AXIALLY ORIENTED SHINGLE FACE SEAL FOR TURBINE ROTOR AND RELATED METHOD

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ABSTRACT
An axial seal arrangement is provided between a rotor and a stator. The rotor is provided with a first disk having a substantially flat sealing face surface. The stator is provided with a second annular disk surrounding the rotor, supporting proximate ends of a plurality of axially extending, flexible, compliant seal elements arranged in an annular array of plural, circumferentially-overlapping radial layers to thereby provide a tortuous path for radially outward leakage flow.
Figure 1
AXIALLY ORIENTED SHINGLE FACE SEAL FOR TURBINE ROTOR AND RELATED METHOD

BACKGROUND OF THE INVENTION

[0001] This invention relates to sealing structures between a rotating component and a static component typically found in turbomachinery and, more particularly, to an axially-oriented compliant plate seal arrangement including staggered “shingles” that are effective in reducing leakage in a radial direction.

[0002] Dynamic sealing between a rotating shaft, e.g., a turbine rotor, and a casing or housing, e.g., a turbine stator, is an important concern in turbomachinery. Several methods of sealing have been proposed in the past. In particular, sealing based on radially-oriented flexible members has been utilized including seals described as leaf seals, brush seals, finger seals, shim seals, etc.

[0003] A copending, commonly owned application Ser. No. 11/519,044 entitled, “Shaft Seal Using Shingle Members” discloses a sealing configuration where generally radially-oriented compliant plates (referred to as shingles) slide against a smooth, rotating cylindrical surface, i.e., the surface of the rotor.

[0004] There remains a need, however, for a flexible seal between a nonrotating and rotating machine components that provide good high pressure capability as well as good leakage performance.

BRIEF DESCRIPTION OF THE INVENTION

[0005] The present invention provides an axial sealing configuration between a machine rotating component and surrounding machine nonrotating component.

[0006] In one aspect, the present invention relates to an axial seal arrangement between a rotor and a stator comprising: a rotor provided with a first annular disk having a substantially flat annular sealing surface; a stator provided with a second annular disk surrounding the rotor, the disk supporting proximate ends of a plurality of axially extending, flexible, compliant seal elements arranged in an annular array about the rotor and extending axially towards said annular sealing surface.

[0007] In another aspect, the invention relates to an axial seal arrangement between a rotor and a stator comprising: a rotor provided with a first disk having a substantially flat axial sealing surface; a stator provided with a second disk surrounding the rotor, the second disk supporting proximate ends of a plurality of flexible compliant seal elements extending axially towards said axial sealing surface, said seal elements arranged in a plurality of radially spaced, annular and circumferentially overlapping rows to thereby provide a tortuous path for radially outward leakage flow; wherein the stator is provided with axially extending inner and outer rings secured to the second disk, the compliant seal elements located radially between the inner and outer rings.

[0008] In still another aspect, the invention relates to a method of reducing leakage flow between a rotor and a stator comprising: (a) establishing a first radially extending surface on the rotor; (b) establishing a second radially extending surface on the stator; and (c) locating a plurality of axially extending, flexible, compliant seal elements between the first and said second surfaces.

[0009] The invention will now be described in connection with the drawings identified below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a partial side section illustrating an axial sealing configuration in accordance with an exemplary implementation of the invention disclosed herein; and

[0011] FIG. 2 represents a section through the seal of FIG. 1 but illustrating various possible alternative arrays of flexible sealing elements.

DETAILED DESCRIPTION OF THE INVENTION

[0012] In one non-limiting implementation shown in FIG. 1, a rotor or machine shaft 10 is arranged for rotation about a machine or rotor axis A. The rotor 10 is provided with an integral or attached radial disk 12 that is oriented substantially perpendicular to the shaft 10. The disk 12 is formed with a first annular sealing surface 14 that is substantially flat, and that cooperates with remote ends of the compliant shingles in the shingle-face seal described below.

[0013] A stator 16 which surrounds the rotor 10, is formed with an integral or attached annular plate or disk 18 formed with a center opening 20 through which the rotor 10 passes. The annular disk 18 is thus substantially concentric with the rotor and substantially parallel to the rotor disk 12. The disk 18 thus presents a second annular surface 22 (shown to be flat but need not be) opposed to, and axially spaced from, the first annular sealing surface 14. Inner and outer parallel rings 24 and 26 are attached (e.g., by welding) to the stator disk 18 and extend axially towards the disk 12. The rings 24, 26 are substantially concentric with respect to the rotor 10. Between the rings 24 and 26, an array of compliant plate seal elements or shingles 28 are supported from the second annular surface 22. These compliant shingles 28 are arranged in an array of radially-spaced annular layers or rows 30, 32, 34 and 36, best seen in FIG. 2. The respective annular rows are circumferentially offset thus creating the shingled effect. In an at-rest position, the remote ends of the shingles 28 might, in some applications, engage the surface 14 of disk 12, while in other applications, the remote ends of the shingles may be positioned at some nominal distance from the surface 14.

[0014] During operation of the turbo-machine, however, the seal is designed such that, as the rotor moves relative to the stator, the remote ends of the shingles do not engage the annular sealing surface 14, but do come very close to that surface. This prevents wear, heat and debris generation while providing good sealing of the working fluid. This axially-oriented, shingled seal arrangement will provide reduction in leakage from a high-pressure region at the ID of the disk 12 to a low-pressure region at the OD of the disk 12, or vice versa. In this case, the leakage flow starts at the ID of the rotor disk 12, passes between the gap between the inner ring 24 and sealing surface 14 but is impeded by the tortuous path created by the circumferentially-staggered array of shingles 28. The leakage flow finally exits through the gap between the outer ring 26 and the sealing surface 14, to the OD region of the rotor disc/diaphragm, as best seen in FIG. 1. The shingle geometry may be designed such that the free ends of the shingles come close to but do not contact the annular surface 14 during turbo-machine operation. This provides the benefits of non-contact operation such as reduced heat generation. A variety of shingle shapes and cross-sections may be utilized within the scope of this invention, depending on
specific applications and sealing requirements. In addition, it will be appreciated that the seal orientation could be reversed, with the compliant shingles 28 and rings 24, 26, supported on the disk 12, extending axially towards the disk 18.

[0015] The key benefits of the axially-shingled design are:

[0016] 1. In comparison to a cylindrical-shingled configuration, if for any reason, the compliant shingles start to contact the annular sealing surface 14, the resulting heat generation will not be as detrimental from a rotor-dynamic instability standpoint. The location of the heat input is further away from the rotor center line and furthermore, the disk 12 is better able to dissipate the heat.

[0017] 2. In comparison to a brush seal, the shingle face seal can be designed with a large fence height (fence height is the axial gap between the ring 24 (and/or ring 26) and the flat annular surface 14), to accommodate large axial excursions, since the shingles 28 do not rely on the inner and outer rings 24, 26 for radial support. This is an improvement over brush elements that necessitate a small fence height due to their lack of stiffness in the leakage flow direction, which in turn limits their effectiveness in high pressure drop applications.

[0018] FIG. 2 also shows an alternative axial seal arrangement where the seal elements comprise an array of axially oriented “brush bristles” 40, also staggered in both radial and circumferential directions. However, due to the aspect ratio of their cross-sections, the bristles 40 are compliant not only in the axial direction, which is desirable to handle rotor axial excursions, but also in the radial direction, which might be undesirable since this limits the pressure capability of the seal.

[0019] In still another arrangement, also shown in FIG. 2, an axial leaf seal 42 is composed of a plurality of axially extending leaf seal elements 44. Because of the leaf element geometry, these are better suited to handle larger pressure drops, but present larger gaps between adjacent leaves at the seal OD as compared to the seal ID. Furthermore, the leaf seal elements may not be stacked with zero gaps even at the ID as this might result in a high stiffness in the axial direction, which is undesirable.

[0020] Accordingly, the shingled-seal arrangement is presently preferred insofar as it provides not only the necessary radial stiffness to allow high pressure capability, but also the staggered or shingled arrangement of the compliant seal elements 28 pose a significantly greater obstacle to radial leakage flow by reason of the tortuous path created by the shingled arrangement. Furthermore, the seal may be designed for non-contact operation which greatly enhances the seal durability while avoiding heat-related problems.

[0021] It will be understood that in each case, the seal elements 28, 40 and 44 extend substantially axially between the disks 18 and 12, and extend circumferentially 360° about the rotor, and that FIG. 2 is merely intended to illustrate alternative compliant seal arrangements.

[0022] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

What is claimed is:

1. An axial seal arrangement between a rotor and a stator comprising:

- a rotor provided with a first annular disk having a substantially flat annular sealing surface;
- a stator provided with a second annular disk surrounding the rotor, said second annular disk supporting proximate ends of a plurality of flexible, compliant seal elements arranged in an annular array about the rotor and extending axially towards said annular sealing surface.
- The axial seal arrangement of claim 1 wherein said stator is provided with axially extending inner and outer rings secured to said second annular disk, said compliant seal elements located radially between said inner and outer rings.
- The axial seal arrangement of claim 1 wherein said compliant seal elements comprise bristles having round cross-sectional shapes.
- The axial seal arrangement of claim 1 wherein said compliant seal elements comprise plural leaf seal elements.
- The axial seal arrangement of claim 1 wherein said compliant seal elements comprise plural annular rows of seal elements, said plural annular rows offset in a circumferential direction.
- An axial seal arrangement between a rotor and a stator comprising:

- a rotor provided with a first disk having a substantially flat axial sealing surface;
- a stator provided with a second disk surrounding the rotor, said second disk supporting proximate ends of a plurality of flexible compliant seal elements extending axially towards said axial sealing surface, said seal elements arranged in a plurality of radially spaced, annular and circumferentially overlapping rows to thereby provide a tortuous path for radial outward leakage flow;

- wherein said stator is provided with axially extending inner and outer rings secured to said second disk, said compliant seal elements located radially between said inner and outer rings.
- The axial seal arrangement of claim 6 wherein each of said flexible, compliant seal elements has a rectangular cross-sectional shape.
- A method of reducing leakage flow between a rotor and a stator comprising:

(a) establishing a first radially extending surface on the rotor;
(b) establishing a second radially extending surface on the stator; and
(c) locating a plurality of axially extending, flexible, compliant seal elements between said first and said second surfaces.
- The method of claim 8 wherein step (c) is carried out by arranging said compliant seal elements in plural radial layers that are staggered in a circumferential direction.
- The method of claim 9 wherein said flexible, compliant seal elements are composed of shingles, each having a rectilinear cross-sectional shape.
- The method of claim 9 wherein said flexible compliant seal elements are composed of bristles, each having a round cross-sectional shape.
- The method of claim 8 wherein said compliant seal elements are attached to said second surface.
- The method of claim 8 wherein said compliant seal elements are attached to said first surface.

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