United States Patent [19]

Smith et al.

[11] **3,733,146**

[45] **May 15, 1973**

[54] GAS SEAL ROTATABLE SUPPORT STRUCTURE

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[22] Filed: **Apr. 7, 1971**

[21] Appl. No.: **131,973**

[52] **U.S. Cl.** .....**415/172**, 415/199 R

[51] **Int. Cl.** **F01d 11/08**, F01d 1/04

[58] **Field of Search**.....416/191, 200, 201, 416/500; 415/191, 192, 193, 194, 199, 115, 171, 172, 117; 60/39, 66

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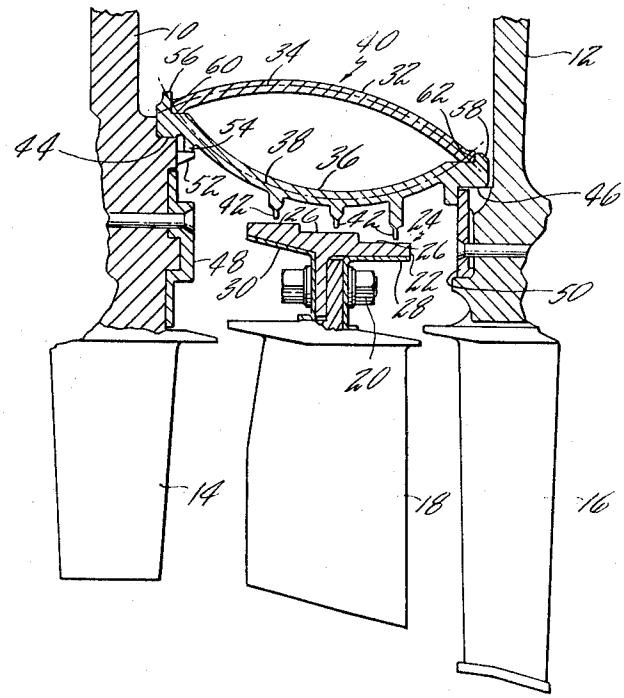
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[57] **ABSTRACT**

A toroidal structure which is lenticular in cross section and rotatable in a gas turbine environment is disclosed. The structure is described as a support member for the rotating component of a seal assembly in a high temperature application, such as a turbine rotor.

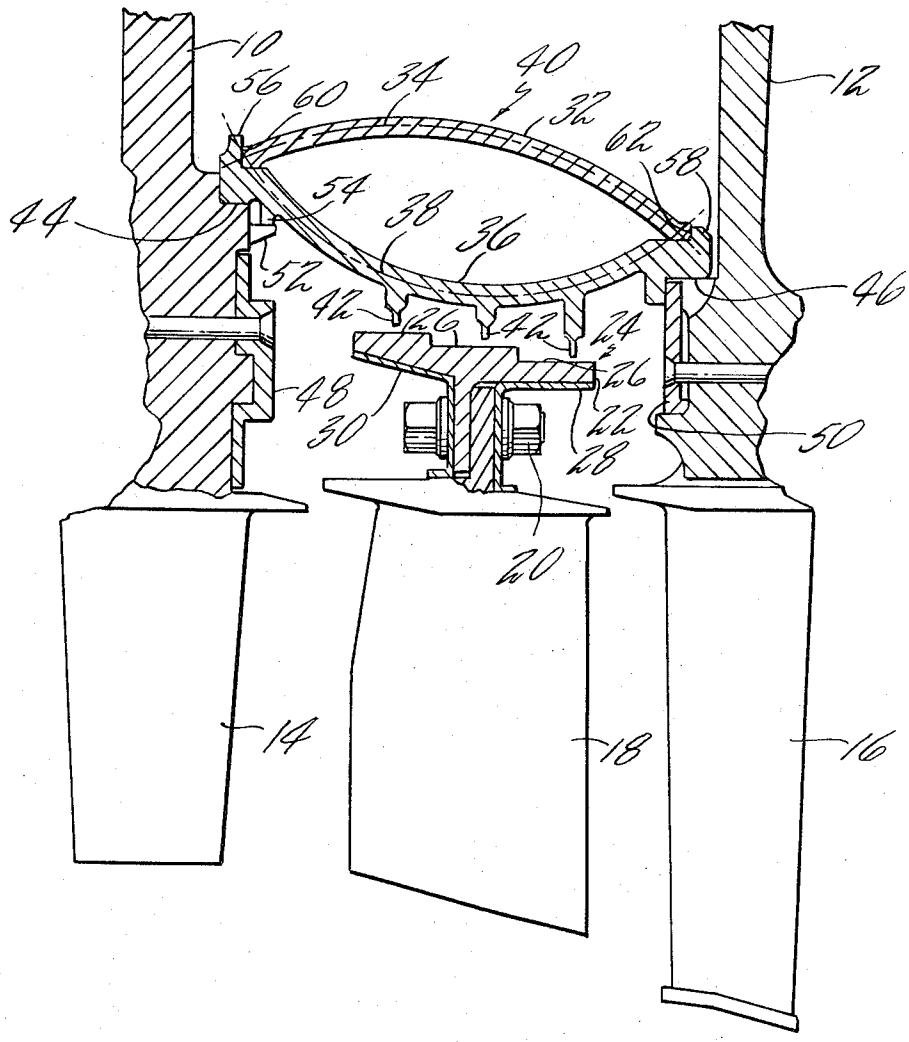
The structure is radially supported by a pair of adjacent turbine disks and comprises a pair of curved plates which cooperate during rotation to cause a low net stress in the plates. The outer plate has a raised ridge along each of its circumferential edges and correspondingly the inner plate has a butt face along each of its circumferential edges. During rotation of the lenticular structure, the ridge edges tend to draw closer together and the butt face edges tend to spread apart and since the inner plate edges are restrained by the outer plate ridges, a transfer of axial loads between the plates occurs, resulting in a reduction in the net stress in the structure.

4 Claims, 1 Drawing Figure



PATENTED MAY 1 5 1973

3,733,146



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GAS SEAL ROTATABLE SUPPORT STRUCTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a curved rotatable structure having internal circumferential stresses which are reduced by self-induced loads, and more particularly, to a toroidal gas seal support structure which is lenticular in cross section.

2. Description of the Prior Art

In a typical gas turbine arrangement, several turbine wheels each comprising a row of blades on the periphery of a disk make up a rotor which is enclosed within an engine stator. The working medium passes across the turbine blades and gas leakage around the ends of the blades is minimized by a seal arrangement at the tips of the blades. On opposite sides of the rows of blades are rows of stator vanes which direct the flow of the working medium. The stator vanes are rigidly attached to the engine case and project inward toward the engine rotor. Leakage of the working medium around the inner ends of the stator vanes of each row is minimized with a seal arrangement analogous to that provided at the tip of the turbine blades; the rotating member of the seal is supported by structure which is essentially a cylinder extending between adjacent disks and rotating therewith. The seal is located immediately adjacent to the inner ends of the stator vanes. This type of gas seal between the various pressure stages in turbines has been used repeatedly and effectively.

Relatively large diameter gas turbine engines which operate at conditions of greatly increased temperatures and rotational speeds are presently being developed. As operating conditions such as rotational speed and turbine temperature become more demanding, design limitations which were not prevalent in the small diameter engines are becoming apparent. For example, the stress experienced by a rotating cylinder is proportional to the distance the cylinder is from the center of rotation and rotational speed. For a given material at a given operating temperature and speed of rotation, there is a maximum radius from the center of rotation beyond which the component may not be located without exceeding the acceptable stress limit for that component; this radius is sometimes referred to as the self-sustaining radius.

The operating parameters of some engines are such that the rotating portion of a seal in some stator sections of the engine exceeds the self-sustaining radius, a condition which is intolerable since it can lead to structural failures. To avoid the problem, a platform structure may be added at the tips of the stators so that the seal is located closer to the engine centerline, with the rotating portion of the seal within the self-sustaining radius limitation.

The platform extension avoids the above-mentioned structural shortcoming, however, a different problem is introduced. There is a pressure differential across the stator in the direction of gas flow; also, the stator is supported at its outer end (at the point of maximum stator radius) by the engine casing so that the stator is essentially a cantilevered structure. The pressure differential across the platform section causes the stator to bend in the direction of lower pressure more than would otherwise occur. In some cases, the combination of distance between the seal and the support provided the stator at the casing, and the pressure drop across the seal is sufficient to cause the stator to bend and interfere with the next stage of the turbine rotor, thereby causing grinding of the rotor by the stator extension in the area of the seal.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a gas seal for a relatively large diameter, high temperature gas turbine application.

According to the present invention, an annular rotatable structure, lenticular in cross section and formed into a toroid about a central axis of rotation is radially supported by a pair of rotors in a gas turbine; the structure comprises a curved annular outer shell having circular edge surfaces whose distance of separation along the axis of rotation tends to be reduced during rotation, and a curved annular inner shell also having circular edge surfaces which mate with the edge surfaces of the outer shell and which tend to separate along the axis during rotation; the spreading axial tendency of the inner shell counteracts the contracting axial tendency of the outer shell resulting in net reduced stress in the toroidal structure during rotation.

An advantage of the present invention is the elimination of connecting bolts between the rotating seal structure and the adjacent gas turbine rotors. In addition, the bolting of the disks to the seal support develops internal axial loading and bending in the disks.

A further advantage of this invention is the ability to provide a rotating support member for a seal in a gas turbine at a distance from the center of rotation which would otherwise be beyond the self-sustaining radius. Also, since the structure is supported radially by the turbine disks, the structure has a radial growth during acceleration which is matched to that of the disks.

The present invention also minimizes the overturning moment experienced by a stator vane since the distance between the sealing surface and the point at which the stator is rigidly held at one end by the engine case is reduced.

One feature of the present invention is the thermal fitting of the inner and outer shells; sufficient heating and cooling of the outer and inner shells respectively are required to allow the inner shell to be positioned internal of the outer shell and then to expand to fit securely between the retaining ridges as both shells approach an equilibrium temperature.

An additional feature of this invention is that the lenticular structure tends to stiffen the gas turbine rotors between which such an assembly is located. Further, this invention affords a greater safety margin since the seal support structure (the lenticular member) operates with a net stress which is lower than would otherwise be possible.

The foregoing and other objects, features and advantages of the present invention will become more apparent in the light of the following detailed description of a preferred embodiment thereof as illustrated in the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The sole FIGURE herein is a simplified schematic drawing of a seal in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention takes the form of a rotating shell structure which is located between adjacent disks of the high pressure turbine in a large diameter gas turbine engine. As shown in the drawing, each of a pair of turbine disks **10** and **12** supports on its periphery a turbine blade **14** and **16**, respectively. A stator vane **18** extends inwardly from an engine case (not shown) and is connected by means of bolts **20** to a stationary ring **22** of a segmented seal assembly **24** having a series of lands **26**. Each of the turbine blades **14** and **16** as well as the stator vane **18** are but one of a circular row of respectively similar items. Blocking plates **28** and **30** are also attached by the bolts **20** to the opposite sides of the ring **22** to prevent gas leakage between adjacent seal segments.

The seal structure mounted between the turbine disks includes an inner curved shell **32** having a meridian **34** and outer curved shell **36** having a meridian **38** which together form a double annular structure **40** having a lenticular shaped cross section. A series of knife edges **42** which mate with the lands **26** to form the seal assembly **24** is supported by the outer shell **36**. Side plates **48** and **50** form part of the structural assembly and are mounted on the adjacent faces of the turbine disks. An antirotation lug **52** projects from the turbine disk **10** and cooperates with an extension member **54** of the outer shell **36** thereby preventing any relative rotary motion between the double annular structure **40** and the turbine disks.

The magnitude of the circumferential stress in the outer shell **36** allows the stator vanes to be sealed at a much larger radius than was previously possible due to the presence of the curved inner shell **32**; both these shells are designed so that when the structure is rotated, meridional tensile [normal to the circumferential stress] is produced in the outer shell and meridional compressive load is produced in the inner shell because the two shells interact with each other such that the axial loads (parallel to engine centerline) imposed by one shell on the other tend to cancel one another. The net circumferential stress experienced by each of the shell members is reduced by a negative circumferential stress produced by the induced axial load in each shell.

The double annular structure **40** is supported radially by the turbine disks **10** and **12** by pilots **44** and **46**, respectively. During rotation of the structure **40**, the central region of the outer shell **36** tends to grow radially in the direction of the stator vanes due to the rotary motion and the edge ridges **56** and **58** tend to move axially toward each other. Simultaneously, the center region of the inner shell also tends to move in the direction of the stator vanes, in much the same manner as the outer shell **36** reacted to rotation, with the edges or butt faces **60** and **62** of the inner shell **32** tending to spread or move away from one another in the axial direction. As the edge ridges **56** and **58** move toward one another, the inner shell **32** is subjected to a compressive axial load which is counteracted in the outer shell by the tensile axial load resulting from the axial spreading of the butt faces **60** and **62** of shell **32**.

The operating tensile circumferential stress is thereby reduced by a negative circumferential stress produced by the induced axial load in each shell. Additional circumferential stress reduction is produced by radial restraint on the ends of structure **40** at pilots **44** and **46**.

The overall result is both the inner and outer shells of the double annular structure **40** have relatively low net internal circumferential stresses; the axial loads in each shell, due to the restraints each shell puts on movement of the ends of the other shell, yields a circumferential stress which is less than that which a cylindrical structure would experience at the same radius, speed and temperature.

When it became evident that right cylindrical shells and the platform extension structure previously mentioned were not satisfactory in highly stressed seal support applications, a curved shell which could be bolted to the adjacent turbine disks was considered. While a rotating support structure consisting of a single sleeve is conceptually feasible, this approach is undesirable because the bolt holes in the turbine disks near the rim have been found to reduce low cycle fatigue life resulting in increased disk weight to regain the lost low cycle fatigue life. In additional, the bolting of the disks to the seal support develops internal axial loading and bending in the disks. By way of contrast, the double annular rotating seal support structure in accordance with this invention does not require holes in the adjacent turbine disks for attachment purposes.

The axial support for a single curved shell bolted to the adjacent disks is provided by both the axial stiffness of the disks and the spacer between disks. Since the disks are generally circular plates which are inefficient axial load carrying members, less axial meridional load can be maintained in a bolted single shell than in an unbolted lenticular shell, and under the same operating conditions, the single shell experiences greater circumferential stress.

Since the stationary segmented portion of the seal has a controlled response to thermal cycle changes, the overall characteristic of the seal is controlled seal clearances during acceleration of an engine followed by a period when the seal clearances slowly approach the steady state clearance and a fairly constant clearance of the sealing members during deceleration with no rubbing of mating seal surfaces due to differences in thermal growth at any time in the cycle.

Since both the inner shell and the outer shell are one piece annular members, their assembly into a double annular structure is done in the following manner. The inner or smaller diameter shell is cooled and the outer or larger diameter shell is heated until the outside diameter of the butt face **62** of the inner shell is less than the inside diameter of the end ridge **58** of the outer shell. By way of example, if the shells are stainless steel having a diameter of approximately 30 inches, and the end ridge height is approximately 100 mils, a temperature difference between the inner and outer shell of approximately 1,000° has been found sufficient to allow the described joining to be accomplished.

Although the invention has been described with respect to preferred embodiments thereof, it should be understood to those skilled in the art that the foregoing and other changes in the form and detail thereof can be made therein without departing from the spirit and the scope of the invention.

Having thus described typical embodiments of our invention, that which we claim as new and desire to secure by Letters Patent of the United States is:

1. In a gas turbine engine having an axial centerline, a rotatable gas seal support structure having a toroidal shape which is lenticular in cross section, the structure comprising:

a curved annular outer shell which is unpenetrated by bolt holes and has a raised ridge along each of its circular end surfaces and is symmetrically disposed about the axis so that during rotation of the structure about the axis, the center of the outer shell tends to move away from the axis and the distance of separation between the two ridges along the axis tends to decrease; and

a curved annular inner shell which is unpenetrated by bolt holes and has a butt face along each of its circular edge surfaces and is positioned between the raised ridges of the outer shell so that during rotation of the structure the center of the inner shell tends to move away from the axis and the distance of separation between the two butt faces along the axis tends to increase.

2. The invention according to claim 1 including means attached to one of the adjacent turbine wheels for preventing relative rotational motion between the turbine wheel and the double annular shell.

3. The invention according to claim 1 wherein the curved outer shell supports a knife edge member of a seal, the knife edge cooperating with a land member of the seal which is attached to a stationary member of the gas turbine.

4. In a gas turbine engine having a pair of adjacent, rotatable, blade retaining, wheels with each wheel having an axially extending and a radially extending containing surface symmetrically disposed about the centerline axis of the engine, a rotatable gas seal support structure having a toroidal shape which is lenticular in cross section, the structure comprising an outer annular shell which is curved concavely from the axial centerline and has two circular end surfaces, and an inner annular shell which is curved convexly from the axial centerline and has two circular edge surfaces, the inner of said edge surfaces being held in axial restraint by a corresponding outer end surfaces, the two annular shells being axially and radially contained by the support surfaces of the pair of wheels, the shells having no holes therethrough to accommodate axial load bearing attachment means between the structure and the wheels.

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