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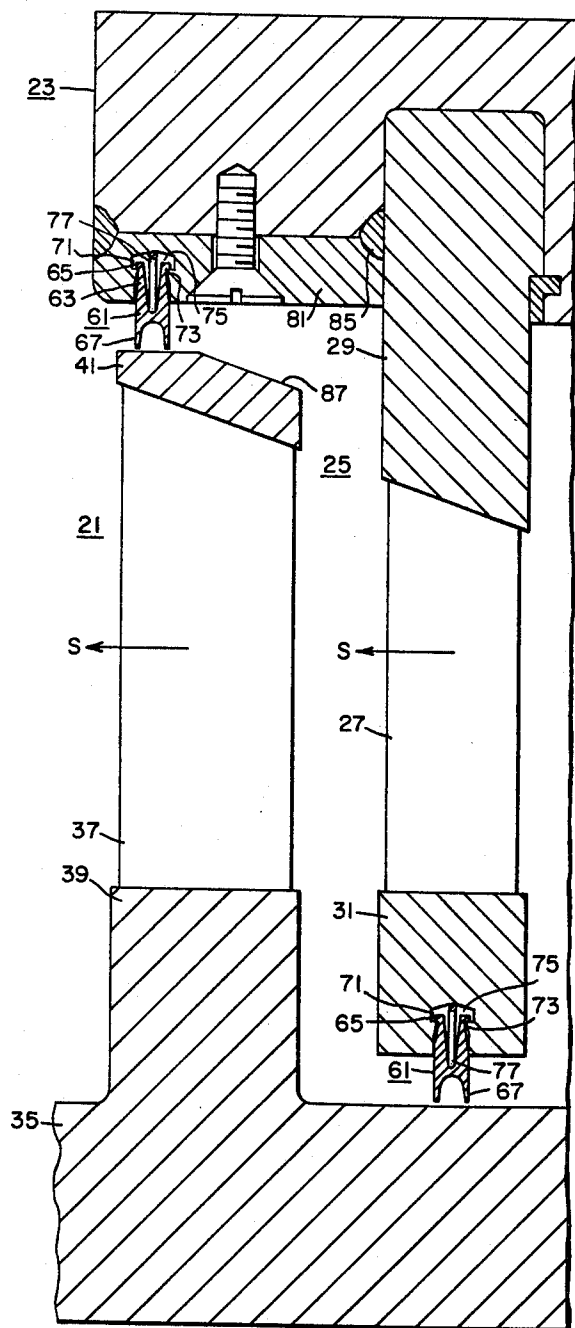
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3,501,246

AXIAL FLUID-FLOW MACHINE

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2 Sheets-Sheet 1



WITNESSES:

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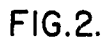
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AXIAL FLUID-FLOW MACHINE

2 Sheets-Sheet 2



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3,501,246

AXIAL FLUID-FLOW MACHINE

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13 Claims

ABSTRACT OF THE DISCLOSURE

A turbine 21 (FIG. 1) having a readily removable snap-on vapor-leakage seal 61 interposed in the space between the rotor 35 and the diaphragm 25 and its support 23. The seal may be made up of a plurality of arcuate coextensive segments or strips (FIGS. 2 through 6), each segment having yieldable legs 63 which snap into a grooved opening 71 in the diaphragm 25 or its support 23 as required. The segments 61 may be fed into the opening 71 by compressing the legs 63 and pushing the section radially into the opening 71 with a snap-in action. The seal segments are movably disposed in the opening and are urged outwardly by a spring 77 into firm engagement with the lips of the opening so that the seal seals itself against leakage.

BACKGROUND OF THE INVENTION

This invention relates to axial fluid-flow machines such as turbines and compressors and has particular relationship to turbines of the elastic-fluid operated type, such as steam turbines. An axial fluid-flow machine has a plurality of expansion stages, each stage including an annular array of rotating blades carried by a rotor shaft and an annular array of stator blades or vanes through which the fluid flows in directed paths. It is necessary that leakage of this fluid around the directed paths through the spaces between the rotor and stationary parts be suppressed and this invention concerns itself with suppression of this leakage. While this invention is, in the interest of concreteness, disclosed herein as embodied in a steam turbine, the scope of this invention is intended to extend to other axial fluid-flow machines to the extent that this invention is applicable to such machines.

A steam turbine has a plurality of stages including rotor means having an annulus of rotating blades and a stationary part or stator which includes an annulus of diaphragms or stator blades and their support. The stator blades cooperate with the rotor blades to direct the steam into driving relationship with the rotor blades at each stage. The steam then expands into the succeeding stage to produce a like driving operation. There is space between the rotors and the stationary parts through which vapor may undesirably escape with resulting loss of power and efficiency and it is necessary to interpose loss-leakage seals between these parts. Such seals are sometimes referred to in the art as labyrinth seals.

In accordance with early teachings of the prior art, followed for many years, caulked-in sealing segments or strips are provided between the rotor and stationary parts. In such seals the caulking material becomes corroded by the hot vapor and, particularly in the case of a steam turbine, from the moisture which condenses from the steam. The seals are locked-in by the corrosion products and when it is necessary to replace these seals, they must be removed by costly machining processes. An additional high-cost item is involved in the installation of the seals. The sealing strips must be machined in place to achieve the necessary clearances and this task must frequently be performed by hand in the field where the turbine is to be used rather than at the manufacturing plants.

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In accordance with later teachings of the prior art, each sealing segment or strip is held in a lateral key-way-like groove in the stationary parts of the turbine. In this case the groove must be provided in corrosion-resistant material, typically stainless steel. Because of the form which the groove must have and the necessity for self-sealing of the seal, this material cannot be installed as a liner bolted or rim welded to a carbon steel base. The stationary parts in which these prior-art seals are installed either must be cast as a whole from the corrosion-resistant material with the groove in the casting, or the carbon-steel base must be clad with the corrosion-resistant material and the cladding machined to produce the grooves and related structures. Both expedients are costly and time consuming.

It is an object of this invention to overcome the disadvantages of the prior art and to provide a turbine with a low-cost vapor-leak sealing means which shall be readily installed and readily removable, shall not become locked-in by corrosion products, and shall not require that substantial parts of the turbine be composed of corrosion-resistant material cast or overlaid at a high cost.

SUMMARY OF THE INVENTION

In accordance with this invention a turbine is provided which has snap-in seal means. The seal includes an annular array of arcuate segments or strips having resilient legs which may be snapped into an annular groove having projections to receive and hold the legs. The strips may be snapped into grooves either in the rotor blades or in the stationary parts of the turbine but preferably are in the stationary parts. The provisions of the sealing segments in the rotary parts of the turbine would subject the sealing segments to high dynamic stresses because of the high speeds (3600 r.p.m. typically) at which these parts rotate. Typically the sealing means includes annular grooves or slots in the stationary parts into which the annular array of arcuate sealing strips or segments are snapped. Each strip is inserted in its groove by compressing the resilient legs at one end of the strip, inserting the strip in the groove and then progressively compressing the legs of the strip and pushing it into the groove. The legs should extend beyond the rim of the groove which bounds the space between each rotor blade and the stationary parts adjacent to it. This mode of inserting the strips circumferentially requires that the stationary part of the turbine be formed of two abutting halves through the ends of which the strips are inserted as taught by Patent 3,309,095 granted to Gate et al. on Mar. 14, 1967 and assigned to Westinghouse Electric Corporation. Alternatively the segments may be inserted or snapped in radially by compressing the strip progressively along its length and inserting the strip like a tire is mounted on a hub of an automobile wheel.

The strips may fit tightly in the groove and may be held therein by the resilience of the legs or the strips may be dimensioned so that they have play in the groove and may be urged outwardly into sealing relationship with the associated rotor blade shroud by a spring. The spring, which may be of the garter type, may be pushed into the groove like the strips or it may be attached to fishing wire and pulled through. In either case the stator must be formed in halves as taught by Gate et al.

The spring has several advantages. It urges the legs of the strips outwardly into engagement with the lips of the groove. The legs being resilient engage the lips under pressure, sealing the strips themselves against leakage. To enhance this self-sealing, the boundary of the groove adjacent the lips of the groove may taper inwardly. The spring also permits the strips to yield when, as a result of eccentricity of the rotor shaft, the rotor bows toward the tips of the seal; the strips return to

sealing relationship with the rotor under the force of the spring when the rotor returns to its normal concentric running position. The spring also locks the strips in the groove and the strips may be readily unlocked by removing the spring.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of this invention, both as to its organization and as to its method of operation, together with additional objects and advantages thereof, reference is made to the following description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a fragmental view in longitudinal section showing a stage of a turbine in accordance with this invention;

FIG. 2 is a fragmental isometric view of a sealing-strip segment of the turbine shown in FIG. 1;

FIG. 3 is an isometric view showing two abutting and overlapping sealing-strips illustrated in FIG. 2;

FIG. 4 is an enlarged transverse view of the above sealing strip arrangement;

FIG. 5 is a view in transverse section showing the vapor sealing strip of the apparatus shown in FIG. 1 and presenting, for the purpose of aiding in the practice of this invention and not with any intention of limiting the scope of the invention in any way, typical dimensions of such a strip;

FIG. 6 is a fragmental view in section showing a modification of this invention;

FIG. 7 is a fragmental view in section showing another modification of this invention;

FIG. 8 is a fragmental view in section showing still another modification of this invention; and

FIG. 9 is a fragmental view in section showing still another modification of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The apparatus shown in the drawings is a part of an axial-flow elastic-fluid utilizing machine, for example a steam turbine 21. As shown in FIG. 1 the turbine 21 has an outer casing or supporting ring structure 23 of circularly cylindrical shape which is formed by abutting semi-circular halves (not shown) mating with each other as disclosed by Gate et al. above. As shown in FIG. 1 the turbine has a motive-fluid expansion stage including a stationary vaned diaphragm structure 25 having an annular row of radially extending vanes 27 (only one shown) peripherally attached to the supporting ring 23. The vanes 27 extend between an outer ring 29 secured to the supporting ring 23 and an inner ring 31. The rings 29 and 31 are composed of corrosion-resistant material. The above described structure may be called the stationary part of the turbine.

As shown in FIG. 1 the expansion stage of the turbine also includes a rotor having a shaft 35. An annular row or array of rotatable blades 37 (only one shown) extend from circumferential rims 39 (only one shown) of the shaft outwardly into the annular flow passage through which flows motive fluid S designated by arrows. The blades 37 are bounded by an annular shroud 41. The turbine 21 may include a number of expansion stages 27-37, although only one stage is shown, and described as embodying this invention; it is contemplated that, to the extent desired, the other stages may incorporate this invention.

The shroud 41 is spaced from the supporting ring or casing 43 and each inner ring 31 is spaced from the shaft 35 of the rotor and it is necessary that the leakage of steam through these spaces throughout each expansion stage, which would reduce the flow through the vane 27 and introduce undesirable cross currents, be suppressed. This purpose is achieved in accordance with this invention with sealing means including in the case of each seal a plurality of coextensive arcuate sealing

strips or segments 61 of fork-like cross section which extend from the stationary part of the turbine into sealing relationship with the rotor. Each strip 61 has resilient legs 63 hook-shaped at the ends 65. The tines or prongs 67 of the fork-like structure extend from the strip opposite the legs 63. The legs 63 are removably secured in the stationary parts 25 of the turbine 21 and the tines 67 extend into closely sealing engagement with the opposite rotor surfaces. Typically the spacing between the tips of the tines 67 and the surface of the rotor (typically of shaft 35 and shroud 41) may be about .035 inch.

Cross-sectional dimensions of a typical sealing strip or segment 61 are presented in FIG. 5. The strip may be formed of two abutting parts 61a and 61b whose cross sections are substantially mirror images of each other and which may be joined by a weld 62 along the arcuate dimension, for example with an electron beam. The strip 61 is composed of a corrosion-resistant material such as 300-series stainless steel.

The inner ring 31 is composed of corrosion-resistant material and the strips or segments 61 which make up each seal extends from an annular groove 71 in the ring 31 to the shaft 35. The strips or segments 61 are successively inserted in the opening 71. Each strip may be inserted by compressing the legs 63 progressively along the strip and as the legs are compressed inserting the compressed legs radially into the groove 71 much like a tire is inserted in the rim of an automobile wheel hub. The strip 61 may also be inserted circumferentially by compressing the legs 63 at the leading end and inserting the strip in the opening 71 (in each abutting half of the ring 31) and thereafter progressively compressing the legs 63 along the strip and pushing or thrusting it into the opening 71. The opening 71 is provided with projections 73 in which the hook-like ends 65 engage. The strips 61 extend in an annulus around the periphery of the ring 31. The arcuate strips 61 forming the annulus may be formed in a manner to abut or overlap each other at their ends by rabbeting or both abut and overlap as shown in (FIG. 3).

Preferably the groove 71 is dimensioned so that there is play radially for the strips 61. Typically the radial width of the space 75 between the inner ends of the legs 63 and inner boundary of the groove 71 is about .100 inch. The strips 61 are urged outwardly into sealing engagement with the shaft 35 by a spring 77 which may be of serpentine shape extending along the groove 71 as best shown in FIG. 2. The spring 77 may be thrust into the groove 71 or it may be pulled through by a fishing wire. The spring 77 permits the strip 61 to retract, when urged to do so by rubbing of the shaft 31 which may occur due to bowing of the shaft. The strip 61 then returns when the shaft straightens.

The legs 63 extend radially beyond the rim of the opening 71. The spring 77 causes the walls of the strips 61 to engage the walls of the groove 71 and to seal the strip 61 against self-leakage.

Coextensive sealing segments 61 are also provided between the supporting ring 23 and the shroud 41. Typically the body of the ring 23 is composed of carbon steel. Since it is essential that the sealing segments 61 and spring 77 shall not be corroded by the steam or by the hot condensate condensed from the steam, the ring 23 is provided with an annular corrosion resistant liner ring 81 for the seal. The liner 81 may be secured by a rim weld 85 to the carbon steel base of the ring 35 and may also be bolted to the base. The liner 81 is provided with an annular groove 71 in which an annular array of sealing strips 61 similar to the strips in the inner ring 31 is inserted. The strips 61 are in sealing relationship with the shrouds 41. Typically the liner ring 81 may have a thickness of about 1/2 inch.

The forked strip 61 has particular advantage when mounted to seal against leakage between a shroud 41 having a tapered surface 87 and the stationary parts of

the turbine 21. During operation the rotor 35-37-41 expands substantially (typically up to $\frac{3}{8}$ inch). The seal 61 may then become displaced by differential expansion with reference to the shroud 41 so that its sealing tips 67 are in part over the surface 87. One of the tines 67 may then not be in sealing relationship with the shroud 41 but the other still provides a seal.

The seal shown in FIG. 6 includes strips or segments 91 having outer serrations 93 and a corresponding inwardly serrated groove 95.

The seal shown in FIG. 7 includes a supporting structure for the strips or segments 103 in the form of an annular ring 105 of corrosion-resistant material which is secured to the base 107 by welding or the like. The ring 105 has a projecting portion with an inwardly serrated groove 109 in which the strips 103 are snapped.

The strips or segments 111 shown in FIG. 8 have more than two tines 113 and are supported on an annular ring 114 having an outwardly serrated projection 115 over the outside of which the inwardly serrated legs 117 of the strips 111 snap. The projection 115 has a groove 119 for a spring 121.

The strip 131 of FIG. 9 is supported similarly to the strip 61 but is urged outwardly by a garter spring 133.

The following summary may aid in the understanding of this invention.

In the prior-art turbines, the sealing strips or segments are caulked to minimize steam leakage between stationary and rotating parts of a turbine. The strips become locked in by corrosion products. To replace the seals, they are frequently removed by machining. Original installation requires machining of the strips in place to obtain proper clearances—a task performed by hand-fitting when installed in the field.

In accordance with this invention a snap-in sealing means including snap-in strips or segments 61 is provided and no caulking is used. The grooves 71 instead of being straight sided and/or dove-tailed to permit the upset caulking strip to lock are, in the seal according to the invention, serrated on each side of the grooves 71 or have projections. Spring action against the serrations resiliently holds the seal in place and also seals against loss steam flow through the seal.

With the spring-back feature which is desirable, the strips 61 or segments which are abutted or overlap are short, typically 20" for a 160" diameter stationary part 23. An overlapping rabbeted matched joint (FIG. 3) is preferred to reduce end-gap leakage and the groove 71 must permit radial movement when a rubbing of the strips 61 occurs. Without the spring back feature, up to 180° strips 61 can be installed.

Because the seal is not solid within the groove 71 it cannot be "frozen in" by corrosion, and therefore is readily removable.

Since the resilient legs 63 of the strips 61 are longer than their penetration into the groove 71, the seal can be collapsed to release it from the serration. The two seal edges produce a symmetrical cross section which facilitates roll-bending into the proper diameter. They also produce an axially insensitive seal. As long as one edge remains on the sealing area, there is a seal (see shroud 41).

Separate springs 77 or 121 are not required if the spring-back feature is not desired. Many types of springs can be used—a garter spring 121 for example or a serpentine shape of wire. The snap-in seal can be entirely contained within mechanically attached erosion shields that afford the erosion protection required in the high-moisture regions of high-pressure and low-pressure turbines. There is no other readily removable or spring-back seal which has this advantage.

The seal according to this invention is dimensioned for proper clearance before installation.

While preferred embodiments of this invention have been disclosed herein many modifications thereof are feasible.

I claim as my invention:

1. An elastic-fluid utilizing machine including a rotor member having an annular array of rotary blades, a stationary member having an annulus of vanes associated with said rotor member, said rotor and stationary members cooperating to direct a stream of fluid through said blades and vanes, and having relatively movable surfaces defining an annular region between which leakage of said fluid may undesirably take place, an annular groove in at least one said members opening into the surface of said one member defining said region and an annular sealing member of the snap-in type, snapped into said groove and extending across said region to the surface of the other of said member defining said region in loss-leakage sealing relationship, and said sealing member having a pair of resilient legs which are disposed in biased relationship with the sides of the groove.

2. The machine of claim 1 wherein the annular groove is in the stationary member bounding the annular region and extends around the periphery of the stationary member past which the rotor member moves throughout this annular region and the sealing member also extends around the whole periphery of said stationary member throughout the annular region sealing-off one side of said region from the other.

3. The machine of claim 1 wherein the sealing member is made up of a plurality of coextensive arcuate segments.

4. The machine of claim 1 wherein the sealing member is made up of a plurality of coextensive arcuate segments extending around the periphery in abutting relationship with each other.

5. The machine of claim 1 wherein the sealing member is made up of a plurality of coextensive segments extending around the periphery in overlapping relationship.

6. The machine of claim 1 wherein the groove is serrated to receive the sealing member.

7. The machine of claim 1 wherein the sealing member is displaceable radially in the groove and is urged outwardly in sealing relationship with the region by resilient means, said resilient means also locking said member in said groove.

8. The machine of claim 1 wherein the sealing member is fork-like having a plurality of sealing tines in sealing relationship with the region.

9. The machine of claim 1 wherein the stationary member includes a part composed of a non-corrosion-resistant material having secured thereto a liner of corrosion-resistant material, said liner being, over a substantial portion of the surface at which it abuts the non-corrosion-resistant material, metallurgically separate from said non-corrosion-resistant material, the groove and snap-in sealing member extending from said liner.

10. The machine of claim 9 wherein the non-corrosion-resistant material is carbon steel and the corrosion-resistant material is stainless steel.

11. A sealing segment for the machine of claim 1 composed of longitudinal half segments, the cross section of one of said half segments being substantially the mirror image of the other, said half segments being joined by an electron beam weld.

12. The machine of claim 1 wherein the legs have serrations and the grooves have serrations with which the grooves of the legs mate.

13. An elastic-fluid utilizing machine including a rotor member having an annular row of blades, a stationary member having an annulus of vanes associated with said rotor member, said rotor and stationary members cooperating to direct a stream of fluid through said blades

and vanes, and having relatively movable surfaces defining an annular region between which leakage of said fluid may undesirably take place, an annular sealing member of the snap-in type, an annular ring projecting outwardly from one of said members, said sealing member having a pair of resilient legs which snap into a biased relation with said ring, said sealing member being urged in sealing relationship with the region by resilient means, and said sealing member being fork-like and having a plurality of sealing tines in sealing relationship.

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