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(54) **Title**: ADJUSTABLE BLADE OUTER AIR SEAL APPARATUS

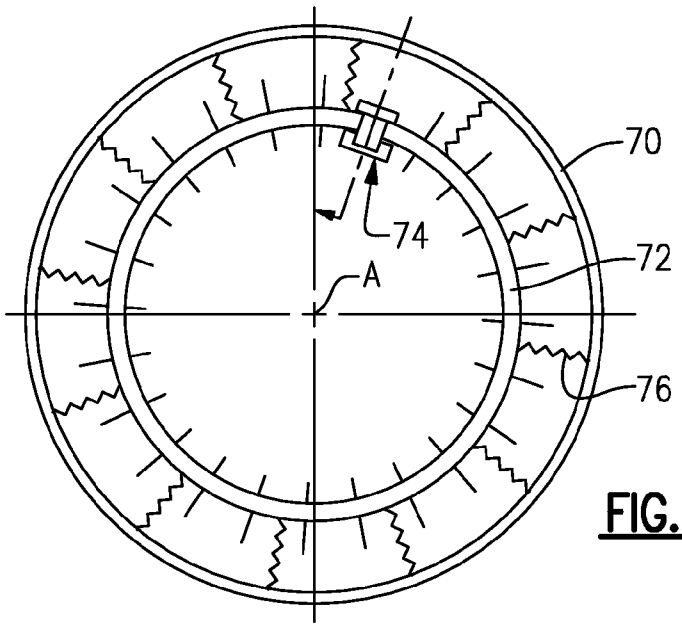


FIG.2

(57) **Abstract**: An adjustable blade outer air seal apparatus includes a case structure that extends circumferentially, a support ring structure mounted radially inwards of the case structure and at least one blade outer air seal segment radially adjustably mounted relative to the support ring structure.

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ADJUSTABLE BLADE OUTER AIR SEAL APPARATUS

REFERENCE TO RELATED APPLICATION

This application claims priority to United States Application No. 13/396,016, filed on February 14, 2012.

BACKGROUND

This disclosure relates to blade outer air seals and, more particularly, to adjustable blade outer air seals.

Compressor sections and turbine sections of gas turbine engines typically include one or more stages of static vanes and rotating blades. A casing is typically provided circumferentially around the stages and a shroud inside of the casing provides a relatively tight clearance with tips of the rotating blades to reduce gas leakage. In some examples, a tip clearance control mechanism adjusts the radial position of the shroud. Typically, the shroud is indirectly moved by moving the case or other support structure, for example, which inhibits the ability to move the shroud quickly and precisely.

SUMMARY

An adjustable blade outer air seal apparatus according to an exemplary aspect of the present disclosure comprises of a case structure extending circumferentially, a support ring structure mounted radially inwards of the case structure, and at least one blade outer air seal segment radially adjustably mounted relative to the support ring structure.

In a further embodiment of the foregoing adjustable blade outer air seal apparatus, the at least one blade outer air seal segment includes a threaded shaft extending through an unthreaded opening in the support ring structure.

In a further embodiment of the adjustable blade outer air seal apparatus, the at least one blade outer air seal segment includes a threaded shaft and a cavity extending through the threaded shaft.

In a further embodiment of the adjustable blade outer air seal apparatus, includes a sensor probe at least partially within the cavity.

In a further embodiment of the adjustable blade outer air seal apparatus the cavity has an end that opens at a radially inner seal surface of the at least one blade outer air seal segment.

In a further embodiment of the adjustable blade outer air seal apparatus includes a sensor probe at least partially within the cavity, the sensor probe having a probe end that is flush with the seal surface.

In a further embodiment of the adjustable blade outer air seal apparatus includes an actuation arm engaging a threaded portion of the threaded shaft and a clamp member secured on the threaded shaft such that the actuation arm is secured between the clamp member and the support ring structure.

In a further embodiment of the adjustable blade outer seal apparatus includes an actuation arm in threaded engagement with the at least one blade outer air seal segment.

In a further embodiment of the adjustable blade outer air seal apparatus includes an adjustable spacer mounted adjacent the support ring structure, the adjustable spacer including an adjustable radial dimension that controls a radial position of the at least one blade outer air seal segment relative to the support ring.

In a further embodiment of the adjustable blade outer air seal apparatus, the support ring structure is non-rigidly mounted to the case structure.

In a further embodiment of the adjustable blade outer air seal apparatus, the at least one blade outer air seal segment and the support ring structure include an anti-rotation feature that limits rotation of the at least one blade outer air seal segment about a radial axis, the anti-rotation feature comprising a tab and a slot received in the tab.

An adjustable blade outer air seal apparatus according to an exemplary aspect of the present disclosure includes a case structure extending circumferentially, a support ring structure mounted radially inwards of the case structure, an adjustable spacer mounted adjacent the support ring structure, the adjustable spacer including an adjustable radial dimension, and a blade outer air seal segment mounted relative to the support ring structure such that the adjustable radial dimension of the adjustable spacer controls a radial position of the blade outer air seal segment relative to the support ring structure.

In a further embodiment of the adjustable blade outer air seal apparatus the adjustable spacer includes a plurality of washers.

In a further embodiment of the adjustable blade outer air seal apparatus the blade outer air seal segment includes a threaded shaft extending through an

unthreaded opening in the support ring structure and an actuation arm engaging a threaded portion of the threaded shaft.

In a further embodiment of the adjustable blade outer air seal apparatus the blade outer air seal segment includes a threaded shaft and an actuation arm engaging a threaded portion of the threaded shaft, and including a clamp member secured on the threaded shaft such that the actuation arm is secured between the clamp member and the support ring structure.

In a further embodiment of the adjustable blade outer air seal apparatus includes a bushing between the actuation arm and the support ring structure, and the adjustable spacer is between the bushing and the support ring structure.

In a further embodiment of the adjustable blade outer air seal apparatus the adjustable spacer is between the actuation arm and the support ring structure.

A method of adjusting a blade outer air seal apparatus according to an exemplary aspect of the present disclosure includes radially adjusting at least one blade outer air seal segment relative to a support ring structure that is mounted radially inwards of a case structure extending circumferentially.

In a further embodiment of the method includes radially adjusting the at least one blade outer air seal segment in response to at least one of an aircraft maneuver and a detected engine temperature.

In a further embodiment of the method includes radially adjusting the at least one blade outer air seal segment in a response time of less than one second between a signal to move the at least one blade outer air seal segment and movement between radial positions of the at least one blade outer air seal segment.

A gas turbine engine according to an exemplary aspect of the present disclosure includes a compressor section, a combustor section in fluid communication with the compressor section, a turbine section in fluid communication with the combustor, and at least one of the compressor section and the turbine section including an adjustable blade outer air seal apparatus comprising a case structure extending circumferentially about an engine central axis, a support ring structure mounted radially inwards of the case structure and at least one blade outer air seal segment radially adjustably mounted relative to the support ring structure.

In a further embodiment of the gas turbine engine includes a fan coupled to be driven through a gear assembly by the turbine section.

BRIEF DESCRIPTION OF THE DRAWINGS

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

Figure 1 illustrates an example gas turbine engine.

Figure 2 illustrates a cross-section through selected portions of a gas turbine engine.

Figure 3 illustrates an example adjustable blade outer air seal apparatus.

Figure 4 illustrates an example threaded shaft of an adjustable blade outer air seal apparatus.

Figure 5 illustrates a clamp of an adjustable blade outer air seal apparatus.

Figure 6 illustrates a perspective view of the clamp of Figure 5.

Figure 7 illustrates another example adjustable blade outer air seal apparatus.

Figure 8 illustrates another adjustable blade outer air seal apparatus.

Figure 9A illustrates an example blade outer air seal apparatus in a compressor section of a gas turbine engine.

Figure 9B illustrates another cross-section of the adjustable blade outer air seal apparatus of Figure 9A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 schematically illustrates a gas turbine engine 20. The gas turbine engine 20 is disclosed herein as a two-spool turbofan 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 while the compressor section 24 drives air along a core flowpath for compression and communication into the combustor section 26 then expansion through the turbine section 28. Although depicted as a turbofan gas turbine engine in the disclosed non-limiting embodiment, 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 including three-spool architectures.

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.

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 gear assembly 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. A combustor 56 is arranged between the high pressure compressor 52 and the high pressure turbine 54. 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 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 turbines 46, 54 rotationally drive the respective low speed spool 30 and high speed spool 32 in response to the expansion.

The engine 20 in one example 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 gear assembly 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 pressure measured prior to inlet of low pressure turbine 46 as related to the pressure at the outlet of the low pressure turbine 46 prior to an exhaust nozzle. The gear assembly 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.

A significant amount of thrust is provided by the bypass flow 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 lbm of fuel being burned divided by lbf of thrust the engine produces at that minimum point. "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 1.45. "Low corrected fan tip speed" is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of [(Tambient 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.

Figure 2 schematically illustrates a cross-section through the turbine section 28 of the engine 20, although the examples herein are also understood to be applicable to the compressor section 24 or other rotatable machinery. As shown, the engine 20 includes a case structure 70 that extends generally circumferentially around the axis A of the engine 20. A support ring structure 72 is mounted radially inwards of the case structure 70 with regard to the axis A. As further shown, at least one blade outer air seal segment 74 (one shown) is mounted relative to the support ring structure 72. It is to be understood that a plurality of blade outer air seal segments 74 may be provided to form a complete annular shroud around central axis A. As will be described in more detail below, the at least one blade outer air seal segment 74 is radially adjustable relative to the support ring structure 72, which provides the ability to directly adjust the radial position of the blade outer air seal segment 74 without having to indirectly adjust the position by moving the case structure 70 and/or support ring structure 72.

In the example non-limiting embodiment, the support ring structure 72 is "floating" with regard to the case structure 70. That is, the support ring structure 72 is non-rigidly connected with the case structure 70 using spring connections 76. The spring connections 76 serve to center the support ring structure 72 relative to the case structure 70 and axis A. Thus, under certain load conditions, the support ring structure 72 is permitted to move relative to the case structure 70. Due at least in part to the "floating" design of the support ring structure 72 and case structure 70, the blade outer air seal segments 74 are radially adjustable relative to the support ring structure 72 and are not rigidly affixed relative to the case structure 70. Although this

embodiment includes the "floating" arrangement, it is to be understood that other embodiments and the disclosed examples disclosed are not limited to a "floating" arrangement.

Figure 3 shows an example adjustable blade outer air seal apparatus 80 that incorporates the blade outer air seal segment 74. In this example, the blade outer air seal segment 74 includes a lower body portion 82 that generally extends between a leading end 84 and a trailing end 86, circumferential sides 88 (one shown) and a radially inner seal surface 90. The seal surface 90 is a gas path surface that faces in a direction toward rotating blade B.

In this example, the blade outer air seal segment 74 includes a threaded shaft 92 that extends radially outwardly from the lower body portion 82. The threaded shaft 92 extends through an unthreaded opening 94 in the support ring structure 72. A threaded portion 96 on the periphery of the upper part of the threaded shaft 92 threadingly engages an actuation arm 98. The actuation arm 98 extends between a first end 98a, which is threadingly engaged with the threaded portion 96 of the threaded shaft 92, and a second end 98b that is used to rotate the actuation arm 98 relative to radial axis C.

In the illustrated embodiment, the first end 98a of the actuation arm 98 is secured between a clamp member 100 and a radially outer surface of the support ring structure 72. Optionally, an adjustable spacer 102, seal bushing 104 and thrust plate 106 are provided between the first end 98a of the actuation arm 98 and the radially outer surface of the support ring structure 72.

In operation, the actuation arm 98 is rotated about radial axis C, which is generally perpendicular to axis A. The clamp member 100 limits movement of the actuation arm 98 such that the threaded engagement between the first end 98a of the actuation arm 98 and the threaded portion 96 of the threaded shaft 92 causes the blade outer air seal segment 74 to move radially. As an example, an actuation mechanism (not shown) is mechanically connected with the second end 98b to rotate the actuation arm 98 an appropriate amount to change the radial position of the blade outer air seal segment 74. In one example, each actuation arm 98 of each blade outer air seal 74 includes a dedicated actuator, such as a motor. Alternatively, the actuation arms 98 are coupled to a common actuator through a unison ring, for example.

In a further example, a thread pitch of the threaded portion 96 of the threaded shaft 92 is selected such that for a given angular rotation of the actuation arm 98, the

blade outer air seal segment 74 moves a predetermined amount in a radial direction along axis C. In a further embodiment, the thread pitch is 28 threads per inch (11 threads per centimeter) such that approximately 10° rotation of the actuation arm 98 causes a radial position change of the blade outer air seal segment 74 of approximately 0.001 inches (0.00254 centimeters). Thus, the adjustable blade outer air seal apparatus 80 provides fine control of the radial position of the seal surface 90. Given this description, one of ordinary skill in the art will recognize other suitable thread pitches to meet their particular needs. Put another way, if greater or lesser angular rotation is desired of the actuation arm 98, a different thread pitch can be used. However, using a relatively fine pitch allows for very small and precise movement of the blade outer air seal segment 74 in order to adjust a radial distance R between the seal surface 90 of the blade outer air seal segment 74 and a tip of the rotating or rotatable blade B.

In a further example, the position of the blade outer air seal segment 74 is radially adjusted in response to at least one of an aircraft maneuver and a detected engine temperature. As an example, an aircraft maneuver, such as a change in aircraft pitch, can cause the engine 20 to deflect. To limit rub between the blade outer air seals 74 and the blades B, the aircraft maneuver causes a control signal to be sent to the actuator or actuators to radially retract the blade out air seals 74. By limiting rub during such aircraft maneuvers, the lifetime of the blade outer air seals 74 is extended. In another example, a detected change temperature can cause thermal expansion or contraction in portions of the engine 20. In response to a detected change in temperature or predetermined temperature threshold, a control signal is sent to the actuator or actuators to radially move the blade out air seals 74.

In a further example, because the blade outer air seals 74 are directly mechanically moved instead of moving the case structure 70 or support ring structure 72 to indirectly move the blade outer air seals 74, the adjustable blade outer air seal apparatus 80 is able to rapidly respond to a signal to move. In one example, the blade outer air seals 74 are radially adjusted in a response time of less than one second between initiating a control signal to move and movement between radial positions.

In a further example where the adjustable spacer 102 is used, the adjustable spacer 102 is used to initially set the radial position of the blade outer air seal segment 74. As shown, the adjustable spacer 102 has a radial dimension 102a that is adjustable to control an initial radial position of the blade outer air seal segment 74

relative to the support ring structure 72. That is, for a selected relatively smaller radial dimension 102a, the initial position of the blade outer air seal segment 74 is relatively closer to axis A in along radial axis C. For a selected relatively larger radial dimension 102a, the radial position of the blade outer air seal segment 74 is relatively farther from axis A along radial axis C.

In a further embodiment, the adjustable spacer 102 is a stacked washer system. For example, greater or fewer number of washers are provided in the stack to adjust the radial dimension 102a of the adjustable spacer 102 to set an initial radial position of the blade outer air seal segment 74. In this manner, a user initially sets a desirable clearance R between the seal surface 90 and the tip of the rotating blade B and thereafter finely adjusts the clearance R using the actuation arm 98. In another alternative, the adjustable spacer 102 is a shim that has predetermined radial dimension 102a to set a desired initial radial position of the blade outer air seal segment 74.

In a further example where the thrust plate 106 and bushing 104 are used, the bushing 104 provides an air seal between the unthreaded opening 94 in the support ring structure 72 and the gas path surface provided by the seal surface 90. Further, as the gas flowing over the blade B varies in pressure, the pressure variations are reacted through the blade outer air seal segment 74 into the thrust plate 106. Thus, the thrust plate 106 facilitates load management in the adjustable blade outer air seal apparatus 80.

In a further embodiment, the blade outer air seal segment 74 optionally includes a cavity 108 that extends through the threaded shaft 92 and lower body portion 82. In this example, the cavity 108 includes an end 108a that opens at the seal surface 90 of the blade outer air seal segment 74. In a further example, a sensor probe 110 is received at least partially within the cavity 108. The sensor probe 110 facilitates determining the clearance R. For example, the sensor probe 110 includes an end 110a that is flush with the seal surface 90 at the open end 108a of the cavity 108 and the radial axis C along which the cavity 108 extends is centered with regard to the lower body portion 82 in order to gauge the blade outer air seal 74 position at the center. The sensor probe 110 is a laser sensor, microwave sensor, or other suitable type of sensor for use within a gas turbine engine environment.

Referring to Figure 4, a portion of another example threaded shaft 192 is shown. In this disclosure, like reference numerals designate like elements where

appropriate and reference numerals with the addition of one-hundred or multiples thereof designate modified elements that are understood to incorporate the same features and benefits of the corresponding elements. The threaded shaft 192 shown in Figure 4 may be used in place of the threaded shaft 92 as shown in Figure 3. In this example, however, the threaded portion 196 of the threaded shaft 192 includes trapezoidal threads 196a, also known as acme threads. As an example, the trapezoidal threads 196a provide a high strength threaded connection between the threaded shaft 192 and the actuation arm 98.

Figures 5 and 6 schematically show selected portions of two neighboring adjustable blade outer air seal apparatuses 80, as previously described. In the drawing, only the support ring structure 72, first end 98a of the actuation arm 98 and clamp member 100 are shown. In this example, the cross-section is taken perpendicular to axis A to show the clamp member 100. The clamp member 100 in this example is common between the neighboring adjustable blade outer air seal apparatuses 80. That is, the clamp member 100 extends between at least two actuation arms 98 to clamp the respective first ends 98a onto the support ring structure 72. The common clamp member 100 is rigidly secured directly to the support ring structure 72 using fastener 100a. Although the common clamp member 100 is shown as securing two actuator arms 98 in this example, it is to be understood that the clamp member 100 can alternatively be adapted to clamp a single actuation arm 98 or greater than two actuation arms 98 in other examples.

Figure 7 shows another example adjustable blade outer air seal apparatus 280 that is somewhat similar to the adjustable blade outer air seal apparatus 80 as described with reference to Figure 3. In this example, the blade outer air seal segment 74 and the threaded shaft 292 are integrally formed as a single, monolithic structure with the cavity 208 extending there through to end 208a that is flush with a seal surface 290 of the blade outer air seal segment 274. A sensor probe 210 is located at least partially within the cavity 208 such that an end 210a of the sensor probe 210 is flush with the seal surface 290. In this example, a retaining nut 210b secures the sensor probe 210 relative to the blade outer air seal segment 274. In this regard, a threaded interface 210c is provided between the retainer nut 210b and the upper portion of the threaded shaft 292.

In this example, the adjustable blade outer air seal apparatus 280 includes an upper bushing 294a located between the first and 98a of the actuation arm 98 and

clamp member 100, and a lower bushing 294b between the first end 98a of the actuation arm 98 and the support ring structure 272. Further, an adjustable spacer 202 in this example is located between the lower bushing 294b and the support ring structure 272. Alternatively, the adjustable spacer 202 is provided over the lower bushing 294b and between the lower bushing 294b and the first end 98a of the actuation arm 98.

In a further embodiment, the support ring structure 272 and blade outer air seal segment 274 are additionally provided with an anti-rotation feature 290a located the leading end 284, the trailing end 286 or both. In this example, the anti-rotation feature 290a includes a tab 290b extending circumferentially and a slot 290c that inter-fit to limit rotational movement about radial axis C. In the example shown, the tab 290b is provided on the blade outer air seal segment 274 and a slot 290c is provided in the support ring structure 272, however, it is to be understood that the tab 290b can alternatively be provided on the support ring structure 272 and a slot 290c on the blade outer air seal segment 274.

Figure 8 illustrates another embodiment of an adjustable blade air seal apparatus 380. In this example, the threaded shaft 392 and the lower body portion 382 of the blade outer air seal segment 374 are non-integral. In this regard, the lower body portion 382 of the blade outer air seal segment 74 includes a boss 382a for connection with the threaded shaft 392. In one example, the boss 382a is integrally formed with the lower body portion 382. Alternatively, the boss 382a is a separate piece that is affixed, such as by welding, to the lower body portion 382. In this example, the threaded portion 396 of the threaded shaft 392 is received into the boss 382a and engages a corresponding threaded portion 382b of the boss 382a. Rotation of the threaded shaft 392 thereby causes movement of the lower body portion 382.

Because the threaded portion 396 in this example engages the boss 382a, there is not a threaded connection between the first end 398a of actuation arm 398. Instead, in this example, a splined connection 399 is provided between the first end 398a and an upper portion of the threaded shaft 392. The splined connection 399 allows the first end 398a of the actuation arm 398 to be slid onto the threaded shaft 392 and rotate the shaft with regard to axis C. The rotation of the threaded shaft 392 moves the lower body portion 382 of the blade outer air seal segment 374 through the threaded engagement with the boss 382a.

Figures 9A and 9B illustrate cross-sections of selected portions of another example adjustable blade outer air seal apparatus 480 used in the compressor section 24. In the drawing, the threaded shaft 392 and connection with the actuation arm 398, as described with reference to Figure 8, are not shown. The blade outer air seal segment 474 and support ring structure 472 include a seal 491. The seal 491 limits gas leakage around the blade outer air seal segment 474 through cavity P from the trailing end 486 back to the leading end 484. Thus, in operation, the seal limits flow of relatively higher pressure gas that is already passed over the blade B around the blade outer air seal segment 474 back to an upstream position at the leading end 484.

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

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

CLAIMS

What is claimed is:

1. An adjustable blade outer air seal apparatus, comprising:

a case structure extending circumferentially;

a support ring structure mounted radially inwards of the case structure;

at least one blade outer air seal segment radially adjustably mounted relative to the support ring structure.

2. The adjustable blade outer air seal apparatus as recited in claim 1, wherein the at least one blade outer air seal segment includes a threaded shaft extending through an unthreaded opening in the support ring structure.

3. The adjustable blade outer air seal apparatus as recited in claim 1, wherein the at least one blade outer air seal segment includes a threaded shaft and a cavity extending through the threaded shaft.

4. The adjustable blade outer air seal apparatus as recited in claim 3, including a sensor probe at least partially within the cavity. –

5. The adjustable blade outer air seal apparatus as recited in claim 3, wherein the cavity has an end that opens at a radially inner seal surface of the at least one blade outer air seal segment.

6. The adjustable blade outer air seal apparatus as recited in claim 5, including a sensor probe at least partially within the cavity, the sensor probe having a probe end that is flush with the seal surface.

7. The adjustable blade outer air seal apparatus as recited in claim 3, including an actuation arm engaging a threaded portion of the threaded shaft and a clamp member secured on the threaded shaft such that the actuation arm is secured between the clamp member and the support ring structure.

8. The adjustable blade outer air seal apparatus as recited in claim 1, including an actuation arm in threaded engagement with the at least one blade outer air seal segment.

9. The adjustable blade outer air seal apparatus as recited in claim 1, including an adjustable spacer mounted adjacent the support ring structure, the adjustable spacer including an adjustable radial dimension that controls a radial position of the at least one blade outer air seal segment relative to the support ring.

10. The adjustable blade outer air seal apparatus as recited in claim 1, wherein the support ring structure is non-rigidly mounted to the case structure.

11. The adjustable blade outer air seal apparatus as recited in claim 1, wherein the at least one blade outer air seal segment and the support ring structure include an anti-rotation feature that limits rotation of the at least one blade outer air seal segment about a radial axis, the anti-rotation feature comprising a tab and a slot received in the tab.

12. An adjustable blade outer air seal apparatus, comprising:

a case structure extending circumferentially;

a support ring structure mounted radially inwards of the case structure;

an adjustable spacer mounted adjacent the support ring structure, the adjustable spacer including an adjustable radial dimension; and

a blade outer air seal segment mounted relative to the support ring structure such that the adjustable radial dimension of the adjustable spacer controls a radial position of the blade outer air seal segment relative to the support ring structure.

13. The adjustable blade outer air seal apparatus as recited in claim 12, wherein the adjustable spacer includes a plurality of washers.

14. The adjustable blade outer air seal apparatus as recited in claim 13, wherein the blade outer air seal segment includes a threaded shaft extending through an unthreaded opening in the support ring structure and an actuation arm engaging a threaded portion of the threaded shaft.

15. The adjustable blade outer air seal apparatus as recited in claim 12, wherein the blade outer air seal segment includes a threaded shaft and an actuation arm engaging a threaded portion of the threaded shaft, and including a clamp member secured on the threaded shaft such that the actuation arm is secured between the clamp member and the support ring structure.

16. The adjustable blade outer air seal apparatus as recited in claim 15, including a bushing between the actuation arm and the support ring structure, and the adjustable spacer is between the bushing and the support ring structure.

17. The adjustable blade outer air seal apparatus as recited in claim 15, wherein the adjustable spacer is between the actuation arm and the support ring structure.

18. A method of adjusting a blade outer air seal apparatus, comprising:

radially adjusting at least one blade outer air seal segment relative to a support ring structure that is mounted radially inwards of a case structure extending circumferentially.

19. The method as recited in claim 18, including radially adjusting the at least one blade outer air seal segment in response to at least one of an aircraft maneuver and a detected engine temperature.

20. The method as recited in claim 18, including radially adjusting the at least one blade outer air seal segment in a response time of less than one second between a signal to move the at least one blade outer air seal segment and movement between radial positions of the at least one blade outer air seal segment.

21. A gas turbine engine comprising:

a compressor section;

a combustor section in fluid communication with the compressor section; and

a turbine section in fluid communication with the combustor, and

at least one of the compressor section and the turbine section including an adjustable blade outer air seal apparatus comprising a case structure extending circumferentially about an engine central axis, a support ring structure mounted radially inwards of the case structure and at least one blade outer air seal segment radially adjustably mounted relative to the support ring structure.

22. The gas turbine engine as recited in claim 21, including a fan coupled to be driven through a gear assembly by the turbine section.

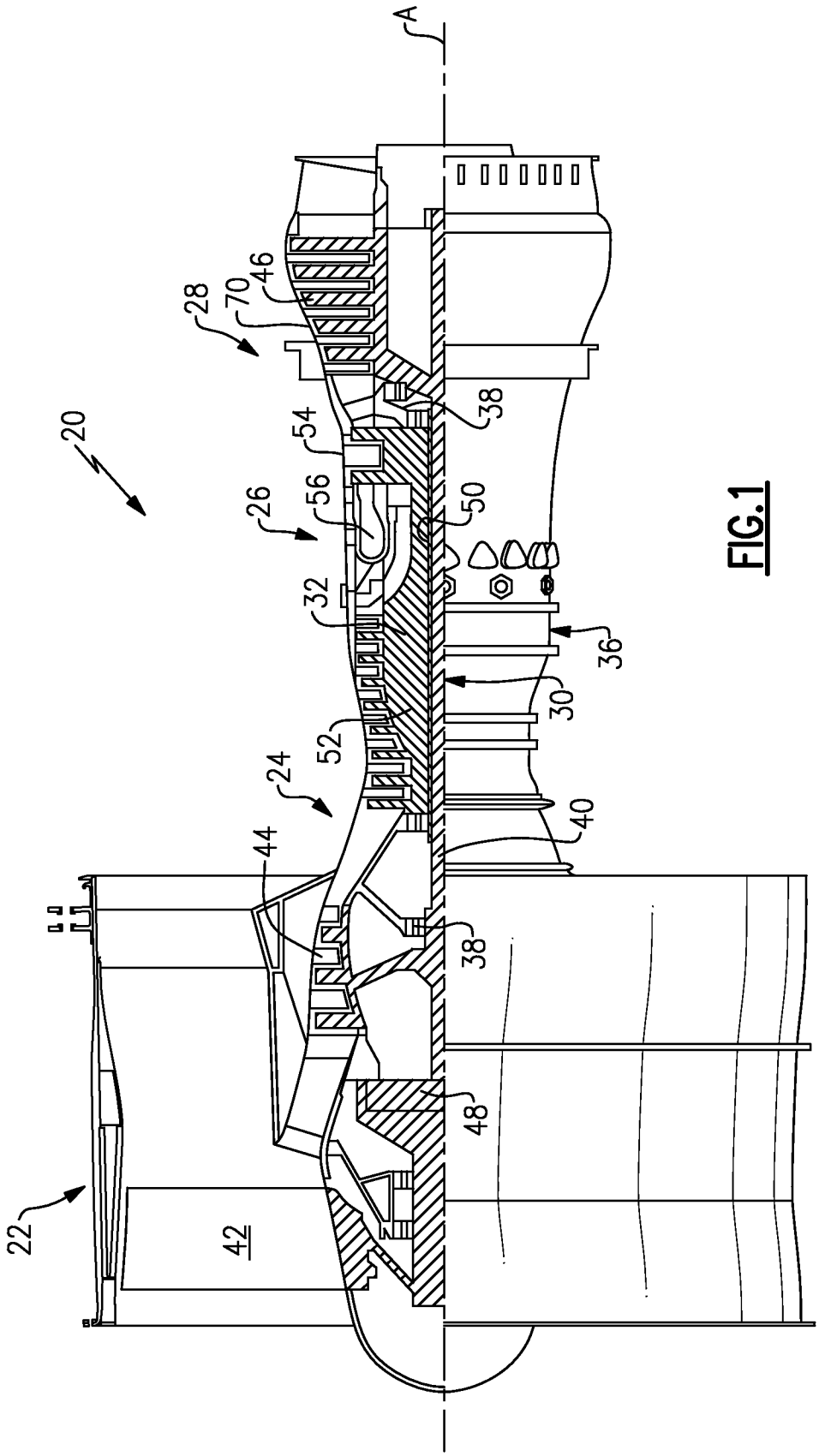


FIG.1

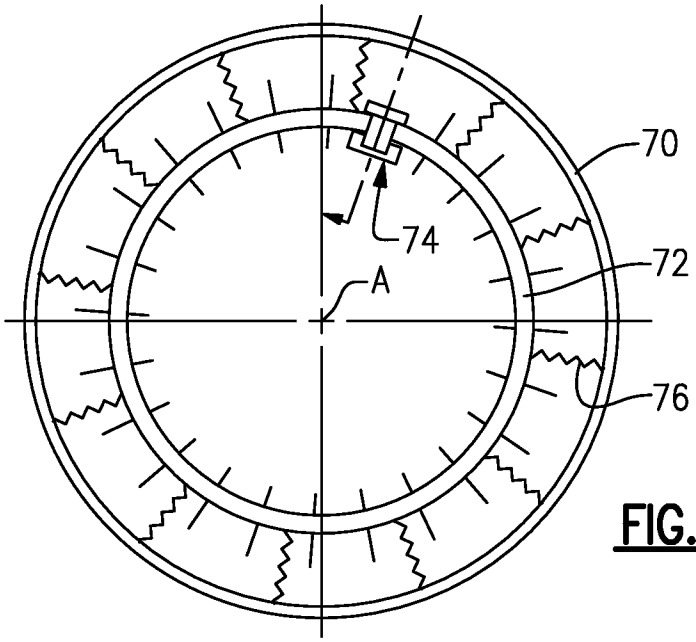

70
74
72
A
76

FIG.2

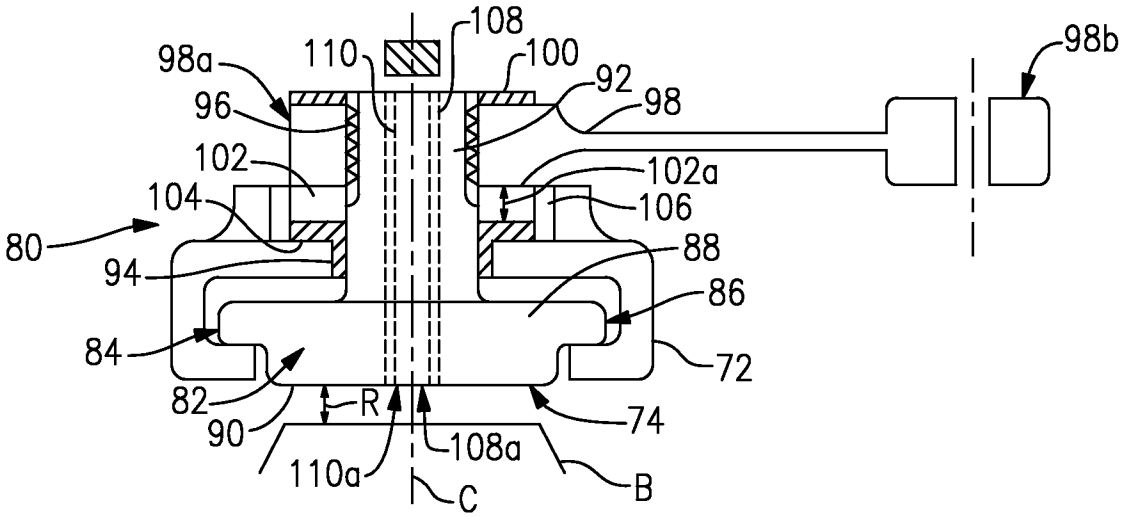

108
98a
110
100
98b
92
96
98
102
102a
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106
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88
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84
72
82
R
74
90
108a
110a
B
C

FIG.3

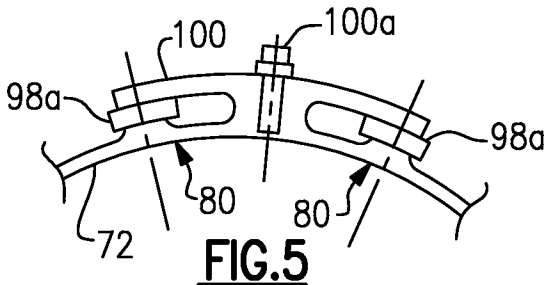


FIG.5

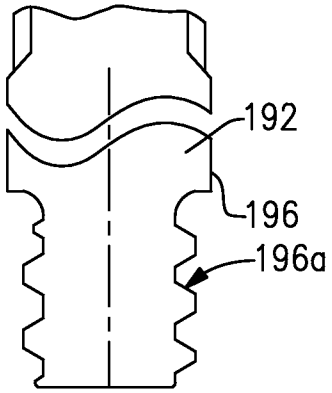


FIG.4

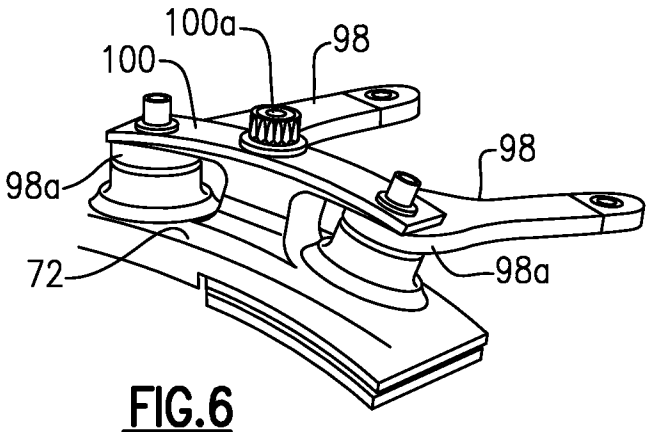


FIG.6

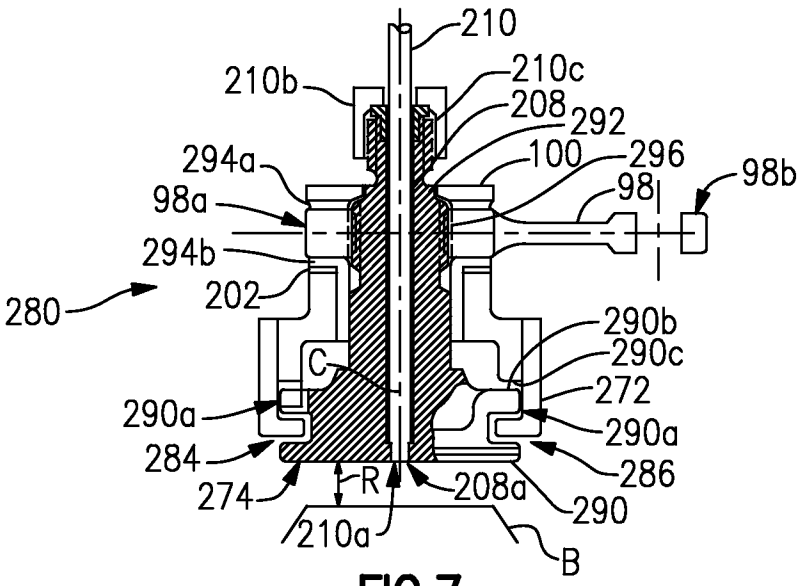


FIG.7

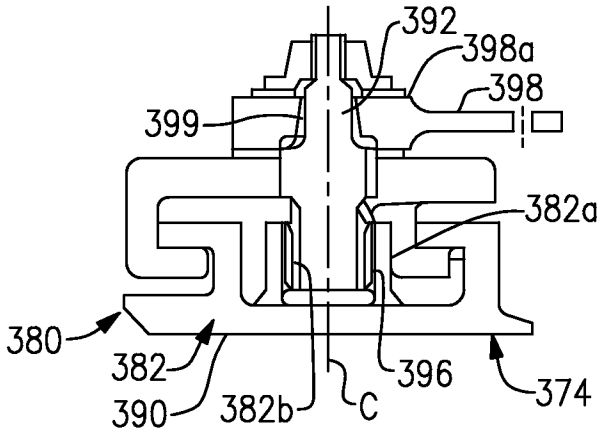


FIG.8

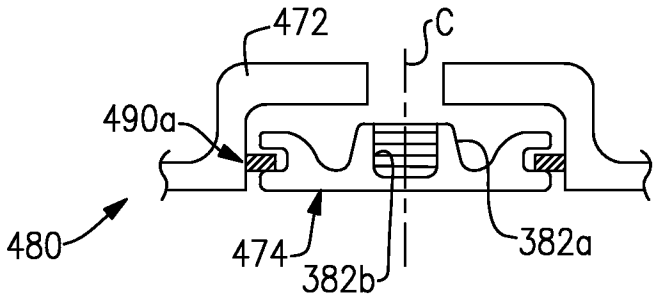


FIG.9A

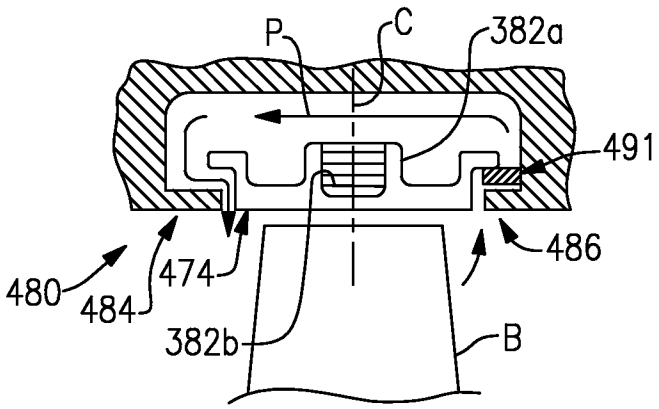


FIG.9B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/026117

A. CLASSIFICATION OF SUBJECT MATTER

F01D 11/14(2006.01)i, F01D 11/10(2006.01)i, F02C 7/28(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01D 11/12; F01D 11/08; F01D 25/12; F01D 17/16

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: ring, spacer, washer, air, seal, foil, adjust, ring, and spring

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2090754 A2 (UNITED TECHNOLOGIES CORPORATION) 19 August 2009 See paragraphs [0009],[0011]-[0014] and figures 1,2.	1,10,18,21,22
Y		9,12,13
A		2-8,11,14-17,19,20
Y	US 2011-0044803 A1 (DI PAOLA et al.) 24 February 2011 See paragraph [0033]; claim 10; and figure 9.	9,12,13
A	US 6997673 B2 (MORRIS et al.) 14 February 2006 See column 6, lines 35-38 and figure 3.	1-22
A	WO 2009-130262 A1 (ABB TURBO SYSTEMS) 29 October 2009 See abstract and figure 3	1-22
A	US 2009-0208322 A1 (MCCAFFREY, WINDSOR) 20 August 2009 See paragraph [0027] and figure 4.	1-22

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

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 May 2013 (27.05.2013)	**02 June 2013 (02.06.2013)**
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. 82-42-472-7140	Authorized officer SONG, Ho Keun Telephone No. 82-42-481-5580

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/026117

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