BRUSH SEALING WITH POTTING COMPOUND FOR ROTARY MECHANISMS

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ABSTRACT
A brush seal for use in a rotary machine includes a rotary component disposed inside a stationary component. A brush sealing system is disposed between the stationary component and the rotary component. The brush sealing system includes a seal housing that contains a matrix of potting compound, coupled to the stationary component. A plurality of bristles is provided, each bristle having a first end embedded in the potting compound and a second end protruding from the seal housing towards the rotary component. The potting compound is formed from a ceramic suitable for use at high temperatures that is capable of bonding to non-metallic bristles.
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BACKGROUND

[0001] The invention relates generally to a brush sealing system, and more particularly to a brush sealing system incorporating a potting compound to hold the bristles of the brush seal.

[0002] The efficiency of a rotary machine used for doing work on a fluid depends upon the internal tolerances of the machine’s components. A loosely-toleranced machine may have a relatively poor fit between internal components and may therefore exhibit poor efficiency due to leakage occurring within the device from regions of high pressure to regions of lower pressure. The traditional approach to this situation is to decrease the amount of clearance on these critical interfaces and to provide mechanisms to seal the gaps that remain.

[0003] For example, compressors and turbines like those found in gas turbine engines may have one or more seals, e.g., labyrinth seals, at the interface between a series of rotating blades disposed within a casing or vane. These seals preserve a pressure differential across the rotating components, e.g., blades, between upstream and downstream sides of the rotary machine. Another example of the use of such a seal is in a bearing sump system to limit the amount of gas required to vent the sump. These seals are often subjected to relatively high temperatures, thermal gradients, and thermal expansion and contraction of the components during various operational stages. For example, the clearance can increase or decrease during various operational stages of the rotary machine. While additional clearance can be used to accommodate such variances, this extra clearance also reduces the efficiency and performance of the rotary machine by allowing additional leakage across the seal.

[0004] Brush seals are one type of seal that may be used between moving components in order to accommodate a certain amount of operationally induced variance in the geometry of the sealed components. A brush seal uses a mass of individual bristles that can individually flex to accommodate geometric variations, but that provide a barrier to flow across the thickness of the bristles.

[0005] In order to operate in high temperature environments, there is a need for improved brush seal systems and components.

BRIEF DESCRIPTION

[0006] In one embodiment of a system as described herein, a rotary machine has a first component and second component, with the second component rotatably disposed with respect to the first component. A brush sealing system is disposed between the first and second components. The brush sealing system includes a seal housing that is coupled to the first component, a plurality of bristles each having a first end and a second end, and a matrix of potting compound disposed on the seal housing. The potting compound is configured to bond to the first end of the bristles and to hold the bristles such that the second end of the bristles protrude from the seal housing toward the second component. The potting compound is a ceramic cement.

[0007] In another embodiment of a brush sealing system as described herein, a first component has a seal housing, and a matrix of ceramic cement potting compound is disposed upon the seal housing. A plurality of non-metallic bristles each has a first end embedded in the matrix and a second end that protrudes from the seal housing toward a second component, the second component being rotatably disposed relative to the first component. The bristles are configured to contact the rotary component to reduce leakage of a pressurized fluid between the first component and the second component.

DRAWINGS

[0008] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0009] FIG. 1 is a diagrammatical view of a rotary machine, e.g., an electrical generator including a plurality of brush seals in accordance with an exemplary embodiment of the described brush sealing system;

[0010] FIG. 2 is a diagrammatical view of a brush seal segment of a brush seal in accordance with the aspects of FIG. 1; and

[0011] FIG. 3 is a diagrammatical view of a brush seal segment in accordance with aspects of FIG. 2.

DETAILED DESCRIPTION

[0012] A brush sealing system will be described herein for use in a rotary machine, for example: an electric generator, a gas turbine, or the like. The brush seal includes a seal housing coupled to a component of the rotary machine that is configured to rotate with respect to another component of the rotary machine. The exemplary seal includes a plurality of bristles coupled to the seal housing by having one end of each bristle embedded into a matrix of potting compound disposed within a seal housing. Specific embodiments of such brush seals suitable for use in higher temperature environments are discussed below with reference to FIGS. 1-3.

[0013] One example of such an environment is in a compressor seal for use with a gas turbine engine, such as an aircraft engine. Although such seals are not located in the hottest portion of the engine, such as those portions exposed directly to combustion products, heat from various hot portions of an operating gas turbine can be conducted to the location of a seal, causing the temperature of the seal and the sealed components to rise. During operation, the temperature of a seal often rises as high as 300 degrees Fahrenheit.

[0014] In addition to experiencing such elevated temperatures during operation, the seal may be exposed to even higher temperatures during the period after engine shut down. During this time period, the hot portions of the engine continue to radiate and conduct heat into the surrounding engine mass as they cool, but there is no airflow through the engine to help carry heat away from the rest of the engine. As a result, the temperature of a compressor seal may actually rise as the hottest engine portions cool down. Seal temperatures can exceed 500 deg Fahrenheit during this period of time typically referred to as “soak back.”

[0015] Such temperatures can have undesirable effects on brush seals. For example, the components that make up a brush seal can break down. While an abrupt catastrophic failure of a seal may not always occur, progressive breakdown by cracking, abrasive wear, or chemical alteration due to elevated temperature and thermal cycling can reduce the usable lifetime of such seals and their components.
To address these issues, brush seals with components capable of remaining intact and stable at higher temperatures can be used. One example of such a seal is described below.

FIG. 1 illustrates an exemplary embodiment of a rotary machine 10 that includes a brush sealing system 11 having two brush seals 12, 14. Brush seal 12 is shown in greater detail in the subsequent figures, discussed below. In accordance with the illustrated embodiment, brush seal 14 is similar to brush seal 12, and the description of brush seal 12 below also serves a description of brush seal 14. In the illustrated embodiment, the rotary machine 10 is an electric generator. However, those of skill in the art will appreciate that other examples of suitable rotary machines may include without limitation: centrifugal compressors, steam turbines, gas turbines, bearings, sumps, and the like. It may also be noted that the applications of the seals and sealing systems described herein are not limited to rotary machines and may be associated with other machines or mechanisms that are sealed against fluid pressure drop during machine operation. For instance, seals for use in oscillating, translating or reciprocating machinery may also make use of the brush seals described herein.

In the illustrated embodiment, the rotary machine 10 includes a stator 16, and a rotor 18 coaxially aligned with the stator 16. The rotor 18 is radially spaced apart from the stator 16 to define a gap 20 between the stator 16 and the rotor 18. Although in the illustrated embodiment, the stator 16 circumferentially surrounds the rotor 18, certain other applications may require the rotor to circumferentially surround the stator. A fluid 21 is disposed in the gap 20 in such a way that the fluid 21 has a pressure drop generally transverse to the gap 20. The pressure drop is generated during operation of the machine 10. The brush seal 12 in accordance with aspects of one embodiment of the system described herein includes a plurality of graphite or carbon bristles 22 configured to contact the rotor 18 to reduce leakage of fluid and also reduce temperature at a seal-rotor interface. The brush seal 12 is explained in greater detail with respect to FIGS. 2 and 3 below.

Referring to FIGS. 2 and 3, the brush seal 12 includes a seal housing 24 coupled to the stator 16 (of FIG. 1). The plurality of bristles 22 are coupled to the seal housing 24 by embedding one end of each bristle into a matrix 42 of potting compound placed within the seal housing. In accordance with one embodiment, each bristle 22 may have a diameter in the range of 0.1 to 1 mils. Typically, the bristles 22 are canted radially at an angle, for example, forty-five degrees, with respect to a radial line through the axis of the rotating component. As known to those skilled in the art, the canting of bristles 22 improves the compliance of the seal with the rotor 18. It will also be understood that in specific applications it may also be desirable to cant the bristles in the axial direction as well (not illustrated).

FIG. 3 shows an exemplary embodiment of a brush seal 12 for use in the rotary machine of FIG. 1. Each bristle 22 includes a first end 34 embedded into the matrix 42 of potting compound. Each bristle also has a second end 36 that extends away from the potting compound toward the rotor 18. In certain exemplary embodiments, the second end of the bristle is configured to contact the rotor 18. In the illustrated embodiment, the seal housing 24 includes a first plate 38 and a second plate 40 that define a cavity between them. The matrix 42 of potting compound is disposed in this cavity between the first plate 38 and the second plate 40. In various exemplary embodiments, the first and second plates 38, 40 may be constructed using a metallic material, a composite material, or a combination of metallic and composite materials. The bristles 22 are held between the first and the second plates 38, 40 and bonded in place by the potting compound.

In one embodiment of a seal as described herein, carbon bristles 22 are used to minimize wear and provide suitable temperature resistance for the bristles. In particular exemplary embodiments, the bristle material can include carbon or graphite. In other exemplary embodiments, the seal material may include other non-metallic materials. In accordance with particular embodiments of the systems described, the diameter of each bristle is maintained in the range of 0.1 to 1 mils so that a clearance of 0.1 mils may be maintained between the brush seal 12 and the rotor 18.

As noted above, a potting compound is disposed within the cavity of the seal housing 24 to form a matrix 42 to retain the first end of the bristles. In order to provide appropriate operational life in the brush seal, it is desirable that the matrix bond effectively to the material of the bristles 22. The matrix is desirably also stable when subjected to the thermal cycling associated with the operation of the rotary machine and sustained temperatures of up to 700 degrees Fahrenheit. In particular, bristle retention in the seal housing is more difficult when non-metallic bristles are used, because they cannot generally be welded or metallically bonded to the seal housing itself.

In one exemplary embodiment, the potting compound includes a ceramic cement that can be cured in place around the bristles to secure the bristles to the seal housing. As used herein, “ceramic cement” refers to an encapsulating adhesive cement produced from essentially inorganic, non-metallic substances.

The matrix is desirably formed from a potting compound suitable for operation at temperatures of up to 700 degrees Fahrenheit without significant loss of mass or change of chemical properties at that temperature. As used herein, the term “stable” will be used to describe a material that experiences a mass loss rate of less than 0.00040 mass fraction per hour when exposed to a given temperature after an initial 50 hours burn-in at that temperature. “Mass fraction” is understood to mean the mass that is lost as a fraction of the initial mass, and may be expressed in units such as grams/gram, or other suitable units. For example, a compound which experienced an initial mass fraction loss rate of 0.00170 per hour for 30 hours at 500 degrees Fahrenheit and whose mass fraction loss rate fell to 0.00020 per hour by the 40th hour at 500 degrees Fahrenheit would be said to be stable at 500 degrees Fahrenheit. By contrast, a compound which experienced an initial mass fraction loss rate of 0.00080 per hour for the first 50 hours at 700 degrees Fahrenheit and whose mass fraction loss rate then leveled off at 0.00060 per hour at 700 degrees Fahrenheit after 50 hours would not be considered stable at 700 degrees Fahrenheit.

Stability is important because at a given operating temperature, a less stable compound has a shorter effective life span than a more stable compound. For instance, a potting compound that loses mass more rapidly may necessitate seal inspection and replacement every 1000 hours of operation at 500 degrees Fahrenheit. While one with a lower mass fraction loss rate may only require replacement every 25000 hours of operation. Furthermore, a compound which is stable at higher temperatures is more resistant to rapid decay due to tempera-
ture spikes or conditions that go beyond the normal operating conditions, such as the soak back experienced after engine shut-down, described above.

[0026] In some applications, for example those involving lubricating oils, the use of metallic bristles in a brush seal can be problematic. Rapid bristle wear leads to the entrainment of bristle particles in the oil, which can lead to wear and reliability issues. Non-metallic bristles are a desirable substitute in such brush seals. Non-metallic bristles also can provide a lower wear rate, a lower hardness, and a smaller bristle diameter than metallic bristles, each of which can reduce bearing damage. Appropriate non-metallic bristles can be made from materials such as carbon fibers and polyaramids such as poly(paraphenylene terephthalate). However, such fibers cannot be attached to the seal housing using the same techniques as metallic fibers, which are typically welded to the housing. The use of an appropriate potting compound to secure and retain the bristles in the seal housing helps to extend the life of the seal. Failure to properly retain the non-metallic bristles can cause similar problems as the loss of metal bristles would. In addition to reducing the effectiveness of the seal, lost bristles can migrate into the machinery and cause undesirable wear and friction within the system. Prior art potting compounds, particularly organic potting compounds tend to be insufficiently stable at temperatures above 500 degrees Fahrenheit for reliable long-term use in the applications described above.

[0027] In addition to being thermally stable, a desirable potting compound will retain adhesion to non-metallic bristles when subjected to operating temperatures in order to inhibit the loss of bristles from the brush. One suitable potting compound is formed by placing a ceramic precursor, in either a liquid or paste form, into the cavity of the seal housing. The precursor wets the perimeter of the end of the bristle within the cavity. The precursor also fills the interstitial volume between the bristles and the seal housing. Once in place, the precursor can be treated by air-setting, chemical-setting, or hydraulic setting to convert the precursor to a ceramic. The choice of setting may be based on the particular binder phase used in the ceramic precursor.

[0028] For instance, in one embodiment air-setting may be used. This technique may be effective when the binder phase is a silicate. Chemical setting may be used when the binder phase is a silicate, a metal phosphate or a magnesium oxysulfate. In various embodiments, the ceramic precursor may also include fillers such as zirconia, silica or alumina.

[0029] One particular embodiment of a suitable potting compound is formed by curing a two-part precursor composition comprised of a sodium silicate solution and a powder of sieved zirconium silicate. The aqueous sodium silicate solution may have a chemical formula of the form Na₂O(SiO₂)ₓ. The zirconium silicate powder may also include traces of crystalline silica and fluorosilicic acid (FC₆H₆(OH)₂O₇H) as a condensation catalyst, as well as traces of crystalline silica. This solution and powder are available commercially from Saueressen of Pittsburgh, Pa. as Saueressen Low Expansion Cement No. 29, Liquid and Powder, respectively.

[0030] In one embodiment, a 50/50 weight ratio of solution to powder is mixed and placed into the cavity of the seal housing. Bristles are then embedded into the cavity. The seal holder is vibrated to de-gas the mixture, and then cured at 140 degrees Fahrenheit for 25 hours. The ceramic potting compound formed by this process was tested and found to be stable at 700 degrees Fahrenheit, and retained adhesion to carbon fiber bristles at those temperatures.

[0031] Other embodiments may make use of different weight ratios of solution to powder, and different curing processes. For example, a mixture of 80% by weight powder to 20 percent by weight solution may be used, and cured for 18-24 hours at room temperature (75 degrees Fahrenheit).

[0032] In addition to providing a means for retaining and securing non-metallic bristles within a brush seal, the use of a potting compound to cement the bristles in place provides certain other advantages that are more difficult to achieve with traditional techniques for bonding bristles to a seal. For example, because each bristle is held at a specific orientation within the matrix of potting compound, the bristles may be mounted at an angle to the radial direction. This allows for the bristles to be canted in both the axial and circumferential directions. Such geometry is especially difficult to achieve in techniques where the bristles are cramped into the seal housing.

[0033] The various embodiments of brush seals and techniques for constructing brush seals described above thus provide a way to achieve greater thermal stability for a potting compound in a seal. These techniques and systems also allow for the use of non-metallic bristles in a brush seal.

[0034] Of course, it is to be understood that not necessarily all such objects or advantages described above may be achieved in accordance with any particular embodiment. Thus, for example, those skilled in the art will recognize that the systems and techniques described herein may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other objects or advantages as may be taught or suggested herein.

[0035] Furthermore, the skilled artisan will recognize the interchangeability of various features from different embodiments. For example, the use of a specific ceramic cement as a potting compound described with respect to one embodiment can be adapted for use with a particular bristle material described with respect to another. Similarly, the various features described, as well as other known equivalents for each feature, can be mixed and matched by one of ordinary skill in this art to construct additional systems and techniques in accordance with principles of this disclosure.

[0036] Although the systems herein have been disclosed in the context of certain preferred embodiments and examples, it will be understood by those skilled in the art that the invention extends beyond the specifically disclosed embodiments to other alternative embodiments and/or uses of the systems and techniques herein and obvious modifications and equivalents thereof. Thus, it is intended that the scope of the invention disclosed should not be limited by the particular disclosed embodiments described above, but should be determined only by a fair reading of the claims that follow.

1. A rotary machine, comprising:
   a first component;
   a second component rotatably disposed with respect to the first component; and
   a brush sealing system disposed between the first component and the second component, comprising:
   a seal housing coupled to the first component;
   a plurality of bristles, each bristle having a first end and a second end; and
a matrix of potting compound disposed upon the seal housing and configured to bond to the first end of the bristles and to hold the bristles such that the second end of the bristles protrude from the seal housing toward the second component, wherein the potting compound comprises a ceramic cement.

2. The rotary machine of claim 1, wherein the potting compound comprises a cured composition of an aqueous sodium silicate solution and a zirconium silicate powder.

3. The rotary machine of claim 2, wherein the potting compound comprises a cured composition with a pre-cure aqueous sodium silicate mass fraction between 15 percent and 60 percent.

4. The rotary machine of claim 2, wherein the potting compound comprises a cured composition with a pre-cure aqueous sodium silicate mass fraction between 40 percent and 55 percent.

5. The rotary machine of claim 1, wherein the potting compound is stable at a temperature of 700 degrees Fahrenheit for at least 10,000 hours.

6. The rotary machine of claim 1, wherein the bristles comprise a non-metallic fiber.

7. The rotary machine of claim 6, wherein the bristles comprise carbon fibers.

8. The rotary machine of claim 6, wherein the bristles comprise a polyaramid fiber.

9. The rotary machine of claim 1, wherein the first component comprises a bearing seal on a gas turbine engine.

10. The rotary machine of claim 1, wherein the first component comprises a sump seal on an engine.

11. The rotary machine of claim 1, wherein the second end of each bristle is configured to contact the second component to reduce leakage of pressurized fluid between the first component and the second component during operation of the machine.

12. A brush sealing system, comprising:

- a first component having a seal housing;
- a matrix of ceramic cement potting compound disposed upon the seal housing; and
- a plurality of non-metallic bristles, each bristle having a first end embedded in the matrix and a second end protruding from the seal housing towards a second component which is rotatably disposed relative to the first component, wherein the bristles are configured to contact the rotary component to reduce leakage of a pressurized fluid between the first component and the second component.

13. The brush sealing system of claim 12, wherein the potting compound comprises a cured composition of an aqueous sodium silicate solution and a zirconium silicate powder.

14. The brush sealing system of claim 13, wherein the potting compound comprises a cured composition with a pre-cure aqueous sodium silicate mass fraction between 15 percent and 60 percent.

15. The brush sealing system of claim 13, wherein the potting compound comprises a cured composition with a pre-cure aqueous sodium silicate mass fraction between 40 percent and 55 percent.

16. The brush sealing system of claim 12, wherein the potting compound is stable at a temperature of 700 degrees Fahrenheit for at least 10,000 hours.

17. The brush sealing system of claim 12, wherein the bristles comprise a non-metallic fiber.

18. The brush sealing system of claim 17, wherein the bristles comprise carbon fibers.

19. The brush sealing system of claim 17, wherein the bristles comprise a polyaramid fiber.

20. The brush sealing system of claim 12, wherein the first component comprises a bearing seal on a gas turbine engine.

21. The brush sealing system of claim 12, wherein the first component comprises a sump seal on an engine.

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