A seal support comprises a body, a seal carrier disposed circumferentially around an outer surface of the body, and a meshing ring extending axially forward of the seal carrier.
MID-TURBINE FRAME HPT SEAL SUPPORT MESHING

BACKGROUND

[0001] The described subject matter relates generally to gas turbine engines and more particularly, to arrangements for separating hot and cold flows in gas turbine engines.

[0002] Compact engines require closer packing of components, which in turn requires more crossing of hot and cold gas flows. Without adequate thermal protection, seals, and insulation between these flows, smaller engines suffer from a loss of efficiency. One system developed for certain engines is the mid-turbine frame (MTF), also known as the turbine center frame (TCF) or interturbine frame. This can be disposed between intermediate stages of the turbine section and can have numerous components serving a variety of functions, including bearing support, engine backbone, combustion gas flow path, among others.

[0003] These engine frames support axial, radial, and circumferential engine loads. In the event of a component failure in or proximate the MTF, the failure loads should be isolated or transmitted to other components to reduce the risk of catastrophic damage.

SUMMARY

[0004] A mid-turbine frame for a gas turbine engine comprises a radially outer case, a radially inner case, a plurality of load spokes, and a circumferential seal support. The radially inner case is disposed inward from the radially outer case defining an annular passage therebetween. The plurality of load spokes extend through the annular passage securing the outer case with the inner case. The circumferential seal support is disposed axially forward of the inner case, the seal support including a seal carrier and a meshing ring extending axially forward of the seal carrier.

[0005] A case assembly comprises a substantially cylindrical case element, and a circumferential seal support disposed axially forward of the inner case. The seal support includes a seal carrier and a meshing ring extending axially forward of the seal carrier.

[0006] A seal support comprises a body, a seal carrier disposed circumferentially around an outer surface of the body, and a meshing ring extending axially forward of the seal carrier.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a schematic cross-sectional view of a turbofan gas turbine engine according to the present description.

[0008] FIG. 2 isometrically depicts an example embodiment of a mid-turbine frame for a gas turbine engine.

[0009] FIG. 3A shows an exploded isometric view of an example inner case assembly for the mid-turbine frame depicted in FIG. 2.

[0010] FIG. 3B is a partially cut away cross-sectional view of the mid-turbine frame of FIG. 2.

[0011] FIG. 4A shows one embodiment of an inner case assembly relative to an adjacent turbine rotor stage.

[0012] FIG. 4B shows an alternative embodiment of an inner case assembly relative to an adjacent turbine rotor stage.

DETAILED DESCRIPTION

[0013] FIG. 1 schematically illustrates an example gas turbine engine 20 that includes fan section 22, compressor section 24, combustor section 26 and turbine section 28. Alternative engines might include an augmenter section (not shown) among other systems or features. Fan section 22 drives air along bypass flow path B while compressor section 24 draws air in along core flow path G where air is compressed and communicated to combustor section 26. In combustor section 26, air is mixed with fuel and ignited to generate a high pressure exhaust gas stream that expands through turbine section 28 where energy is extracted and utilized to drive fan section 22 and compressor section 24.

[0014] Although the disclosed non-limiting embodiment depicts a turbofan gas turbine engine, it should be understood that the concepts described herein are not limited to use with turbofans as the teachings may be applied to other types of turbine engines; for example a turbine engine including a three-spool architecture in which three spools concentrically rotate about a common axis and where a low spool enables a low pressure turbine to drive a fan via a gearbox, an intermediate spool that enables an intermediate pressure turbine to drive a first compressor of the compressor section, and a high spool that enables a high pressure turbine to drive a high pressure compressor of the compressor section.

[0015] The example engine 20 generally includes low speed spool 30 and high speed spool 32 mounted for rotation about an engine central longitudinal axis A relative to an engine static structure 34 via several bearing systems 35. It should be understood that various bearing systems 35 at various locations may alternatively or additionally be provided.

[0016] Low speed spool 30 generally includes inner shaft 36 that connects fan 37 and low pressure (or first) compressor section 38 to low pressure (or first) turbine section 39. Inner shaft 36 drives fan 37 through a speed change device, such as geared architecture 40, to drive fan 37 at a lower speed than low speed spool 30. High-speed spool 32 includes outer shaft 41 that interconnects high pressure (or second) compressor section 42 and high pressure (or second) turbine section 43. Inner shaft 36 and outer shaft 41 are concentric and rotate via bearing systems 35 about engine central longitudinal axis A.

[0017] Combustor 44 is arranged between high pressure compressor 42 and high pressure turbine 43. In one example, high pressure turbine 43 includes at least two stages to provide a double stage high pressure turbine 43. In another example, high pressure turbine 43 includes only a single stage. As used herein, a “high pressure” compressor or turbine experiences a higher pressure than a corresponding “low pressure” compressor or turbine.

[0018] The example low pressure turbine 39 has a pressure ratio that is greater than about 5. The pressure ratio of the example low pressure turbine 39 is measured prior to an inlet of low pressure turbine 39 as related to the pressure measured at the outlet of low pressure turbine 39 prior to an exhaust nozzle.

[0019] Mid-turbine frame 46 of engine static structure 34 is arranged generally between high pressure turbine 43 and low pressure turbine 46. Mid-turbine frame 46 further supports bearing systems 35 in turbine section 28 as well as setting airflow entering low pressure turbine 46.

[0020] The core airflow G is compressed by low pressure compressor 38 then by high pressure compressor 42 mixed with fuel and ignited in combustor 44 to produce high speed exhaust gases that are then expanded through high pressure turbine 43 and low pressure turbine 46. Mid-turbine frame 46 includes vanes 58, which are in the core airflow path and function as an inlet guide vane for low pressure turbine 39.
Utilizing vane 58 of mid-turbine frame 46 as the inlet guide vane for low pressure turbine 39 decreases the length of low pressure turbine 39 without increasing the axial length of mid-turbine frame 46. Reducing or eliminating the number of vanes in low pressure turbine 39 shortens the axial length of turbine section 28. Thus, the compactness of gas turbine engine 20 is increased and a higher power density may be achieved.

[0021] The disclosed gas turbine engine 20 in one example is a high-bypass geared aircraft engine. In a further example, gas turbine engine 20 includes a bypass ratio greater than about six (6), with an example embodiment being greater than about ten (10). The example geared architecture 40 is an epicyclical gear train, such as a planetary gear system, star gear system or other known gear system, with a gear reduction ratio of greater than about 2.3.

[0022] In one disclosed embodiment, gas turbine engine 20 includes a bypass ratio greater than about ten (10:1) and the fan diameter is significantly larger than an outer diameter of low pressure compressor 38. It should be understood, however, that the above parameters are only exemplary of one embodiment of a gas turbine engine including a geared architecture and that the present disclosure is applicable to other gas turbine engines.

[0023] A significant amount of thrust is provided by bypass flow B due to the high bypass ratio. Fan section 22 of 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 pound-mass (Ibm) of fuel per hour being burned divided by pound-force (Ibf) of thrust the engine produces at that minimum point.

[0024] “Low fan pressure ratio” is the 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 1.50. In another non-limiting embodiment the low fan pressure ratio is less than about 1.45.

[0025] “Low corrected fan tip speed” is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of [(T sala °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.

[0026] The example gas turbine engine includes fan 37 that comprises in one non-limiting embodiment less than about 26 fan blades. In another non-limiting embodiment, fan section 22 includes less than about 20 fan blades. Moreover, in one disclosed embodiment low pressure turbine 39 includes no more than about 6 turbine rotors schematically indicated at 33. In another non-limiting example embodiment low pressure turbine 39 includes about 3 turbine rotors. A ratio between number of fan blades 37 and the number of low pressure turbine rotors is between about 3.3 and about 8.6. The example low pressure turbine 39 provides the driving power to rotate fan section 22 and therefore the relationship between the number of turbine rotors at 33 in low pressure turbine 39 and number of blades in fan section 22 disclose an example gas turbine engine 20 with increased power transfer efficiency.

[0027] FIG. 2 shows MTF 46, and includes outer case 48, outer case flanges 50A, 50B, inner case assembly 52, vane pack 56, inner vane pack wall 57A, outer vane pack wall 57B, and vanes 58.

[0028] An example embodiment of MTF 46 has outer case 48 with axially opposed outer case flanges 50A, 50B for mounting MTF 46 to adjacent engine component cases (e.g., cases of HPT 43, LPT 39). Outer case 48 can also be radially secured to inner case assembly 52 to define an engine support frame. In one non-limiting example, a plurality of radially extending and circumferentially distributed load spokes (not visible in FIG. 2) structurally join outer case 48 with inner case assembly 52. A forward end of inner case assembly 52 can include one or more seal retention members as described below to provide at least some convective sealing proximate HPT section 43, helping to isolate cold and hot gas flows through and around MTF 46.

[0029] Vane pack 56 operates as a first stage inlet stator for LPT 39 as described above. MTF 46 can be alternatively arranged between other pairs of adjacent turbine stages. Vane pack 56 is shown here as having vanes 58 integrally formed monolithic inner and outer walls 57A, 57B. In certain embodiments, vanes 58 can be removably secured to one or both walls. Inner and outer walls 57A, 57B can alternatively be segmented. In embodiments with one or both inner and outer walls 57A, 57B being segmented, the segments may be joined together such as by brazing, welding, or other semi-permanent metal-jointing processes. The joints may include seals or other features to minimize leakage between segments.

[0030] FIG. 3A shows inner case assembly 52 and includes inner case element 60, circumferential seal support 62, aft seal support flange 64, complementary case mounting surface 66, seal carrier 68, seal support body 70, and meshing ring 72.

[0031] FIG. 3A shows an exploded version of one embodiment of inner case assembly 52. Circumferential seal support 62 is disposed forward of inner case element 60, and secured via aft seal support flange 64 or other suitable connecting means to a complementary mounting surface 66 at a forward end of inner case 60. Circumferential seal support 62 includes at least one seal retention member, which in this example is represented by seal carrier 68 disposed circumferentially around an outer surface of seal support body 70. Meshing ring 72 is disposed axially forward of seal carrier 68. When installed as part of MTF 46, meshing ring 72 extends axially toward a pocket formed in an adjacent turbine rotor assembly, which reduces the distance between the upstream turbine rotor assembly and the mid-turbine frame as shown in FIGS. 4A-4B. In the event of failure of the rotor assembly, failure loads are preferentially directed axially through inner case assembly 52 to rather than through vane pack 56 or other more dangerous areas of MTF 46 as explained below.

[0032] The subject matter is described generally with respect to an inner case assembly with a separate inner case element removably securable to the circumferential seal support. In alternate embodiments, an example of which is shown in FIG. 4B, the circumferential seal support can be integral with the inner case element. It should also be noted that circumferential seal support 62 may optionally include other features such as a flow discourager portion or other ancillary elements falling outside the scope of this disclosure.

[0033] FIG. 3B shows a partial sectional view of a radially inner section of MTF 46, and also includes inner case assembly 52, vane pack 56, inner vane pack wall 57A, vanes 58,
inner case element 60, circumferential seal support 62, aft seal support flange 64, complementary case mounting surface 66, seal carrier 68, seal support body 70, meshing ring 72, piston ring seal 74, spoke 76, and vane pack forward end 78.

The forward end of inner case assembly 52 can optionally be sealed to inner vane pack wall 57A proximate HPT 43 (shown in FIG. 1). In this example, seal carrier 68 is configured to retain piston ring seal 74, which minimizes intrusion of combustion gases from HPT 43 into the cavity formed between vane pack 56 and inner case assembly 52. However, the seal assembly may take any suitable alternative form depending on weight and sealing requirements. Vane pack 56 can include one or more hollow vanes 58 which also retain load spokers 76. Spokes 76, in certain embodiments are also hollow in order to provide cold section flow radially through MTF 46. The aft end of MTF 46 may be similarly sealed (not shown) to direct combustion gases into LPT 39. Alternatively, the connection and seal between MTF 46 and LPT 39 may take any other suitable form.

Meshing ring 72 extends forward from seal carrier 68. Meshing ring 72 causes a forward end of inner case assembly to be disposed further forward than forward end 78 of vane inner vane pack wall 57A. As seen below, meshing ring 72 can extend into a pocket formed into an aft portion of an axially adjacent rotor assembly, allowing circumferential seal support 62 to be mounted closer to a first turbine rotor located upstream of MTF 46 as compared to forward vane pack end 78.

FIG. 4A shows a forward portion of MTF 46 immediately downstream of final HPT stage 80, and also includes inner case assembly 52, inner vane pack wall 57A, vane 58, inner case element 60, circumferential seal support 62, aft seal support flange 64, complementary case mounting surface 66, seal carrier 68, seal support body 70, meshing ring 72, piston ring seal 74, vane pack forward end 78, turbine rotor 80, rotor blade 82, rotor blade root 84, aft rotor disc 86, pocket 88, and aft turbine blade platform portion 90.

FIG. 4A includes inner case assembly with separate inner case element 60 and circumferential seal support 62 secured via respective flanges 68, 66. As shown above, meshing ring 72 extends forward from seal carrier 68 toward turbine rotor 80, and is disposed further forward than inner vane pack forward end 78. In this example, rotor 80 is the final stage of HPT 43 and includes rotor blade 82, rotor blade root 84, and aft rotor disc 86. Turbine rotor 80 can alternatively be any other turbine rotor stage adjacent to a mid-turbine frame, interturbine frame, or similar system.

Meshing ring 72 extends into pocket 88 formed into an aft portion of turbine rotor 80. Pocket 88 is formed by a radially outer portion of aft rotor disc 86 and an aft portion of turbine blade platform 90. Meshing ring 72 causes a forward end of circumferential seal support 62 to be mounted closer to upstream turbine rotor 80 as compared to forward vane pack end 78.

In the unlikely event of failure of turbine rotor 80, at least some of turbine rotor 80 is pushed axially backward into MTF 46. The failure load is then transmitted axially through inner case assembly 52 toward the forward rotor stage of LPT 39 (shown in FIG. 1), located immediately downstream of MTF 46. Meshing of HPT 43 and LPT 39 allows both rotor stages to come gradually to a stop with a minimum of catastrophic damage such as ruptured oil lines or bearing supports.

Other solutions for meshing of HPT 43 with LPT 39 have involved transmitting the axial failure load through an interturbine duct, such as vane pack 56. However, there are several shortcomings to this approach which must be accounted for in designing other portions of the engine. For example, a rigid interturbine duct may successfully transmit the failure loads to the downstream turbine stage. However, this causes the duct to slide axially relative to support struts and fluid lines that may pass radially through hollow vanes in the interturbine duct. It has been suggested to move the interturbine duct forward such that the struts and fluid lines are not centered in the vane, but this can cause a weight and structural imbalance in the frame.

In contrast, meshing ring 72 engages with the rotor disc pocket 88 soon after failure, which begins to transmit the resultant loads without axially displacing vane pack 56 and the attendant risks thereof. In more severe failures, rotor disc 80 may still transmit some failure loads through vane pack 56, but such loads are greatly reduced, requiring little or no forward displacement of vane pack 56 to protect the internal struts and fluid lines.

A separate circumferential seal support 62 can be manufactured from various resilient high-temperature nickel or cobalt alloys. The alloy used to form circumferential seal support 62 can optionally be manufactured to be more resilient as compared to inner case element 60. In certain embodiments, circumferential seal support 62 can be configured to have a lower stiffness in a range between about 50% to about 80% of the attached inner case element stiffness, as measured by any suitable test or relevant industry standard. Lower seal support stiffness can be accomplished by forming seal support 62 from a structural alloy having a bulk modulus value in a range between about 50% to about 80% of the attached inner case element 60 bulk modulus. Alternatively, the seal support geometry can be tailored to provide a lower stiffness in a range between about 50% to about 80% of the stiffness of the complementary inner case element 60. It will also be appreciated that both the structural alloy and its geometry can be both used in tandem to configure circumferential seal support 62 with a reduced stiffness as compared to complementary inner case element 60. This can allow circumferential seal support 62 to preferentially deform without rupturing, absorbing some of the axial failure loads while reducing the total meshing load that must be transmitted axially toward LPT 39.

In one illustrative but non-limiting example, the separate circumferential seal support may be cast or machined from nickel alloys such as those meeting the requirements of AMS 5663. Generally speaking, these are alloys containing about 15 wt % to about 23 wt % chromium, similar in composition to those sold commercially as Inconel® 718 and its equivalents. The alloy can then be heat treated above about 1725° F. (about 940° C.), according to the AMS 5663 specification to result in a bulk modulus at or above about 30 ksi (about 200 MPa). In contrast, in certain of these optional embodiments, inner case element 60 may be a different nickel alloy having a higher bulk modulus (e.g., at least about 45 ksi or about 300 MPa).

FIG. 4B shows an alternative embodiment of inner case assembly 152 immediately downstream of final HPT stage 80, and also includes inner vane pack wall 57A, vane 58, piston ring seal 74, vane pack forward end 78, turbine rotor 80, rotor blade 82, rotor blade root 84, aft rotor disc 86, pocket 88, aft turbine blade platform portion 90, circumferential seal...
support portion 160, inner case portion 162, seal carrier 168, seal support body 170, and meshing ring 172.

[0045] In this alternative example, inner case assembly 152 is integrally formed with inner case portion 160 and circumferential seal support portion 162. Meshing ring 172 engages with the rotor disc pocket 88 in a manner similar to that described above with respect to FIG. 4A. However, integral inner case assembly may be used to simplify the manufacturing process in applications where the expected meshing loads do not warrant the additional absorption of meshing loads provided by separate case and seal support elements.

[0046] While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

Discussion of Possible Embodiments

[0047] The following are non-exclusive descriptions of possible embodiments of the present invention.

[0048] A mid-turbine frame for a gas turbine engine comprises a radially outer case, a radially inner case, a plurality of load spokes, and a circumferential seal support. The radially inner case is disposed inward from the radially outer case defining an annular passage therebetween. The plurality of load spokes extend through the annular passage securing the outer case with the inner case. The circumferential seal support is disposed axially forward of the inner case, the seal support including a seal carrier and a meshing ring extending axially forward of the seal carrier.

[0049] The mid-turbine frame of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components.

[0050] A mid-turbine frame for a gas turbine engine according to an exemplary embodiment of this disclosure includes, among other possible things, a radially outer case, a radially inner case, a plurality of load spokes, and a circumferential seal support. The radially inner case is disposed inward from the radially outer case defining an annular passage therebetween. The plurality of load spokes extend through the annular passage securing the outer case with the inner case. The circumferential seal support is disposed axially forward of the inner case, the seal support including a seal carrier and a meshing ring extending axially forward of the seal carrier.

[0051] A further embodiment of foregoing mid-turbine frame, wherein the meshing ring extends axially toward a pocket formed in a first turbine rotor assembly, the first turbine rotor assembly disposed upstream of the mid-turbine frame.

[0052] A further embodiment of any of the foregoing mid-turbine frames, wherein the circumferential seal support is integral with the inner case assembly. A further embodiment of any of the foregoing mid-turbine frames, wherein the circumferential seal support is a separately formed seal support and is removably securable to a forward portion of the inner case. A further embodiment of any of the foregoing mid-turbine frames, wherein the seal carrier supports a piston ring seal engaging with an outer wall of a vane pack disposed in the annular cavity between the outer case and the inner case. A further embodiment of any of the foregoing mid-turbine frames, wherein the meshing ring is disposed closer to a first turbine rotor upstream of the mid-turbine frame as compared to an axial distance between a forward end of the vane ring and the turbine rotor immediately upstream of the mid-turbine frame. A further embodiment of any of the foregoing mid-turbine frames, wherein the meshing ring extends into a pocket formed at an aft end of the upstream turbine rotor.

[0053] A case assembly comprises a substantially cylindrical case element, and a circumferential seal support disposed axially forward of the inner case. The seal support includes a seal carrier and a meshing ring extending axially forward of the seal carrier.

[0054] The case assembly of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components.

[0055] A case assembly according to an exemplary embodiment of this disclosure includes, among other possible things, a substantially cylindrical case element, and a circumferential seal support disposed axially forward of the inner case. The seal support includes a seal carrier and a meshing ring extending axially forward of the seal carrier.

[0056] A further embodiment of foregoing case assembly, wherein the circumferential seal support is integral with the inner case assembly.

[0057] A further embodiment of any of the foregoing case assemblies, wherein the circumferential seal support is a separately formed seal support and is removably securable to a forward portion of the inner case. A further embodiment of any of the foregoing case assemblies, wherein the circumferential seal support has a bulk modulus value lower than a bulk modulus value of the inner case. A further embodiment of any of the foregoing case assemblies, wherein the meshing ring is disposed axially adjacent to an adjacent turbine rotor upstream of the inner case assembly. A further embodiment of any of the foregoing case assemblies, wherein the meshing ring engages a pocket formed on an aft end of the adjacent turbine rotor. A further embodiment of any of the foregoing case assemblies, wherein the seal carrier is configured to support a piston ring seal in conjunction with a vane ring disposed radially adjacent to the case assembly.

[0058] A seal support comprises a body, a seal carrier disposed circumferentially around an outer surface of the body, and a meshing ring extending axially forward of the seal carrier.

[0059] The seal support of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components.

[0060] A seal support according to an exemplary embodiment of this disclosure includes, among other possible things, a body, a seal carrier disposed circumferentially around an outer surface of the body, and a meshing ring extending axially forward of the seal carrier.

[0061] A further embodiment of the foregoing seal support, wherein the circumferential seal support is configured to have a stiffness value in a range between about 50% to about 80% of a stiffness value of a complementary inner case element. A further embodiment of any of the foregoing seal supports, wherein the seal support is formed integrally with an inner
case element. A further embodiment of any of the foregoing seal supports, wherein the meshing ring is disposed axially adjacent to an adjacent turbine rotor upstream of the seal support. A further embodiment of any of the foregoing seal supports, wherein the meshing ring engages a pocket formed on an aft end of the adjacent turbine rotor. A further embodiment of any of the foregoing seal supports, wherein the seal carrier is configured to support a piston ring seal in conjunction with a vane ring radially outward of the seal support.

1. A mid-turbine frame for a gas turbine engine, the mid-turbine frame comprising:
   a radially outer case;
   a radially inner case disposed inward from the radially outer case, the radially outer and inner cases defining an annular passage therebetween;
   a plurality of load spokes extending through the annular passage securing the outer case with the inner case; and
   a circumferential seal support disposed axially forward of the inner case, the circumferential seal support including a seal carrier and a meshing ring extending axially forward of the seal carrier.

2. The mid-turbine frame of claim 1, wherein the meshing ring extends axially toward a pocket formed in a first turbine rotor assembly, the first turbine rotor assembly disposed upstream of the mid-turbine frame.

3. The mid-turbine frame of claim 1, wherein the circumferential seal support is integral with the inner case assembly.

4. The mid-turbine frame of claim 1, wherein the circumferential seal support is a separately formed seal support and is removably securable to a forward portion of the inner case.

5. The mid-turbine frame of claim 1, wherein the seal carrier supports a piston ring seal engaging with an outer wall of a vane pack disposed in the annular cavity between the outer case and the inner case.

6. The mid-turbine frame of claim 5, wherein the meshing ring is disposed closer to a first turbine rotor upstream of the mid-turbine frame as compared to an axial distance between a forward end of the vane ring and the turbine rotor immediately upstream of the mid-turbine frame.

7. The mid-turbine frame of claim 6, wherein the meshing ring extends into a pocket formed at an aft end of the upstream turbine rotor.

8. A case assembly comprising:
   a substantially cylindrical case element; and
   a circumferential seal support disposed axially forward of the inner case, the seal support including a seal carrier and a meshing ring extending axially forward of the seal carrier.

9. The case assembly of claim 8, wherein the circumferential seal support is integral with the inner case assembly.

10. The case assembly of claim 8, wherein the circumferential seal support is a separately formed seal support and is removably securable to a forward portion of the inner case.

11. The case assembly of claim 10, wherein the circumferential seal support has a bulk modulus value lower than a bulk modulus value of the inner case.

12. The case assembly of claim 8, wherein the meshing ring is disposed axially adjacent to an adjacent turbine rotor upstream of the inner case assembly.

13. The case assembly of claim 12, wherein the meshing ring engages a pocket formed on an aft end of the adjacent turbine rotor.

14. The case assembly of claim 8, wherein the seal carrier is configured to support a piston ring seal in conjunction with a vane ring disposed radially adjacent to the case assembly.

15. A seal support comprising:
   a substantially cylindrical body;
   a seal carrier disposed circumferentially around an outer surface of the body; and
   a meshing ring extending axially forward of the seal carrier.

16. The seal support of claim 15, wherein the circumferential seal support is configured to have a stiffness value in a range between about 50% to about 80% of a stiffness value of a complementary inner case element.

17. The seal support of claim 15, wherein the seal support is formed integrally with an inner case element.

18. The seal support of claim 15, wherein the meshing ring is disposed axially adjacent to an adjacent turbine rotor upstream of the seal support.

19. The seal support of claim 18, wherein the meshing ring engages a pocket formed on an aft end of the adjacent turbine rotor.

20. The seal support of claim 15, wherein the seal carrier is configured to support a piston ring seal in conjunction with a vane ring radially outward of the seal support.

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