Method for controlling the clearance between rotating and stationary components of a gas turbine engine are disclosed. Techniques for achieving close correspondence between the radial position of rotor blade tips and the circumscribing outer air seals are disclosed. In one embodiment turbine case temperature modifying air is provided in flow rate, pressure and temperature varied as a function of engine operating condition. The modifying air is scheduled from a modulating and mixing valve supplied with dual source compressor air. One source supplies relatively low pressure, low temperature air and the other source supplies relatively high pressure, high temperature air. After the air has been used for the active clearance control (cooling the high pressure turbine case) it is then used for cooling the structure that supports the outer air seal and other high pressure turbine component parts.

1 Claim, 5 Drawing Figures
GAS TURBINE ENGINE ACTIVE CLEARANCE CONTROL

The invention described herein was made in the performance of work under NASA Contract No. NASA320646 and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958 (72 Stat. 435; 42 U.S.C. 2457).

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation of application Ser. No. 317,633, filed on Nov. 2, 1981, now abandoned.

TECHNICAL FIELD

This invention relates to gas turbine engines, and more specifically to the active control of clearances between opposing seal elements of the rotor and stator assemblies.

BACKGROUND ART

It is well known in the gas turbine industry that engine performance is proportional to the leakage of working medium gases between opposing seal elements of the rotor and stator assemblies. Techniques and concepts for reducing such clearances are continually under investigation and development.

One class of techniques are those relating to "active clearance control" in which the clearances are set as a function of engine operating condition. The objective is to establish minimum clearances under stable operating conditions, yet to provide sufficient clearance during transient operation to preclude destructive interference between relatively rotating components.

In accordance with one detailed embodiment of the invention the case temperature modifying air is flowable to one or more annular spaces circumscribing the cases to be controlled, and thence internally of the cases for cooling of components in proximity to the engine flow path.

A primary feature of the present invention is the utilization of dual source air for modifying the temperature of each engine case. Relatively low pressure, low temperature compressor air is mixed with relatively high temperature high pressure air at one or more modulating valves. The valves are capable of varying the proportions of air from each source for effecting case cooling at differing flow rates and temperatures.

In one detailed embodiment a shroud circumscribes each engine case to be controlled and is spaced apart therefrom. Case temperature modifying air is flowable to the space. The modifying air is subsequently flowable through apertures in the case into the interior of the engine for cooling components adjacent the engine flow path.

A principal advantage of the present invention is the judicious use of case temperature modifying air for controlling case diameter. Internal clearances at seals between rotor and stator structure are minimized by matching the case diameter to expected rotor growth under varied engine operation conditions. As viewed from another aspect, turbine cooling air utilized to protect engine components adjacent the flow path is diverted en route to preliminarily modify the temperature of the engine case. Improved engine performance results from the sequential use of compressor air for such auxiliary purposes as well as from actual clearance control.

The foregoing features and advantages of the present invention will become more apparent in the light of the following detailed description of the best mode for carrying out the invention and in the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a simplified side elevation view of a gas turbine engine with portions broken away in cross section;
The modulating and mixing valve 54 is capable for receiving the dual source air from the compressor and modulating the flow of each to produce an effluent having a desired temperature, pressure, and flow rate. In some embodiments the valve may be collaterally capable of producing dual effluents, each having individualized temperatures, pressures, and flow rates. Effluent from the valve is flowed to the turbine section of the engine through one or more conduits 58. In the structure illustrated a second modulating and mixing valve on the reverse side of the engine is capable of discharging effluent through a second conduit 60 to a downstream position on the turbine. The first conduit 58 illustrated is capable of discharging to the high pressure turbine 16; the second conduit 60 illustrated is capable of discharging to the low pressure turbine 18.

The FIG. 3 turbine cross section view illustrates the distribution of effluent from the modulating and mixing valves via the first conduit 58 to the high pressure turbine 16 and via the second conduit 60 to the low pressure turbine 18.

To illustrate the flow characteristics of this invention at the high pressure turbine, the structure of the high pressure turbine disclosed in FIG. 3 is enlarged in FIG. 5. As noted, the modulated air is conducted through conduit 58 where it is admitted into the manifold 59 which are segmented around the periphery of the row of high pressure turbine blades 40. The air is transmitted through a plurality of apertures where it is directed to impinge on the high pressure turbine case 36. The air is then directed inwardly toward the engine centerline where it serves to cool the structure of manifold 59 and the supporter hooks 63 and the attendant structure. A portion of this air leaks between the adjacent supporting structure and then into the engine air stream downstream of the high pressure turbine blades 40 while the remaining air is directed downstream through openings 65 and 67 in the support structure and then between the shield 69 and the inner diameter of the high pressure turbine case 36 where it dumps into the low pressure turbine section downstream thereof.

In this manner, and as is apparent from the foregoing, the air utilized to control the gap between the outer air seal 46 and the tips of the high pressure turbine blades 40 is also used to cool the supporting structure. This negates the need to bring in air from a separate source to cool these components as was done in the heretofore systems. Consequently, this avoids putting an undue thermal stress on the high pressure turbine case that would otherwise occur by having air from two different sources where one source may be cooler than the other and hence create a situation where considerably hotter air is opposite the cooler impinging air and impairing its intended function of shrinking the case to close the gap or vice versa. In the low turbine the case 38 is formed of double wall construction including an inner case 62 and an outer case or shroud 64. Effluent from the modulating and mixing valve is flowable to a space 66 between the inner case and shroud for the purpose of modifying the temperature of the case as a function of engine operating condition. The modifying air is hence flowable through apertures 68 in the inner case to the interior of the engine for subsequently cooling engine components in the turbine.

During operation of the engine, working medium gases are compressed within the compressor section to pressure ratios on the order of thirty to one (30:1) and burned with fuel in the combustion section. The hot
effluent from the combustion section is expanded through the turbine section to provide the motive force driving the compressor. Pressures across the compressor section of a typical engine increase at each successive stage from atmosphere pressure to the order of four hundred fifty pounds per square inch absolute (450 psia) at sea level take-off conditions. Correspondingly, temperatures across the compressor section increase at each successive stage from ambient conditions to the order of ten thousand degrees Fahrenheit (1150°F) at sea level take-off conditions. Corresponding temperatures at the inlet to the turbine section are on the order of twenty-five hundred degrees Fahrenheit (2500°F). Radical variations in engine temperatures over the operating cycle of the engine establish the need for control of clearances between rotating and stationary structures under the influence of differing environments.

The concepts of the present invention employ case heating and case cooling in accord with the engine cycle to achieve close growth correspondence between the rotor and the case supported seals. Case temperature modifying air is utilized for such heating and cooling. The modifying air comprises varied proportions of heating and cooling air ducted from the engine compressor to the case segment to be cooled. Representative characteristics of case temperature modifying air produced as the effluent from a modulating and mixing valve, such as that described herein, is shown in the tabular reproduced below. The temperature, pressure, and flow rate data is representative of a forty thousand (40,000) pound thrust class engine at idle, sea level take-off and cruise conditions. Data is for a split-type system in which a first modulating valve is supplied with dual source air for discharge and temperature control of the high pressure turbine case and a second modulating valve is supplied with dual source air for discharge and temperature control of the low pressure turbine case.

<table>
<thead>
<tr>
<th>Low Pressure</th>
<th>High Pressure</th>
<th>High Temperature</th>
<th>Modifying Air Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Pressure</td>
<td>High Pressure</td>
<td>Temperature</td>
<td>Source</td>
</tr>
<tr>
<td>Idle</td>
<td>Pressure 27 psia</td>
<td>61 psia</td>
<td>25 psia</td>
</tr>
<tr>
<td></td>
<td>Temp 290°F</td>
<td>430°F</td>
<td>430°F</td>
</tr>
<tr>
<td></td>
<td>Flow Rate 0.0 lb/sec</td>
<td>0.0 lb/sec</td>
<td>0.0 lb/sec</td>
</tr>
<tr>
<td></td>
<td>Sea Pressure 196 psia</td>
<td>431 psia</td>
<td>130 psia</td>
</tr>
<tr>
<td></td>
<td>Level Temperature 720°F</td>
<td>1110°F</td>
<td>970°F</td>
</tr>
<tr>
<td></td>
<td>Take-Off Flow Rate 0.10 lb/sec</td>
<td>0.22 lb/sec</td>
<td>0.10 lb/sec</td>
</tr>
<tr>
<td></td>
<td>Cruise Pressure 65 psia</td>
<td>197 psia</td>
<td>60 psia</td>
</tr>
<tr>
<td></td>
<td>Temp 580°F</td>
<td>900°F</td>
<td>580°F</td>
</tr>
<tr>
<td></td>
<td>Flow Rate 0.155 lb/sec</td>
<td>0.00 lb/sec</td>
<td>0.155 lb/sec</td>
</tr>
</tbody>
</table>

Referring again to the FIG. 4 "pinch point" diagram curve C represents the radial position of an outer air seal to the rotor of the gas turbine engine. The gap Y represents the attainable relative clearance between the tips of the rotor blades and the corresponding outer air seal. Clearance is not only greatly reduced from the non-controlled conditions, but closely corresponds in contour to the radial position of the tips. The minimum clearance necessary to avoid destructive interferences is provided.

Although the invention has been described with respect to a particular turbine embodiment, it should be understood that the invention is not so limited and that various changes and modifications may be made without departing from the spirit and scope of this novel concept.

**We claim:**

1. A method of controlling the clearance between opposing seal elements of the rotor assembly and the stator assembly including supporting structure of a dual rotor gas turbine engine having high pressure compressor and high pressure turbine, low compressor and high pressure turbine rotors comprising the steps of:

   - flowing relatively low pressure, low temperature air from the compressor of the engine to a modulating and mixing valve;
   - flowing relatively high pressure, high temperature air from the compressor of the engine to said modulating and mixing valve;
   - mixing said relatively low pressure, low temperature air and said relatively high pressure, high temperature air at the modulating valve in proportions functionally related to engine operating condition to produce a mixture of air having a desired temperature, pressure and flow rate at that operating condition for thermally modifying the diameter of the turbine case adjacent said high pressure turbine;

   - flowing said mixed air to the high pressure turbine section of the engine and against the case thereof for thermally varying the diameter of said case to achieve control over clearances between the rotor and stator assemblies of said high pressure turbine and admitting the effluent mixed air from said case internally thereof so as to cool said supporting structure;

   - flowing relatively low pressure, low temperature air from the compressor of the engine to a second modulating and mixing valve;
flowing relatively high pressure, high temperature air from the compressor of the engine to said second modulating and mixing valve; mixing said relatively low pressure, low temperature air and said relatively high pressure, high temperature air at the second modulating valve in proportions functionally related to engine operating condition to produce a mixture of air having a desired temperature, pressure and flow rate at that operating condition for thermally modifying the diameter of the turbine case; and flowing said air mixed at the second modulating valve to the case of the low pressure turbine at a location downstream of the location to which the air mixed at the first modulating valve was flowed and against the case at that downstream location for thermally varying the diameter of the case at that location.