 72 defining an upstream portion 68 of the inner cooling fluid flow path 18 and an axis 76 aligned with the leading end linear portion 62 of the first turn flow splitter 56.

The serpentine cooling channel 14 of the cooling system 12 may also include a third leg 78 in fluid communication with the second leg 52 via a second turn 80, as shown in Figures 6 and 12. The second leg 52 and third leg 78 direct cooling fluid flow in generally opposite directions to each other. The cooling system 12 may also include one or more second turn flow splitters 82 positioned in the second turn 80 creating an inner cooling fluid flow path 18 and an outer cooling fluid flow path 20 in the second turn 80. A trailing end 84 of the second turn flow splitter 82 may extend radially outward further than a leading end 86 of the second turn flow splitter 82. The

trailing end 84 of the second turn flow splitter 82 may extend into the third leg 78 a distance of at least 15 percent of a span height 88 of the generally elongated, hollow airfoil 30. In at least one embodiment, the span height 88 may be a distance between the tip 40 and a platform 90 separating the airfoil 30 and the root 44. In at least one embodiment, as shown in Figure 6, the trailing end 84 of the second turn flow splitter 82 may extend into the third leg 78 a distance of between 15 percent and 45 percent of the span height 88. In another embodiment, the trailing end 84 of the second turn flow splitter 82 may extend into the third leg 78 a distance of about 30 percent of a span height. A trailing end linear portion 92 of the second turn flow splitter 82 may extend linearly radially outward from a chordwise extending axis 94 aligned with the leading end 86 of the second turn flow splitter 82. A leading end linear portion 96 of the second turn flow splitter 82 may be generally aligned with a trailing end linear portion 92 of the second turn flow splitter 82.

In at least one embodiment, the second turn flow splitter 82 may be configured such that a downstream portion 98 of the inner cooling fluid flow path 18 has a larger cross-sectional area than an upstream portion 100. In particular, a distance between the trailing end linear portion 92 of the second turn flow splitter 82 and an inner surface 102 of an inner rib 104 defining a downstream portion 98 of the inner cooling fluid flow path 18 in the second turn 80 is greater than a distance taken orthogonally between an inner surface 106 of the inner rib 104 defining an upstream portion 100 of the inner cooling fluid flow path 18 of the second turn 80 and the leading end linear portion 96 of the second turn flow splitter 82. In at least one embodiment, the distance between the trailing end linear portion 92 of the second turn flow splitter 82 and the inner surface 102 of the inner rib 104 defining the downstream portion 98 of the inner cooling fluid flow path 18 in the second turn 80 is between 1.25 times and 2.5 times greater than a distance taken orthogonally between the inner surface 106 of the inner rib 104 defining an upstream portion 100 of the inner cooling fluid flow path 18 of the second turn 80 and the leading end linear portion 96 of the second turn flow splitter 82.

In at least one embodiment, the second turn flow splitter 82 may include one or more perforations 110 placing the inner and outer cooling fluid flow paths 18, 20 in fluid communication through the second turn flow splitter 82. The perforations 110

may have any appropriate size and configuration. In at least one embodiment, the perforation 10 may extend from inner surfaces forming the pressure and suction sides 36, 38 of the airfoil 30. The second turn flow splitter 82 may include a first perforation 112 upstream of an axis 114 aligned with an inner rib 104 separating the second and third legs 52, 78 of the serpentine cooling channel 14 and a second perforation 116 downstream of the axis 114 aligned with the inner rib 104 separating the second and third legs 52, 78 of the serpentine cooling channel 14.

In at least one embodiment, as shown in Figures 6 and 9, the first leg 50 of the serpentine cooling channel 14 may be a leading edge cooling channel. The third leg 78 of the serpentine cooling channel 14 may be a trailing edge cooling channel with a plurality of exhaust orifices 120 extending from the third leg 78 through an outer wall 122 at the trailing edge 24, as shown in Figures 6 and 11. One or more exhaust orifices 124 may also be positioned in a radially outer wall 126 forming the tip 40 of the airfoil 30 to exhaust cooling fluids at the tip 40 of the airfoil 30, as shown in Figure 10.

The serpentine cooling channel 14 may be feed with cooling fluid via an inlet 130 at an inboard end 132 of the first leg 50, as shown in Figure 6. The serpentine cooling channel 14 may be feed with cooling fluid via a supply channel 134 in fluid communication with the second turn 80. The second turn 80 may be located at an inboard end 132 of the airfoil 30. The supply channel 134 may supply cooling fluid to the third leg 78 of the serpentine cooling channel 14.

One or more of the first, second and third legs 50, 52, 78 of the serpentine cooling channel 14 may include one or more turbulators 136, as shown in Figures 6-12. The turbulators 136 may be positioned orthogonal to the flow of cooling fluids through the serpentine cooling channel 14, nonorthogonal and nonparallel to the flow of cooling fluids through the serpentine cooling channel 14 or in another position. The turbulators 136 may extend into the serpentine cooling channel 14 a distance less than half a distance between inner surfaces of the outer walls forming the pressure and suction sides 36, 38, and, in some embodiments, a distance less than fifteen percent of a distance between inner surfaces of the outer walls forming the pressure and suction sides 36, 38.

In at least one embodiment, the serpentine cooling channel 14 may be an improved serpentine cooling channel, such as, but not limited to being a three pass channel in a large turbine blade 10, such as, but not limited to, a Row 3 blade 10. The flow splitters 16 may separate cooling fluid flow into inner and outer fluid flow paths 18, 20 upstream of the turn 22. The cooling fluid, such as, but not limited to air, in the inner fluid flow path 18 may stay adjacent the inner rib 72, 104 and reduce the recirculation zone for better heat transfer. The flow splitter 16, 82 in the second turn 80, which may be near the root 44 of the airfoil 10 may extend radially outward to prevent cooling fluid from prematurely exiting through the exhaust orifices 120 in the trailing edge 24. The flow splitter 16 in the second turn 80 may also configured to connect the inner ceramic core for the inner cooling fluid flow path 18 with the outer ceramic core for the outer cooling fluid flow path 22 during the casting process to have a better manufacturing yield by improving the ceramic core structural rigidity. The serpentine cooling channel 14 with flow splitters 16 provides improved cooling fluid flow patterns, improves heat transfer and reduces the maximum temperature within the airfoil, as shown in Figures 13 and 14.

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 (10), characterized in that:
a generally elongated, hollow airfoil (30) having a leading edge (32), a trailing edge (24), a pressure side (36), a suction side (38) on an opposite side of the airfoil (30) from the pressure side (36), a tip section (40) at a first end (42), a root (44) coupled to the airfoil (30) at an end (46) generally opposite the first end (42) for supporting the airfoil (30) and for coupling the airfoil (30) to a disc, and a cooling system (12) formed from at least one cavity (48) in the elongated, hollow airfoil (30);
wherein the cooling system (12) includes a serpentine cooling channel (14) formed from at least one first leg (50) in fluid communication with a downstream second leg (52) via a first turn (54), wherein the first leg (50) and second leg (52) direct cooling fluid flow in generally opposite directions to each other; and
at least one first turn flow splitter (56) positioned in the first turn (54) creating an inner cooling fluid flow path (18) and an outer cooling fluid flow path (20) in the first turn (54).
2. The turbine airfoil (10) of claim 1, characterized in that a trailing end (58) of the at least one first turn flow splitter (56) extends radially inward further than a leading end (60) of the at least one first turn flow splitter (56).
3. The turbine airfoil (10) of claim 1, characterized in that a leading end linear portion (62) of the at least one first turn flow splitter (56) is generally aligned with a trailing end linear portion (64) of the at least one first turn flow splitter (56).
4. The turbine airfoil (10) of claim 1, characterized in that a distance between the trailing end linear portion (64) of the at least one first turn flow splitter (56) and an inner surface (70) of an inner rib (72) defining a downstream portion of the inner cooling fluid flow path (18) is greater than a distance taken orthogonally between an inner surface (74) of the inner rib (72) defining an upstream portion of

the inner cooling fluid flow path (18) and an axis (76) aligned with the leading end linear portion (62) of the at least one first turn flow splitter (56).

5. The turbine airfoil (10) of claim 1, characterized in that the serpentine cooling channel (14) of the cooling system (12) further comprises a third leg (78) in fluid communication with the second leg (52) via a second turn (80), wherein the second leg (52) and third leg (78) direct cooling fluid flow in generally opposite directions to each other and further comprising at least one second turn flow splitter (82) positioned in the second turn (80) creating an inner cooling fluid flow path (18) and an outer cooling fluid flow path (20) in the second turn (80).

6. The turbine airfoil (10) of claim 5, characterized in that a trailing end (84) of the at least one second turn flow splitter (82) extends radially outward further than a leading end (86) of the at least one second turn flow splitter (82).

7. The turbine airfoil (10) of claim 6, characterized in that the trailing end (84) of the at least one second turn flow splitter (82) extends into the third leg (78) a distance of at least 15 percent of a span height of the generally elongated, hollow airfoil (30).

8. The turbine airfoil (10) of claim 6, characterized in that a trailing end linear portion (92) of the at least one second turn flow splitter (82) extends linearly radially outward from a chordwise extending axis (94) aligned with the leading end (86) of the at least one second turn flow splitter (82).

9. The turbine airfoil (10) of claim 5, characterized in that a leading end linear portion (96) of the at least one second turn flow splitter (82) is generally aligned with a trailing end linear portion (92) of the at least one second turn flow splitter (82).

10. The turbine airfoil (10) of claim 5, characterized in that a distance between the trailing end linear portion (92) of the at least one second turn flow

splitter (82) and an inner surface (102) of an inner rib (104) defining a downstream portion (98) of the inner cooling fluid flow path (18) in the second turn (80) is greater than a distance taken orthogonally between an inner surface (102) of the inner rib (104) defining an upstream portion (100) of the inner cooling fluid flow path (18) of the second turn (80) and the leading end linear portion (96) of the at least one second turn flow splitter (82).

11. The turbine airfoil (10) of claim 10, characterized in that the distance between the trailing end linear portion (92) of the at least one second turn flow splitter (82) and the inner surface (102) of the inner rib (104) defining a downstream portion (98) of the inner cooling fluid flow path (18) in the second turn (80) is between 1.25 times and 2.5 times greater than a distance taken orthogonally between an inner surface (106) of the inner rib (104) defining an upstream portion (100) of the inner cooling fluid flow path (18) of the second turn (80) and the leading end linear portion (96) of the at least one second turn flow splitter (82).

12. The turbine airfoil (10) of claim 5, characterized in that the second turn flow splitter (82) includes at least one perforation (11) placing the inner and outer cooling fluid flow paths (81, 20) in fluid communication through the second turn flow splitter (82).

13. The turbine airfoil (10) of claim 12, characterized in that the second turn flow splitter (82) includes a first perforation (112) upstream of an axis (114) aligned with an inner rib (104) separating the second and third legs (52, 78) of the serpentine cooling channel (14) and a second perforation (116) downstream of the axis (114) aligned with the inner rib (104) separating the second and third legs (52, 78) of the serpentine cooling channel (14).

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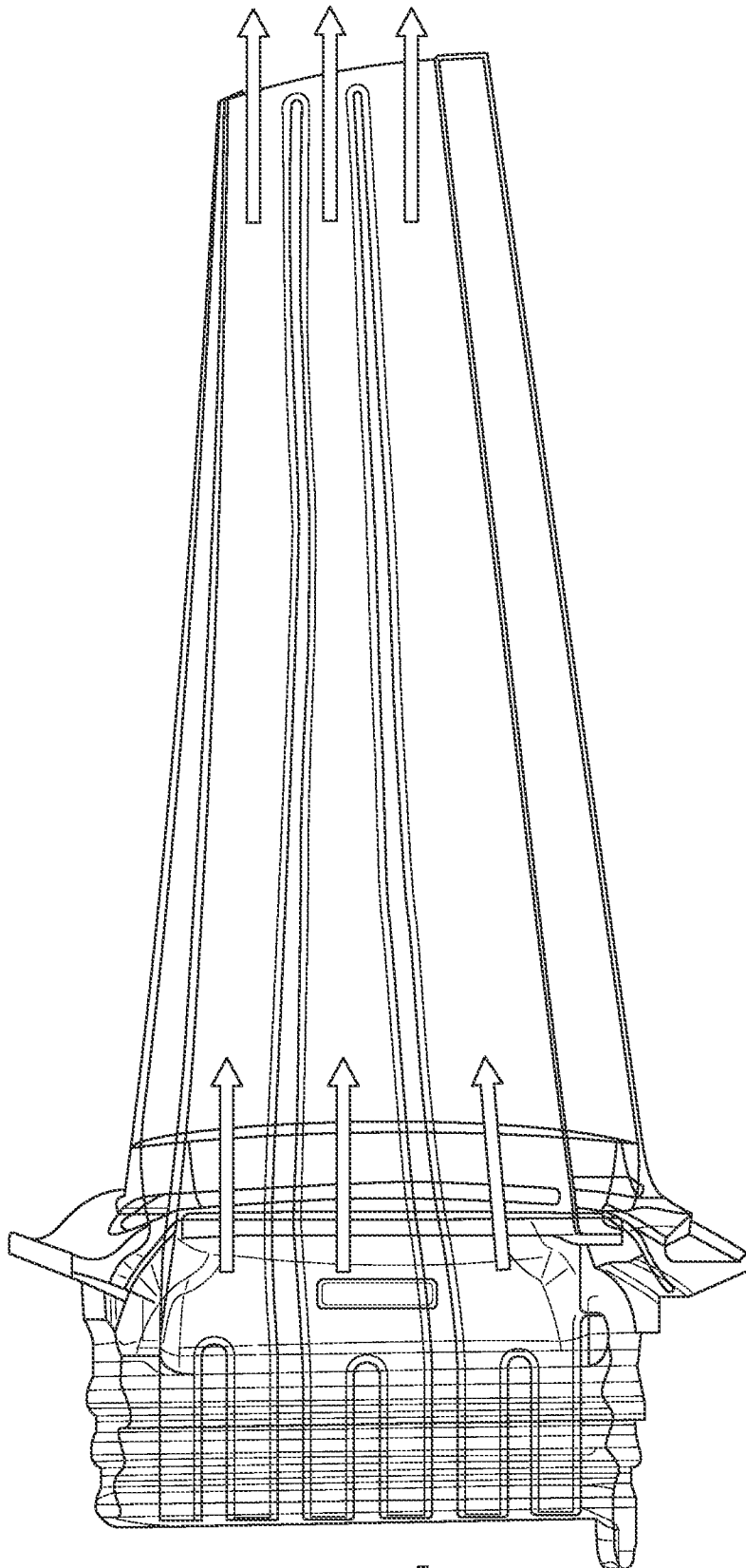


FIG. 1
(PRIOR ART)

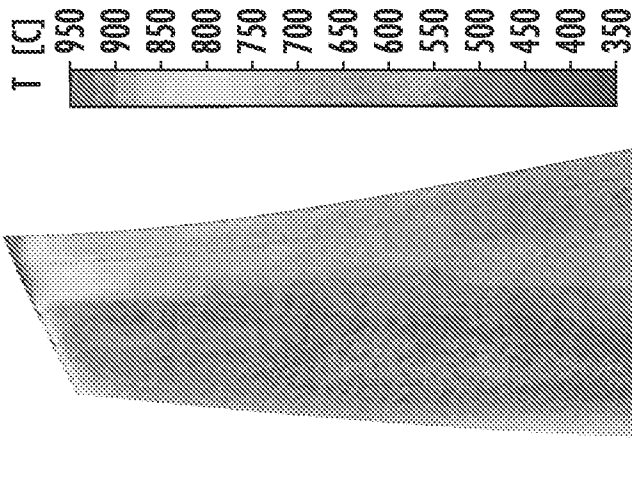


FIG. 4
(PRIOR ART)

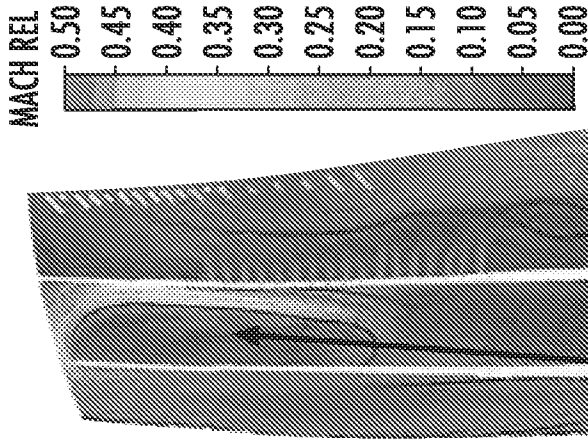


FIG. 3
(PRIOR ART)

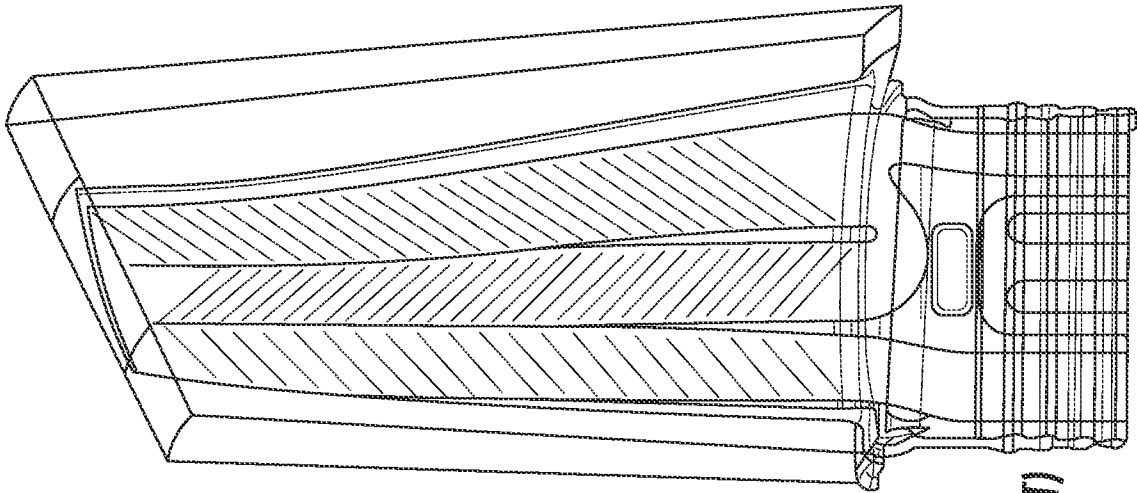


FIG. 2
(PRIOR ART)

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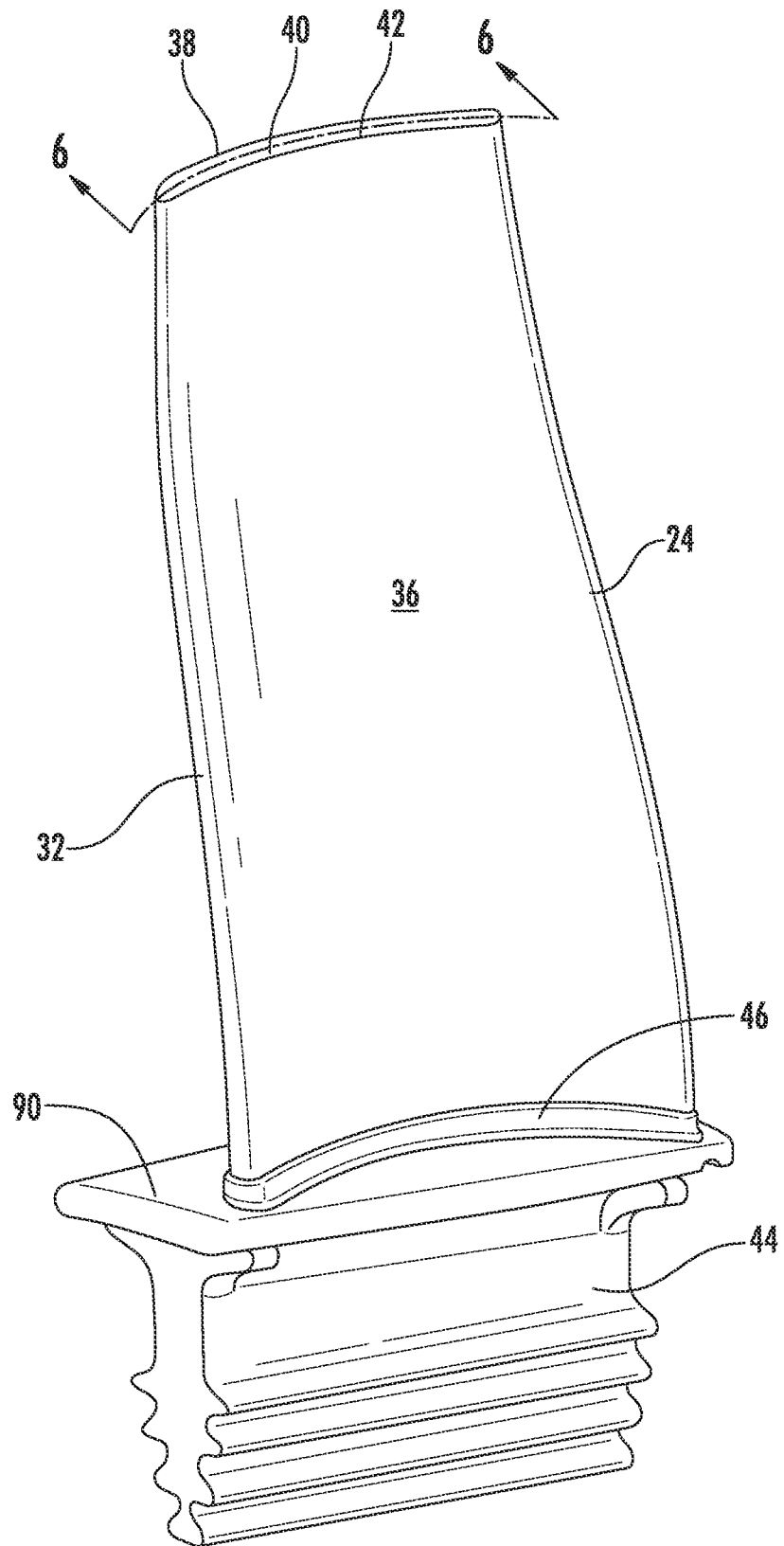
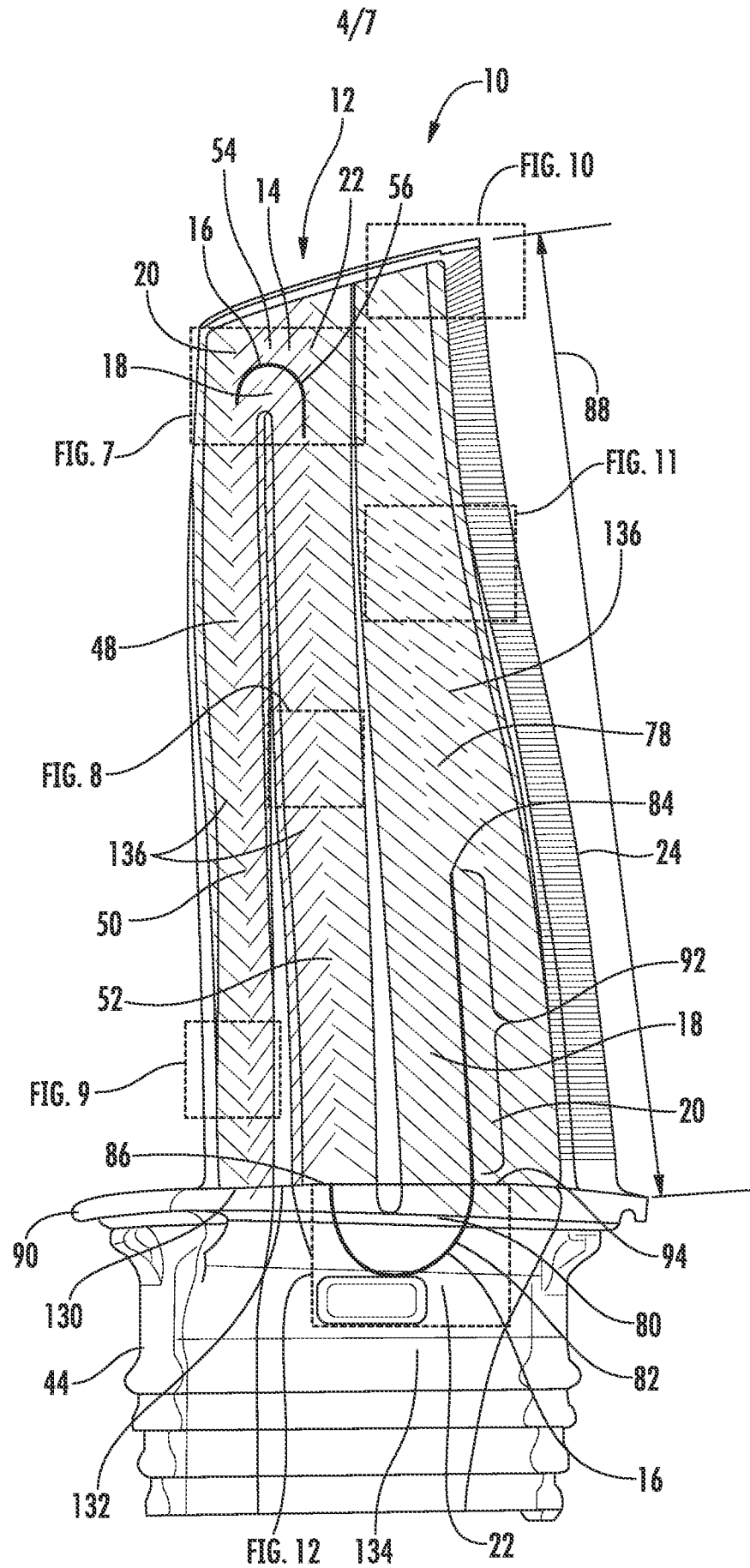
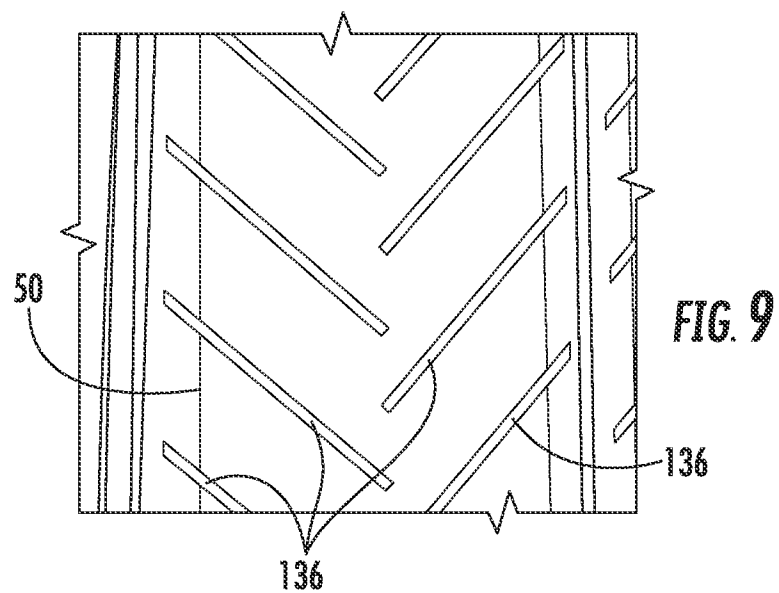
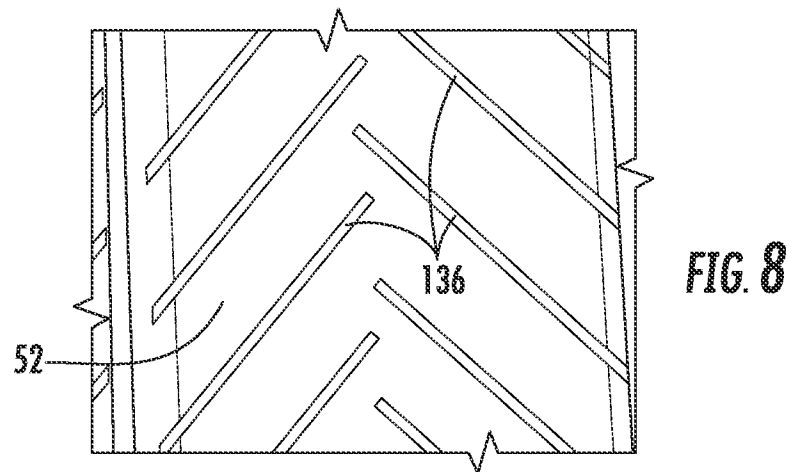
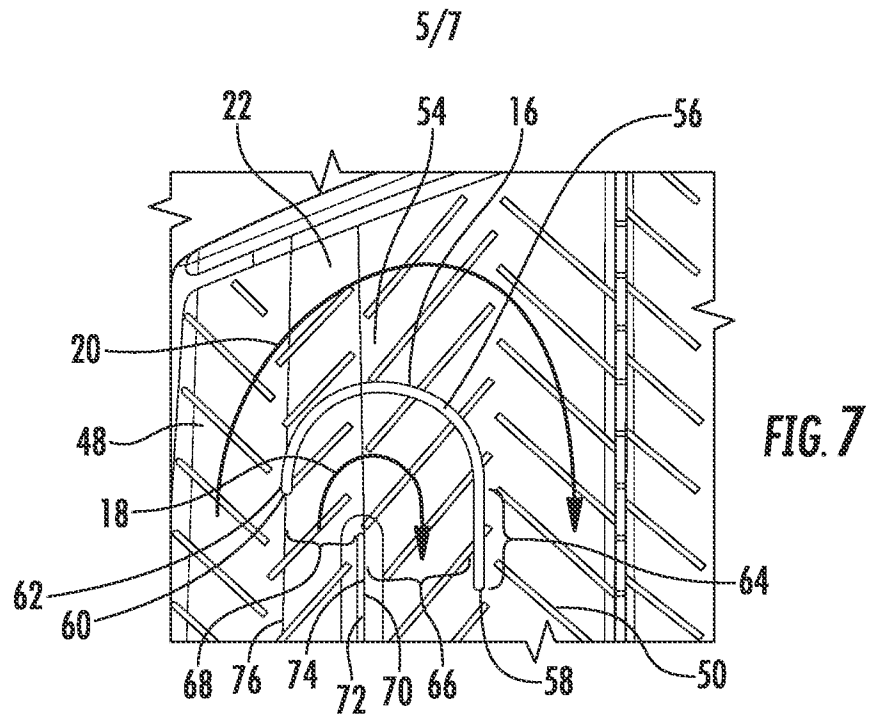


FIG. 5





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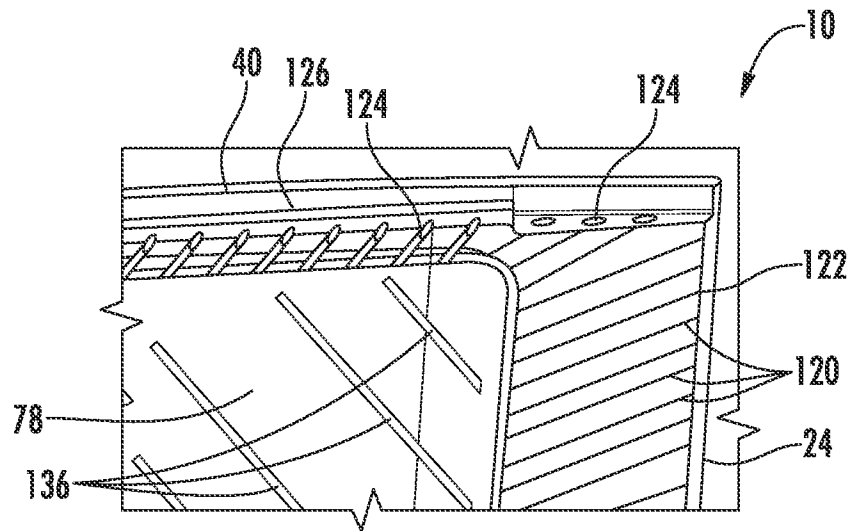


FIG. 10

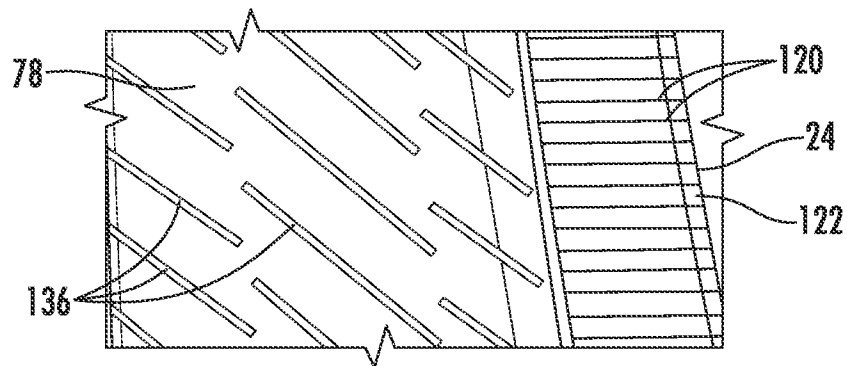


FIG. 11

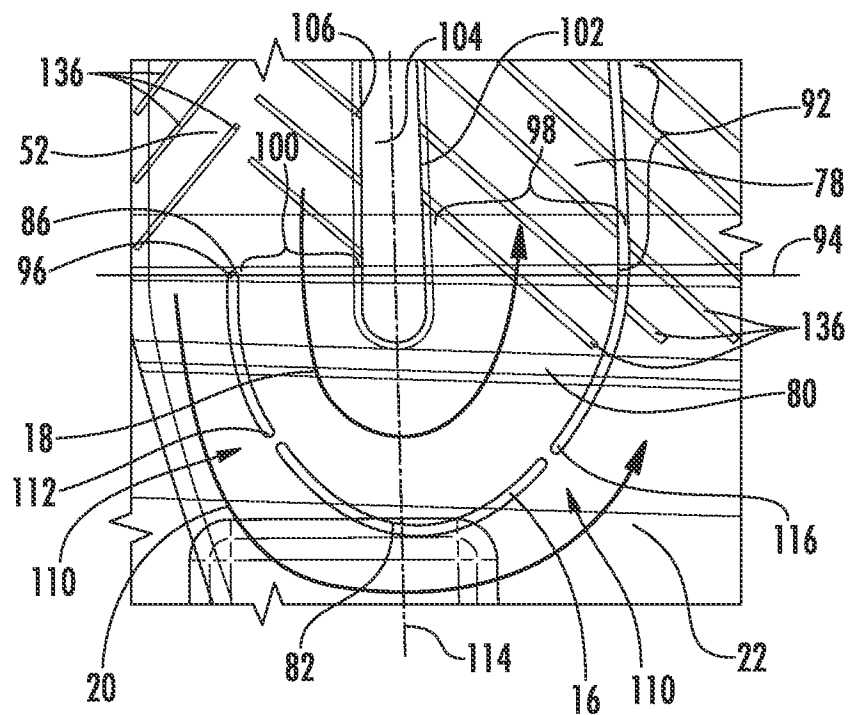


FIG. 12

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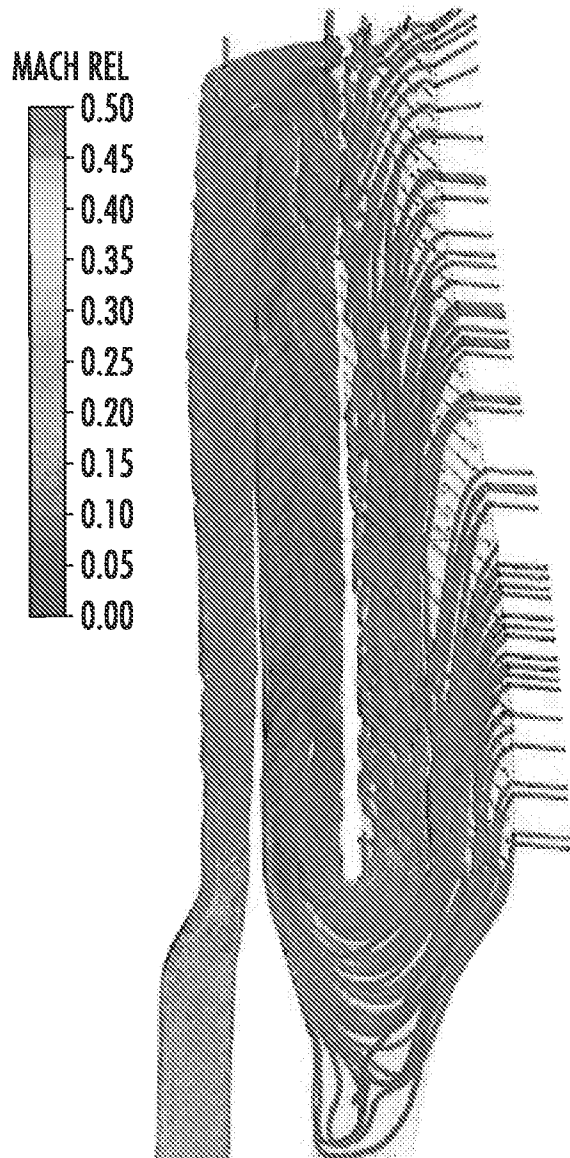


FIG. 13

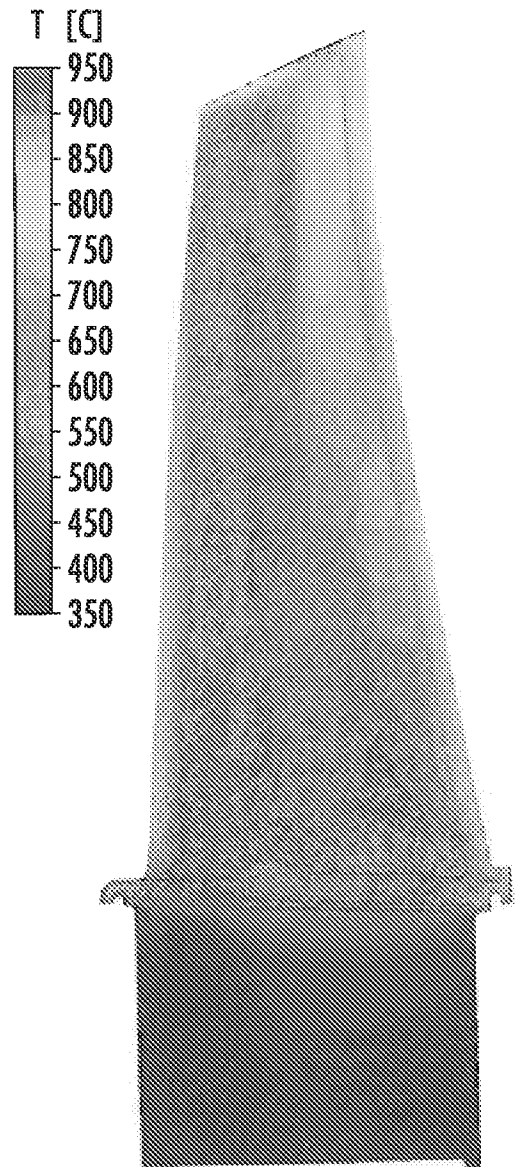


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/024453

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01D5/18
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	EP 2 489 838 A2 (ROLLS ROYCE PLC [GB]) 22 August 2012 (2012-08-22) paragraphs [0043] - [0048] figures 6,8 -----	1-5,9-11
X	US 5 498 126 A (PIGHETTI ANNETTE M [US] ET AL) 12 March 1996 (1996-03-12) columns 4,5 figure 3 -----	1-6,9,10
X	EP 1 607 576 A2 (UNITED TECHNOLOGIES CORP [US]) 21 December 2005 (2005-12-21) paragraphs [0012] - [0021] figures 1-3 -----	1-3,5-9, 12
X	US 2002/176776 A1 (PARNEIX SACHA [CH] ET AL) 28 November 2002 (2002-11-28) the whole document -----	1-3,5,9, 12,13



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

8 January 2016

Date of mailing of the international search report

19/01/2016

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/024453

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