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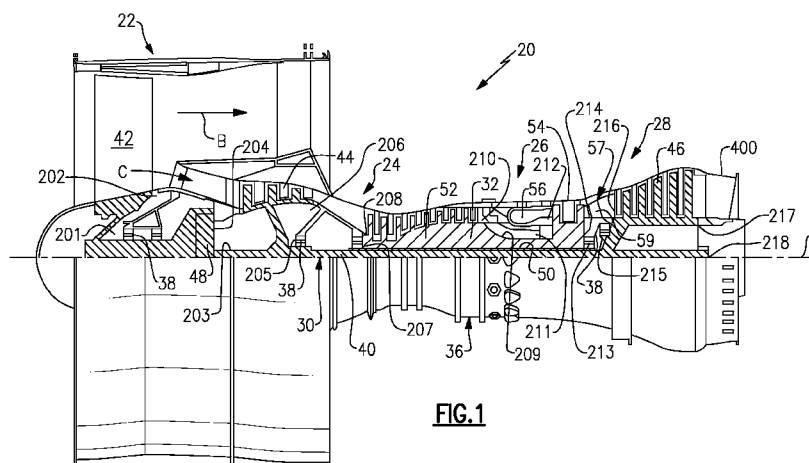


FIG. 1

(57) Abstract: In a featured embodiment, a gas turbine engine has a turbine section and an air moving section upstream of the tur-
bine section. A thrust balance chamber is defined within one of the air moving and turbine sections. The thrust balance chamber is
defined between a static structure and a rotating component that is part of at least one of the air moving section and the turbine sec-
tion. The thrust balance ' chamber is sealed by a first non-contact seal at a radially inner location and a second non-contact seal at a
radially outer location. In another embodiment according to the previous embodiment, the air moving section includes one of a fan
and a compressor.

THRUST BALANCE SYSTEM FOR GAS TURBINE ENGINE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to United States Provisional Application Serial No. 61/591,434, filed January 27, 2012.

BACKGROUND OF THE INVENTION

[0002] This application relates to a thrust balancing chamber in a gas turbine engine that has reduced leakage.

[0003] Gas turbine engines are known, and typically include a fan delivering air into a compressor, and also outwardly of the compressor as bypass air. The air is compressed in the compressor and delivered downstream into a combustion section where it is mixed with fuel and ignited. Products of this combustion pass downstream over turbine rotors, driving the turbine rotors to rotate. The turbine rotors in turn rotate the compressors and fan. Recently, a gear reduction has been provided between a low pressure (or low spool) compressor and the fan such that a low pressure (or low spool) turbine can drive both of these components but at different speeds.

[0004] There are a number of thrust balancing surfaces within a gas turbine engine. Historically, some of these have been formed into cavities sealed by contact seals such as knife edge or brush seals to help control bearing thrust loads. Unfortunately, such seals are either prone to leakage (KE seals) or significantly deteriorate over time (brush seals). Both characteristics lower the effectiveness of the enclosed thrust balance cavity to moderate the baseline thrust load.

SUMMARY OF THE INVENTION

[0005] In a featured embodiment, a gas turbine engine has a turbine section and an air moving section upstream of the turbine section. A thrust balance chamber is defined within one of the air moving and turbine sections. The thrust balance chamber is defined between a static structure and a rotating component that is part of at least one of the air moving section and the

turbine section. The thrust balance chamber is sealed by a first non-contact seal at a radially inner location and a second non-contact seal at a radially outer location.

[0006] In another embodiment according to the previous embodiment, the air moving section includes one of a fan and a compressor.

[0007] In another embodiment according to any of the previous embodiments, the turbine section drives a fan through a gear reduction.

[0008] In another embodiment according to any of the previous embodiments, the first and second non-contact seals each include a shoe that is biased radially inwardly and outwardly relative to a carrier at least in part based upon a spring force.

[0009] In another embodiment according to any of the previous embodiments, high pressure air is delivered into a cavity within each non-contact seal to drive the shoe toward an opposed surface.

[0010] In another embodiment according to any of the previous embodiments, a dynamic pressure between the seals and the opposed surfaces tends to bias the shoes away from the surfaces.

[0011] In another embodiment according to any of the previous embodiments, the seal is attached to the static structure, and the surface is a rotating surface that rotates with one of the compressor and turbine sections.

[0012] In another embodiment according to any of the previous embodiments, the shoe and the carrier are formed in segments.

[0013] In another embodiment according to any of the previous embodiments, at least one of the first and second non-contact seals sealing on a surface which is radially inwardly of the at least one of the first and second non-contact seals.

[0014] In another embodiment according to any of the previous embodiments, at least one of the first and second non-contact seals sealing on a surface which is radially outwardly of the at least one of the first and second non-contact seals.

[0015] In another embodiment according to any of the previous embodiments, the thrust balance chamber is defined at a most upstream turbine blade row in the turbine section.

[0016] In another featured embodiment, a gas turbine engine has a fan and a compressor section. The compressor section includes a low pressure compressor and a high pressure compressor, a high pressure turbine, and a low pressure turbine. The low pressure

turbine drives the low pressure compressor, and drives the fan through a gear reduction. The high pressure turbine drives the high pressure compressor. At least one thrust balance chamber is defined within one of the fan, compressor and turbine sections. The thrust balance chamber is defined between a static structure and a rotating component that is part of at least one of the compressor section and the turbine section. The thrust balance chamber is sealed by a first non-contact seal at a radially inner location and a second non-contact seal at a radially outer location.

[0017] In another embodiment according to the previous embodiment, the first and second non-contact seals each include a shoe which is biased radially inwardly and outwardly relative to a carrier at least in part based upon a spring force created by an arm structure.

[0018] In another embodiment according to any of the previous embodiments, high pressure air is delivered into a cavity within each non-contact seal to drive the shoe toward an opposed surface.

[0019] In another embodiment according to any of the previous embodiments, a dynamic pressure between the seals and the opposed surfaces tends to bias the shoes away from the surfaces.

[0020] In another embodiment according to any of the previous embodiments, the seal is attached to the static structure, and the surface is a rotating surface that rotates with at least one of the compressor and turbine sections.

[0021] In another embodiment according to any of the previous embodiments, the shoe and the carrier are formed in segments.

[0022] In another embodiment according to any of the previous embodiments, at least one of the first and second non-contact seals sealing on a surface which is radially inwardly of the at least one of the first and second non-contact seals.

[0023] In another embodiment according to any of the previous embodiments, at least one of the first and second non-contact seals sealing on a surface which is radially outwardly of the at least one of the first and second non-contact seals.

[0024] In another embodiment according to any of the previous embodiments, the thrust balance chamber is defined at a most upstream turbine blade row in the turbine section.

[0025] In another embodiment according to any of the previous embodiments, the thrust balance chamber in combination with many other thrust balance chambers counteracts the net load developed by the combination of all the thrust surfaces within the other modules.

[0026] These and other features of the invention would be better understood from the following specifications and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0027] Figure 1 schematically shows a gas turbine engine.
- [0028] Figure 2 shows a thrust balancing chamber in a gas turbine engine.
- [0029] Figure 3 is a view of a portion of a self-adjusting non-contact seal.
- [0030] Figure 4 is a force diagram of one example of such a non-contact seal.
- [0031] Figure 5 shows an alternative embodiment.

DETAILED DESCRIPTION

[0032] Figure 1 schematically illustrates a gas turbine engine 20. The gas turbine engine 20 is disclosed herein as a two-spool turbopfan that generally incorporates a fan section 22, a compressor section 24, a combustor section 26 and a turbine section 28. Alternative engines might include an augmentor section (not shown) among other systems or features. The fan section 22 drives air along a bypass flowpath B while the compressor section 24 drives air along a core flowpath C for compression and communication into the combustor section 26 where fuel is added, mixed, and burned and then expansion through the turbine section 28. Although depicted as a turbopfan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with turbopfans as the teachings may be applied to other types of turbine engines including three-spool architectures.

[0033] The engine 20 generally includes a low speed spool 30 and a high speed spool 32 mounted for rotation about an engine central longitudinal axis A relative to an engine static structure 36 via several bearing systems 38. It should be understood that various bearing systems 38 at various locations may alternatively or additionally be provided.

[0034] The low speed spool 30 generally includes an inner shaft 40 that interconnects a fan 42, a low pressure compressor 44 and a low pressure turbine 46. The inner shaft 40 is connected to the fan 42 through a geared architecture 48 to drive the fan 42 at a lower speed than the low speed spool 30. The high speed spool 32 includes an outer shaft 50 that interconnects a high pressure compressor 52 and high pressure turbine 54. The terms “high” and “low” as utilized with reference to speed or pressure are relative to each other. The compressor

and turbine associated with the “high” spool 32 operates at higher pressure and speeds than does the compressor and turbine associated with the “low” spool. A combustor 56 is arranged between the high pressure compressor 52 and the high pressure turbine 54. A mid-turbine frame 57 of the engine static structure 36 is arranged generally between the high pressure turbine 54 and the low pressure turbine 46. The mid-turbine frame 57 further supports bearing systems 38 in the turbine section 28. The inner shaft 40 and the outer shaft 50 are concentric and rotate via bearing systems 38 about the engine central longitudinal axis A which is collinear with their longitudinal axes. The shafts can be either co-rotating or counter-rotating.

[0035] The core airflow is compressed by the low pressure compressor 44 then the high pressure compressor 52, mixed and burned with fuel in the combustor 56, then expanded over the high pressure turbine 54 and low pressure turbine 46. The mid-turbine frame 57 includes airfoils 59 which are in the core airflow path. The turbines 46, 54 rotationally drive the respective low speed spool 30 and high speed spool 32 in response to the expansion.

[0036] The engine 20 in one example is a high-bypass geared aircraft engine. In a further example, the engine 20 bypass ratio is greater than about six (6), with an example embodiment being greater than ten (10), the geared architecture 48 is an epicyclic gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3 and the low pressure turbine 46 has a pressure ratio that is greater than about 5. In one disclosed embodiment, the engine 20 bypass ratio is greater than about ten (10:1), the fan diameter is significantly larger than that of the low pressure compressor 44, and the low pressure turbine 46 has a pressure ratio that is greater than about 5:1. Low pressure turbine 46 pressure ratio is the total pressure measured prior to inlet of low pressure turbine 46 as related to the total pressure at the outlet of the low pressure turbine 46 prior to an exhaust nozzle 400. The geared architecture 48 may be an epicycle gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.5:1. It should be understood, however, that the above parameters are only exemplary of one embodiment of a geared architecture engine and that the present invention is applicable to other gas turbine engines including direct drive turbofans. Utilizing the geared architecture 48 enables a high speed low spool which tends to increase the efficiency of the low pressure compressor and the low pressure turbine. Further, it enables greater pressure ratio in fewer stages.

[0037] A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio. The fan section 22 of the engine 20 is designed for a particular flight condition -- typically cruise at about 0.8 Mach and about 35,000 feet. The flight condition of 0.8 Mach and 35,000 ft, with the engine at its best fuel consumption - also known as “bucket cruise Thrust Specific Fuel Consumption (‘TSFC’)” - is the industry standard parameter of lbf of fuel being burned divided by lbf of thrust the engine produces at that minimum point. “Low fan pressure ratio” is the total pressure ratio across the fan blade alone, without a Fan Exit Guide Vane (‘FEGV’) system. The low fan pressure ratio as disclosed herein according to one non-limiting embodiment is less than about 1.45. “Low corrected fan tip speed” is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of $[(T_{\text{ambient deg R}}) / 518.7]^{0.5}$. The “Low corrected fan tip speed” as disclosed herein according to one non-limiting embodiment is less than about 1150 ft / second.

[0038] Figure 2 shows a thrust balance chamber 90, that receives gas to provide a rearward force against a surface 91 of a turbine section 82. In one example, this turbine section 82 may be the most upstream turbine blade row in a high pressure turbine 54. The surface 91 is a thrust balancing surface, and due to the pressure in chamber 90, may equal out an opposed forward-facing thrust surface associated with the compressor.

[0039] These chambers may exist anywhere in the engine, including, but not limited to, the axially front and back faces of the compressor and turbine components of any or all spools, including the fan rotor. The fan and compressor are collectively known as “air moving sections” for purposes of this application. Thus, while one location is disclosed, the application extends to any number of other locations. Further note that the disclosure applies to an enclosed thrust balance cavity with reduced pressure as well as to an enclosed cavity with increased pressure. In addition, more than one cavity may also exist on a particular thrust balance face.

[0040] Exemplary chambers which may utilize the non-contact seals of this invention include the paired locations 201/202 (the rear fan cavity), 203/204 (front low pressure compressor cavity), 205/206 (rear low pressure compressor cavity), 207/208 (front high pressure compressor cavity), 209/210 (rear high pressure compressor cavity), 211/212 (front high pressure turbine cavity), 213/214 (rear high pressure turbine cavity), 215/216 (front low pressure turbine cavity), and 217/218 (rear low pressure turbine cavity). Other locations may also benefit from the teachings of this application.

[0041] When a chamber 90 is utilized in a gas turbine engine provided with a gear reduction between the low pressure compressor and fan, it is often the case that the overall radial envelope of the turbine section is reduced because the low spool can rotate faster since it is no longer speed-limited by the diameter of the fan. This requires a higher pressure in the chamber 90 to counteract this effect than in the prior art. In the prior art, the chamber 90 was sealed with contacting seals wherein a static seal surface contacted rotating surfaces of the rotor 82. Knife edge seals which abut abradable or solid sealed members have been utilized, as well as brush seals or finger seals. Many such contacting seals are prone to wear, and all have undesirable worn-in leakage characteristics. These become particularly acute when the pressure in the chamber 90 increases, as mentioned above. Therefore, there are synergistic benefits when using such seals in an engine having a gear reduction to drive the fan.

[0042] As shown in Figure 2, an outer flow engine core 80 delivers products of combustion to the rotor section 82. A source of air 89, which may be the high pressure compressor 52, as shown in Figure 1, delivers high pressure air to an inlet 88 to the chamber 90. Inlet 88 may be a tangential on-board injector used as a means to pre-swirl the air entering the cavity or a simple hole or other conduit or passage, as often utilized at various locations within a gas turbine engine. The air within chamber 90 is designed to be at a relatively high or low pressure such that the force balance as mentioned above is achieved. A radially outer seal 94 and inner seal 92 seal chamber 90.

[0043] Seals 92 and 94 may be non-contact seals or self-adjusting non-contact seals. Seals 92 and 94 are mounted in a static housing 150. The seals are intended to prevent or limit leakage paths L. The non-contacting seals will be longer-lived than the prior art contact seals, and will greatly reduce the leakage from the chamber 90. Non-contact seal 94 is associated with a surface 84 that is carried by, and rotates with, the turbine rotor 82. Seal 92 is associated with surface 86 that also is carried by, and rotates with, the turbine rotor 82. The seals 92 and 94 are generally not in contact with the surfaces 84 and 86. Note that the actually sealing surface of the non-contacting seals is not limited to the ID of the static structure. Non-contacting seals with OD sealing surfaces are also possible and envisioned.

[0044] Figure 3 shows one example of a non-contact seal. One type of seal may be a HALO™ seal available from ATGI, Advanced Technologies Group, Inc. of Stuart, Florida. The HALO™ seal 100 as shown in Figure 3 has inner shoes 106, and an outer carrier 120. The outer

carrier 120 and the shoes 106 are generally formed from a single piece of metal, and are cut as shown at 104 such that the combined seal 100 is formed into segments. As shown, the cuts 104 actually provide a gap that allow arms associated with the seal to provide a spring force, as mentioned below. The gaps provided by the cut 104 are relatively small, for example less than .050" (.127 cm). The spring force S is shown schematically. As shown in Figure 3, there are portions of three adjacent segments 401, 402, 403, which come together to form the overall seal 100. A cavity 102 receives pressurized air.

[0045] As shown in Figure 4, a spring force, shown schematically at 125, biases the seal shoe 106 toward a neutral position. The rotor 120 may be surfaces 84 or 86 in the present application. The spring force is created as the shoe 106 is otherwise biased toward and away from the rotor 120. That is, there is a natural position of the shoe 106 relative to the carrier 120, and, as it moves away from this position in either direction, it creates an opposing bias force.

[0046] As can be appreciated from Figures 3, taken into combination with Figure 4, air is injected into the cavity 102, and biases the shoe 106 toward the rotor 120. Thus, there is a static pressure force 108 forcing the shoe 106 toward the rotor, and an opposing spring force 125 tending to restore the shoe to a neutral position. In addition, a dynamic pressure 110, whose magnitude depends on the proximity of the shoe to the rotor, forces the shoe away from the rotor.

[0047] These three forces come into equilibrium to center the shoe at a desired location relative to the rotor such that any disturbance to the system will tend to redistribute the forces in a manner that works to restore the shoe to the same material position as prior to the disturbance. In this way, it is self-adjusting, and without need of any external control. These types of self-adjusting non-contacting seals effectively minimize both axi-symmetric (all shoes of the ring behave in the same manner) and non-axisymmetric (each shoe of the ring behaves independent of its neighbors) clearances. As such, these seals achieve very low leakage rates which enable the provision of thrust balance cavities in an effective and efficient manner.

[0048] While the seals are shown on the static housing 150, they may also rotate with rotor 82 and seal on static housing 150. While one particular seal is shown, other types of seals may be utilized. The HALO™ type seal has been proposed in gas turbine engines, but not as combined inner and outer seals for a thrust balance chamber.

[0049] Figure 5 shows an embodiment wherein the seal 602 is biased outwardly towards a surface 604, and away from a rotational centerline A. In this embodiment, the seal is

mounted on a component 600, and seals relative to a component 604. Either component 604 or 600 may be rotating with the other static. Thus, the seals envisioned by this application can either seal radially outwardly or radially inwardly, and can be mounted to either of the static or rotating structure.

[0050] Although embodiments of this invention have been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

CLAIMS

1. A gas turbine engine comprising:
a turbine section and an air moving section upstream of the turbine section; and
a thrust balance chamber defined within one of said air moving and turbine sections, said thrust balance chamber being defined between a static structure and a rotating component that is part of at least one of said air moving section and said turbine section, and said thrust balance chamber being sealed by a first non-contact seal at a radially inner location and a second non-contact seal at a radially outer location.
2. The gas turbine engine as set forth in claim 1, wherein said air moving section includes one of a fan and a compressor.
3. The gas turbine engine as set forth in claim 1, wherein said turbine section drives a fan through a gear reduction.
4. The gas turbine engine as set forth in claim 1, wherein said first and second non-contact seals each include a shoe which is biased radially inwardly and outwardly relative to a carrier at least in part based upon a spring force.
5. The gas turbine engine as set forth in claim 4, wherein high pressure air is delivered into a cavity within each said non-contact seal to drive said shoe toward an opposed surface.
6. The gas turbine engine as set forth in claim 5, wherein a dynamic pressure between the seals and the opposed surfaces tends to bias said shoes away from said surfaces.
7. The gas turbine engine as set forth in claim 6, wherein said seal is attached to said static structure, and said surface is a rotating surface that rotates with one of said compressor and turbine sections.
8. The gas turbine engine as set forth in claim 4, wherein said shoe and said carrier are formed in segments.

9. The gas turbine engine as set forth in claim 1, wherein at least one of said first and second non-contact seals sealing on a surface which is radially inwardly of said at least one of said first and second non-contact seals.

10. The gas turbine engine as set forth in claim 1, wherein at least one of said first and second non-contact seals sealing on a surface which is radially outwardly of said at least one of said first and second non-contact seals.

11. The gas turbine engine as set forth in claim 1, wherein said thrust balance chamber is defined at a most upstream turbine blade row in the turbine section.

12. A gas turbine engine comprising:

a fan, a compressor section, said compressor section include a low pressure compressor and a high pressure compressor, a high pressure turbine, and a low pressure turbine and said low pressure turbine driving said low pressure compressor, and driving said fan through a gear reduction, and said high pressure turbine driving said high pressure compressor; and

at least one thrust balance chamber defined within one of said fan, compressor and turbine sections, said thrust balance chamber being defined between a static structure and a rotating component that is part of at least one of said compressor section and said turbine section, and said thrust balance chamber being sealed by a first non-contact seal at a radially inner location and a second non-contact seal at a radially outer location.

13. The gas turbine engine as set forth in claim 12, wherein said first and second non-contact seals each include a shoe which is biased radially inwardly and outwardly relative to a carrier at least in part based upon a spring force created by an arm structure.

14. The gas turbine engine as set forth in claim 13, wherein high pressure air is delivered into a cavity within each said non-contact seal to drive said shoe toward an opposed surface.

15. The gas turbine engine as set forth in claim 13, wherein a dynamic pressure between the seals and the opposed surfaces tends to bias said shoes away from said surfaces.

16. The gas turbine engine as set forth in claim 15, wherein said seal is attached to said static structure, and said surface is a rotating surface that rotates with at least one of said compressor and turbine sections.

17. The gas turbine engine as set forth in claim 13, wherein said shoe and said carrier are formed in segments.

18. The gas turbine engine as set forth in claim 12, wherein at least one of said first and second non-contact seals sealing on a surface which is radially inwardly of said at least one of said first and second non-contact seals.

19. The gas turbine engine as set forth in claim 12, wherein at least one of said first and second non-contact seals sealing on a surface which is radially outwardly of said at least one of said first and second non-contact seals.

20. The gas turbine engine as set forth in claim 12, wherein said thrust balance chamber is defined at a most upstream turbine blade row in the turbine section.

21. The gas turbine engine as set forth in claim 20, wherein said thrust balance chamber in combination with many other thrust balance chambers counteracts the net load developed by the combination of all the thrust surfaces within said other modules.

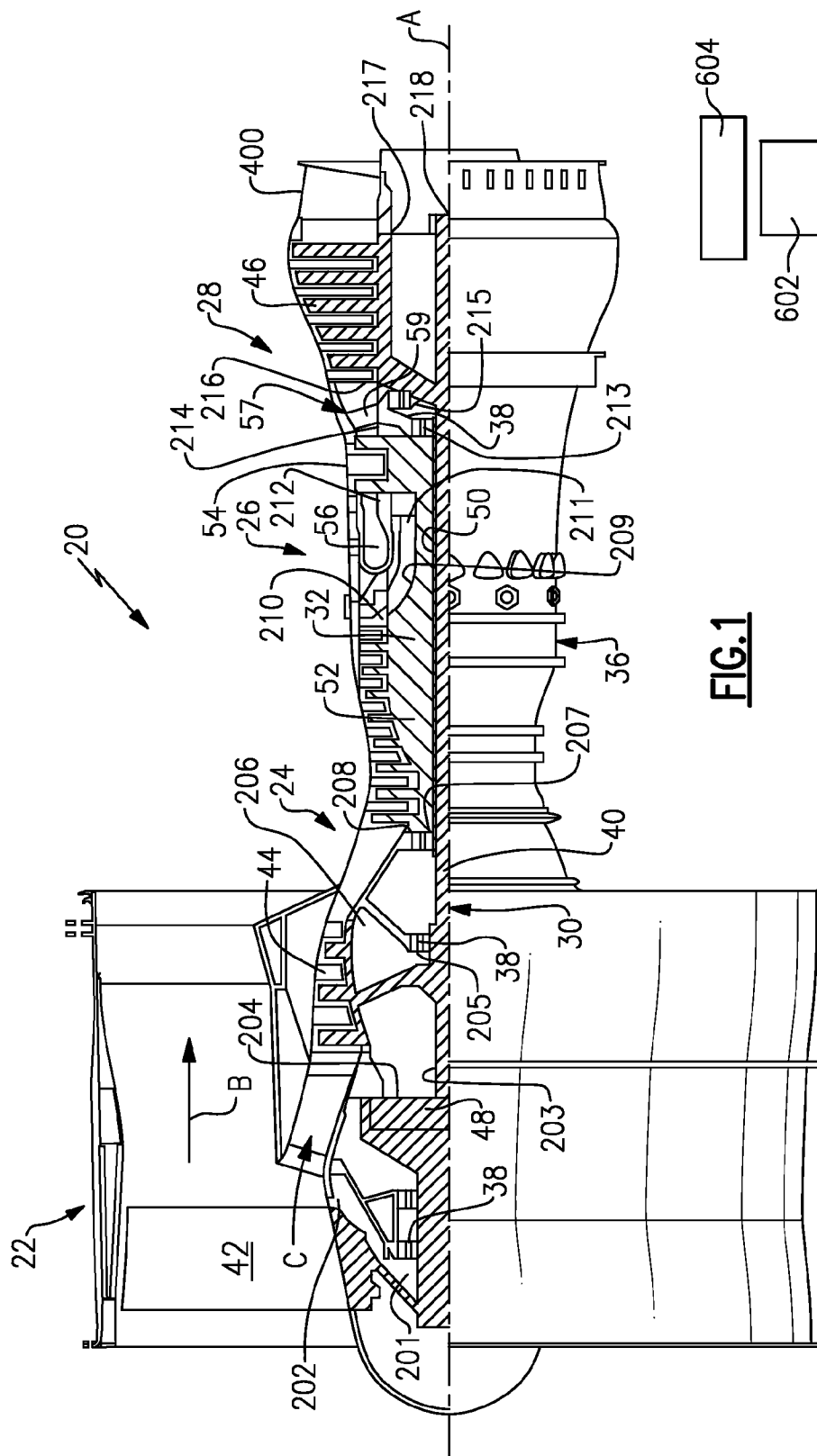


FIG. 1

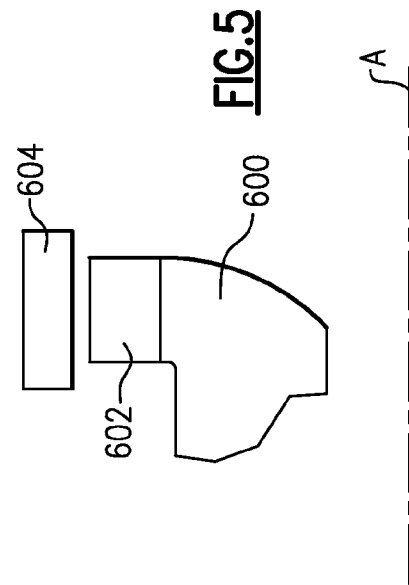
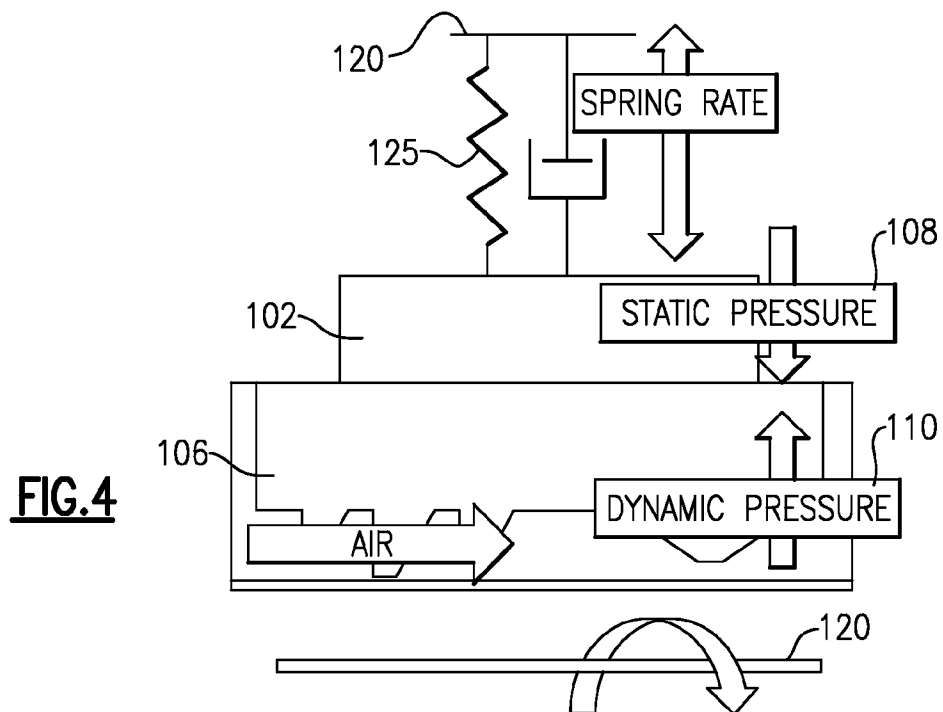
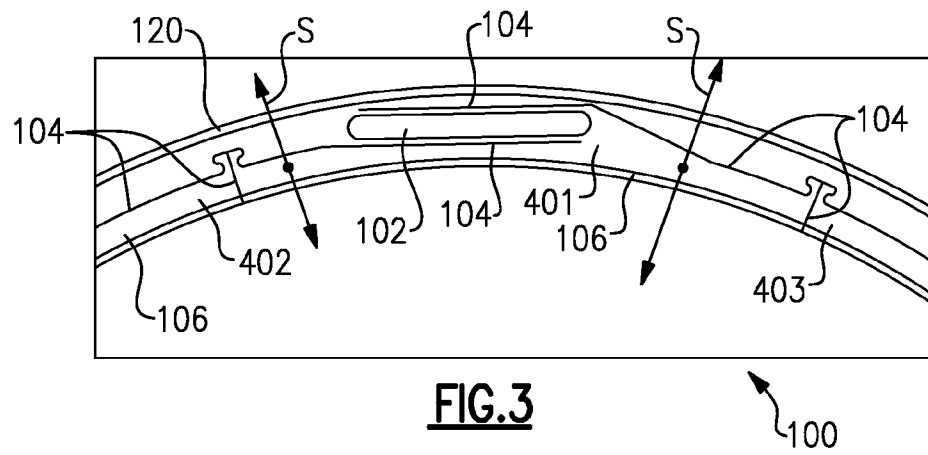
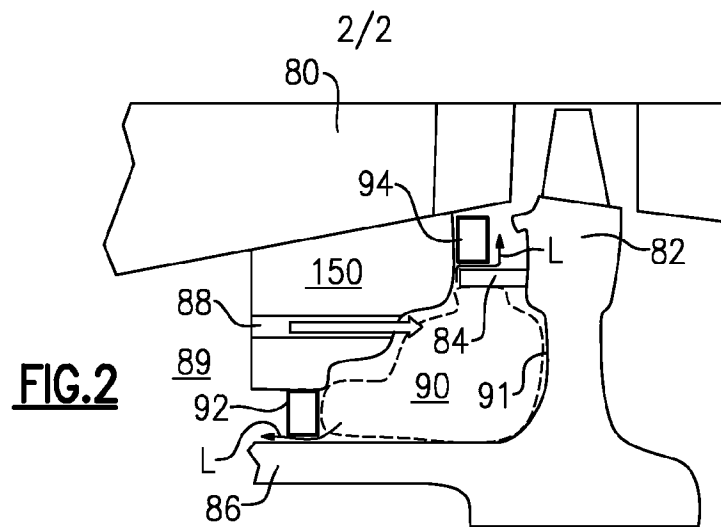


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F01D 17/08 (2013.01)

USPC - 415/126

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)

IPC(8) - F01D 3/00, 3/04, 11/00, 11/02, 11/08, 17/00, 17/08, 25/00 (2013.01)

USPC - 415/126, 170.1, 173.1, 173.5, 174.5

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

CPC - F01D 3/04, 11/02, 11/04, 11/08, 17/00 (2013.01)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase, Google Patents, Google

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2,647,684 A (LOMBARD) 04 August 1953 (04.08.1953) entire document	1, 2, 9-11
Y		3-8, 12-21
Y	US 3,121,526 A (MORLEY) 18 February 1964 (18.02.1964) entire document	3
Y	US 2008/0265513 A1 (JUSTAK) 30 October 2008 (30.10.2008) entire document	4-8, 13-17
Y	US 5,107,676 A (HADAWAY et al) 28 April 1992 (28.04.1992) entire document	12-21
A	US 6,193,462 B1 (KUBOTA) 27 February 2001 (27.02.2001) entire document	1-21

☐ Further documents are listed in the continuation of Box C.

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Date of mailing of the international search report

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