July 3, 1962 R. J. CURTIS ETAL 3,042,365

BLADE SHROUDING

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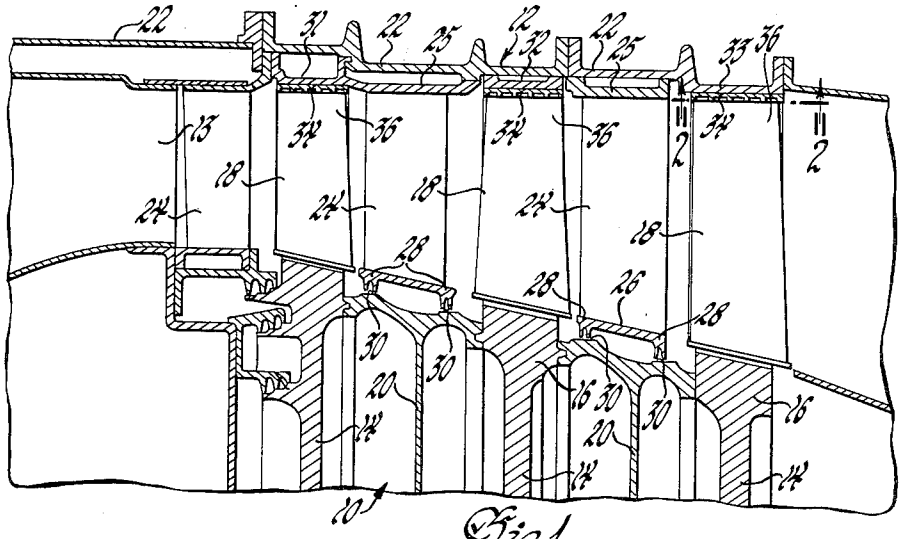


Fig. 1

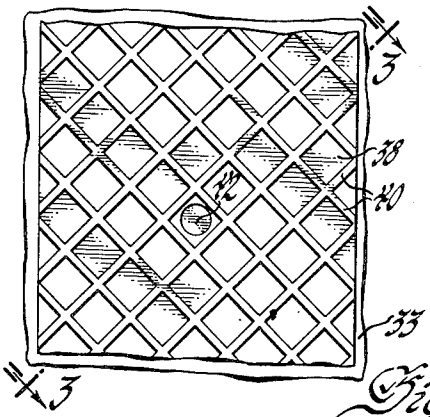


Fig. 2

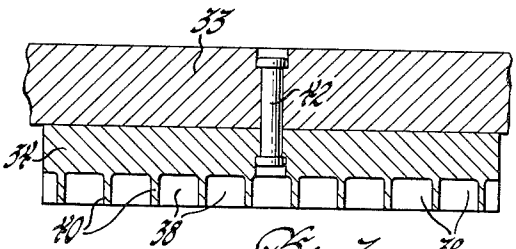


Fig. 3

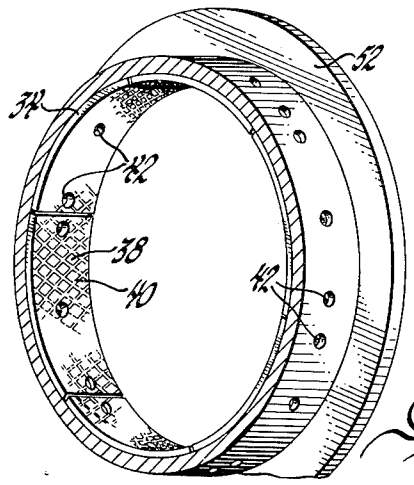


Fig. 4

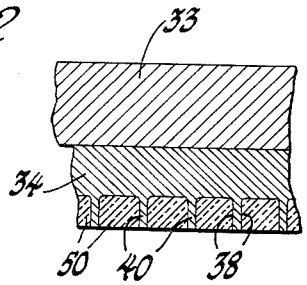


Fig. 5

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BLADE SHROUDING

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This invention relates to turbine engines, and more particularly to a blade tip seal for turbines and compressors.

Generally, a turbine is comprised of a rotor and a housing which respectively carry one or more blade rows. Since the gases driving the turbine are extremely hot, the first and second stages of rotor blades are normally of a very high temperature oxidation-resistant metal, such as a nickel-base alloy, while the later stages are of a somewhat lower temperature oxidation-resistant alloy, such as stainless steel. The annular rotor shrouds for the initial stages of the turbine section should be of extremely high temperature-resistant materials comparable to those of the turbine blades since the temperatures attained from the flow of hot gases often are in excess of 1600° F.

The leakage of gases between the rotor blade tips and the shroud rings is one of the largest single sources of energy loss in turbine engines. The amount of leakage obviously depends upon the amount of operating clearance between the rotor blade tips and the shroud rings, which in turn depends upon the rigidity and dimensional stability of the turbine. Dimensional instability is inherent in turbine operation as a result of differential thermal expansions, warpages and elastic deformations. Conventional shroud rings are unable to accommodate such instability; thus they are initially installed with such high degrees of clearance that excessive gas leakage occurs under some operating conditions. An attempt to reduce the clearance to the minimum for any given number of identically manufactured turbines will result in the binding of the rotor blade tips on the inner periphery of the shroud rings and, consequently, the destruction of some of the turbines when the rotor blades expand during operation. Predetermination of the clearance is not feasible, as even identically manufactured turbines exhibit operating variances in dimensional stability.

A principal object of our invention is to increase the efficiency of gas turbines by reducing air leakage past the turbine blade tips.

Another object of our invention is to construct a shroud ring that is inherently adapted for safe operation at a minimum clearance with respect to a radially aligned row of turbine blades.

The invention is also applicable to compressors, particularly where high temperatures are involved.

Preferably, in accordance with the present invention, an annular ring of readily abradable material is placed as a lining on the inner surface of a shroud ring in radial alignment with a row of turbine rotor blades. During operation of the turbine, the rotor blades expand and the tips of the rotor blades wear away the readily abradable shroud lining, thereby maintaining minimum clearance between the tips of the blades and the annular radially aligned ring. The surface of the shroud lining has indentations therein which form an open-faced pattern of intersecting ridges thereon.

Further objects, features and advantages of the present invention will become apparent from the following description of a preferred embodiment thereof and from the drawings, in which:

FIGURE 1 is a fragmentary sectional view of the turbine of a gas turbine engine;

FIGURE 2 is a fragmentary sectional view along the line 2—2 of FIGURE 1;

FIGURE 3 is a sectional view along the line 3—3 of FIGURE 2;

FIGURE 4 is an axonometric view of an annular shroud ring having the subject type clearance material secured to its inner cylindrical periphery; and

FIGURE 5 is a fragmentary sectional view similar to FIGURE 3 illustrating a modification.

Referring now more in detail to the drawings, FIGURE 1 is a fragmentary sectional view of a typical gas turbine which is comprised generally of a rotor 10 having a housing 12 circumferentially surrounding it. Motive fluid is supplied by combustion apparatus 13. The rotor is comprised of a series of circular, axially-aligned disks 14. The disks are flanged on their outer cylindrical periphery 16 and have serrations therein (not shown) into which rotor blades 18 are fitted. The flanged disks 14 containing the rotor blades 18 are separated by flanged circular disks 20 or separators of smaller diameter, and all the disks are secured to a common shaft (not shown).

The cylindrical casing 12 surrounding the rotor is comprised of several rings 22 each having a row of inwardly radially projecting stator vanes 24 mounted therein. The stator vanes 24 are located between the rows of rotor blades 18 and extend toward the outer surface of the rotor separator disks 20 from an outer shroud 25. Gas leakage between the tips of the stator vanes and the rotor 10 is reduced by labyrinth type seals 28 on the inner shroud 26 of the stator vanes engaging lands 30 on the outer circumferential surface of the spacer disks 20.

A fixed shroud is provided around each rotor stage. Several types of shroud arrangements are shown in FIGURE 1. The rotor tip shroud 31 for the first stage is integral with the stator vane assembly. The shroud 32 for the second stage is a ring independent of the stator vane assembly. The casing ring 22 provides the third stage rotor shroud 33. Shrouds 31 and 32 may be segmented, and likewise shroud 33, if the case is split longitudinally.

The inner cylindrical surface of each shroud ring is lined with a readily abradable clearance material 34 which is in radial alignment with the rotor blades. Coaction of the rotor blade tips 36 with the abradable material 34 during operation of the engine maintains the desired minimum clearance.

The surface of the clearance material exposed to the abrasions of the blade tips is provided with regular indentations 38 which form an open-faced pattern of upstanding lines or ridges 40 on the surface of the clearance material. The open-faced pattern thus formed in the surface of the clearance material reduces the resistance to abrasion thereof due to decreased cross-sectional area at the surface. Additionally, the depressions or indentations of the pattern further provide cavities in which the displaced or abraded metal can collect.

One such pattern which can be employed in this manner is shown in FIGURES 2, 3, and 4. Regular rectangular indentations 38 in the surface of the clearance material 34 form two series of parallel upstanding ridges or lines 40 which intersect one another at an angle of about 90°. The ridges or grid lines project upwardly from the base of the indentations in the clearance material at generally right angles to the surface of the clearance material. The two series of upstanding ridges 40 intersecting one another form the open-faced grid on the surface of the clearance material, the grid thereby being integral with the underlying base of clearance material.

Any high temperature oxidation-resistant, readily abradable material can be employed as a clearance mate-

rial for the present invention. Materials such as nickel and silver have provided particularly satisfactory results and other materials having similar characteristics can be employed, including stainless steel and nickel-base alloys which, for example, have been heat treated to a suitable degree of hardness.

The clearance material contemplated by this invention can be made as a plurality of segments which are separately secure to the inner periphery of the annular shroud ring, as shown in FIGURE 4, or it can be made as an entire annular ring of clearance material to be secured to the inner periphery of the shroud ring, if the shroud ring is continuous. In some instances it may be advantageous to form such an open-faced pattern on the inner surface of the shroud ring itself, should the material thereof have satisfactory abrasion properties.

The pattern can be formed in the surface of the clearance material in any manner which is suitable for the particular material concerned, such as stamping, hobbing, casting, hot roll forming, electroforming, photochemical etching, spark erosion, etc. Electroforming can satisfactorily be employed to form an open-faced grid, such as described above, on a nickel clearance material.

The clearance material can be secured to the shroud ring in any convenient manner and satisfactory results have been obtained when the clearance material was riveted to the shroud ring such as shown in FIGURES 3 and 4. The rivets **42** were depressed from the inner surface of the grid which was exposed to the turbine blades so that abrasion of the grid by the turbine blades did not also abrade the rivet heads.

FIGURE 4 shows an annular continuous shroud ring **52** with clearance material **34**, in segments, fixed thereto by rivets **42**.

Best results are obtained when the ridges **40** are disposed at an angle of about 45° to the direction of blade tip travel. This is believed to be due to improved shearing action of the blade tips on the ridges.

In some instances, it has been found that the open-faced grid pattern, although satisfactory, caused some degree of turbulence at the surface of the grid interfering with the efficiency of the turbine. In such instances, it may be desirable to fill the indentations of the pattern with a readily abradable refractory vitreous enamel. The abradability of the clearance material is not substantially impaired, yet free flow of gases over the surface of the grid is permitted and turbulence of gases passing thereover is inhibited. Such a structure is illustrated in the fragmentary view of FIGURE 5, in which the abradable filling is indicated by the numeral **50**.

Although the preferable dimensions of the grid pattern employed will vary due to variances in abradability of clearance material as well as to differences in overall size of the shroud, satisfactory abrasion characteristics have been obtained when the rectangular depressions are 1/16 to 3/16 inch square, spaced 0.010 to 0.020 apart and with a depth of approximately 0.03–0.10 inch. The overall thickness of the clearance material, including the base, will vary dependent upon the overall clearance between the blade tips and the turbine shroud.

Although this invention has been described in connection with certain specific examples thereof, no limitation is intended thereby except as defined by the appended claims.

We claim:

1. The combination of a rotatably mounted rotor member having a plurality of radially projecting blades thereon, a casing having an inner surface circumferentially surrounding said rotor member, a portion of said inner surface being in radial alignment with said rotor blades, and an annular lining of abradable clearance material secured to said radially aligned inner circumferential surface, said annular lining having an inner circumferential surface exposed to said blades of said rotor, said inner circumferential surface being provided with two series of generally longitudinally, parallel, integral ridges thereon, said two series of ridges intersecting one another generally at an angle of 90° so as to form an open-faced grid pattern with regular indentations between the ridges, and a vitreous enamel filling the said indentations to provide a substantially smooth surface, said open-faced grid pattern being oriented on said inner circumferential surface of said annular lining so as to coact with the tips of said rotor blades with the angle between the ridges and the direction of blade movement about 45°, thereby forming a seal therewith.

2. The combination of a rotatably mounted rotor having a plurality of radially projecting blades thereon, a casing having an inner surface circumferentially surrounding said rotor, a portion of said inner surface being in radial alignment with said rotor blades, and an annular lining of abradable clearance material fixed to said radially aligned inner circumferential surface, said annular lining having an inner circumferential surface exposed to said blades of said rotor, said inner circumferential surface being provided with two series of generally longitudinal, parallel, integral ridges thereon which have a width of about 0.01 to 0.02 inch, said two series of ridges intersecting one another generally at an angle of 90° so as to form an open-faced grid pattern with regular generally square indentations between the ridges, said generally square indentations being approximately 1/16 to 3/16 inch in width and having a depth of approximately 0.03 to 0.10 inch, and a vitreous enamel filling the said indentations to provide a substantially smooth surface, said open-faced grid pattern being oriented on said inner circumferential surface of said annular lining so as to coact with the tips of said rotor blades with the angle between the ridges and the direction of blade movement substantially 45°, thereby forming a seal therewith.

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