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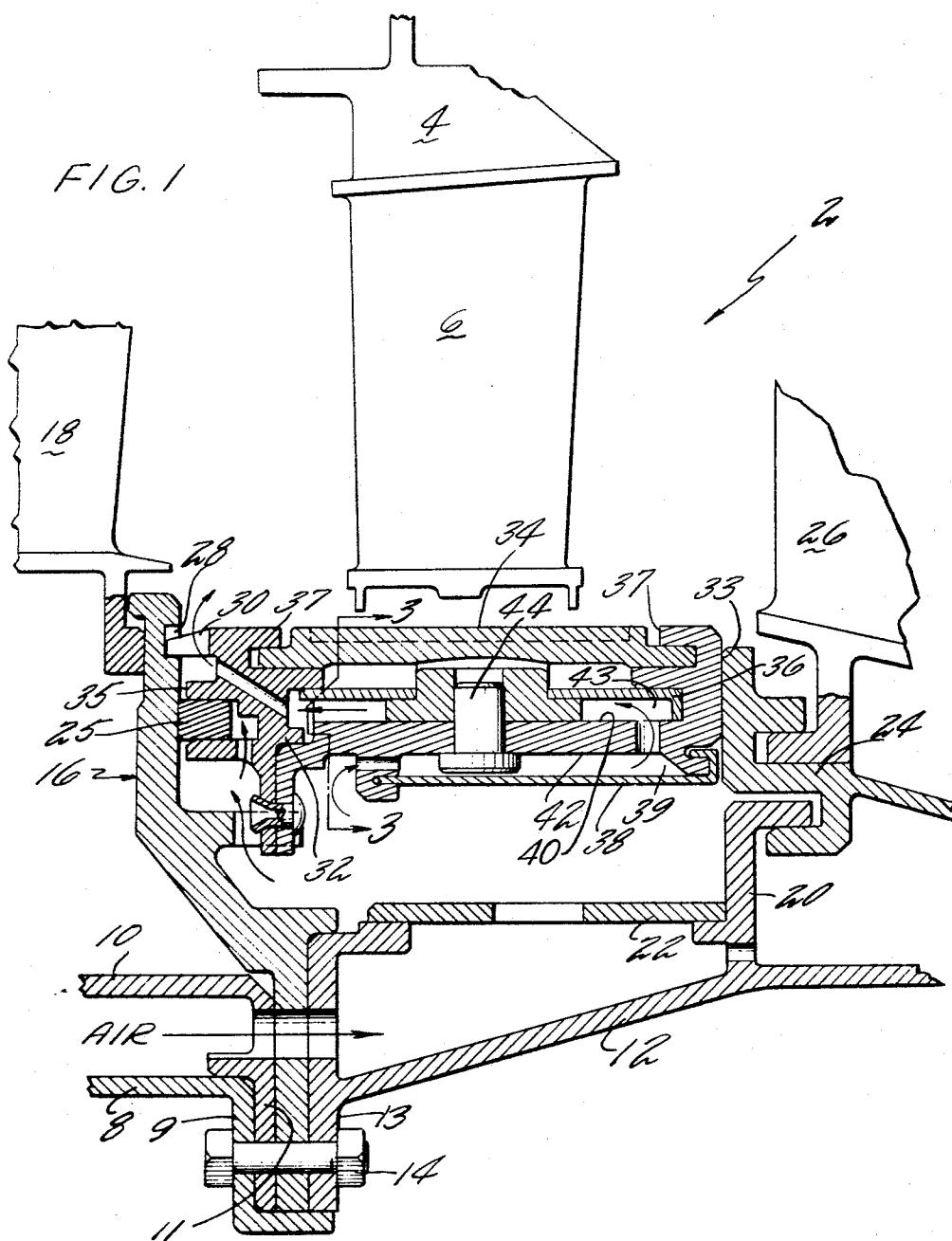
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3,391,904

OPTIMUM RESPONSE TIP SEAL

Filed Nov. 2, 1966

3 Sheets-Sheet 1



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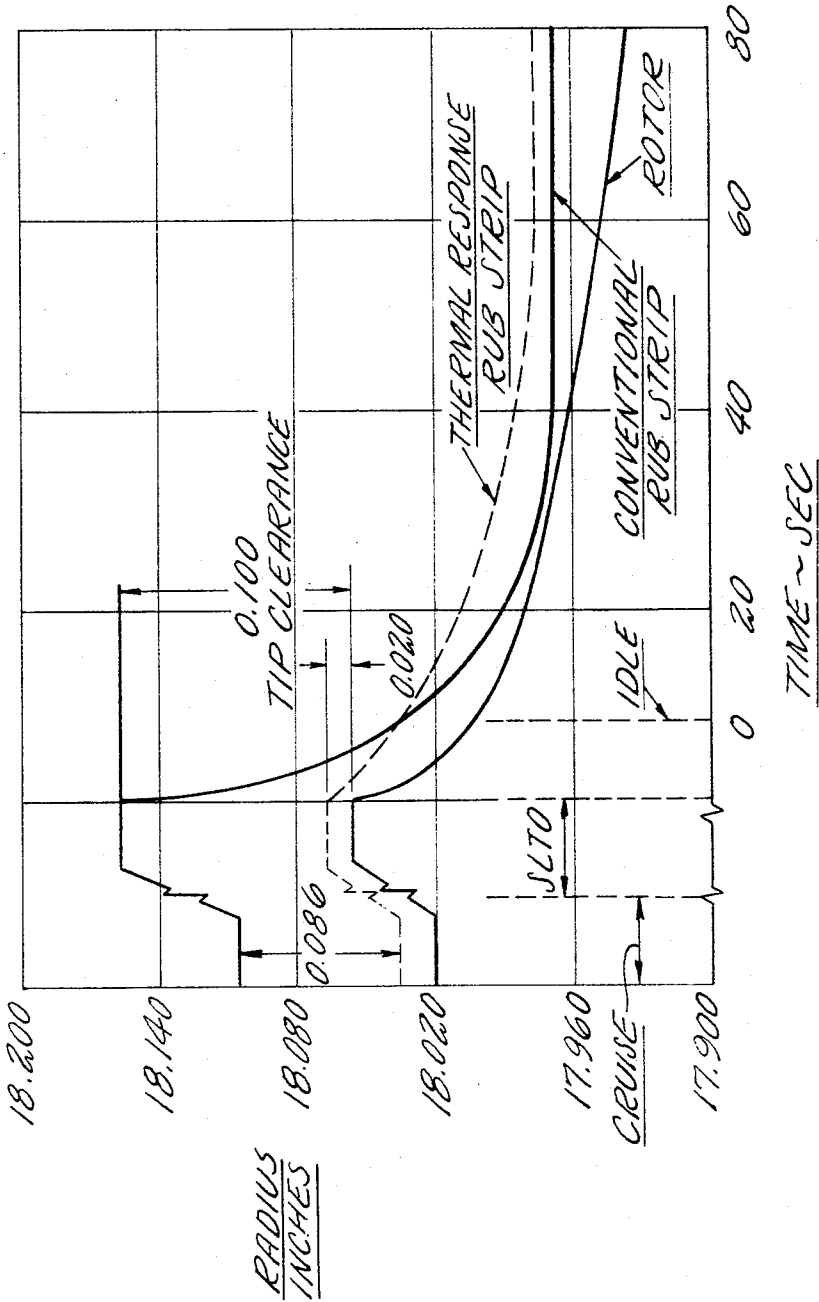
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OPTIMUM RESPONSE TIP SEAL

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FIG. 4



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OPTIMUM RESPONSE TIP SEAL

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ABSTRACT OF THE DISCLOSURE

This invention relates to a seal construction, the rate of expansion or contraction of which closely follows the rate of expansion or contraction of a rotating rotor construction. This seal construction thereby provides the minimum possible blade-to-seal gap during steady-state engine operation and also eliminates transient interference during acceleration or deceleration.

This invention relates to gas turbine engines and more particularly to an arrangement for maintaining the turbine blade tip clearance at the most optimum level for varying flight conditions.

In a gas turbine engine, the turbine rotor must rotate freely at all flight conditions, including transients, so therefore there must be clearance between the turbine blade tips and the surrounding turbine casing seal assemblies. An important feature of this invention is an arrangement by which the rate of expansion or contraction of the turbine casing seal assemblies is made to closely follow the rate of expansion and contraction of the turbine rotor.

Normally in a gas turbine engine the tip clearance is excessive at steady-state conditions because a large cold clearance is necessary to avoid interference during transient operations, and because the high steady-state operating temperature of the turbine casing seal assembly produces excessive growth of this assembly relative to the turbine rotor growth. It should be clear that a reduction in this steady-state tip clearance will produce a significant increase in turbine efficiency with a corresponding decrease in specific fuel consumption. To this extent, it is another feature of this invention to provide a minimum hot running clearance, thereby increasing the turbine efficiency.

It should also be clear that in the turbine area, as a result of the tip clearance, there is leakage of hot gases past the turbine blades. These leakage paths are a function of the thermal growth of the disc, blades and seal assemblies, of the rotative growth of the disc and blade and of the cold assembly gap. Obviously the various engine conditions affect the relative size of the disc, blade and seal assemblies and it is equally obvious that for each engine condition there is an optimum tip clearance. It is yet another feature of this invention to provide an arrangement by which the blade tip clearance for all flight conditions is controlled automatically.

Other features and advantages will be apparent from the specification and claims and from the accompanying drawings which illustrate different embodiments of the invention.

FIGURE 1 is a sectional view of a turbine section of a gas turbine engine showing the device of the invention thereof.

FIGURE 2 is a sectional view of a turbine section of a gas turbine engine showing a second embodiment of the device of the invention.

FIGURE 3 is a sectional view substantially along the line 3—3 of FIGURE 1.

FIGURE 4 is a graphical presentation of the comparative expansion and response of different type turbine seal assemblies.

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In referring to the referenced figures, the numeral 2 indicates a turbine generally. It is understood that all portions and parts of the turbine shown in the referenced figures may be assumed to be consistent with conventionally known gas turbine engines.

The turbine is provided with a rotatable disc 4, the shafts and supporting bearings not being shown. The disc 4 includes the usual turbine blades 6, disposed radially around the outer periphery of the disc (FIGURES 1 and 2). Referring to FIGURE 1, the engine has a forward casing 8, an inner casing 10 and a rear casing 12. The outer casing 8 has an outwardly directed flange 9, the inner casing 10 has an outwardly directed flange 11 and the rear casing 12 has an outwardly directed flange 13. The flanges are connected together by bolt 14, thereby connecting the turbine casings together. Interposed between flange 11 and flange 13 and connected thereto by bolt 14 is an inwardly directed flange 16. Inner casing 10 is radially spaced from forward casing 8 forming an annular passageway for compressor bleed cooling air. Flanges 11, 13 and 16 have axially aligned holes which communicate with this annular passageway and thereby allow cooling air to pass through the flanges.

Flange 16 supports vanes 18 which direct the combustion gases at a predetermined angle onto blades 6. An inwardly directed flange 20 connected to rear casing 12 and axially spaced from the inwardly directed end of flange 13, cooperates with flange 13 in supporting annular ring 22. The ring forms a chamber between the ring and rear casing 12; however, the ring 22 has openings which allow cooling air to pass through the ring and radially inward. Flange 20 also supports vane mounting ring 24, this mounting ring supporting vanes 26.

Cooperating between flange 16 and vane mounting flange 24 is circumferential wear strip retainer 32. The inner circumferential end which is in contact with the first gas has a plurality of axial grooves extending partially through this face to provide for circumferential thermal expansion. In the embodiment of the invention shown in FIGURE 1, the wear strip retainer 32 has axial directed projections 30 which are slidable within radial openings 28 contained at the inner end of flange 16. It is to be understood that these axial directed projections may be on either side of the wear strip retainer and could cooperate within radial openings contained in the vane mounting flange. The radial openings 28 are arranged in such a manner that the projections are restrained circumferentially and therefore they are held concentric with the engine center line and correspondingly, the wear strip retainer is held concentric with the engine center line. Due to the loading of the gas stream, the downstream radial face 33 of the wear strip retainer abuts and is slidable against the vane mounting flange thereby effecting a seal. Slidably connected between flange 16 and the upstream radial face 35 of wear strip retainer 32 is a conventional piston ring seal 25. Since the pressure on the internal side of the piston ring seal is greater than the gas stream pressure, the piston ring seal prevents any blow by or leakage of the cooling air between flange 16 and radial face 35.

Connected between the radial inner faces 37 of wear strip retainer 32 and radially restrained by these faces is circumferential slotted or segmented wear strip 34. The slots or spacing between the segments provide for circumferential thermal expansion (see FIGURE 3). The circumferential wear strip forms a chamber between the wear strip 34 and axial directed inner face 40 of wear strip retainer 32. An axial and circumferential first baffle 36 radially spaced from inner face 40 and radially restrained by faces 37 forms cooling air passageway 43 between first baffle 36 and inner face 40 of wear strip retainer 32. The radial distance between the first baffle

and inner face 40 is critical in that it determines the heat transfer flow coefficient and thereby controls the steady-state temperature and thermal response rate of the wear strip retainer 32. The present embodiment includes a second axial and circumferential baffle 38 which is radially spaced from the outer axial directed face 42 of wear strip retainer 32 and forms cooling air passageway 39 therebetween. It should be clear that the radial spacing of one baffle is sufficient to obtain the desired flow coefficient and thereby maintain the wear strip retainer at the desired steady-state temperature and the desired thermal response rate. The wear strip retainer, wear strip and first baffle are connected together by pin 44 to insure that as the parts expand and contract thermally that they act as a unitary assembly.

FIGURE 2 illustrates a second embodiment of the invention and in this figure the numeral 102 refers to a turbine generally and includes all parts and portions which may be assumed to be consistent with conventionally known gas turbine engines.

The turbine is provided with a rotatable disc 104, the shafts and supporting bearings not being shown. The disc 104 includes the usual turbine blades 106, disposed radially around the outer periphery of the disc. In the embodiment in FIGURE 2, the engine has a forward casing 108 and a rear casing 110, the casings being connected together at outwardly directed flanges 109 and 111 by bolt 114. Casing 108 supports an inwardly directed flange 112, this flange having means for allowing cooling air to pass through it. A second inwardly directed flange 116, axially spaced from flange 112, is also supported from casing 108. Vane 118 is supported and positioned between flanges 112 and 116, and vane 118 directs the combustion gases at a predetermined angle onto blades 106.

Supported from rear casing 110 is an inwardly directed flange 120. Flange 120 supports and positions vane 122 at vane mounting platform 124. Cooperating between flange 112 and vane mounting platform 124 is circumferential wear strip retainer 126. The inner circumferential face 127 which is in contact with the hot gases has a plurality of axial grooves extending partially through the face to provide for circumferential thermal expansion. Wear strip retainer 126 has axial directed projections 128 which are slidable within radial openings 130 contained at the inner end of flange 112. As in the embodiment shown in FIGURE 1, these openings are arranged such that the wear strip retainer is held concentric with the engine center line.

Connected between inner axial face 132 of wear strip retainer 126 and outer axial face 134 of wear strip retainer is slotted or segmented circumferential wear strip 136, the slots or spacing between the segments providing for circumferential thermal expansion. Positioned between and abutting against outer radial face 138 of wear strip 136 and vane mounting platform 124 is seal ring 140.

The circumferential wear strip 136 forms an annular chamber between axial inner face 142 of wear strip retainer 126 and axial surface 144 of wear strip 136. This chamber is divided into two chambers by an axial and circumferential first baffle 146, the chamber between axial inner face 142 and the baffle being a cooling air passageway 148 and the chamber between the baffle and axial surface 144 being a dead air chamber. The embodiment in FIGURE 2 includes a second axial and circumferential baffle 150 but as noted previously one baffle is adequate since the flow coefficient can be obtained by the radial spacing between first baffle 146 and inner face 142.

A conventional piston ring 152 slidably connected between flange 112 and radial face 154 prevents gas from flowing between these members. Pin 156 secures wear strip retainer ring 126, wear strip 136 and first baffle 146 together to insure that they act as a unitary assembly.

In operation, the embodiments illustrated in FIGURES 1 and 2 operate similarly. Cooling air bled from the compressor is supplied to the cooling air passageways, that is,

the spaces between the baffles and the wear strip retainer. The steady-state and transient temperature of the wear strip retainer and therefore the radius of the turbine casing seal assembly is established by the heat transfer flow coefficient which as noted previously is controlled by the radial spacing between the baffles and wear strip retainer. Therefore, by proper selection of the heat transfer film coefficient it is possible to minimize the blade tip clearance during transient and steady-state operating conditions. FIGURE 4 graphically illustrates the turbine blade and disc growth and how the turbine seal assembly responds.

FIGURE 4 also provides a comparison between the invention herein and a conventional rub strip assembly and is based on a specific gas turbine engine design. It can be seen from this figure that for a conventional rub strip in this particular engine design, minimum clearances occur at about 30 seconds from the start of deceleration from sea level takeoff to idle steady state. As a result, steady-state clearances at cruise and sea level take-off powers are in the order of .086 inch radially and .100 inch radially respectively. This results in a serious turbine efficiency penalty. By employing the rub strip assembly, described herein, since it operates at lower temperatures and its response is matched closely to the turbine rotor, it is estimated that steady-state clearances can be reduced to as low as .020 inch radially. This will result in an improvement of the turbine efficiency by as much as 2.2 percent.

It is to be understood that the invention is not limited to the specific description above or to specific figures shown, but may be used in other ways without departure from its spirit as defined by the following claims.

We claim:

1. A turbine blade seal assembly, adapted for use in a turbine casing assembly of a gas turbine engine, which comprises:

a generally circumferential wear strip retainer, said retainer having means for positioning and holding said retainer within a turbine casing and for providing for radial expansion within said casing, said retainer having a plurality of passageways, said passageways directing air around and through said retainer into the engine gas stream;

a circumferential wear strip connected to said retainer, said wear strip being radially spaced from the inner surface of said retainer, thereby defining an annular chamber between said wear strip and said retainer; a first baffle extending axially and circumferentially through said annular chamber thereby forming a passageway between said baffle and said wear strip retainer, the flow coefficient through said passageway being controlled by the radial spacing between the first baffle and the wear strip retainer, the flow coefficient controlling the thermal expansion and contraction response at said retainer, said passageway communicating with said retainer passageways; and means for connecting said retainer, said wear strip and said first baffle thereby insuring that they move radially as a unitary assembly.

2. A seal assembly as in claim 1, in which:

a second baffle extends axially and circumferentially around the outer diameter of said wear strip retainer, said second baffle thereby forming a passageway between said wear strip retainer and said second baffle, the flow coefficient through said passageway being controlled by the radial spacing between the second baffle and the wear strip retainer, the flow coefficient of this passageway contributing to and in some instances solely controlling the thermal expansion and contraction response of said retainer, said passageway communicating with said passageways in said wear strip retainer.

3. A seal assembly as in claim 1, in which:

said wear strip retainer has a plurality of axial grooves, said grooves extending partially through said ring

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so as to provide for the circumferential thermal expansion of said retainer; and
said wear strip has a plurality of axial slots to provide for the circumferential thermal expansion of said wear strip.

4. A seal assembly as in claim 3, in which:

said wear strip is a plurality of segments, said segments thereby providing for circumferential thermal expansion of said wear strip.

5. In a gas turbine engine, a turbine blade seal assembly surrounding and radially spaced from the blade tips of a turbine rotor assembly, comprising:

a turbine casing,

an inwardly projecting flange connected to said casing, said flange having radial openings,

a generally circumferential wear strip retainer, said retainer having means cooperating slidably within said radial openings, thereby maintaining said retainer concentric with the engine axis and providing for radial movement of said retainer in said casing, and said retainer having a plurality of passageways therethrough for directing air through and around said retainer and into the engine gas stream,

a circumferential wear strip slidably connected to said retainer, said wear strip being radially spaced from the inner surface of said retainer thereby defining an annular chamber between said wear strip and said retainer,

a first baffle extending axially and circumferentially through said annular chamber thereby forming a passageway between said baffle and said wear strip retainer, the flow coefficient through said passageway being controlled by the radial spacing between the first baffle and the wear strip retainer, the flow coefficient controlling the thermal expansion and contraction of said retainer, said passageway communicating with said retainer passageways, and

means for connecting said retainer, said wear strip and said first baffle thereby insuring that they move radially as a unitary assembly.

6. A gas turbine engine as in claim 5, in which:

said wear strip retainer has axial grooves extending partially through the portion of said wear strip retainer that is exposed to the engine gas stream, and said wear strip has a plurality of axial slots thereby providing for the circumferential thermal expansion of said wear strip.

7. In a gas turbine engine, a turbine blade seal assembly, comprising:

a turbine casing,

an inwardly projecting flange connected to said casing, said flange having radial slots;

a generally circumferential wear strip retainer, said retainer having axially directed lugs, said lugs being slidable within said slots in retainer, said retainer having a plurality of passageways, said passageways directing air through and around said retainer into the engine gas stream,

means for sealing the leakage path between said retainer and said inwardly projecting flange;

a circumferential wear strip connected to said retainer, said wear strip being radially spaced from the inner surface of said retainer thereby defining an annular chamber between said wear strip and said retainer;

a first baffle extending axially and circumferentially through said annular chamber thereby forming a passageway between said baffle and said wear strip retainer, the flow coefficient through said passageway being controlled by the radial spacing between the first baffle and the wear strip retainer, the flow coefficient controlling the thermal expansion and con-

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traction response of said retainer, said passageway communicating with said retainer passageways,

a second baffle extending axially and circumferentially around the outer diameter of said wear strip retainer, said second baffle thereby forming a passageway between said wear strip retainer and said second baffle, the flow coefficient through said passageway being controlled by the radial spacing between the second baffle and the wear strip retainer, the flow coefficient of this passageway contributing to and in some instances solely controlling the thermal expansion and contraction response of said retainer, said passageway communicating with said passageways in said wear strip retainer,

means for sealing the leakage path at the downstream end of said wear strip, and

means for connecting said retainer, said wear strip and said first and second baffles so as to cause them to move radially as a unitary assembly.

8. A gas turbine engine, as in claim 7, wherein:

said wear strip retainer has axial grooves extending partially through the portion of said wear strip retainer that is in contact with the engine gas stream, and

said wear strip has a plurality of axial slots thereby providing for the circumferential thermal expansion of said wear strip.

9. In a gas turbine engine, as in claim 7, in which:

said first baffle divides said annular chamber between said wear strip retainer and said wear strip into two annular chambers, the chamber between said first baffle and said wear strip retainer being a passageway in communication with the other flow passageways within said wear strip retainer, and the chamber between said first baffle and said wear strip being a dead air chamber, thereby being a thermal shield and assisting in maintaining said wear strip retainer at a temperature lower than said wear strip.

10. A gas turbine engine as in claim 5, including:

a second baffle extending axially and circumferentially around the outer diameter of said wear strip retainer, said second baffle forming a passageway between said wear strip retainer and said second baffle, the flow coefficient through said passageway being controlled by the radial spacing between the second baffle and the wear strip retainer, the flow coefficient of this passageway contributing to and in some instances solely controlling the thermal expansion and contraction response of the retainer.

11. A gas turbine engine as in claim 5, including:

means for providing compressor bleed air from an engine compressor to the passageway between the first baffle and the wear strip retainer.

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