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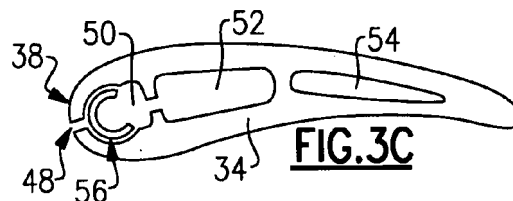
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(54) **Turbine engine airfoil with wrapped leading edge cooling passage**

(57) A turbine engine airfoil (34) includes an airfoil structure having an exterior surface (57) providing a leading edge (38). A radially extending first cooling passage (56) is arranged near the leading edge (38) and includes first and second portions. The first portion extends to the exterior surface (57) and forms a radially extending trench (48) in the leading edge. The second portion is in fluid communication with a second cooling passage (50). In one example, the second cooling passage (50) ex-

tends radially, and the first cooling passage (56) wraps around a portion of the second cooling passage (50) from a pressure side (42) to a suction side (44) between the second cooling passage (50) and the exterior surface (57). In the example, the first portion is arranged between the pressure and suction sides (42, 44). In one example, the first cooling passage (56) is formed by arranging a core in an airfoil mold. The trench is formed by the core in one example.



Description

BACKGROUND

[0001] This disclosure relates to a cooling passage for an airfoil.

[0002] Turbine blades are utilized in gas turbine engines. As known, a turbine blade typically includes a platform having a root on one side and an airfoil extending from the platform opposite the root. The root is secured to a turbine rotor. Cooling circuits are formed within the airfoil to circulate cooling fluid, such as air. Typically, multiple relatively large cooling channels extend radially from the root toward a tip of the airfoil. Air flows through the channels and cools the airfoil, which is relatively hot during operation of the gas turbine engine.

[0003] Some advanced cooling designs use one or more radial cooling passages that extend from the root toward the tip near a leading edge of the airfoil. Typically, the cooling passages are arranged between the cooling channels and an exterior surface of the airfoil. The cooling passages provide extremely high convective cooling.

[0004] Cooling the leading edge of the airfoil can be difficult due to the high external heat loads and effective mixing at the leading edge due to fluid stagnation. Prior art leading edge cooling arrangements typically include two cooling approaches. First, internal impingement cooling is used, which produces high internal heat transfer rates. Second, showerhead film cooling is used to create a film on the external surface of the airfoil. Relatively large amounts of cooling flow are required, which tends to exit the airfoil at relatively cool temperatures. The heat that the cooling flow absorbs is relatively small since the cooling flow travels along short paths within the airfoil, resulting in cooling inefficiencies.

[0005] One arrangement that has been suggested to convectively cool the leading edge is a cooling passage wrapped at the leading edge. This wrapped leading edge cooling passage is formed by a refractory metal core that is secured to another core. The cores are placed in a mold, and a superalloy is cast into the mold about the cores to form the airfoil. The cores are removed from the cast airfoil to provide the cooling passages. However, in some applications, the wrapped leading edge cooling passage does not provide the amount of desired cooling to the leading edge.

[0006] What is needed is a leading edge cooling arrangement that provides desired cooling of the airfoil.

SUMMARY

[0007] A turbine engine airfoil includes an airfoil structure having an exterior surface providing a leading edge. A radially extending first cooling passage is arranged near the leading edge and includes first and second portions. The first portion extends to the exterior surface and forms a radially extending trench in the leading edge. The second portion is in fluid communication with a sec-

ond cooling passage. In one example, the second cooling passage extends radially, and the first cooling passage wraps around a portion of the second cooling passage from a pressure side to a suction side between the second cooling passage and the exterior surface. In the example, the first portion is arranged between the pressure and suction sides. In one example, the first cooling passage is formed by arranging a core in an airfoil mold. The trench is formed by the core in one example.

[0008] These and other features of the disclosure can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 is a schematic view of a gas turbine engine incorporating the disclosed airfoil.

[0010] Figure 2 is a perspective view of the airfoil having the disclosed cooling passage.

[0011] Figure 3A is a cross-sectional view of a portion of the airfoil shown in Figure 2 and taken along 3A-3A.

[0012] Figure 3B is a perspective view of a core that provides the wrapped leading edge cooling passage shown in Figure 3A.

[0013] Figure 3C is a cross-sectional view of the airfoil shown in Figure 3A with the core removed from the airfoil and a trench formed in the leading edge.

[0014] Figure 4A is a partial cross-sectional view of another airfoil leading edge with another example core.

[0015] Figure 4B is a perspective view of the core shown in Figure 4A.

[0016] Figure 5A is a partial cross-sectional view of yet another airfoil leading edge with yet another example core.

[0017] Figure 5B is a perspective view of the core shown in Figure 5A.

[0018] Figure 5C is a front elevational view of the leading edge shown in Figure 5A.

[0019] Figure 6A is a partial cross-sectional view of still another airfoil leading edge with still another example core.

[0020] Figure 6B is a front elevational view of the leading edge shown in Figure 6A.

[0021] Figure 6C is a perspective view of a portion of the core shown in Figure 6A.

DETAILED DESCRIPTION

[0022] Figure 1 schematically illustrates a gas turbine engine 10 that includes a fan 14, a compressor section 16, a combustion section 18 and a turbine section 11, which are disposed about a central axis 12. As known in the art, air compressed in the compressor section 16 is mixed with fuel that is burned in combustion section 18 and expanded in the turbine section 11. The turbine section 11 includes, for example, rotors 13 and 15 that, in response to expansion of the burned fuel, rotate, which drives the compressor section 16 and fan 14.

[0023] The turbine section 11 includes alternating rows of blades 20 and static airfoils or vanes 19. It should be understood that Figure 1 is for illustrative purposes only and is in no way intended as a limitation on this disclosure or its application.

[0024] An example blade 20 is shown in Figure 2. The blade 20 includes a platform 32 supported by a root 36, which is secured to a rotor. An airfoil 34 extends radially outwardly from the platform 32 opposite the root 36. While the airfoil 34 is disclosed as being part of a turbine blade 20, it should be understood that the disclosed airfoil can also be used as a vane.

[0025] The airfoil 34 includes an exterior surface 57 extending in a chord-wise direction C from a leading edge 38 to a trailing edge 40. The airfoil 34 extends between pressure and suction sides 42, 44 in a airfoil thickness direction T, which is generally perpendicular to the chord-wise direction C. The airfoil 34 extends from the platform 32 in a radial direction R to an end portion or tip 33. A cooling trench 48 is provided on the leading edge 38 to create a cooling film on the exterior surface 57. In the examples, the trench 48 is arranged in proximity to a stagnation line on the leading edge 38, which is an area in which there is little or no fluid flow over the leading edge.

[0026] Figure 3A schematically illustrates an airfoil molding process in which a mold 94 having mold halves 94A, 94B provides a mold contour that defines the exterior surface 57 of the airfoil 34. In one example, cores 82, which may be ceramic, are arranged within the mold 94 to provide the cooling channels 50, 52, 54 (Figure 3C). Referring to Figure 3C, multiple, relatively large radial cooling channels 50, 52, 54 are provided internally within the airfoil 34 to deliver airflow for cooling the airfoil. The cooling channels 50, 52, 54 typically provide cooling air from the root 36 of the blade 20.

[0027] Current advanced cooling designs incorporate supplemental cooling passages arranged between the exterior surface 57 and one or more of the cooling channels 50, 52, 54. With continuing reference to Figure 3A, the airfoil 34 includes a first cooling passage 56 arranged near the leading edge 38. The first cooling passage 56 is in fluid communication with the cooling channel 50, in the example shown. One or more core structures 68 (Figures 3A and 3B), such as refractory metal cores, are arranged within the mold 94 and connected to the other cores 82. The core structure 68, which is generally C-shaped, provides the first cooling passage 56 in the example disclosed. In one example, the core structure 68 (shown in Figure 3B) is stamped from a flat sheet of refractory metal material. The core structure 68 is then bent or shaped to a desired contour. The ceramic core and/or refractory metal cores are removed from the airfoil 34 after the casting process by chemical or other means.

[0028] A core assembly can be provided in which a portion of the core structure 68 is received in a recess of the other core 82, as shown in Figure 3A. In this manner, the resultant first cooling passage 56 provided by the

core structure 68 is in fluid communication with the cooling channel 50 subsequent to the airfoil casting process.

[0029] The core structure 68 includes a first portion 72 and a second portion. In the example shown in Figures 3A-3C, the second portion includes multiple, radially spaced first and second sets of arcuate legs 74, 76 that wrap around a portion of the cooling channel 50. The shape of the legs 74, 76 generally mirror the exterior surface 57 of the leading edge 38. The first and second sets of legs 74, 76 are secured to the other core 82. One set of legs 74 is arranged on the pressure side 42 and the other set of legs 76 is arranged on the suction side 44. In the example shown in Figures 3A-3C, the first portion 72 does not extend to the exterior surface 57. The trench 48 is formed by a chemical or mechanical machining process, for example, to fluidly connect the first portion 72 to the leading edge 38. Cooling fluid is provided from the first cooling channel 50 through the first cooling passage 56 to provide a cooling film on the leading edge 38 via the trench 48.

[0030] Referring to Figures 4A and 4B, a core structure 168 is shown that provides the trench 48 during the casting process. The first portion 172 extends beyond the exterior surface and into the mold 94 where the first portion 172 is held by a core retention feature 96, which is provided by a notch in the mold 94, for example. Thus, when the core structure 168 is removed from the airfoil 134, a trench will be provided at the leading edge 138. The legs 174, 176 are at an angle or transverse laterally to the first portion 172. The example core structure 168 provides first and second sets of legs 174, 176 on opposite sides and in radially spaced, alternating relationship from one another. The first portion 172 extends in a direction opposite the other core 82.

[0031] The first cooling passage can be provided by multiple separate networks of passageways, as illustrated in Figures 5A and 5B. The networks of passageways are formed with multiple core structures 86, 88 having first portions 272, 273 that are discrete from one another. One of the cores structures 86 is arranged on the suction side 44 and the other core structure 88 is arranged on the pressure side 42. The legs 274, 276 are only fluidly connected to one another through the cooling channel 50. The first portions 272, 273 extend beyond the exterior surface 57 in the leading edge 238 and can be configured to provide laterally and/or radially staggered trenches 248 on the airfoil 234, as shown in Figure 5C.

[0032] Another arrangement of multiple networks of passageways is shown in Figures 6A-6C. The first cooling passage is provided by two networks of passageways created by core structures 186a, 186b, 188a, 188b provided on each of the pressure and suction sides 42, 44 of airfoil 334. The core structures 186a, 186b, 188a, 188b respectively provide discrete first portions 273a, 273b, 272a, 272b that create trenches 348 in leading edge 338, shown in Figure 6B.

[0033] Although example embodiments have been disclosed, a worker of ordinary skill in this art would rec-

ognize that certain modifications would come within the scope of the claims. For that reason, the following claims should be studied to determine their true scope and content.

Claims

1. A turbine engine airfoil comprising:

an airfoil structure including an exterior surface providing a leading edge, a radially extending first cooling passage near the leading edge including first and second portions, the first portion extending to the exterior surface and forming a radially extending trench in the leading edge, the second portion in fluid communication with a second cooling passage.

2. The turbine engine airfoil according to claim 1, wherein the second cooling passage extends radially and the first cooling passage wraps around a portion of the second cooling passage from a pressure side to a suction side between the second cooling passage and the exterior surface, the first portion arranged between the pressure and suction sides.

3. The turbine engine airfoil according to claim 2, wherein the first cooling passage is generally C-shaped.

4. The turbine engine airfoil according to claim 2 or 3, wherein the first cooling passage is provided by multiple networks of passageways each having a first portion discrete from the other first portion.

5. The turbine engine airfoil according to claim 4, wherein one of the networks of passageways is located on the pressure side and another of the passageways is located on the suction side, each of the networks of passageways including second portions fluidly connected to the second portions of other networks of passageways only through the second cooling passage.

6. The turbine engine airfoil according to claim 5, wherein at least two networks of passageways is arranged on at least one of the pressure and suction sides.

7. The turbine engine airfoil according to claim 6, wherein the at least two networks of passageways each include second portions having multiple radially spaced arcuate legs, the arcuate legs of the at least two networks of passageways arranged in alternating relationship with one another.

8. The turbine engine airfoil according to any of claims

2 to 7, wherein the second portions are provided by first and second sets of radially spaced apart arcuate legs, the first set of legs arranged on the pressure side and the second set of legs arranged on the suction side, the first and second sets of legs extending to a common first portion.

9. The turbine engine airfoil according to any preceding claim, wherein the first cooling passage provides multiple laterally spaced trenches.

10. The turbine engine airfoil according to any preceding claim, wherein the first cooling passage provides multiple radially spaced trenches.

11. A core for manufacturing an airfoil comprising:

a core structure having a generally flat radially extending first portion, and a second portion extending transversely from the first portion, the second portion including multiple radially spaced arcuate legs.

12. A core according to claim 11, wherein the second portion includes a first set of legs extending to one side of the first portion and a second set of legs extending to another side of the first portion opposite the one side, the first and second sets of legs in alternating relationship with one another along a length of the first portion.

13. A core according to claim 11 or 12, wherein the core structure is secured to another core structure, the first portion spaced from the other core structure and extending in a direction opposite from the other core structure.

14. A method of manufacturing an airfoil with internal cooling passages, the method comprising the steps of:

providing a first core having first and second portions;
arranging the first core in a mold at a location corresponding to a leading edge of an airfoil to be formed by the mold, the mold providing an airfoil contour; and
depositing casting material into the mold with the first portion extending into the mold beyond the airfoil contour and the second portion surrounded by the casting material, the first portion corresponding to a trench in the leading edge.

15. The method according to claim 14, comprising the step of arranging a second core radially within the mold, the first portion including a radially extending portion with multiple generally arcuate second portions extending generally chord-wise from the first

portion, the second core supporting the second portions.

16. The method according to claim 14 or 15, comprising the step of retaining the first portion in the mold in a core retention feature, the first portion outside of the casting material. 5
17. The method according to claim 14, 15 or 16, wherein the first core includes at least one core member, the at least one core member wrapping around the leading edge generally mirroring the airfoil contour between sides, which correspond to pressure and suction sides of the airfoil. 10
18. The method according to any of claims 14 to 17, wherein the second core is a ceramic core and the first core is a refractory metal core, the first and second cores secured to one another. 15
19. The method according to any of claims 14 to 18, wherein the first core is provided by stamping a core structure including a desired shape from a refractory metallic material and bending the first core to provide a desired contour. 20
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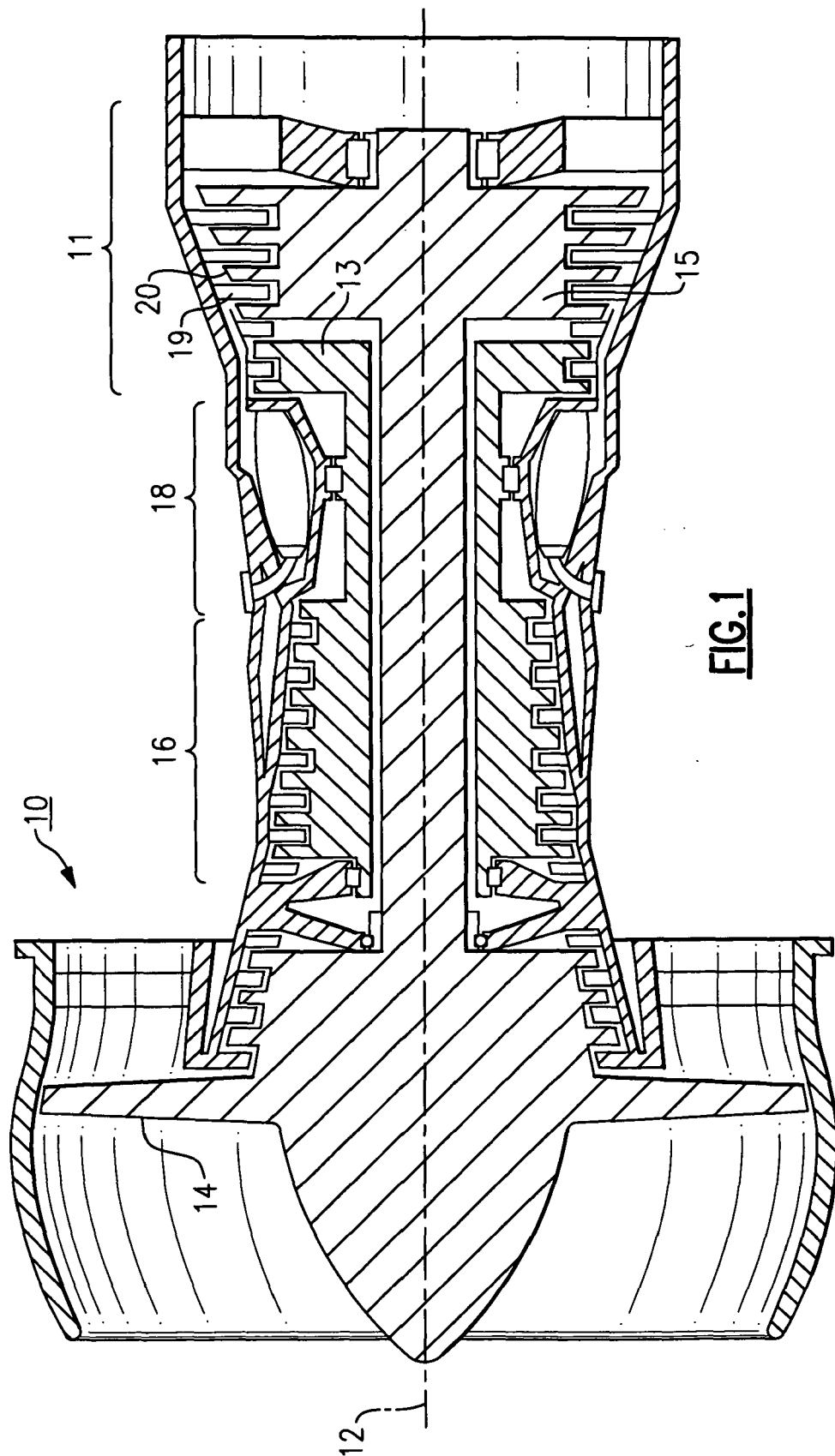


FIG. 1

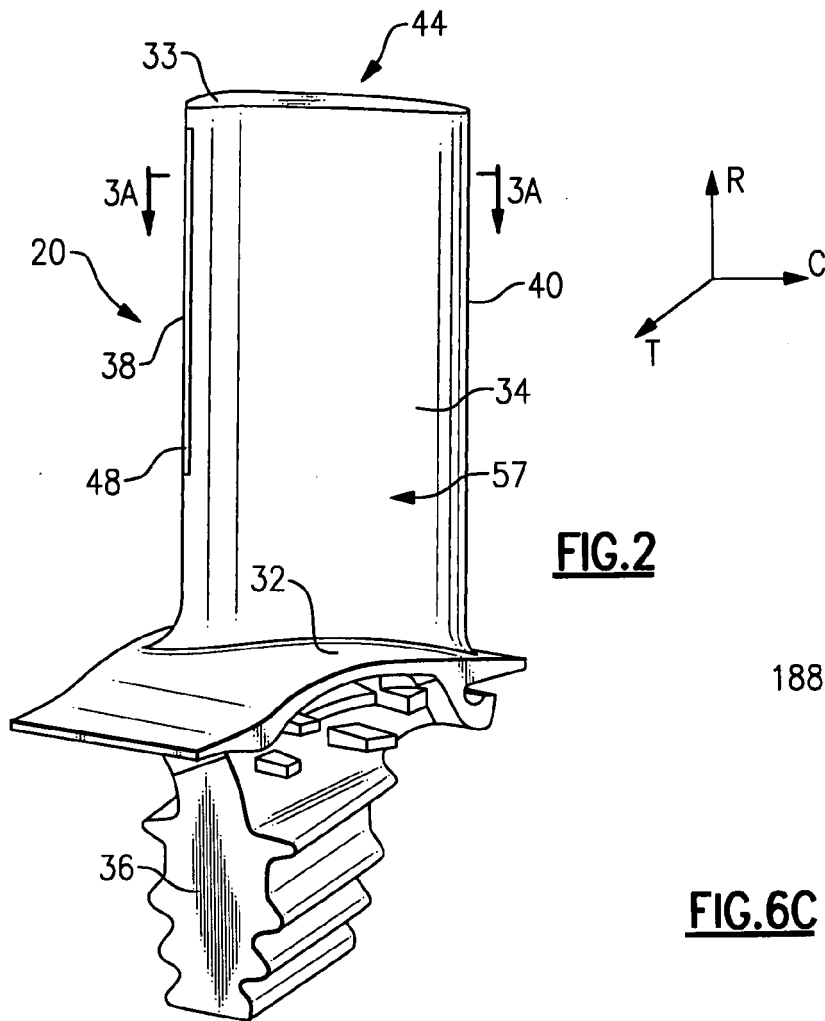


FIG. 2

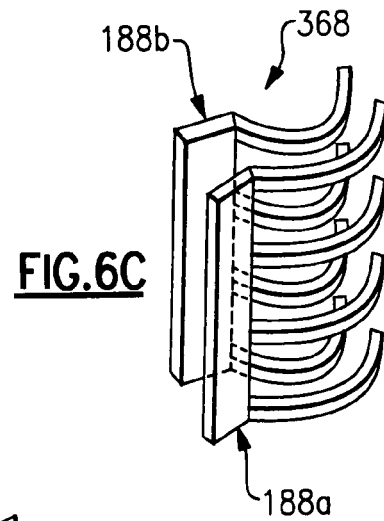


FIG. 6C

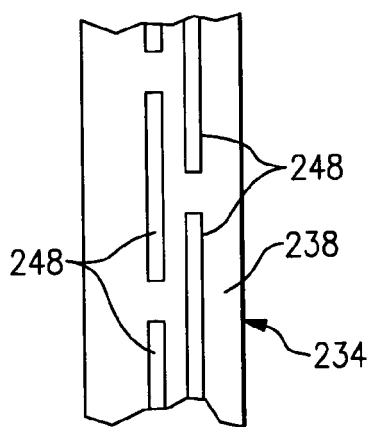


FIG. 5C

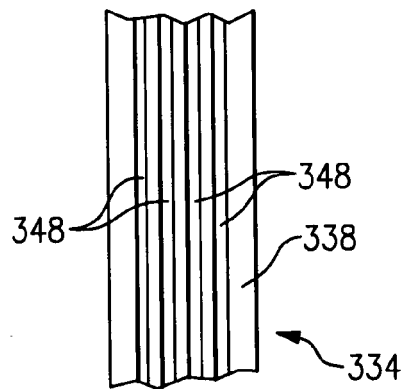
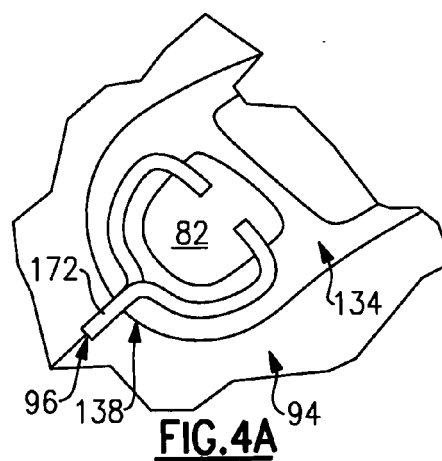
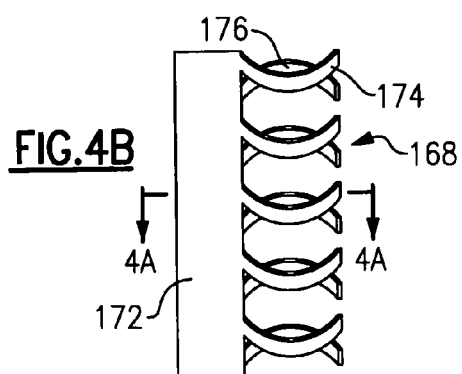
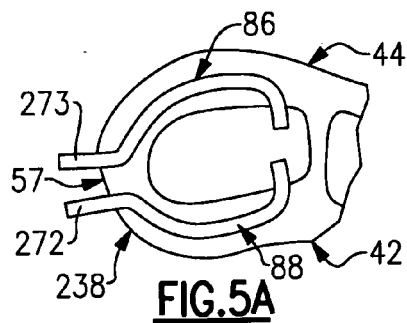
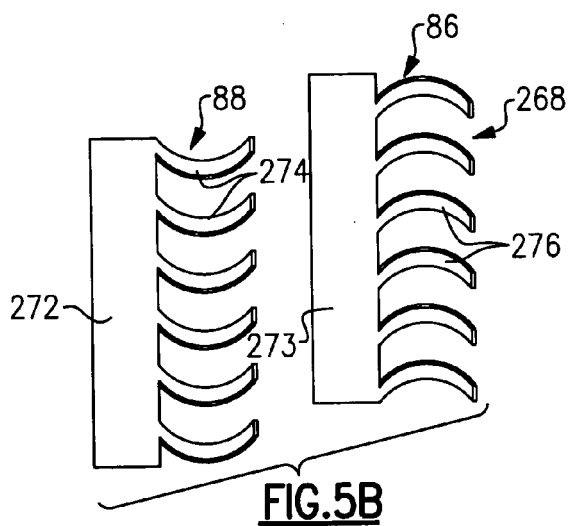
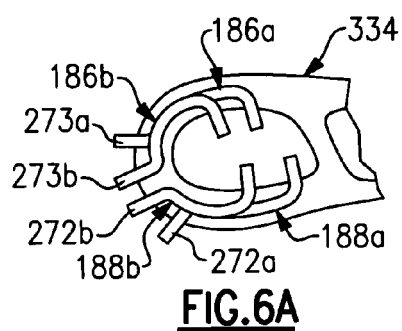
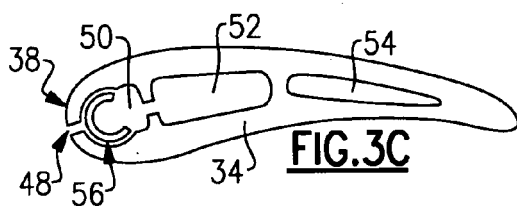
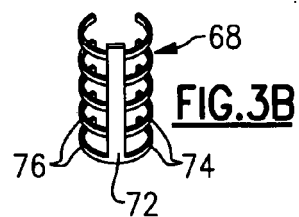
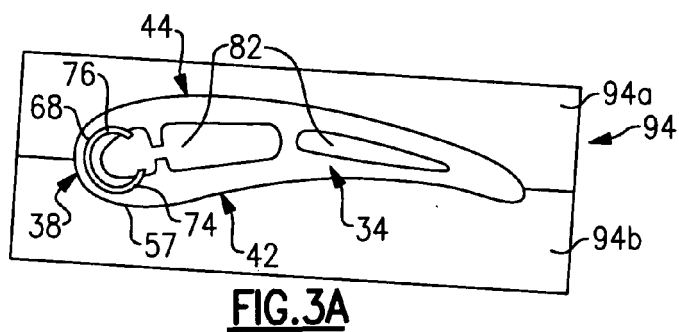


FIG. 6B





EUROPEAN SEARCH REPORT

Application Number
EP 10 00 5822

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Place of search Munich		Date of completion of the search 24 November 2010	Examiner Rau, Guido
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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