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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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(54) **Title**: FAN ASSEMBLY, CORRESPONDING GAS TURBINE ENGINE AND MOUNTING METHOD

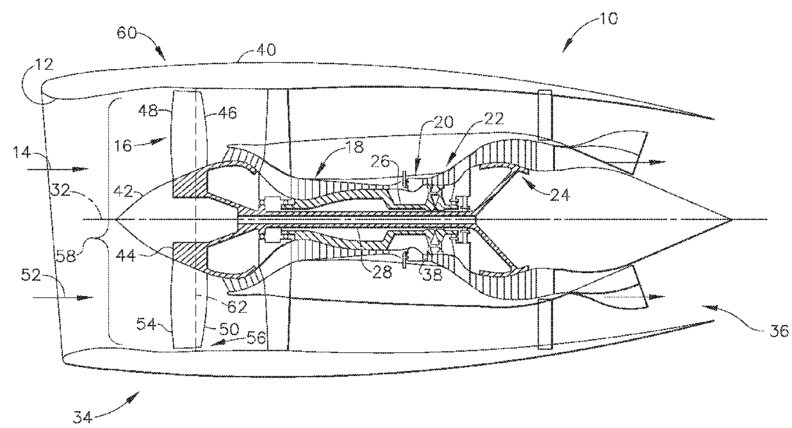

FIG. 1

(57) **Abstract**: A fan assembly is provided. The fan assembly includes a rotor having a hub and a plurality of rotor blades extending radially outward from the hub. Each rotor blade includes a blade tip at a radially distal end of each blade. The rotor blade tips define a rotor diameter. The fan assembly also includes a first cylindrical casing substantially axially aligned with the blade tips, the first casing including a first inner diameter that is greater than the rotor diameter. The fan assembly further includes a brush seal assembly coupled to the blade tip of a least one of the plurality of rotor blades, the brush seal assembly configured to contact the casing segment during a first operational mode of the fan assembly, the brush seal assembly configured to avoid contact with the casing segment during a second operational mode of the fan assembly.

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FAN ASSEMBLY, CORRESPONDING GAS TURBINE ENGINE AND MOUNTING METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This Application claims priority and benefit of U.S. Provisional Patent Application Serial No. 61/666,773 filed June 29, 2012, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] The field of the invention relates generally to gas turbine engines, and more specifically, to a method and assembly for reducing blade tip leakage in gas turbine engines.

[0003] The fan case of a gas turbine engine directs the axial flow of air in conjunction with the fan during normal engine operation, prevents released fan blades from escaping radially or forwardly, and restrains the low pressure shaft radial deflection and blade tips during bird strike events.

[0004] The fan is conventionally used in a gas turbine engine to force a primary air stream through the compressor and turbines of the engine and to force a secondary airflow through an annular radially outward bypass duct. It is essential that the clearance between the rotating fan blades and the internal surface of the fan housing be kept within an acceptable range to optimize the fan efficiency.

[0005] To maintain fan airflow performance in at least some known gas turbine engines, a clearance between impeller blades of the fan and a housing (e.g., casing) of the fan is set to a close distance. The tight clearance facilitates preventing reverse flow leakage around the blade tips through the tip clearance. Higher air pressure downstream of the fan impeller tends to drive the flow back toward upstream, and this is observed at the tip clearance.

[0006] In some operating conditions, such as, but not limited to, extreme operating conditions, the close clearance may result in blade-housing interference and can lead to failures of fan components in the field. Such interference has been addressed by trimming the blade tips to increase the clearance. However, increasing the clearance increases leakage flow around the blade tips and reduces the performance of the fan assembly. The impact on fan performance is two-fold: reduced impeller working area and increased tip clearance that will allow flow leakage the opposite direction to the main flow. The loss in performance caused by the former can be regained to some extent by adjusting blade pitch angles, for example, by twisting the tip of each blade and letting the rest of the blade span follow.

BRIEF DESCRIPTION OF THE INVENTION

[0007] In one embodiment, a fan assembly includes a rotor having a hub and a plurality of rotor blades extending radially outward from the hub. Each rotor blade includes a blade tip at a radially distal end of each blade. The rotor blade tips define a rotor diameter. The fan assembly also includes a first cylindrical casing substantially axially aligned with the blade tips, the first casing including a first inner diameter that is greater than the rotor diameter. The fan assembly further includes a brush seal assembly coupled to the blade tip of at least one of the plurality of rotor blades, the brush seal assembly is configured to contact the casing segment during a first operational mode of the fan assembly, the brush seal assembly configured to avoid contact with the casing segment during a second operational mode of the fan assembly.

[0008] In another embodiment, a gas turbine engine has a cylindrical fan casing with a longitudinal centerline axis extending from an upstream inlet opening to a downstream outlet opening. The gas turbine engine also has a rotor blade rotatably mounted within the fan casing. The rotor blade has a leading edge and a trailing edge in a direction of fluid flow through the fan casing. The rotor blade rotates about the centerline axis in the direction of the leading edge. The rotor blade has a blade tip at a radially distal end. The rotor blade includes a brush seal assembly coupled to at least a portion of the blade tip.

[0009] In yet another embodiment, a method for mounting a brush seal assembly to a fan blade tip of a fan of a gas turbine engine is provided. The brush seal assembly has a base and a brush tip extending from the base at an angle less than 90 degrees from horizontal. The method includes milling a segment of the blade tip about a leading edge of a rotor blade to create a milled tip configured to receive the brush seal assembly. The method also includes applying an adhesive to the milled tip such that the adhesive is configured to bond the base of the brush seal assembly to the blade tip. The method also includes inserting the base of the brush seal assembly into the milled tip such that the brush tip extends in the direction of a trailing edge of the blade at an angle less than 90 degrees from horizontal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 is a schematic illustration of an exemplary high bypass turbofan gas turbine engine that includes a rotor blade.

[0011] Figure 2 is an enlarged side view of a brush seal assembly for use with the rotor blade of Figure 1 under a hot running condition.

[0012] Figure 3 is an enlarged side view of a brush seal assembly for use with the rotor blade of Figure 1 under a cold running condition.

[0013] Figure 4 is an enlarged side view of a brush seal assembly for use with the rotor blade of Figure 1 under a hot running condition.

[0014] Figure 5 is an enlarged side view of a brush seal assembly for use with the rotor blade of Figure 1 under a cold running condition.

[0015] Figure 6 is an enlarged side view of an exemplary high bypass turbofan gas turbine engine that includes a rotor blade illustrating the brush seal region.

DETAILED DESCRIPTION OF THE INVENTION

[0016] The following detailed description illustrates embodiments of the invention by way of example and not by way of limitation. It is contemplated that the invention has general application to providing enhanced sealing between rotating and stationary components in industrial, commercial, and residential applications.

[0017] As used herein, an element or step recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural elements or steps, unless such exclusion is explicitly recited. Furthermore, references to "one embodiment" of the present invention are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

[0018] Embodiments of the present disclosure place a brush seal at a tip of a blade such that, at operational rotating speed, the brush tip contacts the surrounding case, minimizing running clearance. Specific to composite fan blades produced, installation of the brush tip in accordance with the present disclosure is achievable as a function of bonding the blade hardware (metal leading edge and tip cap) encasing the brush between the composite core and metallic tip cap. Installation of the brush tip, however, is possible on any suitable fan blades, including non-composite fan blades.

[0019] According to an embodiment, a brush seal type of structure is bonded to the tip of the blade such that at a cold assembly condition, the brush would not be in contact with the case. Under CF load and blade deflection, the brush contacts the case thus eliminating running clearances.

[0020] Embodiments of the present disclosure enable a reduction in running clearances and a resulting increase in performance. In various embodiments, a removal of approximately 0.140" average running clearance provides approximately +0.5 pt fan efficiency improvement, or approximately .3 SFC. In addition, it is also implied that clearances could be adjusted such that current rubs could be avoided by actually opening the 'hard' clearance, thus reducing or eliminating the chance for the rotor to whirl (e.g., spin in the direction opposite the intended direction of travel). In the event that the rotor does whirl, as might be caused by a gust of wind or by another force applied directly to the rotor, the brush seal would not contact the case, and therefore avoid being damaged. Moreover, case-abradable systems could also be eliminated resulting in nearly a 40 pound weight savings. According to an embodiment of a fan blade with a brush seal at the tip, case-abradable systems could be replaced less frequently, saving maintenance costs.

[0021] Figure 1 is a schematic illustration of an exemplary high bypass, turbofan gas turbine engine 10 having in serial flow communication an inlet 12 for receiving ambient air 14, a fan assembly 16, a compressor 18, a combustor 20, a high pressure turbine 22, and a low pressure turbine 24. High pressure turbine 22 is joined to compressor 18 by a high pressure shaft 26, and low pressure turbine 24 is connected to fan assembly 16 by a low pressure shaft, or drive shaft 28. Engine 10 has a centerline axis 32 extending from an upstream side 34 of engine 10 aft to a downstream side 36 of engine 10. In one embodiment, gas turbine engine 10 is a GE90 engine commercially available from General Electric Company, Cincinnati, Ohio.

[0022] Fan assembly 16 includes a fan casing 40 that includes centerline axis 32. Fan assembly 16 includes a rotor 42 that includes a hub 44 and a plurality of rotor blades 46 extending radially outward from hub 44. Each rotor blade 46 includes a leading edge 48 and a trailing edge 50 in a direction 52 (indicated by an arrow). Each rotor blade 46 includes a blade tip 54 at a radially distal end 56 of rotor blade 46. Blade tips 54 on each rotor blade 46 define a rotor diameter 58.

[0023] Fan assembly 16 includes a first substantially cylindrical casing segment 60 extending circumferentially about and substantially axially aligned with blade tips 54. Casing segment 60 has a first inner diameter 62 that is greater than rotor diameter 58.

[0024] In operation, air flows through fan 16 and compressed air is supplied to high-pressure compressor 18. Highly compressed air is delivered to combustor 20. Combustion gases 38 from combustor 20 propel turbines 22 and 24. High pressure turbine 22 rotates second shaft 26 and high pressure compressor 18, while low pressure turbine 24 rotates first shaft 28 and fan 16 about axis 32.

[0025] Figures 2 and 3 are enlarged side views of a brush seal assembly 200 for use with rotor blade 46 (shown in Figure 1) in accordance with an exemplary embodiment of the present invention. Figures 2 and 3 illustrates both a hot running condition 201 (e.g., a first operational mode) and a cold clearance condition 202 (e.g., a second operational mode). In the exemplary embodiment, brush seal assembly 200 is coupled to rotor blade 46 in a milled tip 206 of rotor blade 46. Milled tip 206 is sized to accommodate brush seal assembly 200. Alternatively, brush seal assembly 200 may be coupled to un-milled blade tip 54. Moreover, brush seal assembly 200 may be coupled to rotor blade 46 using any adhesive, mechanical fastener, etc. that enables brush seal assembly 200 to function as described herein. Brush seal assembly 200 may be integrated into rotor blade 46 such that a plurality of brush tips 207 are integral to the tip of the rotor blade 46.

[0026] Brush seal assembly 200 includes plurality of brush tips 207 coupled to a base 208. Brush tips 207 may be flexible or rigid. In the exemplary embodiment, brush tips 207 are flexible, enabling brush tips 207 to flex while riding against case 40 in hot running condition 201. Brush seal assembly 200 extends from rotor blade 46 towards casing segment 60 to facilitate reducing a clearance 210 between brush seal assembly 200 and rotor blade 46. Brush tips 207 may be sized to accommodate extreme loading and/or pre-determined clearances in hot and/or cold running conditions. Brush seal assembly 200 may include a shroud 213. A bumper (not shown) may be coupled to rotor blade 46 and sized to provide clearance in extreme loading situations.

[0027] In the exemplary embodiment, brush seal assembly 200 is coupled to rotor blade 46 using an adhesively-bonded sandwich structure 215.

Sandwich structure 215 enables brush seal assembly 200 to be added to existing rotor blades 46 without damaging and/or modifying rotor blades 46. Likewise, brush seal assembly 200 may be removed and/or replaced without damaging rotor blade 46.

[0028] Clearance 210, which is reduced by brush seal assembly 200, facilitates reducing rotor whirl during rub events. Moreover, brush seal assembly 200 facilitates reducing and/or eliminating abradable damage and case erosion/wear field issues. During assembly of fan assembly 16, brush seal assembly 200 may facilitate increasing assembly clearance tolerances, thereby reducing needed measurements. During cold clearance condition 202, a clearance between the brush seal assembly 200 and the case 40 mitigates the concern of rubbing the brush while windmilling opposite the direction of normal rotation.

[0029] More particularly as shown in Figure 2, during hot running condition 201, brush seal assembly 200 is configured to contact casing segment 60 as rotor blades 46 lengthen due to centrifugal forces and increased temperatures. As shown in Figure 3, brush seal assembly 200 is further configured to avoid contact with casing segment 60 during cold running/clearance condition 202. Hot running condition 201 includes a power output mode of engine 10. Cold running/clearance condition 202 includes at least an offline mode and an idle mode. A method for reducing clearance between rotor blades and a fan casing includes providing brush seal assembly 200 and coupling brush seal assembly 200 to at least one rotor blade 46 such that brush seal assembly 200 contacts the fan casing during a first mode of operation and avoids contacting the fan casing during a second mode of operation. A method of assembling rotor blade 46 includes coupling brush seal assembly 200 to tip 54 of rotor blade 46. Additionally, rotor blade 46 may be milled to create an opening in rotor blade 46 into which brush seal assembly 200 may be placed.

[0030] In certain rotor blade 46 configurations, a cladding 209 may be applied to the leading edge 48 of the blade, either across entire leading edge 48 or a portion of rotor blade 46. Cladding 209, in some embodiments, serves to sandwich the brush seal assembly 200 between the cladding 209 and the milled portion of the rotor blade 46 tip.

[0031] Figures 4 and 5 are enlarged side views of an alternative brush tip 305 for use with rotor blade 46. Brush tip 305 is coupled to rotor blade 46 and extends towards case segment 60. In a hot running condition (shown in Figure 4), brush tip 305 may contact fan casing 40 and/or case segment 60. In a cold running/clearance condition (shown in Figure 5), brush tip 305 may be separated from case segment 60 by a distance 310. Brush tip 305 may be similar to brush tip 207. A plurality of brush tips (not shown) may be coupled to rotor blade 46 within a brush seal region 315.

[0032] In Figures 2 through 5, brush seal assembly 200 is shown having a plurality of bristles (e.g., brush tip 207) angled away from a direction of rotation of the rotor 42 during the first operational mode of the fan assembly 16. During the second operational mode, when rotor blades 46 are comparatively shorter due to the lack of rotary forces and associated heat, brush seal assembly 200 is shown, in the cold clearance condition 202, as being separated from the case 40 so that rotor blades 46 are able to windmill without rubbing brush seal assembly 200 against case 40 in the direction opposite the normal direction of rotation. Rotation opposite the normal direction with brush seal assembly 200 contacting the case 40 would cause damage to brush seal assembly 200. Brush seal assembly 200 can include a plurality of brush fibers (e.g., brush tip 207) made at least partially from Kevlar® brand engineered elastomer, commercially available from DuPont of Wilmington, Delaware, to increase their resistance to wear.

[0033] According to an embodiment, brush seal assembly 200 is coupled to at least a portion of at least some of the plurality of blade tips 54 adjacent the leading edge 48 of the at least some of the plurality of rotor blades 46. According to an alternative embodiment, brush seal assembly 200 is coupled to at least some of the plurality of blade tips 54 extending the entire width of the blade tips 54 (e.g., brush seal region as shown in Figure 6), from the leading edge 48 to the trailing edge 50 of the at least some of the plurality of rotor blades 46.

[0034] Brush seal assembly 200 may permit a radial excursion of rotor blade 46 such that the rotor blade 46 length can deviate slightly from its designed parameters (e.g., lengthen more than the design specifications) without contacting the case 40.

[0035] According to an exemplary embodiment, gas turbine engine 10 is provided with cylindrical fan casing 40 having longitudinal centerline axis 32 extending from upstream inlet opening (e.g., upstream side 34) to downstream outlet opening (e.g., downstream side 36). Engine 10 includes rotor blade 46 rotatably mounted within fan casing 40 in a direction 52 of fluid flow through fan casing 40. Rotor blade 46 has leading edge 48 and trailing edge 50. Rotor blade 46 rotates about centerline axis 32 in the direction of leading edge 48. Rotor blade 46 has blade tip at radially distal end 56. Rotor blade 46 includes a brush seal assembly 200 coupled to at least a portion of blade tip 54. Brush seal assembly 200 includes a plurality of bristles (e.g., brush tip 207) extending radially opposite a direction of rotation of rotor blade 46 when gas turbine engine 10 is enabled to rotate rotor blades 46. Brush seal assembly 200 is coupled to at least a portion of blade tip 54 adjacent leading edge 48. According to an alternative embodiment, brush seal assembly 200 is coupled to blade tip 54 extending from leading edge 48 to trailing edge 50.

[0036] Brush tip 207 of brush seal assembly 200 is configured to contact the fan casing 40 during a first operational mode of the gas turbine engine 10, which includes a power output mode (e.g., during hot running conditions 201). Brush tip 207 of brush seal assembly 200 is configured to avoid contact with the fan casing 40 during a second operational mode of the gas turbine engine 10, which includes at least one of an offline mode and an idle mode (e.g., during cold clearance conditions 202).

[0037] A method for mounting a brush seal assembly to a rotor blade 46 tip of a fan of a gas turbine engine is disclosed according to an embodiment.

Brush seal assembly 200 has a base 208 (e.g., base portion) and a brush tip 207 (e.g., brush portion), said brush portion 207 extending from said base portion 208 at an angle less than 90 degrees from horizontal. The method includes milling a segment of the rotor blade tip 54 about a leading edge 48 of a rotor blade 46 to create a milled tip 206 configured to receive said brush seal assembly 200. The method also includes applying an adhesive (not shown) to said milled tip 206, wherein the adhesive is configured to bond base 208 of brush seal assembly 200 to milled tip 206. The method also includes inserting base 208 of brush seal assembly 200 into milled tip 206 such that said brush tips 207 extend in the direction of trailing edge 50 of rotor blade 46 at an angle less than 90 degrees from horizontal. According to an embodiment, the method may also include applying a layer of cladding 209 to leading edge 48 of rotor blade 46 wherein the layer of cladding 209 extends from the rotor blade 46 to cover the base 208 of said brush seal assembly 200.

[0038] The above-described embodiments of a fan assembly and method of forming a brush seal assembly for a rotatable member provides a cost-effective and reliable means for reducing a blade-casing interference, while maintaining fan airflow performance. More specifically, the assembly and method described herein facilitate increasing an inner diameter of the rotor in an area of the casing thereby decreasing a blade tip gap. In addition, the above-described assembly and method facilitate mitigating an increase in leakage around the blade by reducing a clearance between a tip of the blade and the casing using a brush seal assembly. As a result, the brush seal and fan assembly and method described herein facilitate reducing impeller blade-casing clearance, while maintaining fan airflow performance in a cost-effective and reliable manner.

[0039] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

WHAT IS CLAIMED IS:

1. A fan assembly comprising a fan casing including a longitudinal centerline axis extending from an upstream inlet opening to a downstream outlet opening, said assembly comprising:

a rotor comprising a hub and a plurality of rotor blades extending radially outward from said hub, said plurality of rotor blades each comprising a leading edge and a trailing edge in a direction of fluid flow through said fan casing, and a blade tip at a radially distal end of said blade, said tips of said plurality of rotor blades defining a rotor diameter, said rotor configured to rotate about said centerline axis;

a first substantially cylindrical casing segment extending circumferentially about and substantially axially aligned with said blade tips, said first casing segment comprising a first inner diameter that is greater than said rotor diameter; and

a brush seal assembly coupled to the blade tip of at least one of the plurality of rotor blades, said brush seal assembly configured to contact the casing segment during a first operational mode of the fan assembly, said brush seal assembly configured to avoid contact with the casing segment during a second operational mode of the fan assembly.

2. A fan assembly in accordance with Claim 1, wherein the first mode comprises a power output mode.

3. A fan assembly in accordance with Claim 1, wherein the second mode comprises at least one of an offline mode and an idle mode.

4. A fan assembly in accordance with Claim 1, wherein said brush seal assembly comprises a plurality of bristles extending radially opposite a direction of rotation of the rotor during said first operational mode of the fan assembly.

5. A fan assembly in accordance with Claim 1, wherein said brush seal assembly comprises a shroud coupled to at least some of the plurality of blade tips.

6. A fan assembly in accordance with Claim 1, wherein said brush seal assembly comprises a shroud coupled to a portion of at least some of the plurality of blade tips.

7. A fan assembly in accordance with Claim 1, wherein the brush seal assembly is coupled to at least a portion of at least some of the plurality of blade tips adjacent the leading edge of the at least some of the plurality of blades.

8. A fan assembly in accordance with Claim 1, wherein the brush seal assembly is coupled to at least some of the plurality of blade tips extending from the leading edge to the trailing edge of the at least some of the plurality of blades.

9. A fan assembly in accordance with Claim 1, wherein said brush seal assembly may permit a radial excursion of said blade.

10. A fan assembly in accordance with Claim 1, wherein said brush seal assembly comprises a plurality of brush fibers made at least partially from Kevlar.

11. A gas turbine engine, said gas turbine engine comprising:

a cylindrical fan casing having a longitudinal centerline axis extending from an upstream inlet opening to a downstream outlet opening;

a rotor blade rotatably mounted within said fan casing, said rotor blade having a radial inner end coupled to a rotor and a radially outer distal end comprising a blade tip, said rotor blade configured to rotate about the centerline axis, said rotor blade comprising a brush seal assembly coupled to at least a portion of said blade tip.

12. A gas turbine engine in accordance with Claim 11, wherein said brush seal assembly comprises a plurality of brush tips extending radially

opposite a direction of rotation of the rotor blade when said gas turbine engine is enabled to rotate the rotor blades.

13. A gas turbine engine in accordance with Claim 11, wherein the brush seal assembly is coupled to at least a portion of said blade tip adjacent the leading edge.

14. A gas turbine engine in accordance with Claim 11, wherein the brush seal assembly is coupled to said blade tip extending from the leading edge to the trailing edge.

15. A gas turbine engine in accordance with Claim 11, wherein a brush tip of said brush seal assembly is configured to contact the fan casing during a first operational mode of the gas turbine engine.

16. A gas turbine engine in accordance with Claim 15, wherein the first mode comprises a power output mode.

17. A gas turbine engine in accordance with Claim 10, wherein a brush tip of the brush seal assembly is configured to avoid contact with the fan casing during a second operational mode of the gas turbine engine.

18. A gas turbine engine in accordance with Claim 17, wherein the second mode comprises at least one of an offline mode and an idle mode.

19. A method for mounting a brush seal assembly to a blade tip of a fan of a gas turbine engine, said brush seal assembly having a base and a brush tip, said brush tip extending from said base at an angle less than 90 degrees from horizontal, the method comprising:

milling a segment of the blade tip about a leading edge of a rotor blade to create a milled tip configured to receive said brush seal assembly;

applying an adhesive to said milled tip, said adhesive configured to bond said base of said brush seal assembly to said blade tip; and inserting said base of said brush seal assembly into said milled tip such that said brush tip extends in the direction of a trailing edge of the rotor blade at an angle less than 90 degrees from horizontal.

20. A method in accordance with Claim 17, further comprising applying a layer of cladding to the leading edge of the rotor blade wherein the layer of cladding covers both the rotor blade and the base of said brush seal assembly.

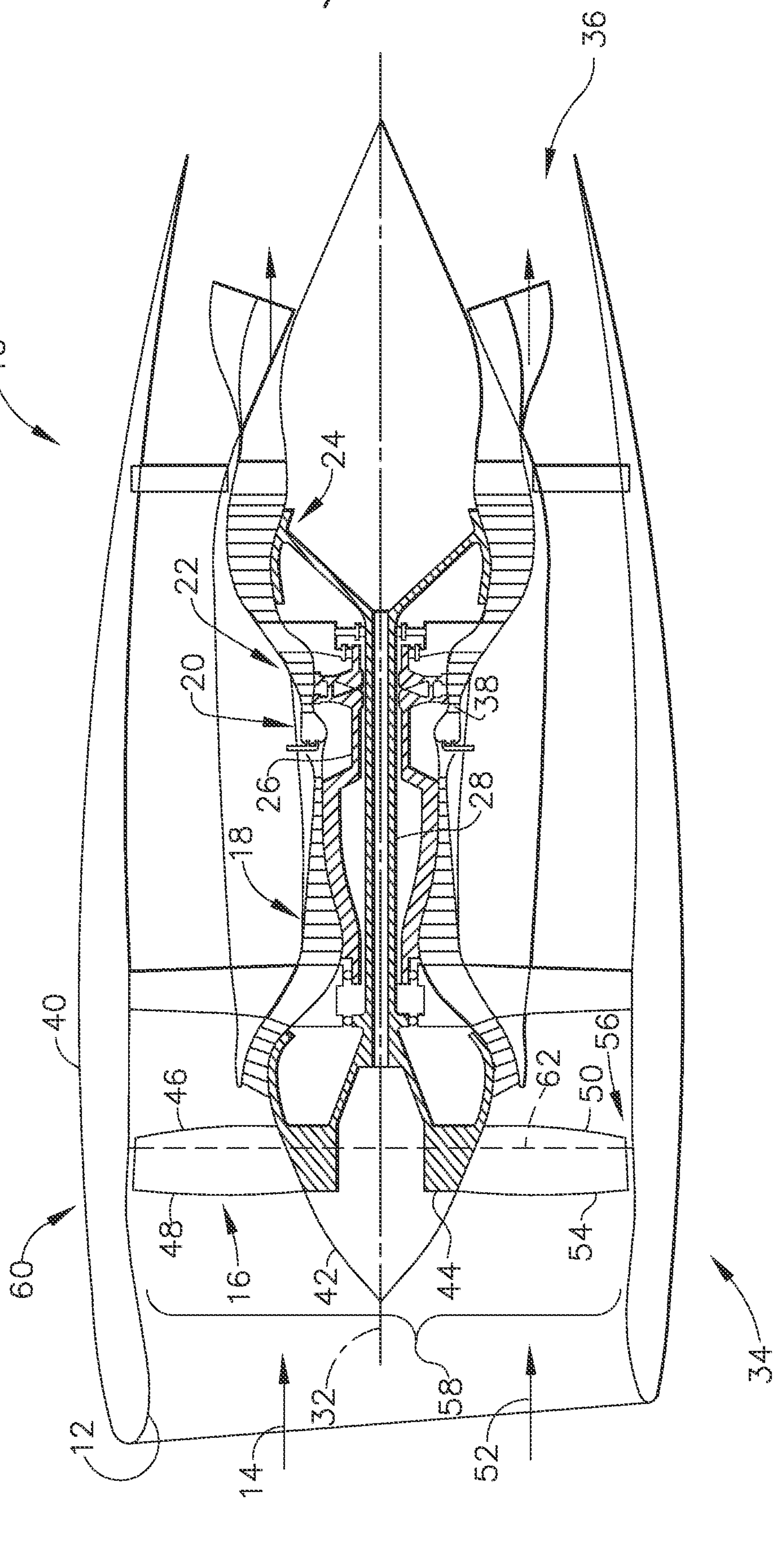
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FIG. 1

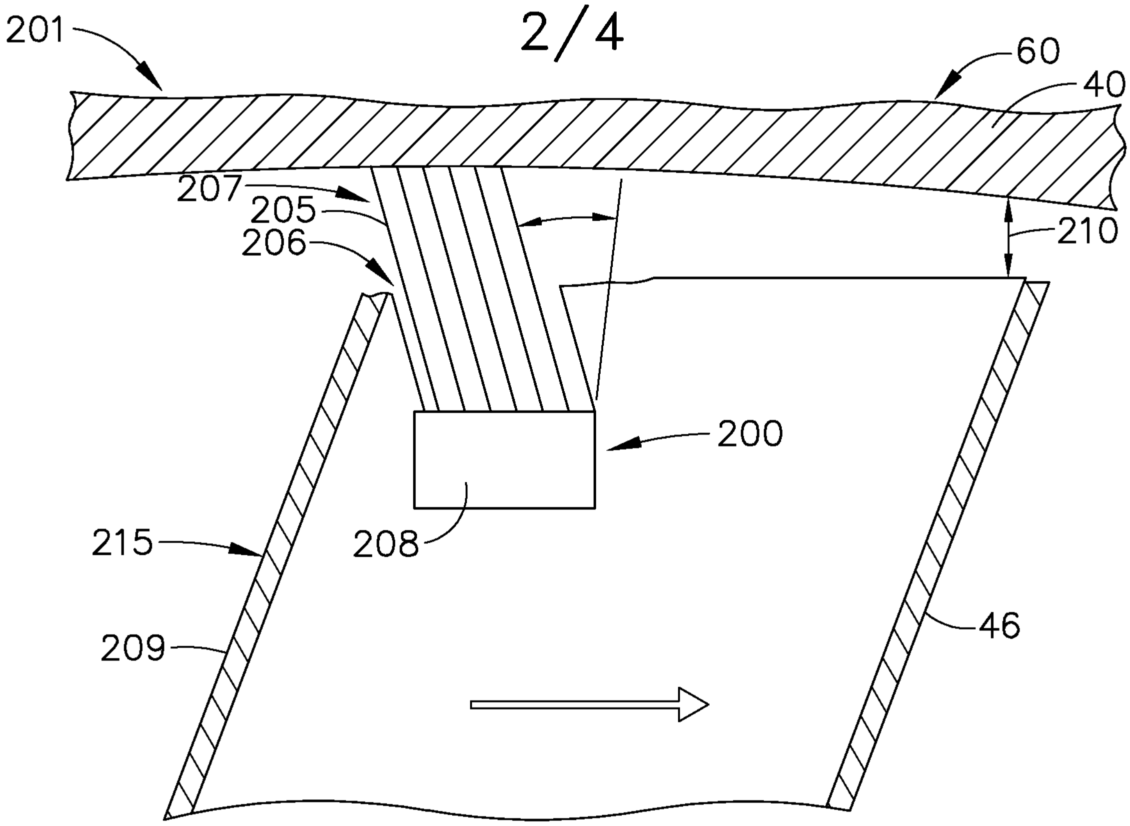
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FIG. 2

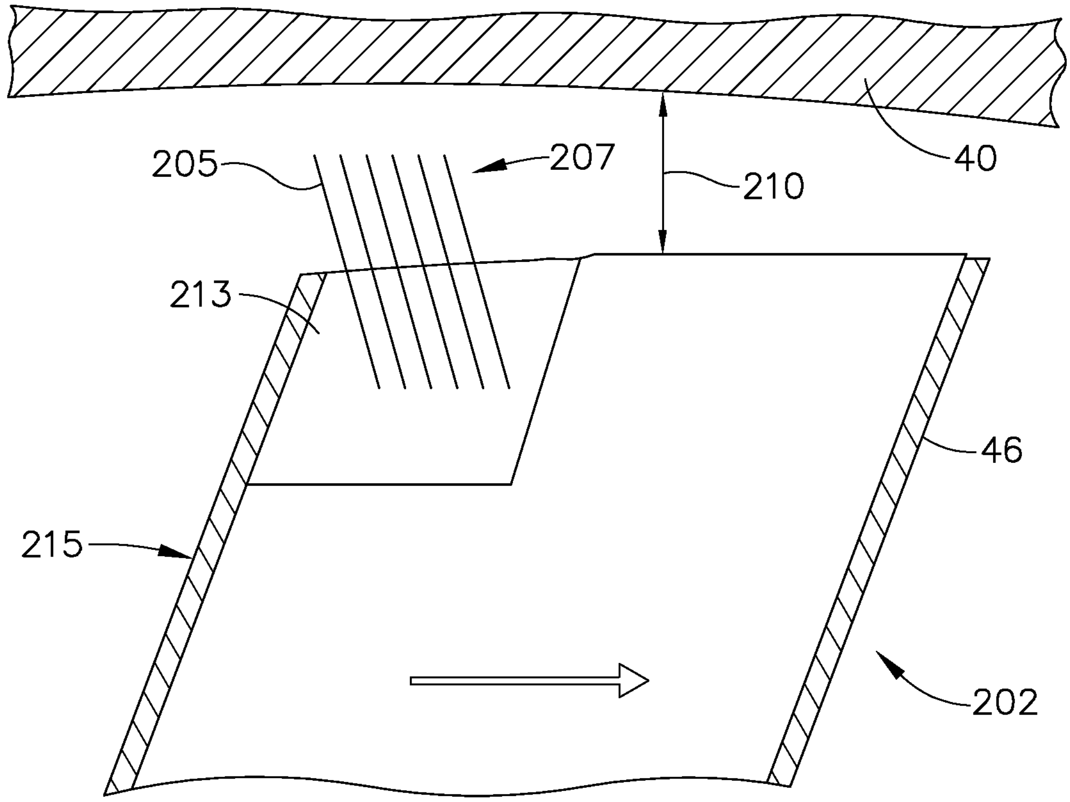
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FIG. 3

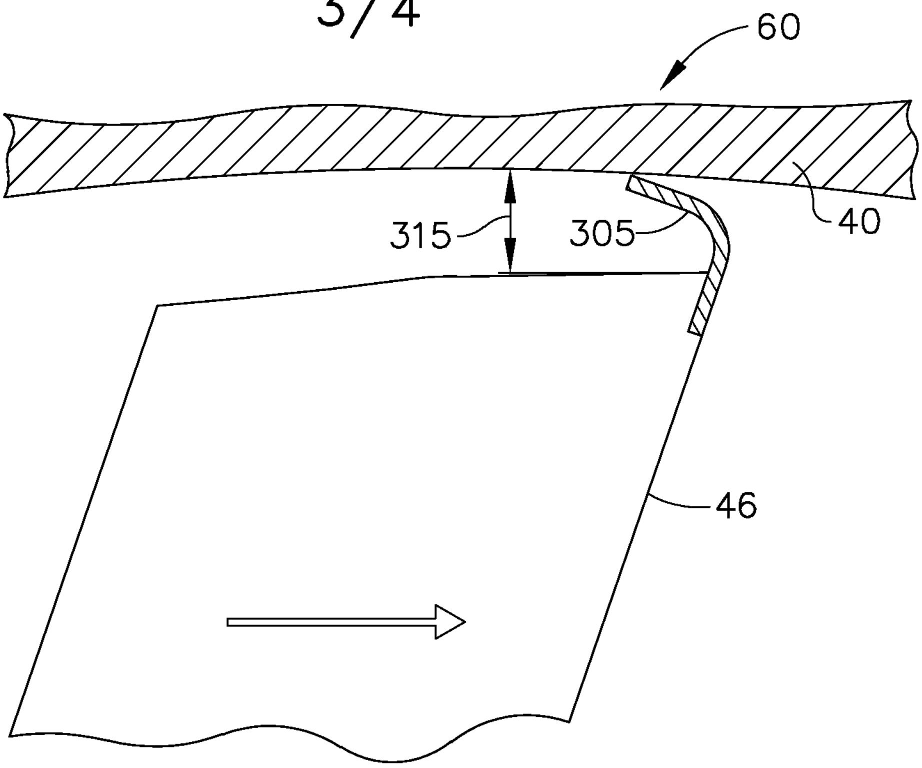

FIG. 4

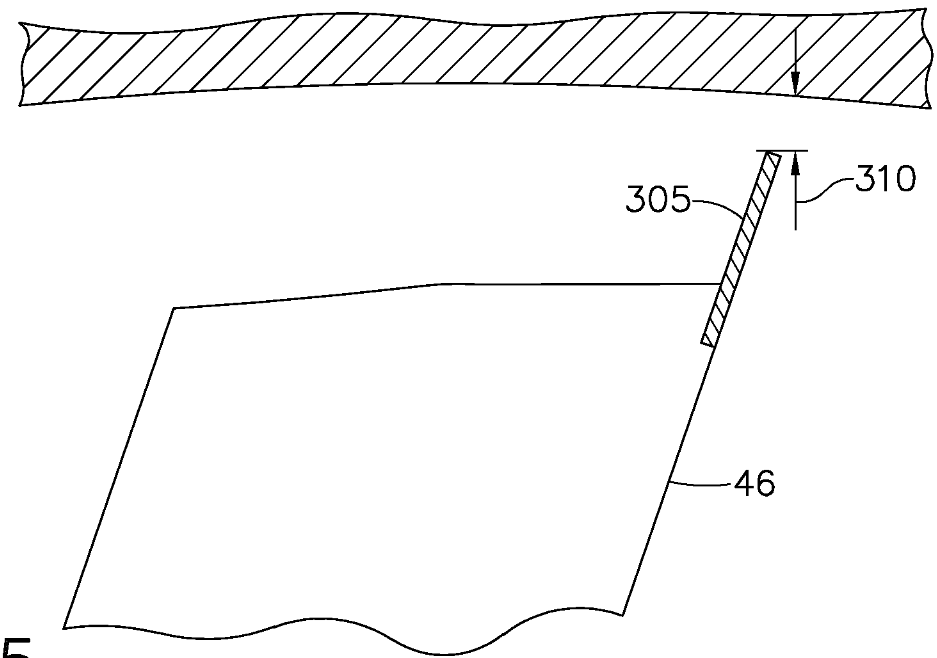

FIG. 5

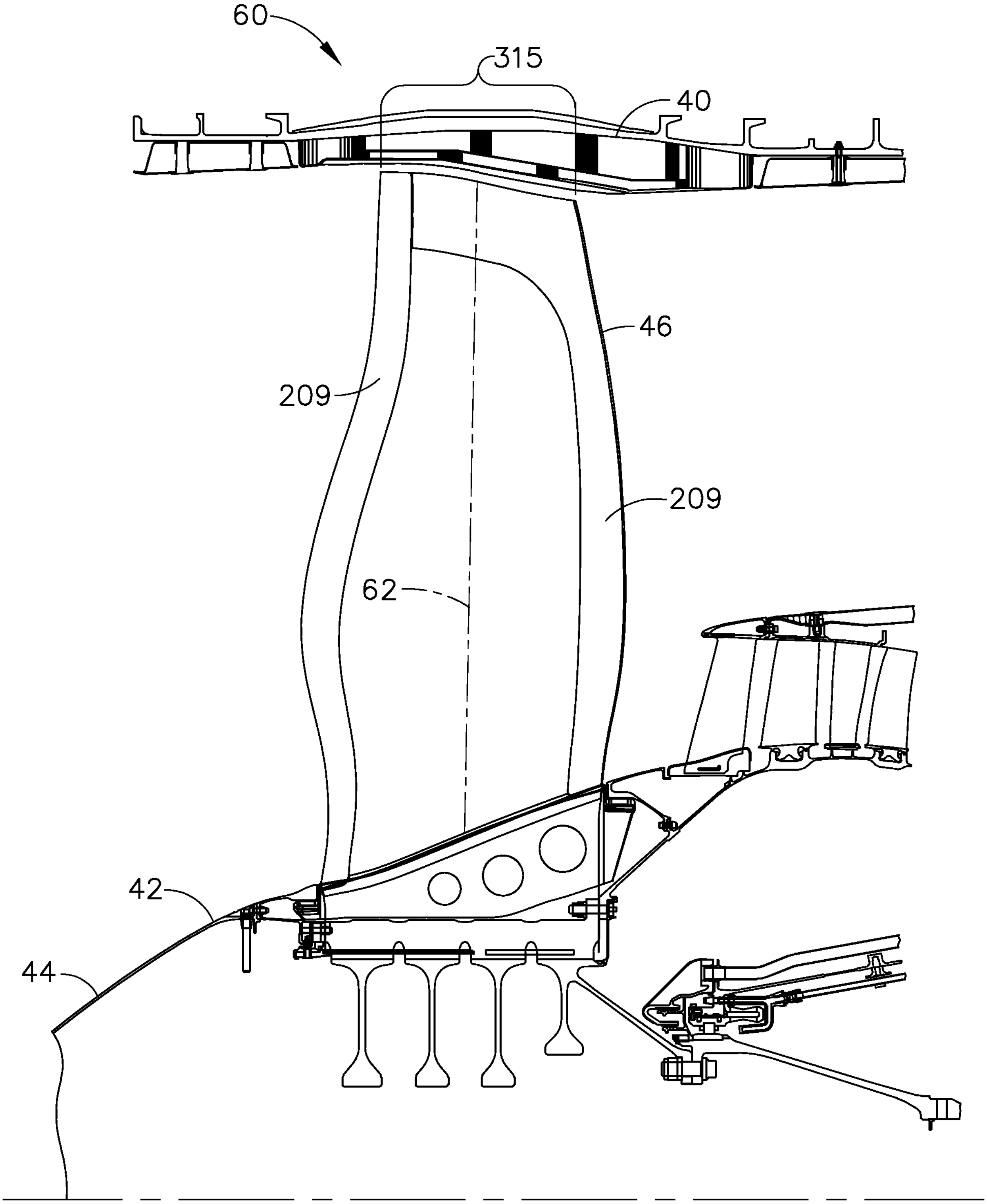

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/043496

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01D11/08 F16J15/32
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 F16J

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 628 622 A (THORE MONIQUE A [FR] ET AL) 13 May 1997 (1997-05-13) figures	1-4,7-18
X	DE 198 03 502 A1 (BEHR GMBH & CO [DE] BEHR GMBH & CO KG [DE]) 12 August 1999 (1999-08-12) figures	1-7,9,10
X	EP 1 167 840 A1 (SIEMENS AG [DE]) 2 January 2002 (2002-01-02) figures	19,20
X	JP H04 41901 A (HITACHI LTD) 12 February 1992 (1992-02-12) figure 6	19

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 July 2013	05/08/2013

Name and mailing address of the ISA/	Authorized officer
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