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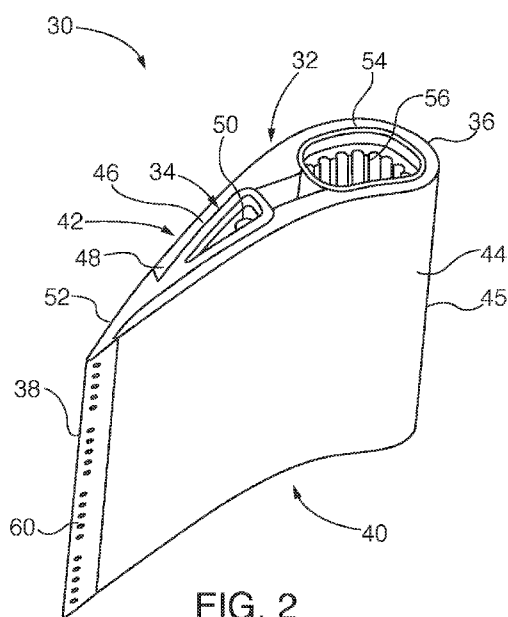
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(54) Title: TURBINE AIRFOIL COMPRISING A CORE SUPPORT STRUCTURE AND A HEAT RESISTANT OUTER SHELL



(57) Abstract: An airfoil (30) for a turbine (10), wherein the airfoil (30) includes leading (36) and trailing (38) edges and high (40) and low (42) pressure surfaces. The airfoil (30) includes a core support structure (34) having first (46) and second (54) support sections that include first (50) and second (56) air inlets, respectively. The airfoil (30) also includes at least one first air channel (62) that extends from the first air inlet (50) and through the first support section (46) to an associated air exit hole (60). In addition, the airfoil (30) includes at least one truss (58) connected between the first (46) and second (54) support sections and at least one second air channel (66) that extends from the second air inlet (56) and through the second support section (54), truss (58) and first support section (46) to an associated air exit hole (60). Further, the airfoil (30) includes a high heat resistant outer shell (32), wherein a portion (48) of the core support structure (30) is located within the outer shell (32). The outer shell may include first and second high heat resistant members.



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TURBINE AIRFOIL COMPRISING A CORE SUPPORT STRUCTURE AND A HEAT RESISTANT OUTER SHELL

FIELD OF THE INVENTION

[0001] This invention relates to airfoils, such as vanes or blades, used in a gas turbine, and more particularly, to an airfoil having a high heat resistant outer shell portion and an internally cooled support structure.

BACKGROUND OF THE INVENTION

[0002] In various multistage turbomachines used for energy conversion, such as gas turbines, a fluid is used to produce rotational motion. Referring to Fig. 1, an axial flow gas turbine 10 includes a multi-stage compressor section 12, a combustion section 14, a multi stage turbine section 16 and an exhaust system 18 arranged along a center axis 20. Air at atmospheric pressure is drawn into the compressor section 12 generally in the direction of the flow arrows F along the axial length of the turbine 10. The intake air is progressively compressed in the compressor section 12 by rows of rotating compressor blades, thereby increasing pressure, and directed by mating compressor vanes to the combustion section 14, where it is mixed with fuel, such as natural gas, and ignited to create a combustion gas. The combustion gas, which is under greater pressure, temperature and velocity than the original intake air, is directed to the turbine section 16. The turbine section 16 includes a plurality of airfoil shaped turbine blades 22 arranged in a plurality of rows R_1 , R_2 , etc. on a shaft 24 that rotates about the axis 20. The combustion gas expands through the turbine section 16 where it is directed in a combustion flow direction F across the rows of blades 22 by associated rows of stationary vanes 24. A row of blades 22 and associated row of vanes 24 form a stage. In particular, the turbine section 16 may include four stages. As the combustion gas passes through the turbine section 16, the combustion gas causes the blades 22 and thus the shaft 24 to rotate about the axis 20, thereby extracting energy from the flow to produce mechanical work.

[0003] A method for increasing the efficiency of a turbine is to increase an operating temperature of the turbine. Operation of a turbine at higher temperatures frequently results in the use of specialized high heat resistant materials for turbine components such as vanes and/or blades. It is desirable to enhance the structural support provided for the high heat resistant materials used in turbine vanes and/or blades.

SUMMARY OF INVENTION

[0004] An airfoil for a turbine, wherein the airfoil includes leading and trailing edges and high and low pressure surfaces. The airfoil includes a core support structure having first and second support sections that include first and second air inlets, respectively. The airfoil also includes at least one first air channel that extends from the first air inlet and through the first support section to an associated air exit hole. In addition, the airfoil includes at least one truss connected between the first and second support sections and at least one second air channel that extends from the second air inlet and through the second support section, truss and first support section to an associated air exit hole. Further, the airfoil includes a high heat resistant outer shell, wherein a portion of the core support structure is located within the outer shell. In accordance with aspects of the present invention, the outer shell may include first and second high heat resistant members.

[0005] Those skilled in the art may apply the respective features of the present invention jointly or severally in any combination or sub-combination.

BRIEF DESCRIPTION OF DRAWINGS

[0006] The teachings of the present disclosure can be readily understood by considering the following detailed description in conjunction with the accompanying drawings, in which:

[0007] Fig. 1 is a partial cross sectional view of an axial flow gas turbine.

[0008] Fig. 2 is a perspective view of a hybrid airfoil in accordance with an embodiment of the present invention.

[0009] Fig. 3 is a perspective view of a core structure of the airfoil.

[0010] Fig. 4 is a partial cross sectional side view of the airfoil and an exemplary first member.

[0011] Fig. 5 is a view of an exemplary first modular support structure.

[0012] Figs. 6A and 6B are views of exemplary first and second members, respectively.

[0013] Fig. 7 is an exploded view of exemplary first and second members and the first modular support structure.

[0014] Fig. 8A depicts an alternate embodiment of the present invention for a modular support structure.

[0015] Fig. 8B is a cross sectional view of a truss along view line 8B-8B of Fig. 8A.

[0016] Fig. 9 depicts an alternate embodiment of the present invention for a member that mates with the modular support structure shown in Figs. 8A and 8B.

[0017] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures.

DETAILED DESCRIPTION

[0018] Although various embodiments that incorporate the teachings of the present disclosure have been shown and described in detail herein, those skilled in the art can readily devise many other varied embodiments that still incorporate these teachings. The scope of the disclosure is not limited in its application to the exemplary embodiment details of construction and the arrangement of components set forth in the description or illustrated in the drawings. The disclosure encompasses other embodiments and of being

practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of “including,” “comprising,” or “having” and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms “mounted,” “connected,” “supported,” and “coupled” and variations thereof are used broadly and encompass direct and indirect mountings, connections, supports, and couplings. Further, “connected” and “coupled” are not restricted to physical or mechanical connections or couplings.

[0019] Referring to Fig. 2, a perspective view of a hybrid airfoil 30 in accordance with an embodiment of the present invention is shown. The airfoil 30 may be either a vane or blade used in a gas turbine 10. In accordance with aspects of the present invention, the airfoil 30 includes a high heat resistant outer shell portion 32 and a core structure 34. This arrangement substantially separates and isolates thermal loading from mechanical loading that occurs in the airfoil 30 during operation of the gas turbine 10. In particular, the outer shell 32 is subjected to a substantial portion of the thermal loading whereas the core structure 34 is subjected a substantial portion of the mechanical loading. The airfoil 30 includes leading 36 and trailing 38 edges and a first airfoil surface having a substantially concave shaped profile to provide a high-pressure surface 40 and a second airfoil surface having a substantially convex shaped profile to provide a low-pressure surface 42. The outer shell 32 includes at least one high heat resistant first member 44 and at least one high heat resistant second member 45 (see Figs. 6A and 6B) arranged in a stacked configuration around the core structure 34 to form a layered configuration. The first 44 and second 45 members are each fabricated from a high heat resistant material suitable for use in a vane or blade used in a gas turbine 10. For example, the material may be a known ceramic matrix composite (CMC) material. Alternatively, at least one first member 44 or second member 45 may be fabricated from one type of high heat resistant material whereas the remaining members 44, 45 may be fabricated from another type of high heat resistant material. The first 44 and second 45 members and core structure 34 are shaped such that a suitable airfoil shape is formed when the first 44 and

second 45 members are stacked or assembled around the core support structure. The first 44 and second 45 members may have equal thicknesses. Alternatively, at least one first member 44 or second member 45 may have a thickness that is greater or less than the thickness of the remaining members 44, 45. In an embodiment of the present invention, a thickness of a first member 44 or second member 45 fabricated from CMC material may be approximately 3 mm.

[0020] Referring to Fig. 3, a perspective view of the core structure 34 is shown. The core structure 34 may be fabricated from an alloy suitable for use in a turbine vane or blade such as INCONEL® alloy available from Special Metals Corporation of New Hartford, NY, US. The core structure 34 includes a first support section 46 having an internal portion 48 located within the outer shell 32. The internal portion 48 includes a first air inlet 50 that extends through the internal portion 48. The first support section 46 also includes an external portion 52 located outside of the outer shell 32 that includes the trailing edge 38. Further, the core structure 34 includes a second support section 54 located within the outer shell 32. The second support section 54 includes a second air inlet 56 that extends through the support section 54. The first 46 and second 54 support sections are connected by at least one truss element 58. For purposes of illustration, four trusses 58 are shown in Fig. 3. During operation, an airfoil 30 is subjected to various loads including centrifugal force due to rotation of the airfoil 30 and a gas bending load. In accordance with aspects of the present invention, use of at least one truss element 58 increases stiffness and load carrying capability of the core structure 34 and thus the airfoil 30.

[0021] A plurality of air exit holes 60 may be formed on the high-pressure surface 40 of the airfoil 30 near the trailing edge 38. Alternatively, the air exit holes 60 may be formed on the low-pressure surface 42 of the airfoil 30. A plurality of first air channels extend through the internal 48 and external 52 portions between the first air inlet 50 and associated air exit holes 60. Referring to Fig. 4, a partial cross sectional side view of the airfoil 30 and exemplary first member 44 is shown. Fig. 4 depicts an exemplary enclosed

first air channel 62 that extends through the internal 48 and external 52 portions between the first air inlet 50 and an associated air exit hole 60. The first air channel 62 is in fluid communication with the first air inlet 50 and the associated air exit hole 60 to form an exemplary first air passageway 64. Each truss 58 includes at least one enclosed second air channel 66 that extends through the truss 58 between the second air inlet 56 and an associated air exit hole 60. The second air channel 66 is in fluid communication with the second air inlet 56 and an associated air exit hole 60 to form a second air passageway 68. Alternatively, the second air channel 66 may feed into the first air channel 62 or the first air inlet 50. In operation, cooling air from the gas turbine 10 is received by the first 50 and second 56 air inlets and flows through the first 62 and second 66 air channels, respectively, and is then ultimately emitted from an associated air exit hole 60 in order to cool the airfoil 30. In accordance with the invention, all airflow through the airfoil 30 occurs within the core structure 34 and thus only the core structure 34 is subjected to an internal pressure load due to cooling airflow and substantially little or no load is placed on the outer shell 32 due to cooling airflow.

[0022] A fastener 47 (shown as dashed lines in Fig. 4) such as a tie bolt may be used to affix or compress the first 44 and second 45 members together. The fastener 47 may be inserted through the second air inlet 56 and spans the length of the second support section 54. The fastener 47 may block middle portions of the second air inlet 56. In accordance with aspects of the present invention, an interior wall 49 of the second air inlet 56 includes a plurality of cutout portions 51 located beyond edges 53 of the fastener 47 such that the cutout portions 51 are not blocked by the fastener 47, thus enabling air flow through the second air inlet 56.

[0023] The first member 44 includes first 70 and second 72 member sections that are connected by an end member section 74. An inner surface 76 of the first 70, second 72 and end 74 member sections contacts the internal portion 48, truss 58 and second support section 54 such that top 78 and bottom 80 sections of the external portion 52 are exposed. The first 70 and second 72 member sections include first 82 and second 84 mating surfaces, respectively, that contact corresponding first 86 and second 88 mating surfaces

of the top 78 and bottom 80 sections, respectively. The first mating surfaces 82, 86 taper away from the trailing edge 38 to form a first projection 90 at the inner surface 76 that extends into the top section 78 to form a first mating joint 92 having a first dovetail configuration that captures the first member section 70. The second mating surfaces 84, 88 also taper away from the trailing edge 38 to form a second projection 94 at the inner surface 76 that extends into the bottom section 80 to form a second mating joint 95 having a second dovetail configuration that captures the second member section 72. The first and second dovetail configurations serve to inhibit movement or separation of the first 70 and second 72 member sections away from the core structure 34. Further, the first member section 70 and top section 78 have substantially convex shapes that together form the low-pressure surface 42 and the second member section 72 and bottom section 80 have substantially concave shapes that together form the high-pressure surface 40.

[0024] The core structure 34 may be divided into a plurality of modular support structures. Referring to Fig. 5, an exemplary first modular support structure 96 is shown. The first modular structure 96 includes first 98 and second 100 modular support sections that correspond to the first 46 and second 54 support sections, respectively, and at least one truss 58 for connecting the first 98 and second 100 modular support sections. The first 98 and second 100 modular support sections include first 102 and second 104 modular air inlets that form part of the first 50 and second 56 air inlets, respectively, shown in Fig. 3. The first 50 and second 56 modular air inlets are in fluid communication with air exit holes 60 via enclosed first and second air channels as previously described.

[0025] First 106 and second 108 edge portions extend from a top portion 110 of the first 98 and second 100 modular support sections to form first 112 and second 114 recesses, respectively. First 116 and second 118 lip portions extend from a bottom portion 120 of the first 98 and second 100 modular support sections having a shape corresponding to the first 112 and second 114 recesses, respectively. In order to assemble a second modular support structure 122 to the first modular structure 96, the first 116 and second 118 lip

portions of the first modular structure 96 are inserted inside the first 112 and second 114 recesses, respectively, of the second modular structure 122. In an embodiment of the present invention, the first 116 and second 118 lip portions and first 112 and second 114 recesses are sized such that a press-fit is formed between the lip portions 116, 118 and recesses 112, 114 to affix the second modular structure 122 to the first modular structure 96. Alternatively, the first 96 and second 122 modular structures may be affixed to each other by brazing. In a still further alternative, shrink fitting could be used. In an embodiment of the present invention, the core structure 34 may include four modular structures although it is understood that additional or fewer modular structures may be used. Use of a modular support structure in accordance with aspects of the present invention enables use of a three dimensional (3D) printing process or a casting process to manufacture the structure, thus minimizing complexity and cost of the airfoil 30 while increasing manufacturing flexibility.

[0026] Referring to Fig. 6A, an exemplary first member 44 is shown. As previously described, the first member 44 includes the first 70 and second 72 member sections that are connected by the end section 74. The first 70 and second 72 member sections are spaced apart to form an aperture 124 for receiving the first 46 and second 54 support sections and a gap 126 for receiving a truss 58. Referring to Fig. 6B, an exemplary second member 45 is shown. The second member 45 further includes a bridge member 128 that connects the first 70 and second 72 member sections at a location on the second member 45 corresponding to the location of the truss 58 (see Fig. 3) to form a structure that is more rigid than the first member 44.

[0027] In accordance with aspects of the present invention, a plurality of second members 45 is stacked in areas of the core structure 34 that do not include a truss 58. Further, a plurality of first members 44 is stacked in areas of the core structure 34 that include a truss 58. Referring back to Fig. 3, a plurality of second members 45 is stacked in first locations 130A-130E locations of the core structure 34 (i.e. locations that do not

include a truss 58). In addition, a plurality of first members 44 is stacked in second locations 132A-132D of the core structure 34 (i.e. areas that include a truss 58).

[0028] Referring to Fig. 7, an exploded view of exemplary first 44 and second 45 members and a first modular support structure 96 is shown. In order to assemble the first 44 and second 45 members to the first modular support structure 96, a plurality of second members 45 is installed and stacked in a first direction 134 onto the first modular support structure 96 in the first location 130A as previously described. A plurality of first members 44 is then stacked in a second direction 136 opposite the first direction 134 in the second location 132A as previously described. Next, a plurality of second members 45 is stacked in the second direction 136 and in the first location 130B above the first members 44 located in the second location 132A.

[0029] Referring to Fig. 8A, an alternate embodiment of the present invention for a modular support structure 140 is shown. The modular structure 140 includes the first 98 and second 100 modular support sections as previously described that are connected by a truss 142. Referring to Fig. 8B, a cross sectional view of the truss 142 along view line 8B-8B is shown. The truss 142 includes first 144 and second 146 raised top edge portions that form a top channel 148 and first 150 and second 152 raised bottom edge portions that form a bottom channel 154 resulting in a substantially I-beam configuration. Referring to Fig. 9, an alternate embodiment of the present invention for a member 156 that mates with the modular support structure 140 is shown. The member 156 includes first 158 and second 160 grooves located in bridge member 128 that form a raised surface 162 located between the first 158 and second 160 grooves. When assembled, the first 150 and second 152 raised bottom edge portions, for example, are received by the first 158 and second 160 grooves, respectively, and the raised surface 162 is received by the bottom channel 154 to form an interlocking arrangement that provides additional structural support for the modular support structure 140. The member 156 also includes first 164 and second 166 raised surfaces located adjacent the first 158 and second 160 grooves that are of

sufficient height so as to cover the truss 142 when the member 156 is assembled to the modular support structure 140.

[0030] It has been found that aspects of the current invention result in a substantial reduction in the temperature of the outer shell 32. In particular, hot spot temperatures are reduced to approximately 1340 degrees C or less. This enables a substantial reduction in the amount of cooling air needed to cool the airfoil 30. In addition, aspects of the current invention also enable operation of a gas turbine at a higher operating temperature, thus increasing turbine efficiency. Further, a thickness of a known thermal barrier coating used on the airfoil 30 may be minimized.

[0031] While particular embodiments of the present disclosure have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the disclosure. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this disclosure.

CLAIMS

What is claimed is:

Claim 1. An airfoil (30) for a turbine (10), wherein the airfoil (30) includes leading (36) and trailing (38) edges and high (40) and low (42) pressure surfaces, comprising:

a core support structure (34) having first (46) and second (54) support sections that include first (50) and second (56) air inlets, respectively;

at least one first air channel (62) that extends from the first air inlet (50) and through the first support section (46) to an associated air exit hole (60);

at least one truss (58) connected between the first (46) and second (54) support sections;

at least one second air channel (66) that extends from the second air inlet (56) and through the second support section (54), truss (58) and first support section (46) to an associated air exit hole (60); and

a high heat resistant outer shell (32), wherein a portion (48) of the core support structure (34) is located within the outer shell (32).

Claim 2. The airfoil (30) according to claim 1, wherein the outer shell (32) includes at least one high heat resistant member (44) that is located on the core support structure (34).

Claim 3. The airfoil (30) according to claim 1, wherein the core support structure (34) is formed by assembling modular support sections (96, 122) each including portions of the first (46) and second (54) support sections and at least one truss (58).

Claim 4. The airfoil (30) according to claim 3, wherein a first modular support section (96) includes lip portions (116, 118) and a second modular support section (122) includes recesses (112, 114) for receiving the lip portions (116, 118).

Claim 5. The airfoil (30) according to claim 4, wherein the lip portions (116, 118) and recesses (112, 114) form a press-fit for securing the first modular support section (96) to the second modular support section (122).

Claim 6. The airfoil (30) according to claim 1, wherein the outer shell (32) includes first (82) and second (84) mating surfaces having first (90) and second (94) projections, respectively, that contact corresponding portions (86, 88) of the core support structure (34) to inhibit movement of the outer shell (32).

Claim 7. The airfoil (30) according to claim 1, wherein a wall (49) defining the second air inlet (56) includes cutout portions (51) to enable air flow.

Claim 8. The airfoil (30) according to claim 1, wherein the air exit holes (60) are located in the trailing edge (38) of the airfoil (30).

Claim 9. An airfoil (30) for a turbine (10), wherein the airfoil (30) includes leading (36) and trailing (38) edges and high (40) and low (42) pressure surfaces, comprising:

- a core support structure (34) having first (46) and second (54) support sections that include first (50) and second (56) air inlets, respectively;

- at least one first air channel (62) that extends from the first air inlet (50) and through the first support section (46) to an associated air exit hole (60);

- at least one truss (58) connected between the first (46) and second (54) support sections;

- at least one second air channel (66) that extends from the second air inlet (56) and through the second support section (54), truss (58) and first support section (46) to an associated air exit hole (60);

- at least one first high heat resistant member (45) located on the core support structure (34), wherein the least one first high heat resistant (44) member includes an opening (124) that receives the first (46) and second (54) support sections; and

at least one second high heat resistant member (44) located on the core support structure (34), wherein the at least one second high heat resistant member (44) includes an opening (124) that receives the first (46) and second (54) support sections and a gap (126) that receives the truss (58).

Claim 10. The airfoil (30) according to claim 9, wherein the core support structure (34) is formed by assembling modular support sections (96, 122) each including portions of the first (46) and second (54) support sections and at least one truss (58).

Claim 11. The airfoil (30) according to claim 10, wherein a first modular support section (96) includes lip portions (116, 118) and a second modular support section (122) includes recesses (112, 114) for receiving the lip portions (116, 118).

Claim 12. The airfoil (30) according to claim 11, wherein the lip portions (116, 118) and recesses (112, 114) form a press-fit for securing the first modular support section (96) to the second modular support section (122).

Claim 13. The airfoil (30) according to claim 9, wherein the at least one first (45) and second (44) high heat resistant members each include first (82) and second (84) mating surfaces having first (90) and second (94) projections, respectively, that contact corresponding portions (86, 88) of the core support structure (34) to inhibit movement of the at least one first (45) and second (44) high heat resistant members.

Claim 14. The airfoil (30) according to claim 9, wherein a wall (49) defining the second air inlet (56) includes cutout portions (51) to enable air flow.

Claim 15. The airfoil (30) according to claim 9, wherein the air exit holes (60) are located in the trailing edge (38) of the airfoil (30).

Claim 16. An airfoil (30) for a turbine (10), wherein the airfoil (30) includes leading (36) and trailing (38) edges and high (40) and low (42) pressure surfaces, comprising:

- a core support structure (34) having first (46) and second (54) support sections that include first (50) and second (56) air inlets, respectively;

- at least one first air channel (62) that extends from the first air inlet (50) and through the first support section (46) to an associated air exit hole (60);

- at least one truss (58) connected between the first (46) and second (54) support sections;

- at least one second air channel (66) that extends from the second air inlet (56) and through the second support section (54), truss (58) and first support section (46) to an associated air exit hole (60);

- at least one first high heat resistant member (45) located on portions (130A-130E) of the first (46) and second (54) support sections that do not include a truss (58); and

- at least one second high heat resistant member (44) located on portions (132A-132D) of the first (46) and second (54) support sections that include a truss (58).

Claim 17. The airfoil (30) according to claim 16, wherein the core structure (34) is formed by assembling modular support sections (96, 122) each including portions of the first (46) and second (54) support sections and at least one truss (58).

Claim 18. The airfoil (30) according to claim 17, wherein the modular support sections (96, 122) are secured to each other by a press fit arrangement.

Claim 19. The airfoil (30) according to claim 17, wherein the at least one first (45) and second (44) high heat resistant members each include first (82) and second (84) mating surfaces having first (90) and second (94) projections, respectively, that contact corresponding portions (86, 88) of the modular support sections (96, 122) to inhibit movement of the at least one first (45) and second (44) high heat resistant members.

Claim 20. The airfoil (30) according to claim 16, wherein a wall (49) defining the second air inlet (56) includes cutout portions (51) to enable air flow.

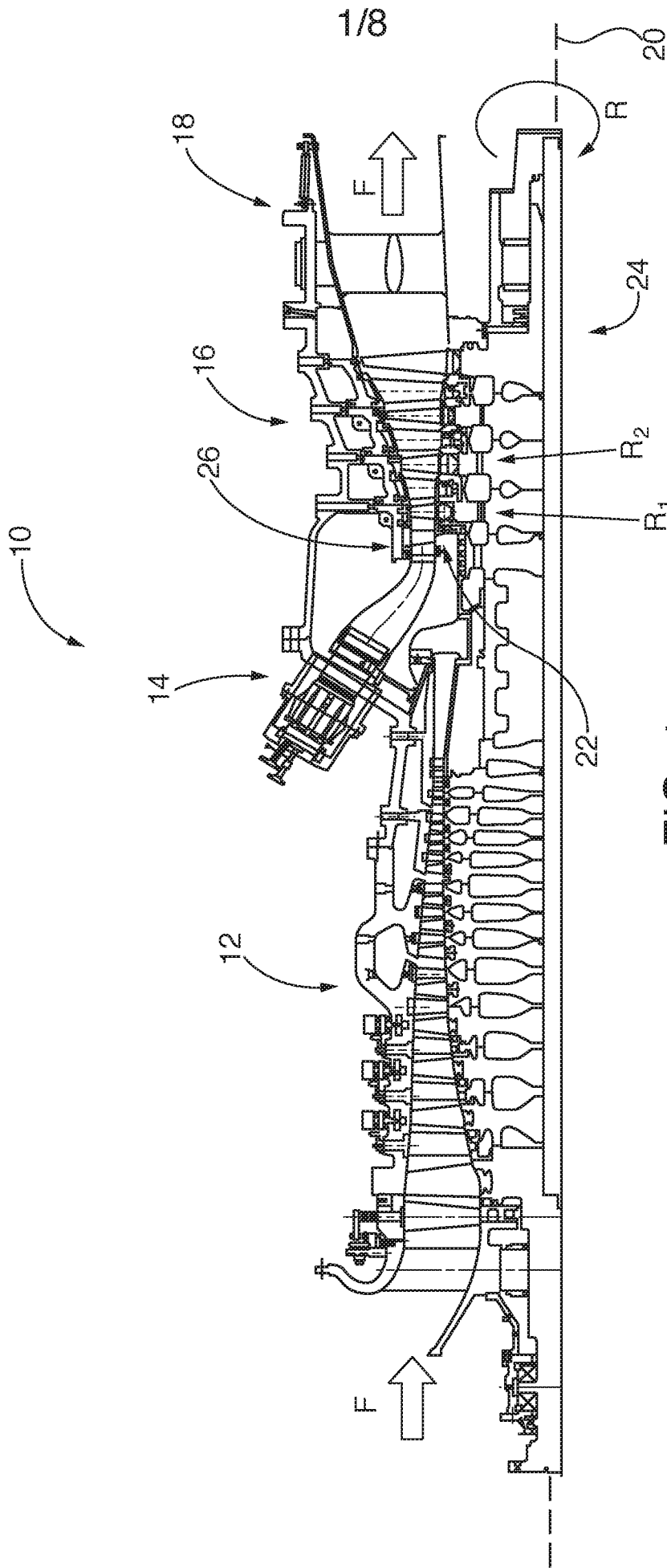


FIG. 1
PRIOR ART

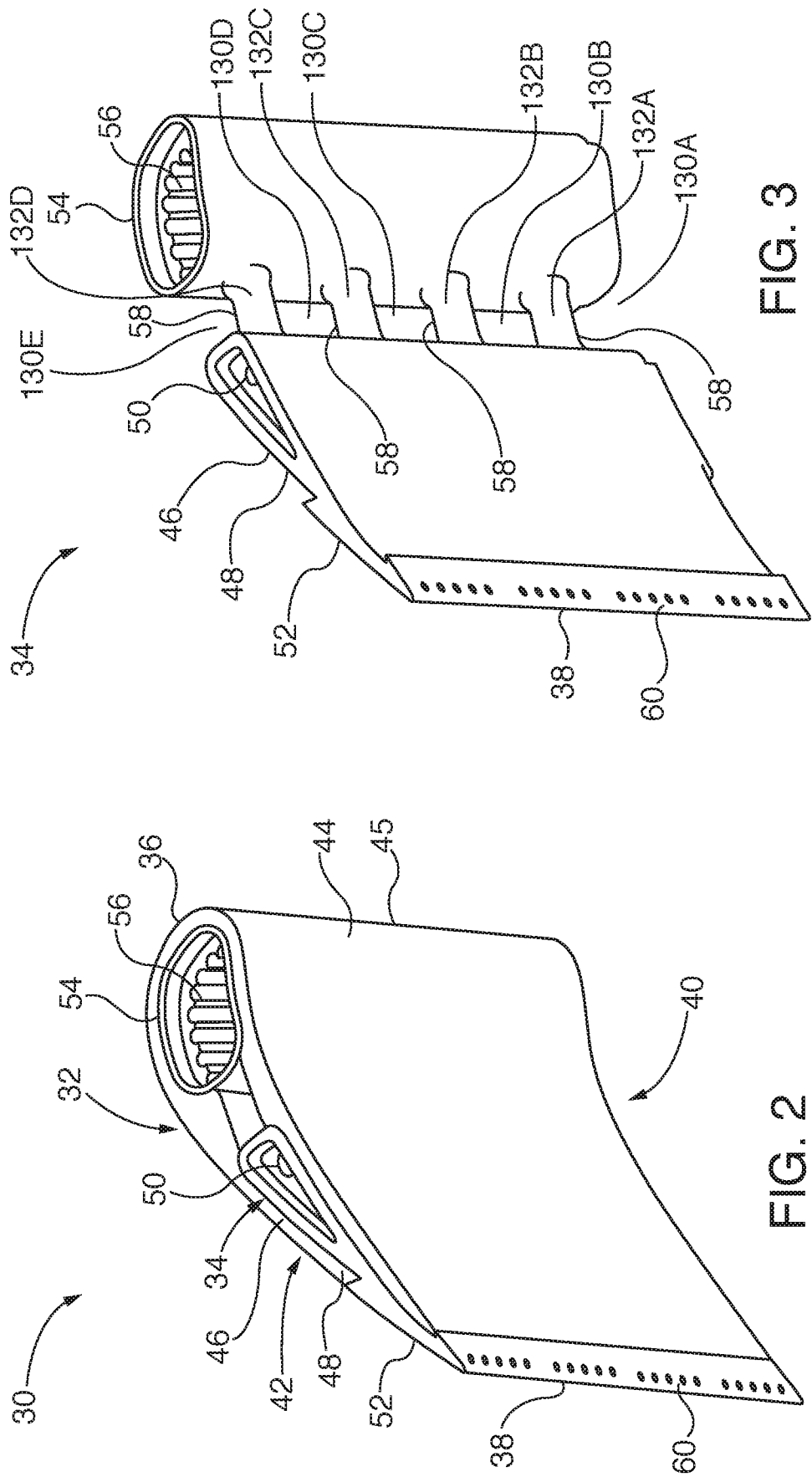


FIG. 3

FIG. 2

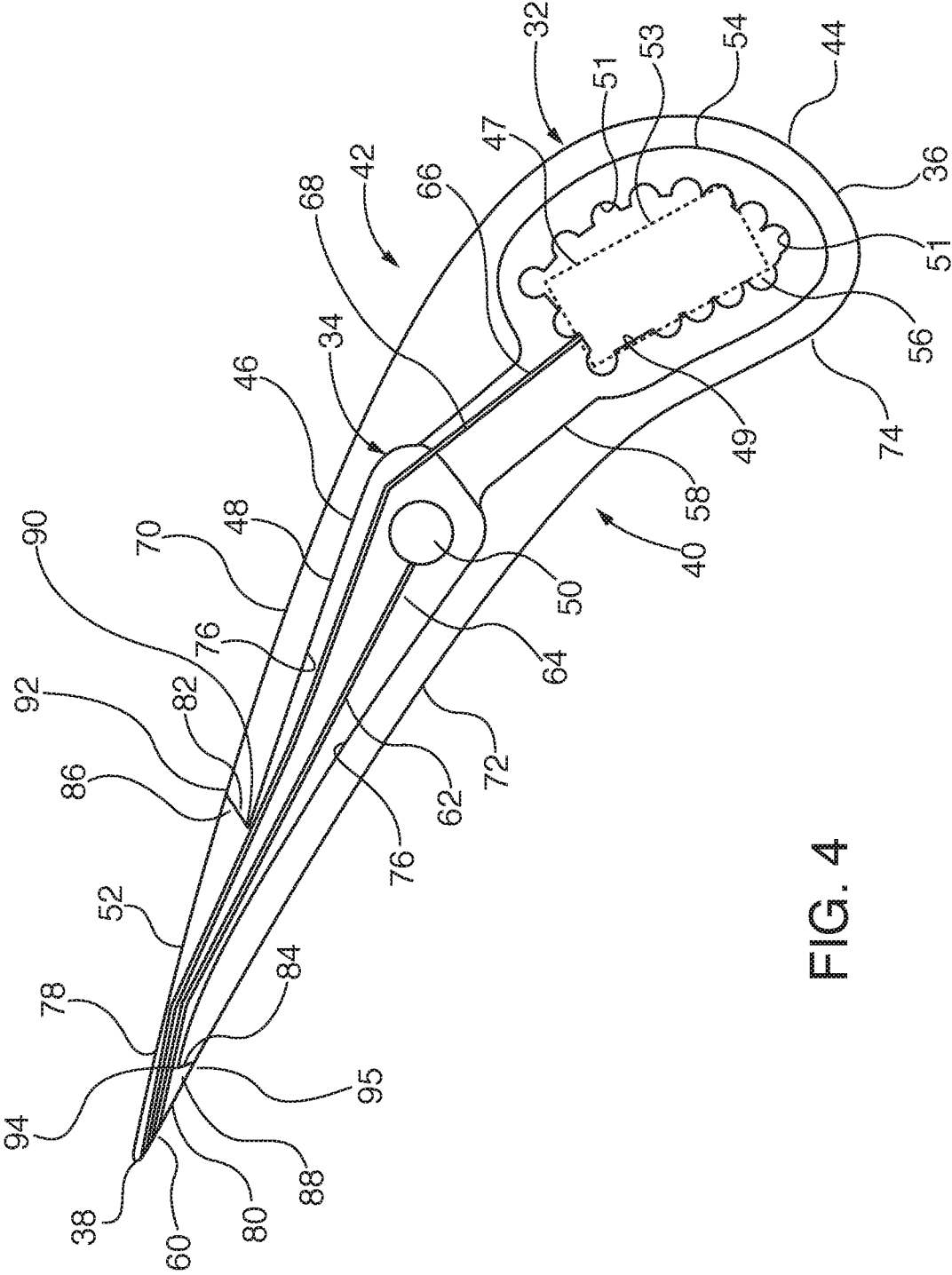


FIG. 4

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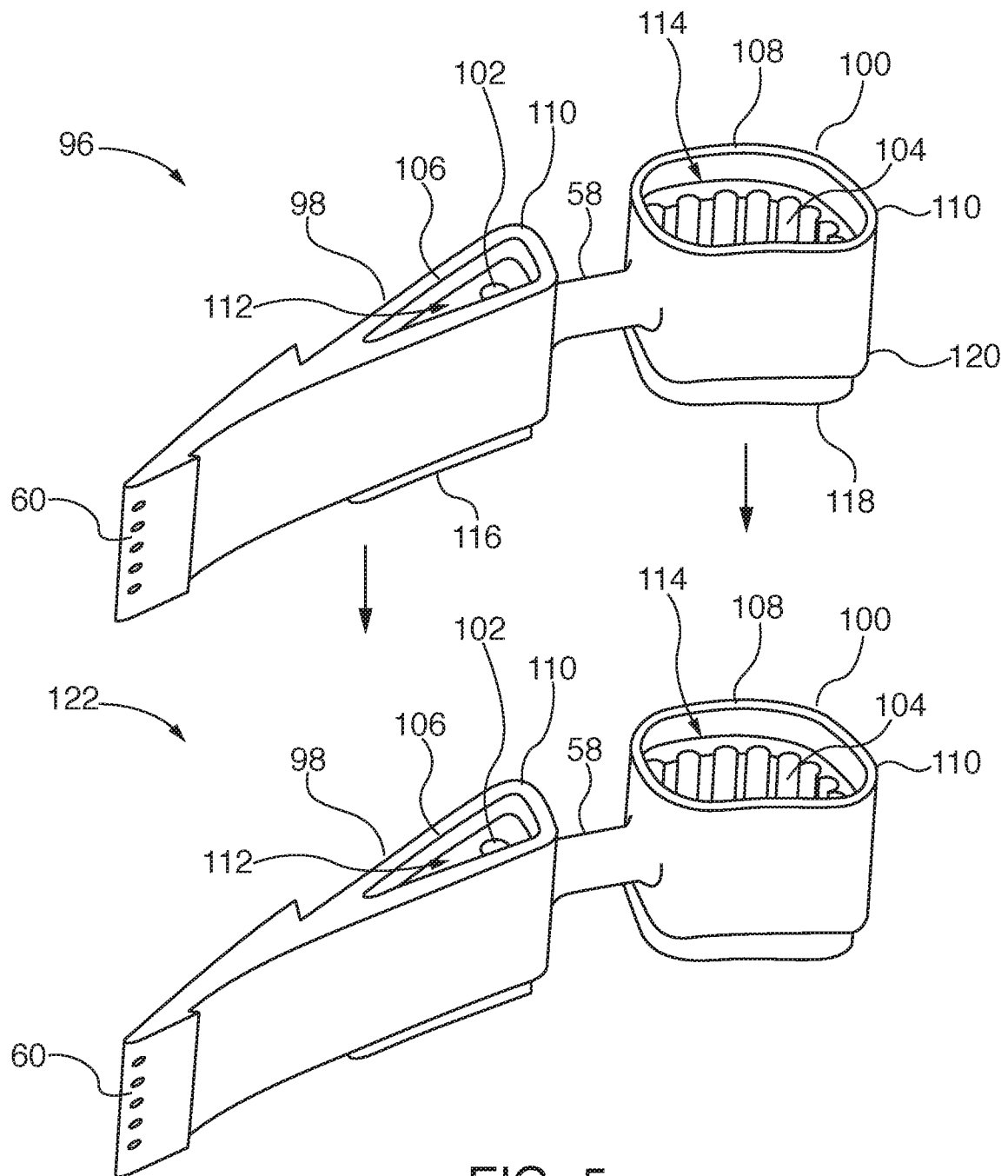


FIG. 5

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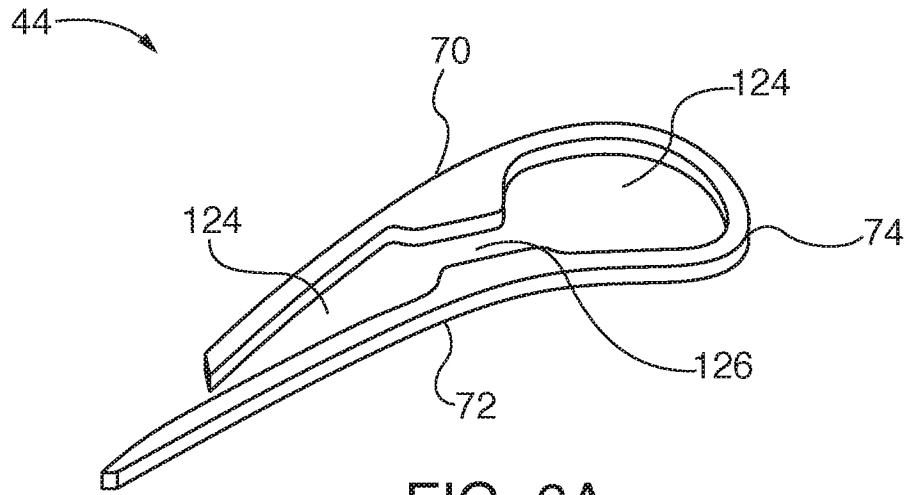


FIG. 6A

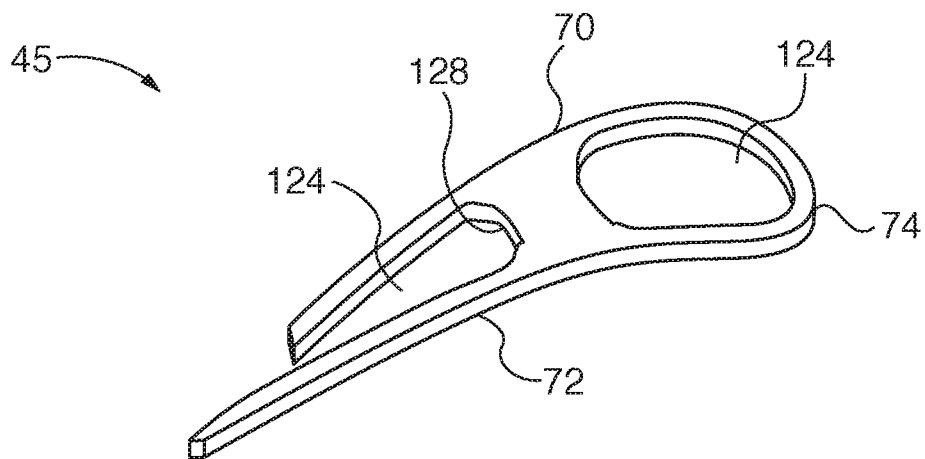


FIG. 6B

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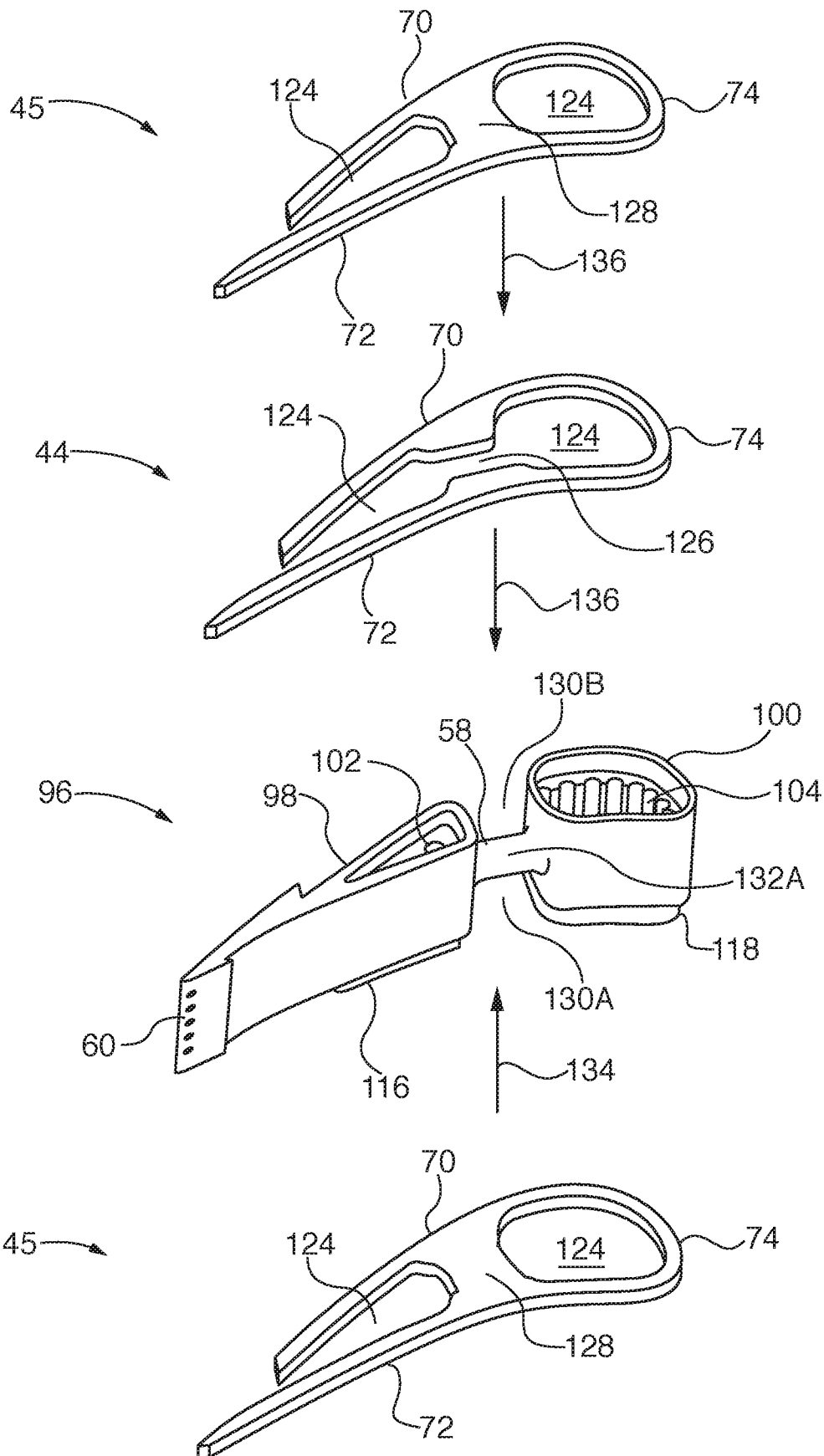


FIG. 7

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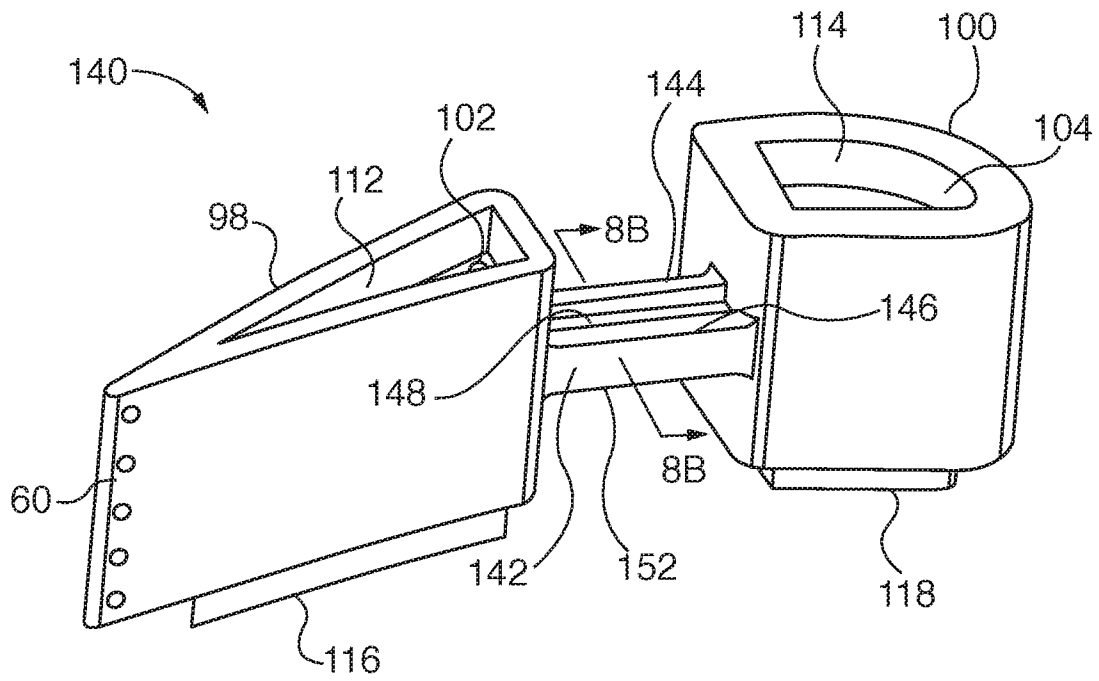


FIG. 8A

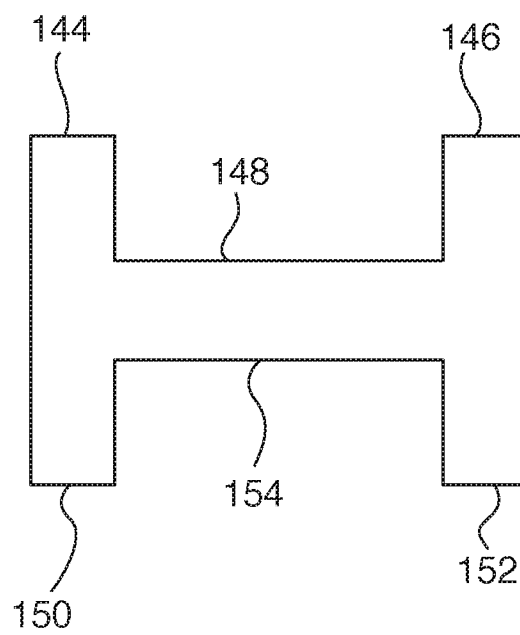


FIG. 8B

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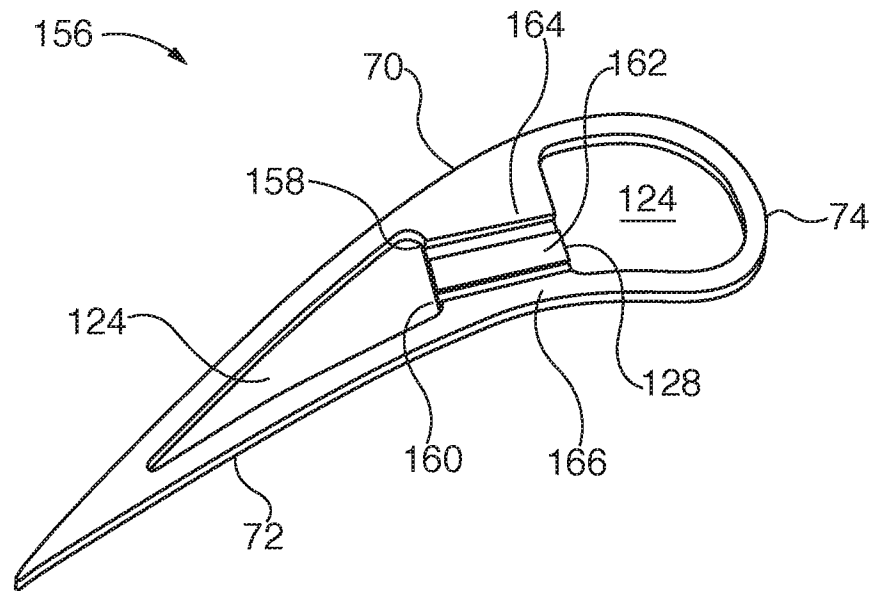


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/065424

A. CLASSIFICATION OF SUBJECT MATTER INV. F01D5/14 F01D5/18 F01D5/28 F01D9/06 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.
A	US 2007/128043 A1 (MORRISON JAY A [US] ET AL) 7 June 2007 (2007-06-07) the whole document -----	1-20
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents :		
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 4 August 2016		Date of mailing of the international search report 02/09/2016
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Lutoschkin, Eugen

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/065424

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007128043	A1	07-06-2007	NONE
