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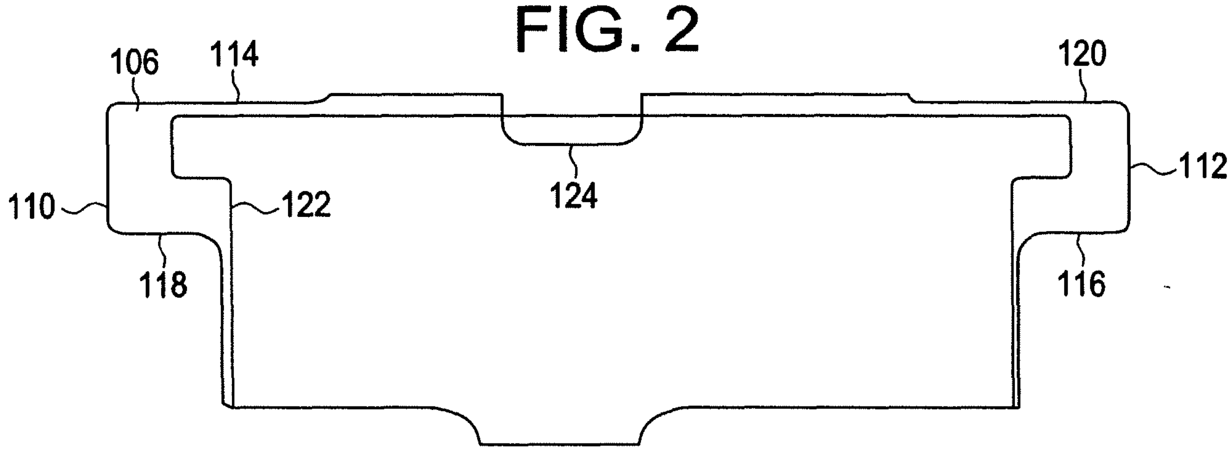
(54) **Gas turbine vane attachment**

(57) Base hooks (110, 112) of a vane (106) includes an approximate two times thicker radial geometry, with dimensioning and tolerancing that results in a line-line to loose fit on the forward OD hook surface (114) and the aft ID hook surface (116). Tolerances thus stack up on the opposite, non-critical surfaces of the hooks (the forward ID hook surface (118) and the aft OD hook surface (120)). The base of the vane (106) is curved to match that of the casing (102). An interface between the vane base and the casing groove (102) includes a metal alloy liner (140). Also, a wear coating is provided on the vane attachment hooks (110, 112). The liner (140) protects the casing groove (102) from wear damage, while the hook coating and the liner (140) provide a wear coupling between the vane base and the casing (102) that provides a barrier between the vane bases and the casing (102) to decrease the wear rate.

FIG. 2



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Description

BACKGROUND OF THE INVENTION

[0001] The subject matter disclosed herein relates to gas turbine engines and, more particularly, to the attachment of vanes within a casing of a compressor of a gas turbine engine.

[0002] Stator vanes located in the back-end stages of a compressor are typically configured as singlets (one airfoil per attachment), and have a square base that includes an attachment hook on the forward and aft sides of the base. The hooks are commonly constructed with a straight geometry such that when they are slid into the radial compressor casing grooves, the resulting reaction load distribution is concentrated at discrete (determinable) point locations or contact zones. This is due in part to the fact that the base of a vane is planar while the casing grooves are curved to some extent. During operation at load, the stators are subject to an unsteady aerodynamic vibratory environment that causes vibration motion to be transmitted to the constraint points in the base hooks. In addition, the responsive mode of vibration can result in a concentration of vibratory stress near these same attachment points. These hook attachment points experience fretting related damage, including fretting wear and fretting fatigue, which significantly shortens the design life of the vane.

[0003] Vanes and case hooks experience fretting wear damage as indicated by stator rock-check measurements and pictures of case hook material degradation upon top-halving a unit. If the stator hook damage becomes excessive before repair, the stator airfoils can clash into the rotating stages in front of the stators, resulting in catastrophic damage to the flowpath components.

[0004] During an outage with the gas turbine not operating, displacement measurements may be performed on the stator attachment bases while pushing the airfoil in a specified direction. These measurements, referred to as a "rock check", indicate the level of hook deterioration associated with the fretting wear and fretting fatigue experienced during operation. If the measured values exceed a specified threshold, then the stators are removed from the compressor. After the required inspection of the compressor discharge casing (CDC) grooves and of the stator attachment hooks, and depending upon the extent of the damage, the casing section can be machined out. After machining, a custom patch ring may then be retrofitted with a custom fit to provide a restored assembly groove for the stators. New stators may then be installed in the patch ring. However, while this solution may provide extended operation capability, it does not address the root cause of the problem. Another stopgap measure is to attach adjacent vanes together in packs through welding or bolting, which again does not address the root cause of the problem.

BRIEF DESCRIPTIONOF THE INVENTION

[0005] According to one aspect of the invention, the base hooks of a vane includes an approximate two times thicker radial geometry of the hooks, with a dimensioning and tolerancing scheme that results in a line-line to loose fit on the forward outer diameter (OD) hook surface and the same on the aft inner diameter (ID) hook surface. Tolerances are thus allowed to stack up on the opposite, non-critical, surfaces of the hooks (i.e., the forward ID hook surface and the aft OD hook surface). The base of the vane is curved to match the curvature of the casing that the base resides in.

[0006] According to another aspect of the invention, a material interface is provided between the vane base and the casing groove. The material interface includes a metal alloy liner that interfaces between the base of the vane and the associated casing in which the vane is disposed. Also, a wear coating is provided on the vane attachment hooks. The liner protects the casing groove from wear damage, while the combination of the hook coating and the liner provide a wear coupling between the base of the vane and the casing. The wear coupling provides a barrier between the vane bases and the casing to decrease the wear rate.

[0007] These and other advantages and features will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWING

[0008] These follows a detailed description of embodiments of the invention by way of example with reference to the accompanying drawings, in which:

[0009] FIG. 1 is a cross-section view of a compressor within a gas turbine engine;

[0010] FIG. 2 illustrates the base of a vane according to an embodiment of the invention overlaid with a vane of the prior art;

[0011] FIG. 3 illustrates the casing for the base of the vane according to an embodiment of the invention overlaid with the casing for the vane within the prior art;

[0012] FIG. 4 illustrates a spring-loaded liner in accordance with an aspect of the invention; and

[0013] FIG. 5 illustrates the base of a vane within a casing groove with the liner of FIG. 4.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Referring to FIG. 1, there illustrated is a cross-section view of a compressor 100 within a gas turbine engine. The compressor includes a discharge case 102 having a number of circular rows or stages 104, wherein each stage 104 has a plurality of vanes 106 that are located around the circumference of the casing 102 within a groove on the inner periphery of the casing 102. As mentioned above, the vanes 106 commonly are slide-in singlets with respect to the groove of the casing 102.

Typically it is the stages 104 located towards the back end of the compressor 100 (i.e., on the right hand side of the compressor 100 when viewing FIG. 1) that experience the most fretting-related damage, as discussed hereinabove. The material of the vanes 106 (particularly those in the back end of the compressor 100) typically comprises a 403cb stainless steel, while the compressor discharge case 102 may typically comprise a 2.25 CrlMo steel alloy material.

[0015] Referring to FIGs. 2 and 3, according to one aspect of the invention, a geometry change to the base hooks 110, 112 of a vane 106 from that of the prior art includes an approximate two times thicker radial geometry of the hooks 110, 112, with a dimensioning and tolerancing scheme that results in a line-line to loose fit on the outer diameter (OD) of the forward hook surface 114 and the same on the inner diameter (ID) of the aft hook surface 116. Tolerances are thus allowed to stack up on the opposite, non-critical, surfaces of the hooks 110, 112 (i.e., the forward ID hook surface 118 and the aft OD hook surface 120). FIG. 2 illustrates the outline of a base of a vane 106 having the geometry features of this aspect of the present invention. FIG. 2 also illustrates the outline of a base of a vane 122 in the prior art, where the vane 106 overlays the vane 122 to illustrate the contrast between the size of the physical features of the hooks of both vanes 106, 122.

[0016] Although not clearly seen in FIG. 2, the base of the vane 106, including the hooks 110, 112, according to an aspect of the present invention has a slight radial curvature to better match the normal curvature of the compressor casing 102. In contrast, the base of the vane 122 of the prior art has no curvature and is straight or planar. An attachment geometry based on curved or radial hooks 110, 112 (instead of planar hooks as in the prior art) with the critical load surfaces (i.e., the forward OD hook surface 118 and the aft ID hook surface 120) thereby achieves a line on line assembly fit, such that the load surfaces of the vanes 106 are established at assembly, minimizing any rigid body relative motion of the hooks 110, 112 to the casing 102, and optimizing the load pressure distribution on the surface of the hooks 110, 112. The optimized load distribution results in the lowest possible pressure placed on the hooks 110, 112, which is the primary parameter in reducing fretting wear.

[0017] The hooks 110, 112 of the vanes 106 of this aspect of the invention are thicker and longer than the prior art designs. The dimensioning and tolerancing scheme for the vane hooks or rails 110, 112 are tighter, allowing for better fit-ups and reduced manufacturing variation. Assembly clearances are increased over that of the prior art for ease of assembly. Because durability of the vanes 106 and the case 102 has been increased, customer down time is reduced.

[0018] FIG. 2 also illustrates a groove 124 formed in the vane 106 of an embodiment of the invention. The groove 124 acts as an error-proofing feature that ensures proper assembly of the vane 106 to the casing 102.

[0019] FIG. 3 illustrates the groove portion 128 of the casing 102 for the base of the vane 106 according to an embodiment of the invention overlaid with the corresponding groove portion 130 of the casing 132 for a vane within the prior art. FIG. 3 illustrates the contrast in size between these features. From FIG. 3 it can be seen that the groove portion 128 of the casing 102 that accommodates the base of the vane 106 has been made larger to accommodate the now larger hooks 110, 112 of the vane 106 according to an aspect of the invention.

[0020] According to another aspect of the invention, a material interface is provided between the base of the vane 106 and the groove 128 of the casing 102. Referring to FIGs. 4 and 5, the material interface includes a pair of spring-loaded liners 140 that interface between the hooks 110, 112 of the base of the vane 106 and the associated groove portion 128 of the casing 102. Fig. 4 illustrates the liner 140 in an unloaded position. In an embodiment of the invention, the liner 140 may comprise a cobalt-based metal alloy that has a thickness of, e.g., 10 mils. The liners 140 may be configured within the casing 102 such that more than one vane 106 (for example, 16 vanes per liner) contacts a single pair of liners 140 within the compressor casing 102. In the alternative, the liner material may comprise a stainless steel with a thermal spray coating on the inner surface of the liner 140. The primary purpose of the liner 140 is to protect the casing groove 128 from wear damage, which is accomplished by the material comprising the liner 140. As seen in FIG. 5, two liners 140 are provided (one for each hook 110, 112) and the liners 140, which are easily assembled in between the hooks 110, 1120 and the casing 102, completely surround the hooks or rails 110, 112 of the base of the vane 106.

[0021] In further accord with an aspect of the invention, a hard-face wear coating may be provided on the surface of the vane attachment hooks 110, 112. The hook coating may comprise a metal alloy, for example, a cobalt-based alloy that may comprise that sold under the trademark Stellite®. The coating may be approximately 5 mils thick and may comprise a thermal spray coating applied by the high velocity oxygen fuel (HVOF) process.

[0022] The hook coating and the liner 140 together provide an improved wear couple for the base of the vane 106 and the casing groove 128. The cobalt-based wear couple provides a barrier between the base of each vane 106 and the casing 102 to decrease the wear rate when compared to the bare 403cb stainless steel vane and 2.25Cr1Mo steel alloy case materials used in the prior art. Also, the improved wear couple provides a wear liner interface to protect the casing material, and provide a load surface for the critical hook surfaces of the vanes. The wear couple liner and the hard-face coating on the hooks 110, 112 provides a long term durable interface in a dynamic environment. Suitable alternative wear coatings include tungsten carbide, chromium carbide, T800, T400, T400C (all cobalt-based materials) or other cobalt-based materials.

[0023] Embodiments of the present invention have been described and illustrated herein for use with stator vanes that are located within a compressor of a gas turbine engine. However, various aspects of the present invention contemplate other types of vanes for use therewith. Also, embodiments of the invention can be retrofitted in the field onto older vanes.

[0024] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

Claims

1. An apparatus, comprising:

> a vane (106) having a base with a hook portion (110, 112) on both a forward facing portion of the base and an aft facing portion of the base; and
> a casing (102) having a groove (128) that is configured to receive the base of the vane (106);

wherein the hook portions (110, 112) each has an overall dimension with respect to a dimension of the casing groove (128) that provides for contact between the vane base at a forward outer diameter (OD) hook surface (114) and at an aft inner diameter (ID) hook surface (116), thereby allowing tolerances to stack up on a forward ID hook surface (118) and an aft OD hook surface (120).

2. The apparatus of claim 1, wherein the casing groove (128) is curved at a predetermined radial amount.

3. The apparatus of claim 2, wherein the vane base is curved at the same predetermined radial amount as that of the casing groove (128).

4. The apparatus of any of claims 1 to 3, further comprising a material interface between the vane base and the casing groove (128).

5. The apparatus of claim 4, wherein the material interface includes a liner (140) that interfaces between the vane base and the casing groove (128).

6. The apparatus of claim 5, wherein the liner (140) comprises a metal alloy.

7. The apparatus of claim 6, wherein the metal alloy comprises a cobalt-based metal alloy.

8. The apparatus of claim 6, wherein the metal alloy comprises a stainless steel with a thermal spray coating on an inner surface of the liner (140).

9. The apparatus of claim 4, wherein the material interface comprises a wear coating disposed on the hook portions (110, 112).

10. The apparatus of claim 9, wherein the wear coating comprises a metal alloy.

11. The apparatus of claim 9, wherein the wear coating comprises a cobalt-based metal alloy.

12. The apparatus of claim 9, wherein the wear coating comprises tungsten carbide or chromium carbide.

13. An apparatus, comprising:

> a vane having a base with a hook portion on both a forward facing portion of the base and an aft facing portion of the base;
> a casing having a groove that is configured to receive the base of the vane; and
> a liner disposed between the vane base and the casing groove.

14. The apparatus of claim 13, further comprising a wear coating disposed on the hook portions.

15. The apparatus of claim 14, wherein the wear coating comprises a metal alloy.

FIG. 1

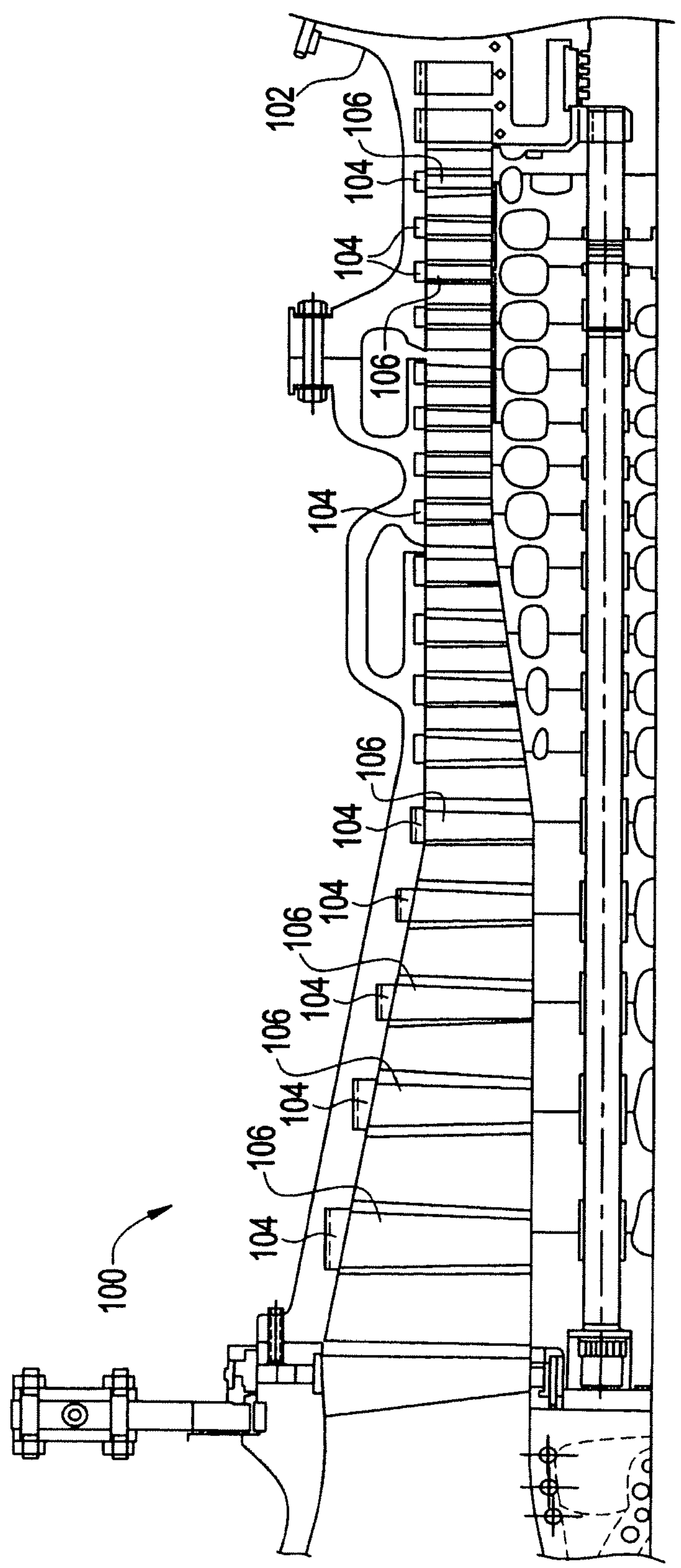

FIG. 2

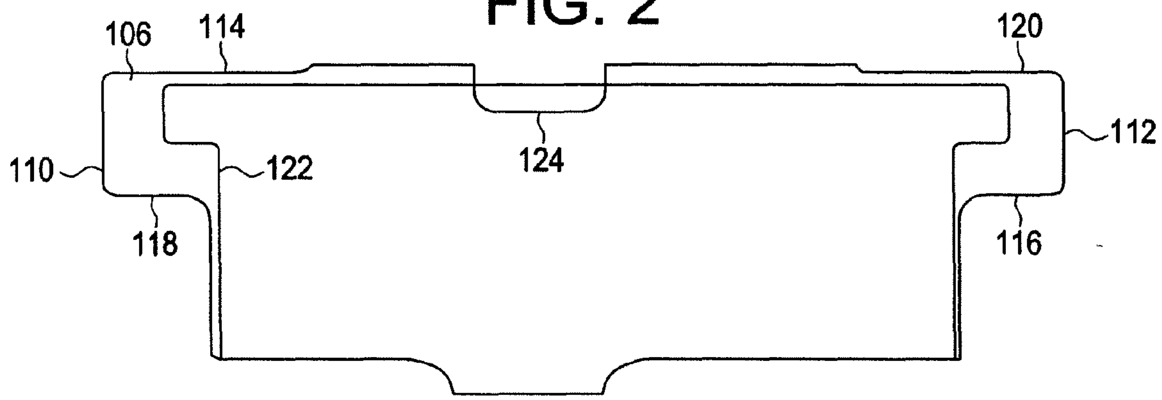

FIG. 3

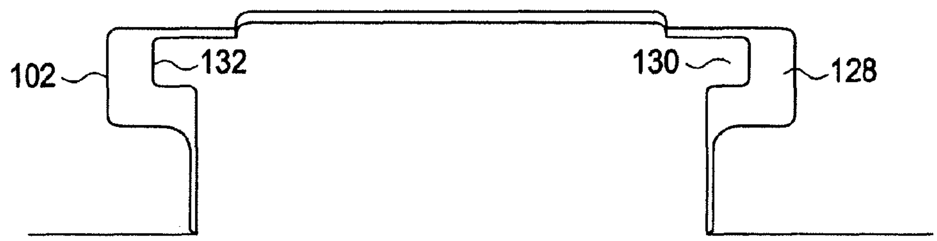

FIG. 4

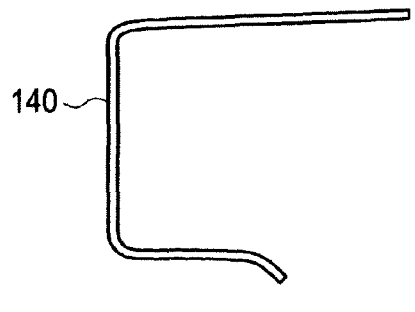

FIG. 5