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(71) Applicant: **UNITED TECHNOLOGIES CORPORATION** [US/US]; One Financial Plaza, Hartford, Connecticut 06101 (US).

(72) Inventors: **STILIN, Nicholas D.**; 790 Candlewood Hill Rd., Higganum, Connecticut 06441 (US). **FOX, Jeremy L.**; 443 Commonwealth Ave., New Britain, Connecticut 06053 (US).

(74) Agent: **KOZIARZ, Matthew L.**; Carlson, Gaskey & Olds/Pratt & Whitney, c/o CPA Global, P.O. Box 52050, Minneapolis, Minnesota 55402 (US).

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(54) Title: AIRFOIL INCLUDING ADHESIVELY BONDED SHROUD

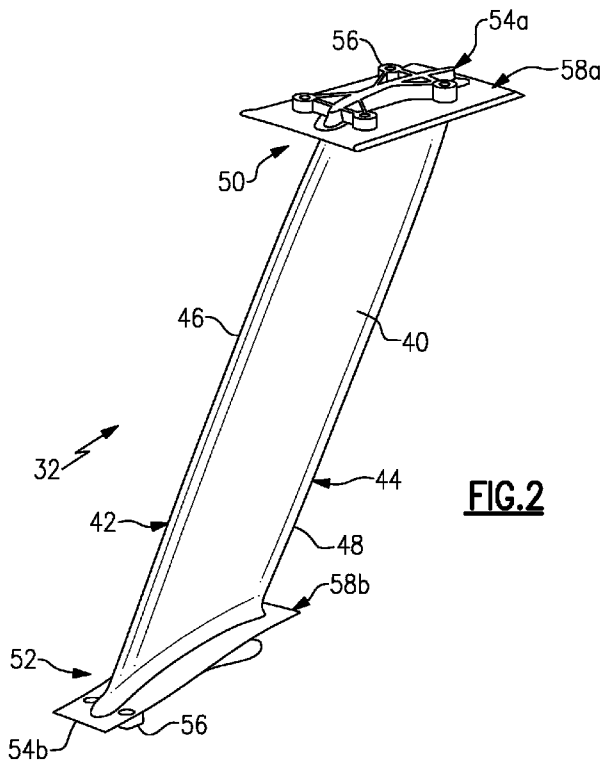

FIG.2

(57) Abstract: An airfoil includes an airfoil body that extends between a leading edge and a trailing edge, a suction side and a pressure side, and a first end and a second end. At least one fitting is located on at least one of the first end and the second end. The fitting includes at least one mounting lug. At least one shroud is adhesively bonded to the at least one fitting.

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AIRFOIL INCLUDING ADHESIVELY BONDED SHROUD

BACKGROUND

[0001] This disclosure relates to improvements in shrouded airfoils.

[0002] Airfoils, such as airfoils in gas turbine engines, may include a shroud at an inner diameter, outer diameter or both. The airfoils are circumferentially arranged such that inner diameter shrouds bound an inner diameter of a gas path and outer diameter shrouds bound an outer diameter of the gas path.

[0003] The airfoils are secured to static structures, such as cases, using fittings at the inner and outer diameters. The fittings and shrouds are integrally formed in a forging process from a suitable metallic alloyor are integrally formed by machining from a single monolithic piece of a suitable metallic alloy.

SUMMARY

[0004] An airfoil according to an exemplary aspect of the present disclosure includes of an airfoil body which extends between a leading edge and a trailing edge, a suction side and a pressure side, and a first end and a second end. At least one fitting is located on at least one of the first end and the second end, the at least one fitting including at least one mounting lug, and at least one shroud adhesively bonded to the at least one fitting.

[0005] In a further non-limiting embodiment of any of the foregoing examples, the at least one fitting includes a flange, and the at least one shroud is adhesively bonded to the flange.

[0006] In a further non-limiting embodiment of any of the foregoing examples, the flange includes a rabbet, and the at least one shroud is adhesively bonded to the rabbet.

[0007] In a further non-limiting embodiment of any of the foregoing examples, the at least one shroud comprises a polymeric material.

[0008] In a further non-limiting embodiment of any of the foregoing examples, the at least one fitting is metallic and the at least one shroud is polymeric.

[0009] A further non-limiting embodiment of any of the foregoing examples comprises of a seal member attached at an edge of the at least one shroud.

[0010] In a further non-limiting embodiment of any of the foregoing examples, the edge of the at least one shroud includes a slot, and the seal member is located in the slot.

[0011] In a further non-limiting embodiment of any of the foregoing examples, the seal member is adhesively bonded to the edge of the at least one shroud.

[0012] In a further non-limiting embodiment of any of the foregoing examples, the at least one shroud includes a plurality of distinct shroud pieces that, when assembled together, circumscribe the at least one fitting.

[0013] In a further non-limiting embodiment of any of the foregoing examples, the at least one shroud includes a shroud body extending between first and second broadsides, perimeter edges and interior edges that define an elongated, arcuate opening extending between the first and second broadsides.

[0014] A shroud for a turbine engine airfoil according to an exemplary aspect of the present disclosure comprises of a shroud body extending between first and second broadsides, perimeter edges and interior edges. The interior edges define an elongated, arcuate opening which extends between the first and second broadsides.

[0015] A further non-limiting embodiment of any of the foregoing examples comprises of a seal member attached to at least one of the perimeter edges.

[0016] In a further non-limiting embodiment of any of the foregoing examples, at least one of the perimeter edges to which the seal member is attached includes a slot, and the seal member is located in the slot.

[0017] In a further non-limiting embodiment of any of the foregoing examples, the seal member is adhesively bonded to the at least one of the perimeter edges.

[0018] In a further non-limiting embodiment of any of the foregoing examples, the shroud body includes separate and distinct pieces that each include a portion of the interior edges such that, when the separate and distinct pieces are assembled together, the separate and distinct pieces define the elongated, arcuate opening.

[0019] In a further non-limiting embodiment of any of the foregoing examples, the shroud body is monolithic.

[0020] In a further non-limiting embodiment of any of the foregoing examples, the shroud body comprises a polymeric material.

[0021] A turbine engine according to an exemplary aspect of the present disclosure comprises of a fan section which includes an airfoil having an airfoil body extending between a leading edge and a trailing edge, a suction side and a pressure side, and

a first end and a second end, at least one fitting located on at least one of the first end and the second end. At least one fitting includes at least one mounting lug, and at least one shroud adhesively bonded to the at least one fitting; a compressor section in communication with the fan section; a combustor in fluid communication with the compressor section; and a turbine section in fluid communication with the combustor.

[0022] A method of assembling an airfoil according to an exemplary aspect of the present disclosure includes providing an airfoil body extending between a leading edge and a trailing edge, a suction side and a pressure side, and a first end and a second end, and at least one fitting located on at least one of the first end and the second end. The one fitting includes at least one mounting lug and adhesively bonding at least one shroud to the at least one fitting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The various features and advantages of the present disclosure will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

[0024] Figure 1 shows an example gas turbine engine.

[0025] Figure 2 shows a perspective view of an airfoil of the gas turbine engine of Figure 1.

[0026] Figure 3 shows an isolated view of a first, outer diameter fitting of the airfoil of Figure 2.

[0027] Figure 4 shows an isolated view of a second, inner diameter fitting of the airfoil of Figure 2.

[0028] Figure 5 shows an isolated view of the first, outer diameter fitting and shroud of the airfoil of Figure 2.

[0029] Figure 6 shows an isolated view of the second, inner diameter fitting and shroud of the airfoil of Figure 2.

[0030] Figure 7 shows a cross-section of a shroud adhesively bonded to a fitting.

[0031] Figure 8 shows an isolated view of a shroud of the airfoil of Figure 2.

[0032] Figure 9 shows another example shroud having a separate and distinct shroud pieces.

[0033] Figure 10 shows a sectioned, perspective view of a fitting and a shroud that includes a seal member.

[0034] Figure 11 shows a perspective view of a second, inner diameter fitting, shroud and seal member.

[0035] Figure 12 shows a perspective view of a first fitting, shroud and seal member.

[0036] Figure 13 shows a portion of a shroud having a slot receiving a seal member.

DETAILED DESCRIPTION

[0037] Figure 1 schematically illustrates a gas turbine engine 20. The gas turbine engine 20 disclosed herein is a two-spool turbofan that generally includes a fan section 22, a compressor section 24, a combustor section 26 and a turbine section 28 that are arranged along a central axis A. Although the illustrated example is a turbofan gas turbine engine and the examples herein are described with reference to an airfoil in the engine 20, it is to be understood that this disclosure is not limited to gas turbine engines or turbine engine airfoils. The teachings herein can be applied to other types of shrouded airfoils and turbine engines, including single- or three-spool architectures.

[0038] The fan section 22 of the gas turbine engine 20 includes a plurality of rotatable blades 30 and a plurality of static, structural exit guide vanes 32. As known, the vanes 32 are circumferentially arranged around the central axis A between an outer structure 34 and an inner structure 36, such as cases.

[0039] Figure 2 shows an example of one of the vanes 32, which is considered to be an airfoil. The vane 32 includes an airfoil body 40 that extends between a leading edge 42 and the trailing edge 44, a suction side 46 and a pressure side 48, and a first end 50 and a second end 52. Relative to the central axis A, the first end 50 is an outer diameter end of the vane 32 and the second end 52 is an inner diameter end of the vane 32.

[0040] The vane 32 further includes a first fitting 54a located at the first end 50 and a second fitting 54b located at the second end 52. Each of the fittings 54a/54b is or includes a metallic material and includes one or more mounting lugs 56 for securing the vane 32 to the respective structures 34/36 in a known manner, such as by using fasteners.

[0041] The vane 32 further includes a first shroud 58a that is adhesively bonded to the first fitting 54a and a second shroud 58b that is adhesively bonded to the second fitting 54b. Thus, in this example, the vane 32 is shrouded at both the first end 50 and the second end 52. It is to be understood, however, that other types of airfoils may be shrouded at only one end, and that the examples herein are also applicable to such airfoils. As can be appreciated, use of the shrouds 58a/58b that are separate and distinct pieces from the airfoil body 40 and the respective fittings 54a/54b permits the shrouds 58a/58b to be made of different material than either the airfoil body 40 or the fittings 54a/54b.

[0042] Figures 3 and 4 show isolated views, respectively, of the first fitting 54a and the second fitting 54b. In this example, each of the fittings 54a/54b is a separate and distinct piece from the airfoil body 40. In this regard, each of the fittings 54a/54b includes a corresponding pocket 60 into which the airfoil body 40 is received. The airfoil body 40 can be adhesively bonded to the respective fittings 54a/54b. In other examples, the fittings 54a/54b can be integral with the airfoil body 40.

[0043] Figures 5 and 6 show isolated views, respectively, of the shrouds 58a/58b adhesively bonded to the fittings 54a/54b. Figure 7 shows a cross-section through an interface between the second fitting 54b and the second shroud 58b adhesively bonded to the second fitting 54b. It is to be understood that the interface between the first fitting 54a and the first shroud 58a is similar to the interface shown in Figure 7. As shown, the second shroud 58a is adhesively bonded to the second fitting 54b by an adhesive 70. In one example, the adhesive 70 is an epoxy adhesive. In other examples, other types of adhesives can be used that are suitable for the expected operating temperature of the airfoil.

[0044] The second fitting 54b includes a flange F to which the second shroud 58a is adhesively bonded. In this example, the flange F includes a rabbet 54b'. The rabbet 54b', or ledge, supports the adhesive 70 for bonding the second shroud 58b thereto. Thus, the second shroud 58b is adhesively bonded to the rabbet 54b'. A method of assembling the vane 32 therefore includes providing the vane 32 as described, and adhesively bonding the shrouds 58a/58b to the fittings 54a/54b.

[0045] Figure 8 shows an isolated view of the first shroud 58a. In this example, the first shroud 58a includes a shroud body 72 that extends between first and second broadsides 74a/74b, perimeter edges 76, which are axially and circumferentially facing surfaces, and interior edges 78 that define an elongated, arcuate opening 80 extending

between the first and second broadsides 74a/74b. The opening 80 is generally elongated in a direction parallel to the central axis A of the gas turbine engine 20. The opening 80 also has the arcuate shape, which corresponds to the arcuate shape of the cross-section of the airfoil body 40.

[0046] The first shroud 58 also optionally includes a plurality of additional openings 82 that correspond to the mounting lugs 56 on the first fitting 54a. Depending on the geometry of the first shroud 58a and location of the mounting lugs 56, other examples may exclude the additional openings 82.

[0047] It is to be understood that the second shroud 58b has similar features as the first shroud 58a with regard to including a shroud body, first and second broadsides, perimeter edges and interior edges that define an elongated, arcuate opening. As can be appreciated, the contouring and size of the second shroud 58b may differ and the elongated, arcuate opening of the second shroud 58b may have a different geometry that corresponds to the cross-section of the airfoil body 40 at the inner diameter. Also, the additional optional openings may be positioned differently to align with the mounting lugs 56 on the second fitting 54b.

[0048] In this example, the first shroud 58a is a monolithic piece. That is, the first shroud 58a is a single piece of material that is free of joints or seams. Thus, in the assembly of the vane 32, the airfoil body 40 extends through the elongated, arcuate opening 80 and into the corresponding first fitting 54a (or second fitting 54b for the elongated arcuate opening of the second shroud 58b).

[0049] Figure 9 shows a modified example of a first shroud 158a. In this disclosure, like reference numerals designate like elements where appropriate and reference numerals with the addition of one-hundred or multiples thereof designate modified elements that are understood to incorporate the same features and benefits of the corresponding elements. In this example, the first shroud 158a includes a plurality of separate and distinct pieces 190a/190b. Each of the pieces 190a/190b includes a portion of the interior edges 78 such that, when assembled together, the pieces 190a/190b define the complete perimeter of the elongated, arcuate opening 80, which circumscribes the first fitting 54a similar to as shown in Figure 6.

[0050] For example, the pieces 190a/190b are initially separate and are then assembled around the first fitting 54a and adhesively bonded thereto to form the complete

first shroud 158a. Thus, the shroud 158a can be fitted onto an existing vane as a retrofit, for example. The use of the separate pieces 190a/190b also facilitates removal of the shroud 158a for replacement with a new, similar shroud, should the shroud 158a require replacement.

[0051] Figure 10 shows a perspective, sectioned view through a portion of the second fitting 54b. In this example, the second shroud 58b further includes a seal member 90 attached at one of the perimeter edges 76 of the second shroud 58b. The second fitting 54b, the second shroud 58b and the seal member 90 are shown in full view in Figure 11. Similarly, as shown in Figure 12, the first shroud 58a can likewise include a seal member 90. When the vanes 32 are circumferentially arranged in the gas turbine engine 20, the seal members 90 bear against a neighboring shroud 58a/58b to provide a gas path seal.

[0052] In the illustrated example, the seal member 90 is adhesively bonded to the second shroud 58b using an adhesive 90a. Similar to the adhesive 70, the adhesive 90a can be an epoxy adhesive. Alternatively, the adhesive 90a can be another type of adhesive that is suitable for the operating temperature of the airfoil. In another alternative, the seal member 90 can be integrally formed with the second shroud 58b, such as in a co-molding or over-molding operation.

[0053] Figure 13 shows a portion of a modified first shroud 258a. In this example, the first shroud 258a includes a slot S extending into one of the perimeter edges 76. The seal member 90 includes a flange 90' that is received into the slot S to secure the seal member 90 and the first shroud 258a together. The slot S can be sized in correspondence with the size of the flange 90' such that there is an interference fit or snap fit between the first shroud 258a and the seal member 90. Alternatively, an adhesive can be used to secure the seal member 90 within the slot S. Similarly, the second shroud 58b can also include a slot for attaching the seal member 90.

[0054] Using the shrouds disclosed herein that are separate and distinct pieces from the airfoil body 40 and the respective fittings 54a/54b permits the shrouds to be made of different materials than either the airfoil body 40 or the fittings 54a/54b. In one example, the shrouds are, or include, a polymeric material. In a further example, the polymeric material is a reinforced polymeric material that includes glass fibers, carbon fibers, or other reinforcement additives. In comparison to airfoils that are made entirely of metal alloys, the airfoils disclosed herein provide a weight reduction because of the use of the polymeric material. Furthermore, metallic shrouds that are integrally formed with fittings require

significant raw material and machining to attain the final geometric configuration. However, by forming the shrouds disclosed herein from the polymeric material, the shrouds can be formed to the required geometry and tolerances using known polymer forming processes, such as injection molding.

[0055] Although a combination of features is shown in the illustrated examples, not all of them need to be combined to realize the benefits of various embodiments of this disclosure. In other words, a system designed according to an embodiment of this disclosure will not necessarily include all of the features shown in any one of the Figures or all of the portions schematically shown in the Figures. Moreover, selected features of one example embodiment may be combined with selected features of other example embodiments.

[0056] The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from the essence of this disclosure. The scope of legal protection given to this disclosure can only be determined by studying the following claims.

CLAIMS

What is claimed is:

1. An airfoil comprising:

an airfoil body extending between a leading edge and a trailing edge, a suction side and a pressure side, and a first end and a second end;

at least one fitting located on at least one of the first end and the second end, the at least one fitting including at least one mounting lug; and

at least one shroud adhesively bonded to the at least one fitting.

2. The airfoil as recited in claim 1, wherein the at least one fitting includes a flange, and the at least one shroud is adhesively bonded to the flange.

3. The airfoil as recited in claim 2, wherein the flange includes a rabbet, and the at least one shroud is adhesively bonded to the rabbet.

4. The airfoil as recited in claim 1, wherein the at least one shroud comprises a polymeric material.

5. The airfoil as recited in claim 1, wherein the at least one fitting is metallic and the at least one shroud is polymeric.

6. The airfoil as recited in claim 1, further comprising a seal member attached at an edge of the at least one shroud.

7. The airfoil as recited in claim 6, wherein the edge of the at least one shroud includes a slot, and the seal member is located in the slot.

8. The airfoil as recited in claim 6, wherein the seal member is adhesively bonded to the edge of the at least one shroud.

9. The airfoil as recited in claim 1, wherein the at least one shroud includes a plurality of distinct shroud pieces that, when assembled together, circumscribe the at least one fitting.

10. The airfoil as recited in claim 1, wherein the at least one shroud includes a shroud body extending between first and second broadsides, perimeter edges and interior edges that define an elongated, arcuate opening extending between the first and second broadsides.

11. A shroud for a turbine engine airfoil, the shroud comprising:

a shroud body extending between first and second broadsides, perimeter edges and interior edges, the interior edges defining an elongated, arcuate opening extending between the first and second broadsides.

12. The shroud as recited in claim 11, further comprising a seal member attached to at least one of the perimeter edges.

13. The shroud as recited in claim 12, wherein the at least one of the perimeter edges to which the seal member is attached includes a slot, and the seal member is located in the slot.

14. The shroud as recited in claim 12, wherein the seal member is adhesively bonded to the at least one of the perimeter edges.

15. The shroud as recited in claim 11, wherein the shroud body includes separate and distinct pieces that each include a portion of the interior edges such that, when the separate and distinct pieces are assembled together, the separate and distinct pieces define the elongated, arcuate opening.

16. The shroud as recited in claim 11, wherein the shroud body is monolithic.

17. The shroud as recited in claim 11, wherein the shroud body comprises a polymeric material.

18. A turbine engine comprising:

a fan section including an airfoil having an airfoil body extending between a leading edge and a trailing edge, a suction side and a pressure side, and a first end and a second end, at least one fitting located on at least one of the first end and the second end, the at least one fitting including at least one mounting lug, and at least one shroud adhesively bonded to the at least one fitting;

a compressor section in communication with the fan section;

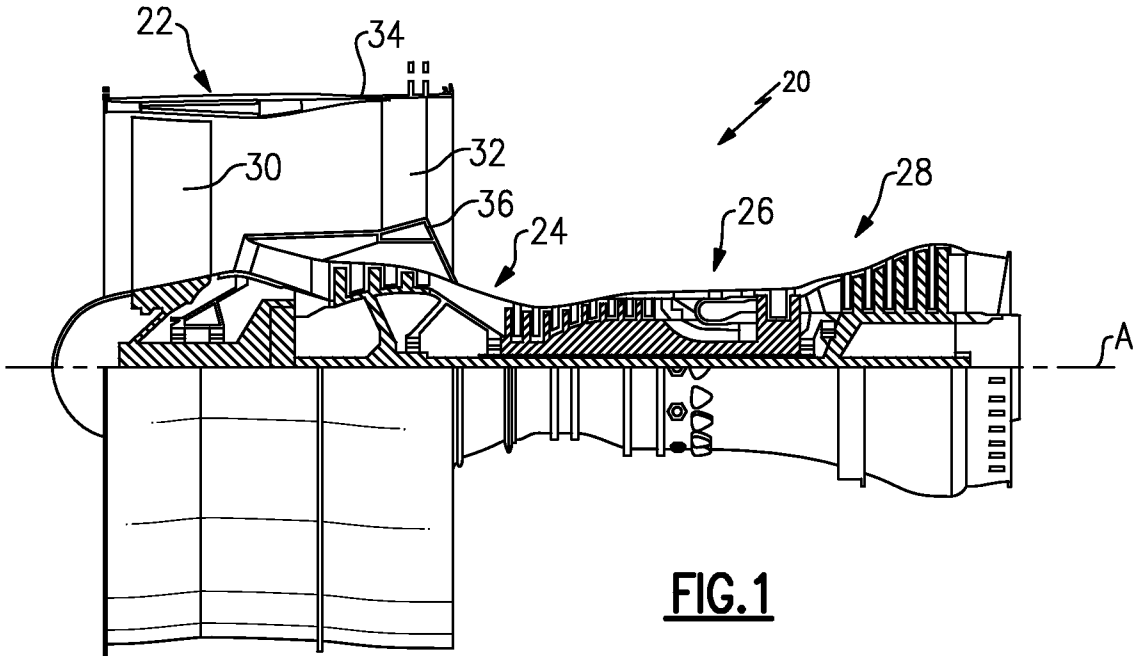
a combustor in fluid communication with the compressor section; and

a turbine section in fluid communication with the combustor.

19. A method of assembling an airfoil, the method comprising:

providing an airfoil body extending between a leading edge and a trailing edge, a suction side and a pressure side, and a first end and a second end, and at least one fitting located on at least one of the first end and the second end, the at least one fitting including at least one mounting lug; and

adhesively bonding at least one shroud to the at least one fitting.


22
34
20
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32
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36
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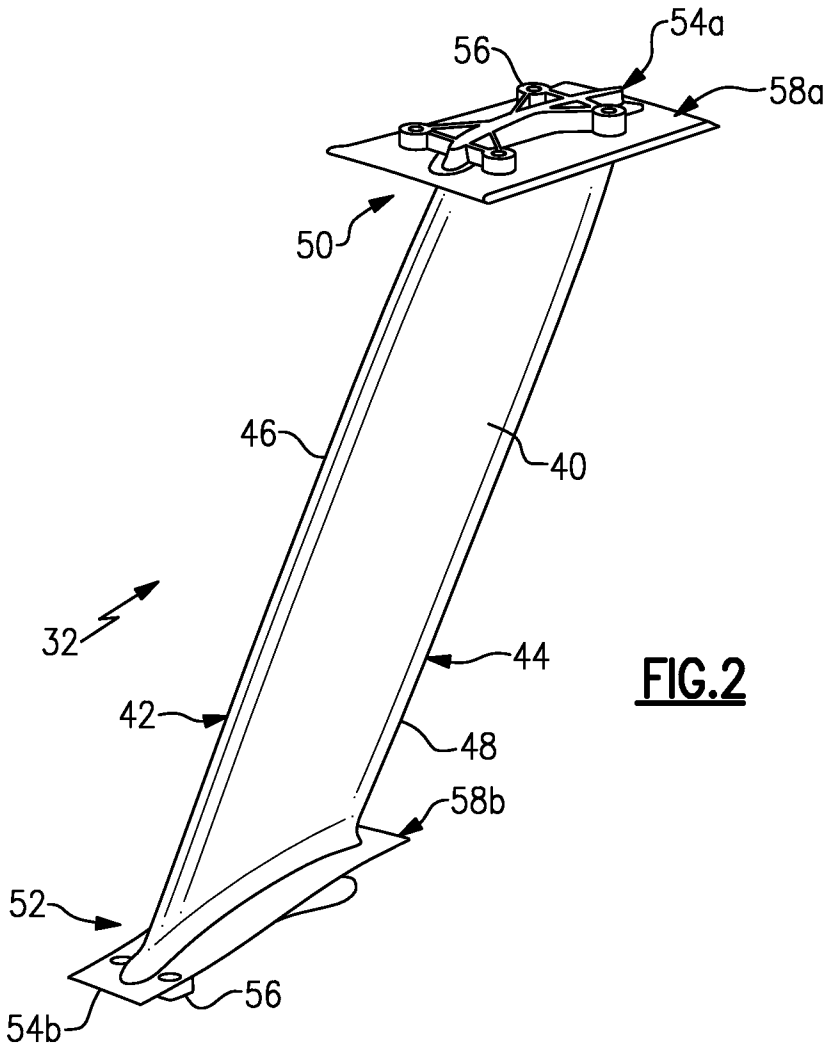
24
A

FIG.1


54a
56
58a
50
46
40
32
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58b
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54b

FIG.2

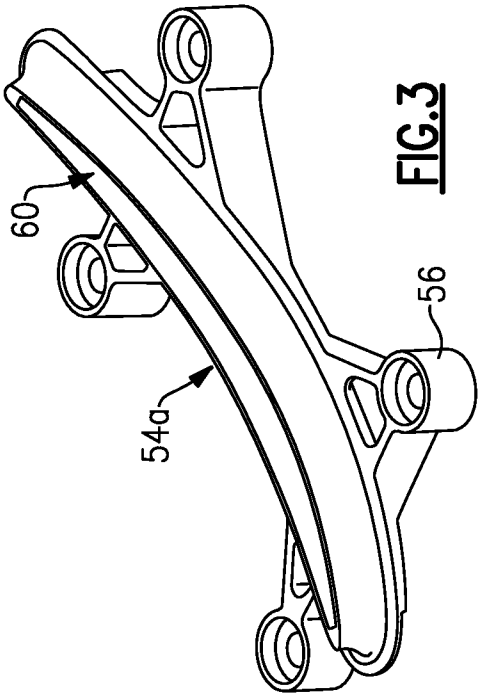

FIG.3

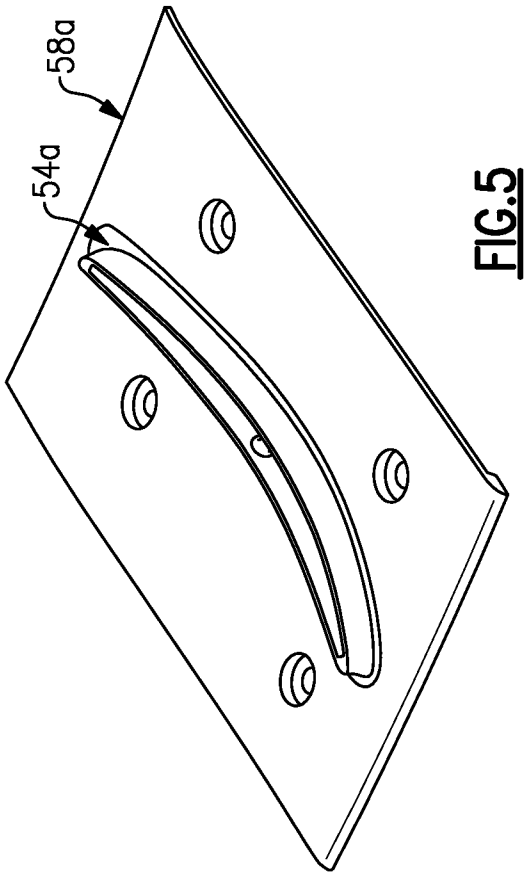

FIG.5

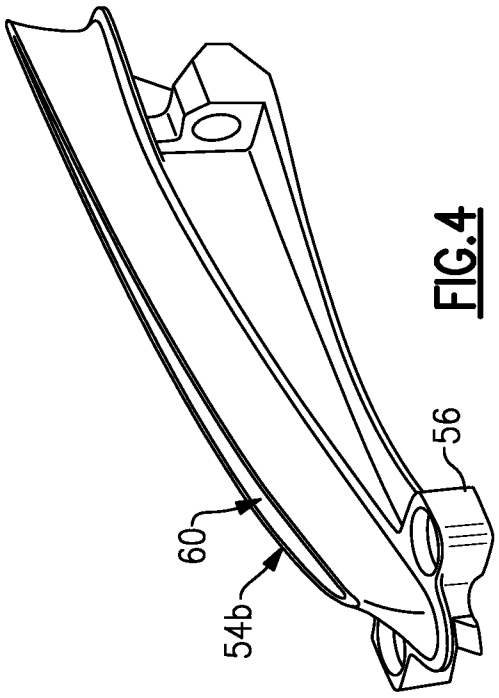

FIG.4

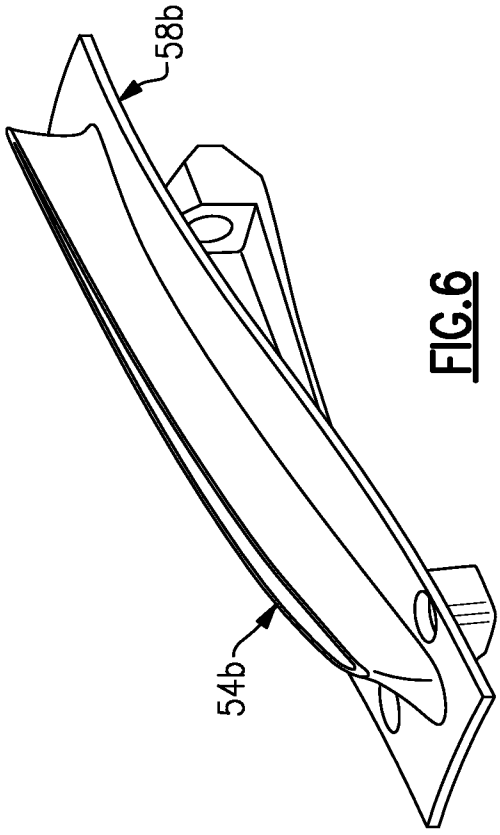

FIG.6

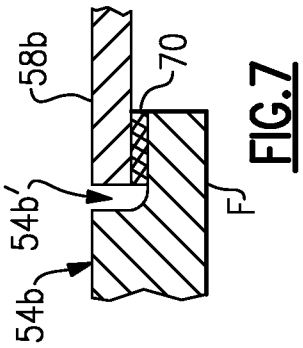

FIG.7

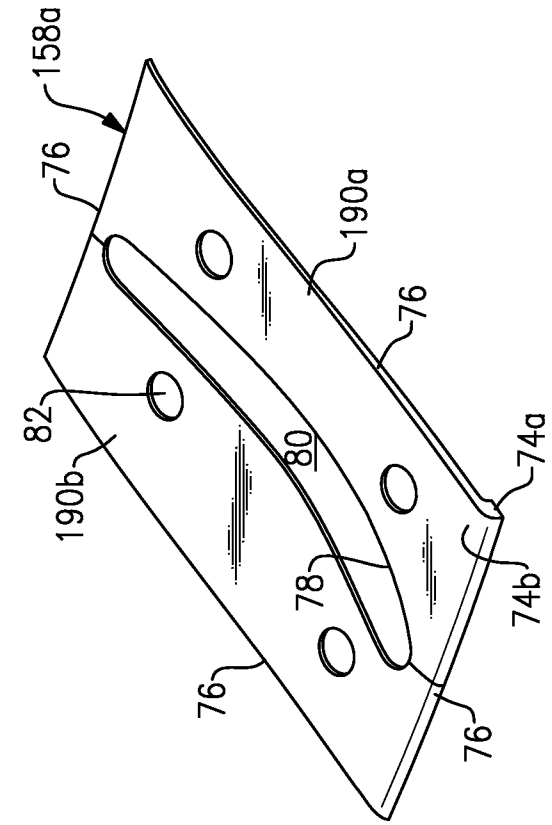

FIG.9

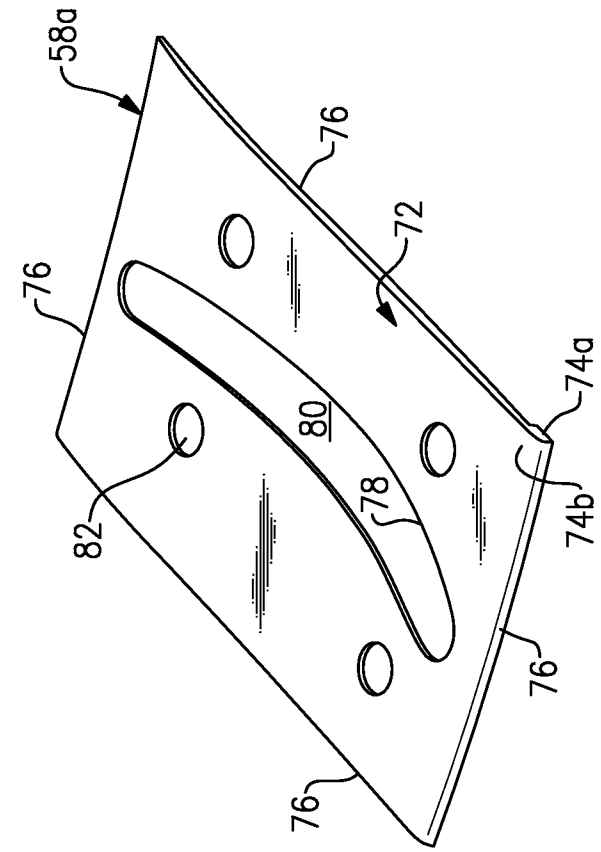

FIG.8

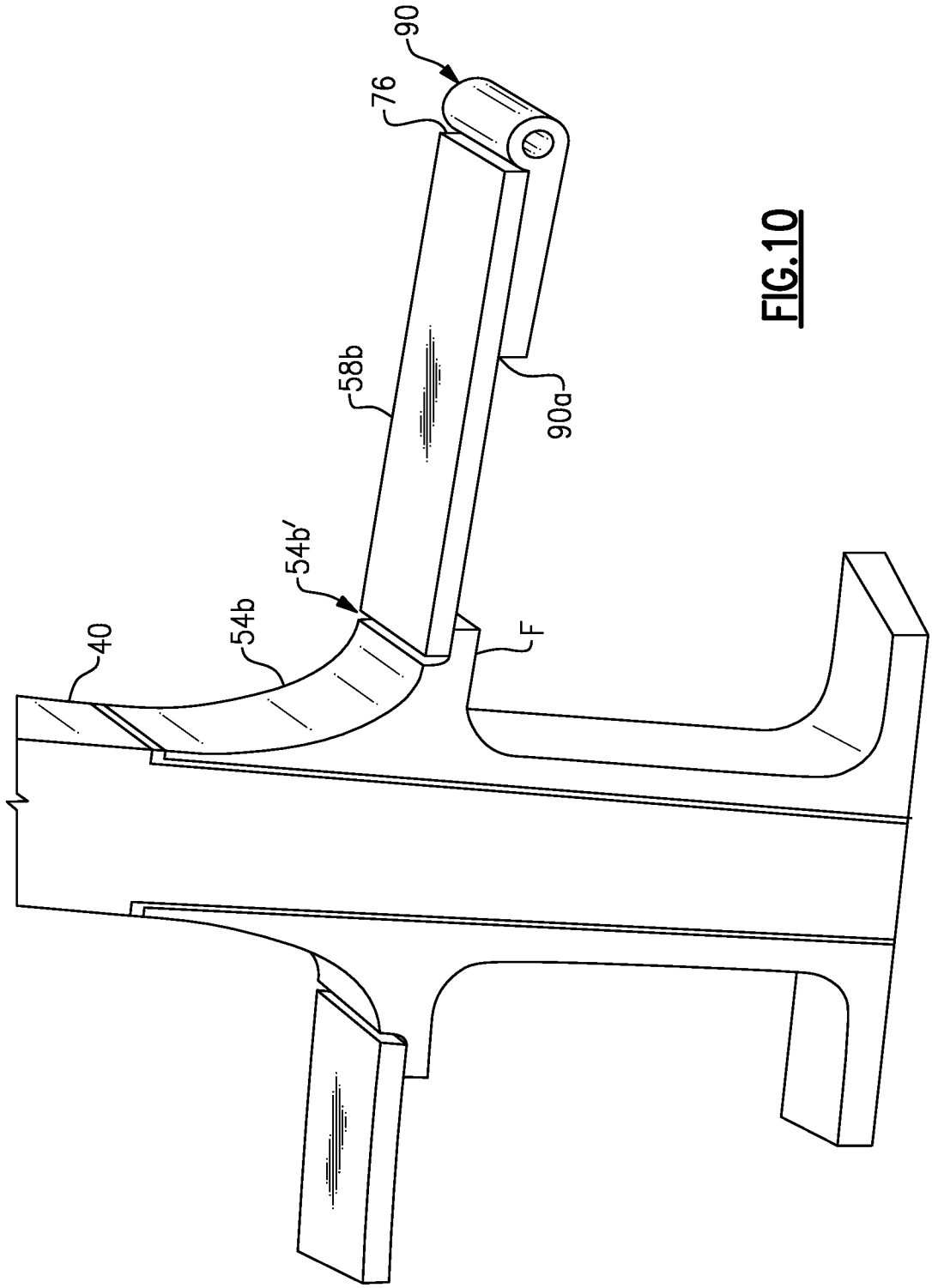

FIG.10

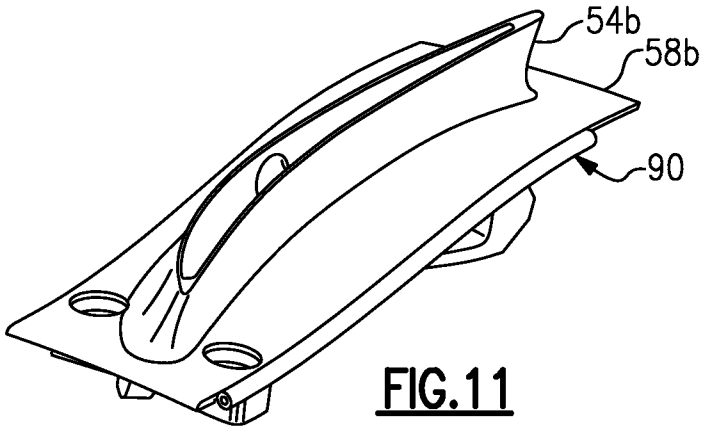

FIG.11

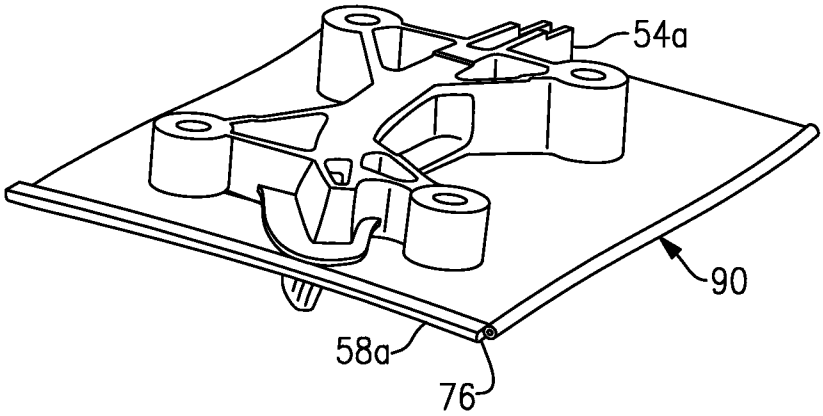

FIG.12

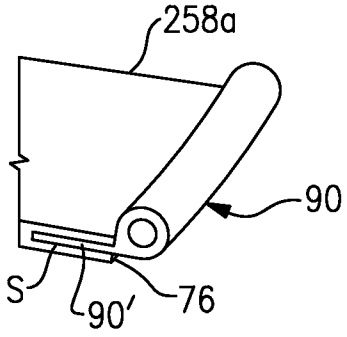

FIG.13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/043815

A. CLASSIFICATION OF SUBJECT MATTER

F02C 7/04(2006.01)i, F02C 3/00(2006.01)i, F02C 9/00(2006.01)i, F02K 3/00(2006.01)i

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)
F02C 7/04; F01D 5/10; F01D 5/14; F01D 5/22; F01D 9/04; F01D 9/00; F02C 3/00; F02C 9/00; F02K 3/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: airfoil, vane, fitting, mounting, lug, leading, trailing, edge, shroud, adhesive, bond

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2002-0076320 A1 (GLOVER et al.) 20 June 2002 See abstract; paragraphs [0022]-[0025]; figures 1,4,5.	1-19
A	US 2008-0253885 A1 (FOOSE et al.) 16 October 2008 See abstract; paragraphs [0015], [0016]; figures 1-3.	1-19
A	US 4,832,568 A (ROTH et al.) 23 May 1989 See abstract; column 3, line 67 - column 4, line 12; figure 2.	1-19
A	US 2007-0172349 A1 (ABGRALL et al.) 26 July 2007 See abstract; paragraphs [0022], [0028]; figure 3.	1-19
A	EP 2221454 A1 (ALSTOM TECHNOLOGY LTD.) 25 August 2010 See abstract; paragraph [0016]; figure 2.	1-19

☐ 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
11 September 2013 (11.09.2013)	**12 September 2013 (12.09.2013)**
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. +82-42-472-7140	Authorized officer HAN Joong Sub Telephone No. +82-42-481-5606

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/043815

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