

June 4, 1963

F. W. W. MORLEY ETAL

3,092,393

LABYRINTH SEALS

Filed Jan. 8, 1959

2 Sheets-Sheet 1

FIG. 1.

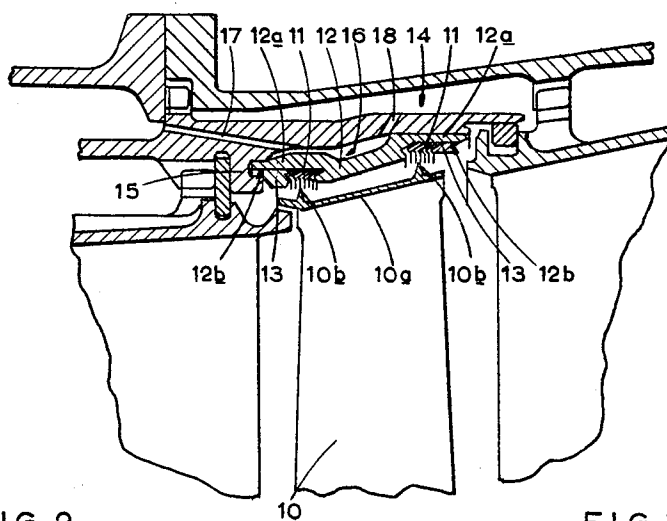


FIG. 2.

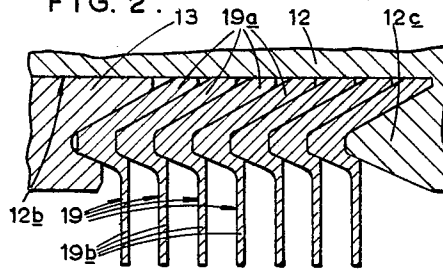


FIG. 3.

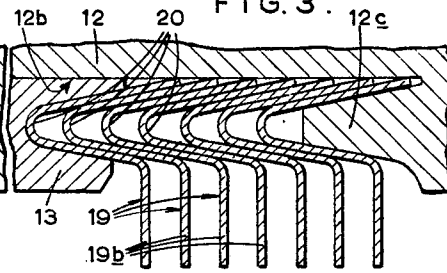


FIG. 5.

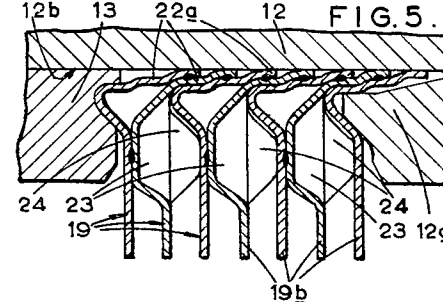
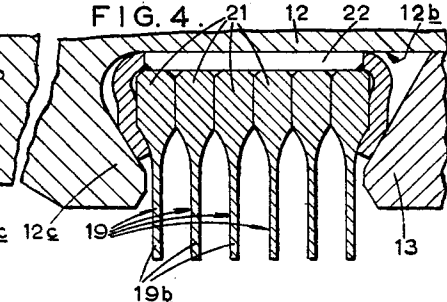


FIG. 4.



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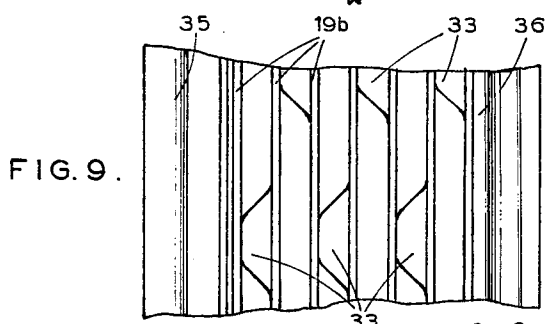
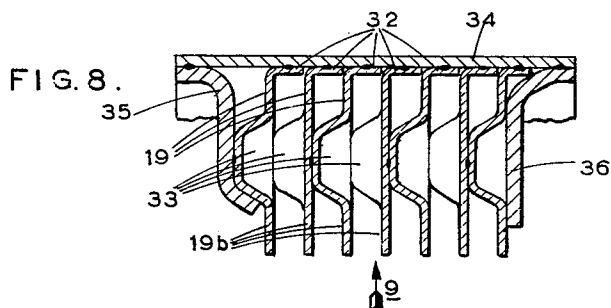
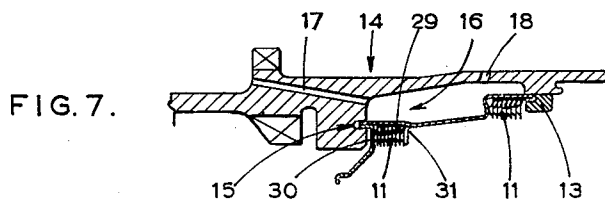
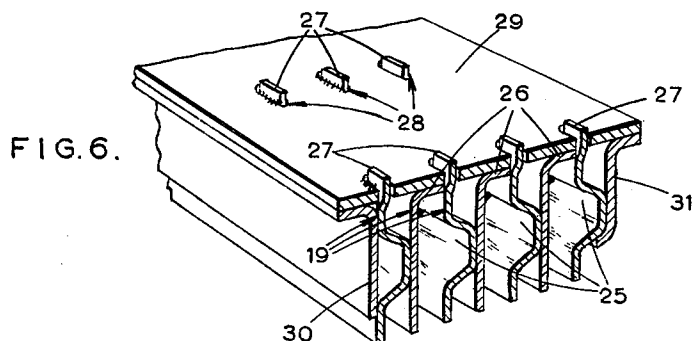
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LABYRINTH SEALS

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15 Claims. (Cl. 277-16)

This invention is for improvements in labyrinth seals of the type which are used to prevent leakage of a fluid between a rotating member and an adjacent stationary member.

Such seals frequently consist of a series of annular fins or projections carried by one or both the members the edges of which are in close proximity to the other member or to like fins or one or more projections on the other member.

According to this invention the sealing member is built up of a plurality of annuli of metal strip each initially separate, or in the form of a continuous spiral mounted as a stack and axially spaced apart at their peripheral sealing edges.

Preferably the annuli are carried by the stator only and co-operate with one or more annular projections on the rotating member, and are of softer metal or one having a lower melting point than these latter projections so that if rubbing occurs it will be these metal annuli which will be worn away.

Thus a tip shroud of a turbine blade of an internal combustion turbine engine may carry one or more annular projections each co-operating with a stack of annuli carried by the surrounding structure to form a gas seal between the tip platform and the surrounding structure.

The annuli of the stack may be secured together by mechanical means or by brazing, welding, resin bonding or the like. The metal from which the annuli are formed is preferably of the order of 2 to 6 thousandths of an inch in thickness, but for some applications where high pressures and/or temperatures are experienced a thicker metal may be found to be desirable.

The spacing means can comprise deformations in each annulus. The deformations are preferably in the portions of the annuli remote from the sealing portions.

The deformations formed in one annulus can be spaced circumferentially with respect to the deformations formed in the adjacent annulus or annuli.

Alternatively the spacing means can comprise deformations formed in alternate annuli only. The intermediate annuli (i.e. the ones lying between the alternate deformed annuli) may in this case, be of substantially uniform section.

The stack of annuli can, for example, be supported in and by an annular housing of substantially U-section.

The stacks of annuli are preferably so mounted in their housing that they can be readily replaced.

In an internal combustion turbine engine one or more stacks of annuli may be carried by a housing attached to the structure surrounding the turbine blade and a supply of cooling air may be provided to cool the housing. Thus an annular cooling chamber may be formed between the housing and the surrounding structure remote from the side of the housing which carries the stack and air may be passed through this cooling chamber.

A method of making the annuli comprises forming a continuous strip to the desired cross-section by extruding, drawing or rolling the strip, winding the formed strip continuously round a mandrel so that the wider surfaces of the strip lie in substantially radial planes to form a spiral of annuli. If separate annuli are employed the

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wound strip is cut axially of the mandrel so as to form the desired plurality of separate annuli.

Some embodiments of this invention will now be described with reference to the accompanying drawings in which:

FIGURE 1 is a section through part of a turbine rotor assembly of a gas turbine engine, incorporating sealing means constructed in accordance with the present invention;

FIGURES 2 to 5 are sections to a larger scale of various constructions of sealing means;

FIGURE 6 is a perspective view of another construction of the sealing means;

FIGURE 7 is a part section through a turbine stator assembly to the same scale as FIGURE 1;

FIGURE 8 is a section to a larger scale of another construction of the sealing means; and

FIGURE 9 is a developed view in the direction of arrow 9 on FIGURE 8;

In FIGURE 1 is shown part of a turbine rotor of a gas turbine engine, the rotor comprising a row of rotor blades 10, each blade being provided with a shroud portion 10a at its radially outer end, said shroud portions 10a each having a pair of axially-spaced outwardly-directed circumferentially-extending ribs 10b.

Each of the ribs 10b co-operates with one of a pair of axially-spaced sealing members 11 secured to a ring 12 which surrounds the shroud portions 10a of the rotor blades 10 and is spaced radially therefrom.

The ring 12 is of substantially frusto-conical form and is provided at each end with an axially-extending portion 12a having an inwardly facing annular recess 12b in which is received the sealing means 11, said sealing means 11 being retained against axial movement by a retaining ring 13 fitted in and welded to the axially-extending portion 12a.

Ring 12 is secured to the surrounding stator structure, indicated generally at 14, by having the left-hand axially-extending portion 12a received in an open-ended axially-facing channel 15 formed in the stator structure 14 and by having the right-hand axially-extending portion 12a tackwelded along its edge to the stator structure 14.

A circumferentially-extending chamber 16, formed between the ring 12 and the stator structure 14, is supplied with a flow of cooling air through a series of drilled passages 17 provided in the stator structure 14, said cooling air flowing out of the chamber 16 through a further series of drilled passages 18.

One form in which the sealing means 11 may be constructed is shown in FIGURE 2 and comprises a stack of thin metallic annuli 19. Each of the annuli 19 has an axially-thickened portion 19a at its outer radial periphery, and an axially thin sealing portion 19b. The axially thin sealing portion 19b is preferably of, say, 6"/1000 thickness. The thickened portion 19a of each annulus 19 is substantially V-shaped in cross section and is received in the corresponding portion of the adjacent annulus. The stack of annuli 19 is assembled in the ring 12 by having the thickened portions 19a co-operating with the inwardly-facing recess 12b, the stack of annuli being restrained from axial movement by having one end abutting a wedge-shaped shoulder 12c, formed on the ring 12, and having the other end abutting the retaining ring 13.

FIGURE 3 shows a construction of a sealing means 11 similar to that shown in FIGURE 2. Each annulus 19 is formed from a constant thickness material of, say, 6"/1000 thickness the outer periphery of each annulus member 19 being provided with a circumferentially-extending corrugation 20 of substantially V-shaped cross-section. The corrugation 20 of each annulus 19 is received in the corresponding corrugation 20 of the adja-

cent annulus. The stack of annuli 19 is assembled in the ring 12 in a manner similar to that described with reference to FIGURE 2.

In FIGURE 4 is shown a further form of construction of a sealing means 11, each annulus 19 is provided with an axially thickened portion 21, the thickened portions 21 abutting one another. The stack of annuli may be retained in the ring 12 in the manner previously described or may be clamped together by means of a U-section clamping ring 22, the whole assembly then being retained in the ring 12.

In the constructions shown in FIGURES 2 to 4 it will be appreciated that the thickened portions 19a, 21 and the corrugations 20 serve to space the sealing portions 19b axially with respect to one another.

FIGURE 5 illustrates a further construction of the sealing means 11, in which each annulus 19 is again formed from a constant thickness material and is provided with an axially directed flange 22a at its outer periphery.

The sealing portions 19b of the annuli 19 are spaced axially apart by means of axially-directed depressions or dimples 23 and 24 both formed on alternate annuli 19. The depressions or dimples 23 are arranged to abut the adjacent annulus 19 immediately to the left hand side of the depression or dimple 23, and the depressions or dimples 24 are arranged to abut the adjacent annulus 19 immediately to the right hand side of the depressions or dimples 24. The annuli 19 against which the depressions or dimples 23 and 24 abut are not provided with depressions or dimples.

Each annulus 19 which is provided with the depressions or dimples 23 and 24 is secured to the adjacent non-dimpled annulus 19, against which the depressions or dimples 23 abut, by means of a spot weld provided at the trough of each depression or dimple 23. The flange 22a of the non-dimpled annulus 19 is arranged to overlap part of the flange 22a provided on the annulus 19 containing the depressions or dimples 23 and 24, the two flanges 22a being seam welded together along their overlapping portions.

In this way the annuli 19 are fastened together in pairs, and each pair of annuli 19 is connected to the adjacent pair by having the axially-directed flange 22a of one pair overlapping the axially-directed flange 22a of the adjacent pair. The axially directed flanges 22a are seam welded, or brazed, together along their overlapping portions. The seal assembly is then retained in the ring 12 in a manner similar to that described with reference to FIGURES 1 to 4.

FIGURE 6 shows a perspective view of a similar construction to that just described with reference to FIGURE 5. In this construction each annulus 19 is provided with a series of depressions or dimples 25. The depressions or dimples 25 on alternate annuli 19 are staggered circumferentially with respect to the depressions or dimples 25 formed on adjacent annuli 19.

Each annulus 19 is provided with an axially directed flange 26 at its outer periphery, and the flange 26 is provided with a pair of saw-cuts in the region of each depression or dimple 25. The portion of the flange lying between each saw-cut is bent radially outwards to form a series of tangs 27 each of which protrudes through a slot 28 formed in the surface of a ring 29 surrounding the outer periphery of the annuli 19.

The tangs 27 serve to locate the annuli 19 circumferentially and adjacent annuli 19 are fastened together by means of spot welds which are provided at the troughs of the depressions or dimples 25. The flanges 26 are seam welded to the ring 29. Also welded to the ring 29 are two end plates 30 and 31 which serve to strengthen the seal assembly. The tangs 27 can be welded or brazed to the ring 29 to prevent leakage, from between each pair of annuli 19, through the slots 28.

The ring 29 and the two end plates 30 and 31 may

form the main structural parts of a pre-fabricated sheet metal ring structure illustrated in FIGURE 7. The pre-fabricated sheet metal structure is retained in the stator structure 14 in a manner similar to that of ring 12 and as described with reference to FIGURE 1.

FIGURES 8 and 9 illustrate another form of sealing means 11 in which each annulus 19 is provided with an axially-directed flange 32 at its radially outer periphery and a series of depressions or dimples 33. The depressions or dimples 33 protrude from the face of each annulus 19 in the opposite direction to the axially-directed flange 32, and the depressions or dimples 33 on each annulus 19 are spaced circumferentially with respect to the depressions or dimples 33 provided on adjacent annulus 19 (seen more clearly in FIGURE 9).

Each annulus 19 is connected to a ring 34 by having its axially directed flange 32 welded thereto and is fastened to the adjacent annulus 19 by means of spot welds provided at the troughs of the depressions or dimples 33.

The stack of annuli 19 are clamped between two end rings 35 and 36 which are L-shaped in cross-section and which are welded to the ring 34.

The annuli 19 may be made by forming a continuous strip of thin metal to the desired cross section, by known methods of drawing, rolling or extruding, and then winding the formed strip continuously around a mandrel so that the wider surfaces of the strip lie in substantially radial planes.

The coiled strip is then cut axially of the mandrel to form a plurality of separate annuli which are then stacked together.

By having the sealing means 11 constructed of thin metal strip of the order of 6"/1000 thickness, the clearance between the sealing portion 19b and the rotatable ribs 10b of the shroud portion 10a is not so critical as with previously known types of seals. If the ribs 10b come into rubbing contact with the sealing portions 19b during operation, part of the sealing portions 19b will melt due to the heat set up by friction and the ribs 10b will therefore cut their own path in the sealing portions 19b.

It will be appreciated that if the two parts of the sealing means 11 do not rub together no damage will be done to the ribs 10b. If the annuli 19 becomes damaged to a degree which entails their replacement, then the tack-welds securing the ring 12 to the stator structure 14 can be machined away and the ring 12 may then be withdrawn from the stator structure 14 so that the damaged stack of annuli 19 can be replaced by a new stack.

In each of the arrangements shown in the drawings the separate annuli can be replaced by a continuous spiral of annuli.

We claim:

1. In apparatus comprising a rotor member and a stator member, the combination of a labyrinth seal carried by one of said members and which comprises a plurality of annuli of metal strip which are axially spaced apart from each other at their peripheral sealing edge portions, said portions being plane, and at least one sharp annular rib which is carried by the other of said members in sealing relationship with said annuli, said rib being more sturdily constructed so as to form its own path in the annuli if rubbing therebetween occurs.

2. An apparatus as claimed in claim 1 in which the annuli have a thickness between 2/1000 and 6/1000 of an inch.

3. In apparatus comprising a rotor member and a stator member, the combination of a labyrinth seal carried by one of said members and which comprises a plurality of annuli of metal strip each having a peripheral sealing edge on a plane border, distance pieces formed integrally with at least some of said annuli and arranged to space the annuli axially apart from each other at their peripheral sealing edges, and said annuli adjacent said edges being radially disposed, at least one rib carried by the

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other of said members and in sealing relationship with said annuli, said rib being constructed of such greater mass than that of an annulus as to form its own path in the annuli if rubbing therebetween occurs without damage to the rib.

4. A seal as claimed in claim 3 in which the annuli carry enlarged portions at their edges remote from the sealing edges which act as distance pieces.

5. A seal as claimed in claim 3 in which the annuli are bent adjacent their edges remote from their sealing edges to abut each other, such bent portions acting as distance pieces.

6. In apparatus comprising a rotor member and a stator member, the combination of a labyrinth seal carried by one of said members and which comprises a plurality of substantially planar annuli of metal strip having circular peripheral sealing edges and at least some of which are provided with deformations remote from said edges which serve to space the annuli axially apart from each other at and adjacent their peripheral sealing edges, and at least one rib which is carried by the other of said members in sealing relationship with said annuli, said rib being of sufficient mass and so constructed to form its own path in the annuli if rubbing therebetween occurs.

7. A seal as claimed in claim 6 in which only alternate annuli are deformed to provide distance pieces to hold the annuli apart.

8. A seal as claimed in claim 6 in which the deformations on one annulus are spaced circumferentially from those on adjacent annuli.

9. In apparatus comprising a rotor and a stator, the combination of a labyrinth seal carried by the stator and which comprises a plurality of annuli of thin metal strip having circular peripheral sealing edges and adjacent planar areas which are axially spaced apart from each other a distance not greater than about three times their thickness, and at least one circumferential rib which is carried by the rotor in sealing relationship with said annuli, said rib being more substantially formed so as to make its own path in the annuli if rubbing therebetween occurs.

10. A seal as claimed in claim 9 in which the sealing

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annuli are of a softer metal than that of the rib on the rotor.

11. A seal as claimed in claim 9 in which the sealing annuli are of a metal having a lower melting point than that of the rib on the rotor.

12. In apparatus comprising a rotor member and a stator member, the combination of a labyrinth seal carried by one of said members and which comprises a channel-shaped ring and a plurality of generally planar annuli of metal strip having circular peripheral sealing edges and mounted in said ring, means spacing said annuli from each other at least at their peripheral sealing edges, and at least one circumferential rib carried by the other of said members in sealing relationship with said annuli, said rib being sufficiently hard to cut its own path in the annuli if rubbing therebetween occurs.

13. A seal as claimed in claim 12 in which the sealing annuli are bent to form flanges which abut laterally against and are integrally fixed to the bottom of the ring channel.

14. A seal as claimed in claim 13 in which at least some of the annuli have tongues which fit into slots in the base of the channel and locate the said annuli.

15. A seal as claimed in claim 12 comprising means for applying cooling fluid to the outside of the ring to cool the latter and the annuli.

References Cited in the file of this patent

UNITED STATES PATENTS

580,049	Heim et al.	Apr. 6, 1897
1,536,014	Junggren	Apr. 28, 1925
1,642,085	Pochobradsky	Sept. 13, 1927
1,708,044	Baumann	Apr. 9, 1929
2,573,530	Zallea et al.	Oct. 30, 1951
2,711,577	Leach	June 28, 1955
2,871,038	Comery	Jan. 27, 1959
2,886,351	Heard	May 12, 1959
2,963,307	Bobo	Dec. 6, 1960

FOREIGN PATENTS

1,145,388	France	May 6, 1957
663,386	Great Britain	Dec. 19, 1951