



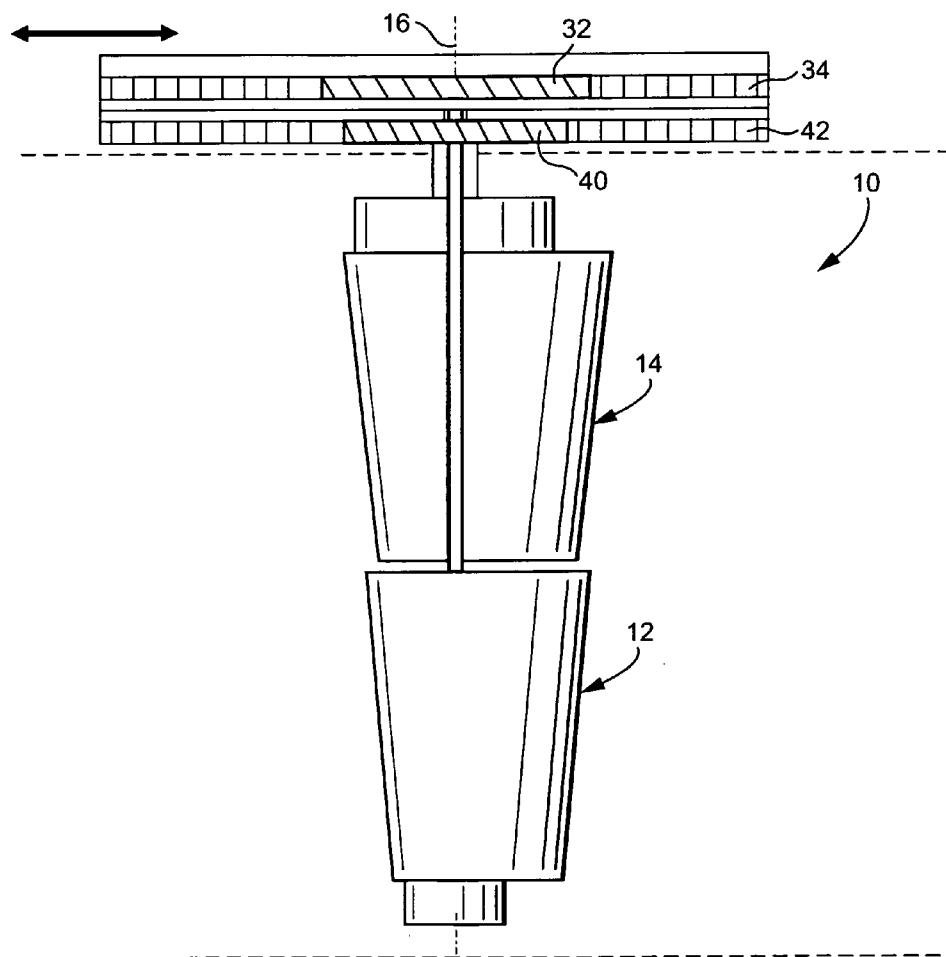
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Martin et al.(10) **Pub. No.: US 2010/0260591 A1**(43) **Pub. Date: Oct. 14, 2010**(54) **SPANWISE SPLIT VARIABLE GUIDE VANE
AND RELATED METHOD**(22) Filed: **Jun. 8, 2007**(75) Inventors: **Nick Martin**, Simpsonville, SC
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Schenectady, NY (US)(21) Appl. No.: **11/808,314**(57) **ABSTRACT**

Accordingly, in one aspect, the invention relates to a variable guide vane for an axial flow compressor comprising: a first radially outer vane section; and a second radially inner vane section; the first and second vane sections angularly adjustable relative to each other about a longitudinal radial axis of the vane.



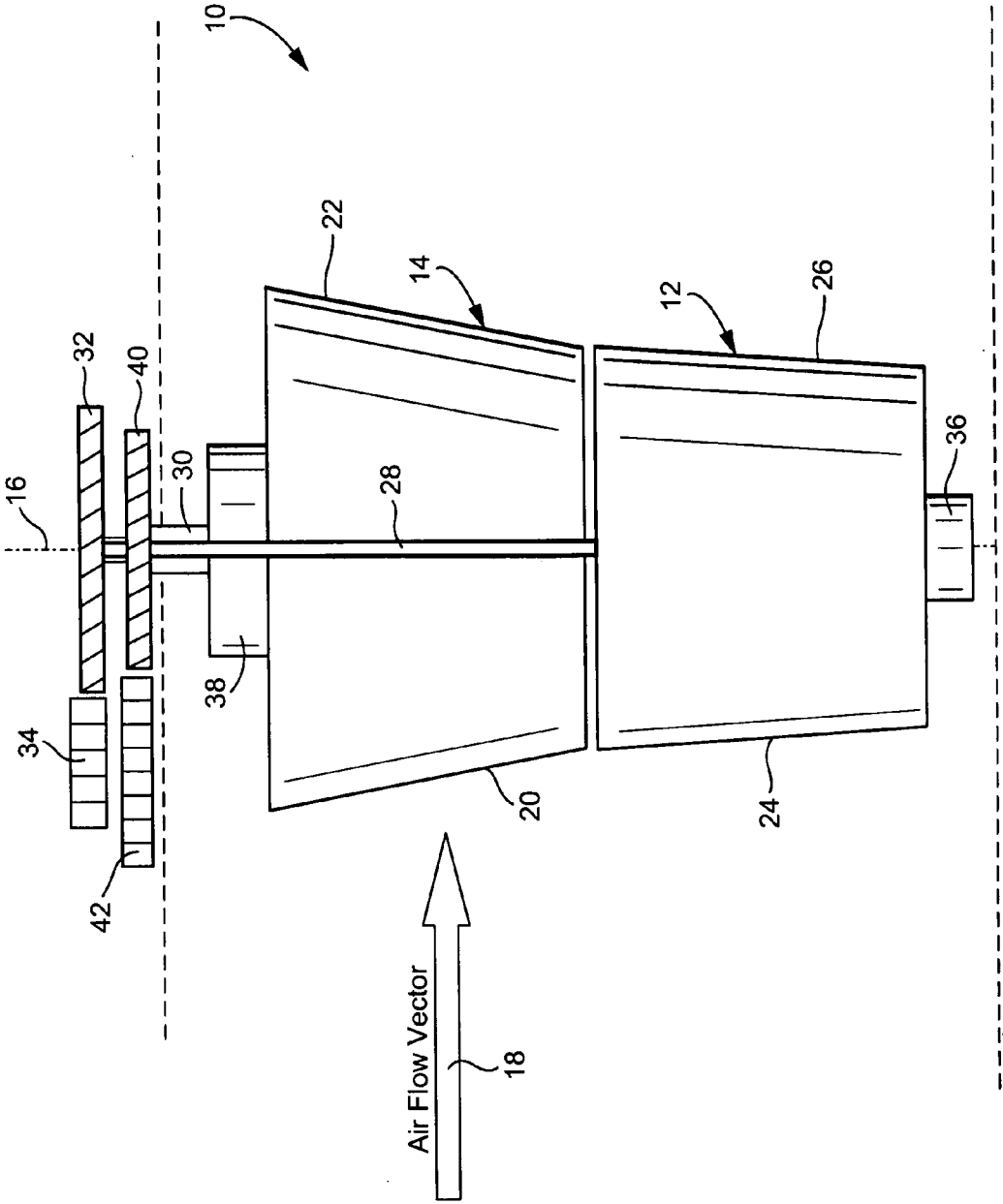


FIG. 1

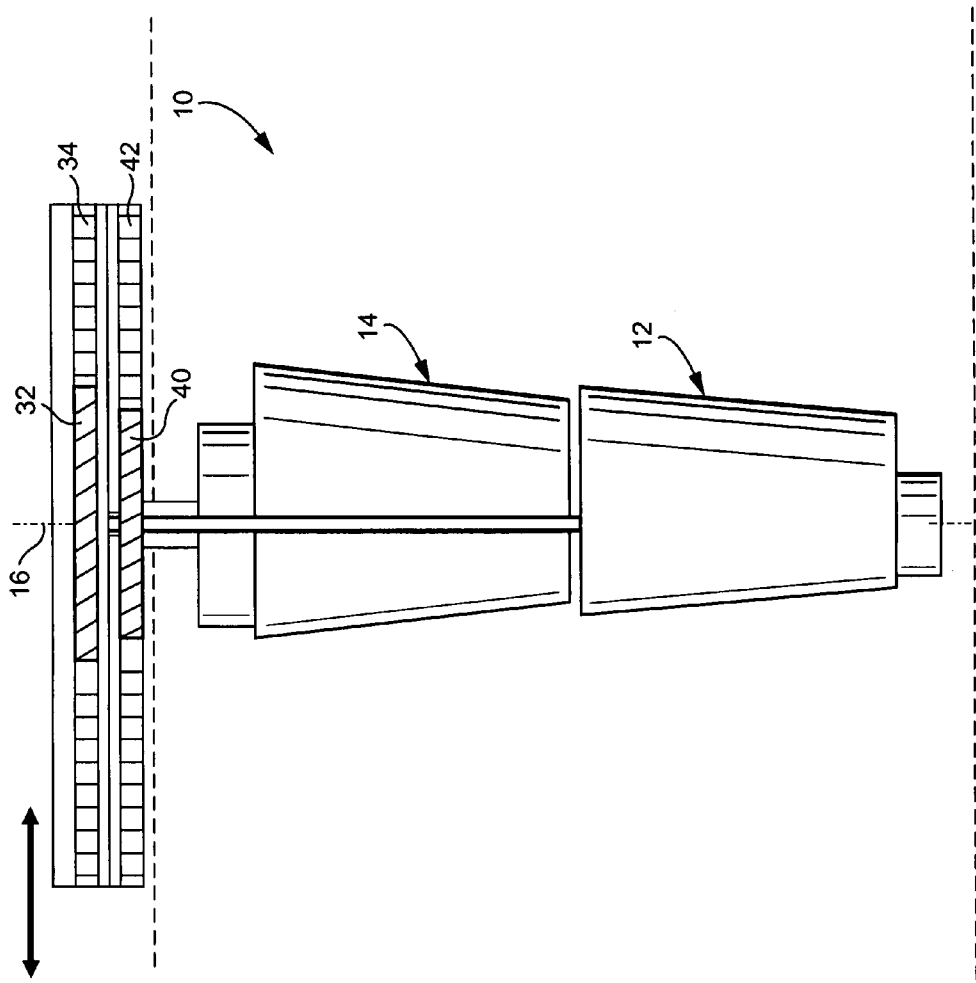
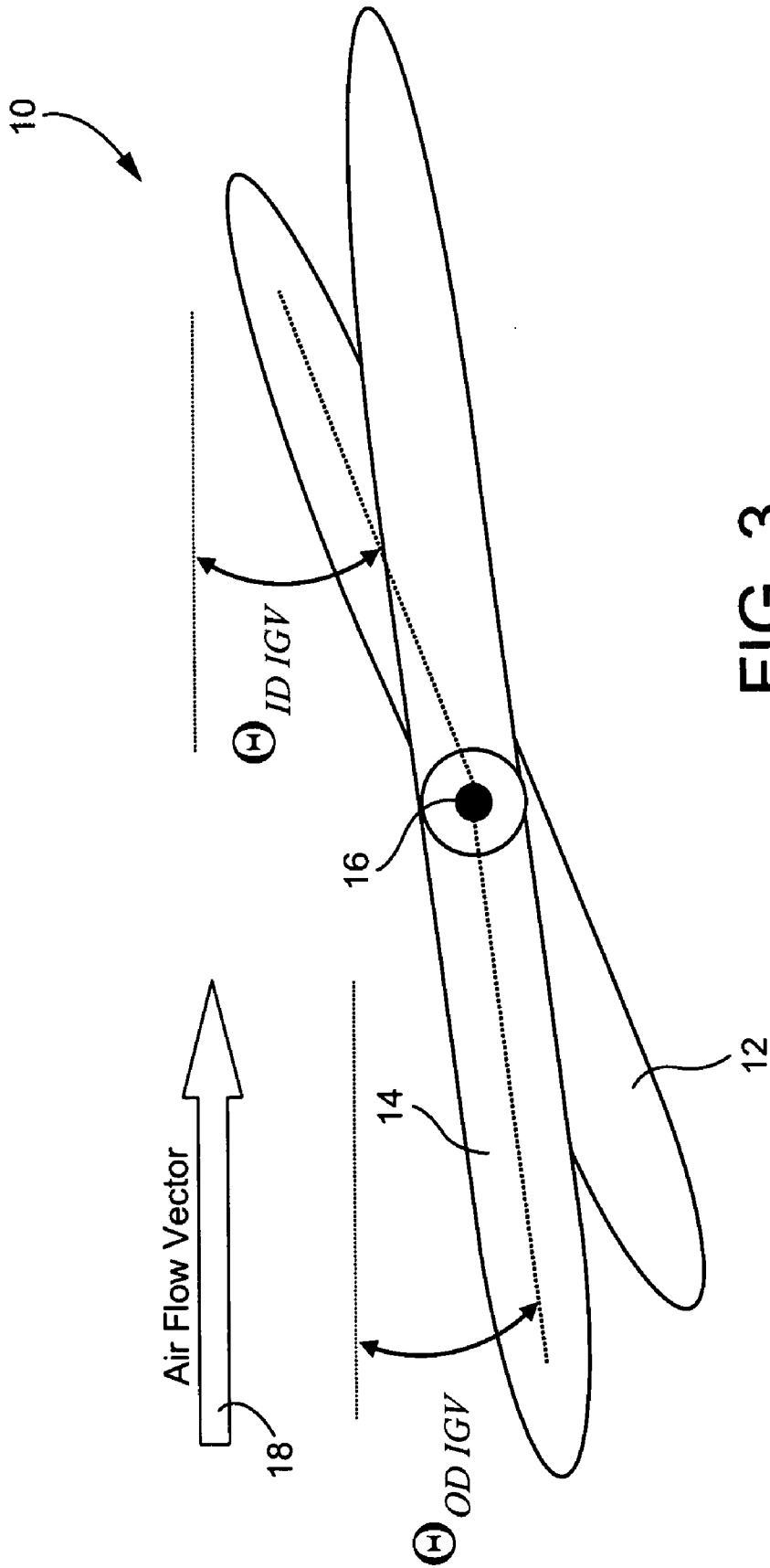


FIG. 2



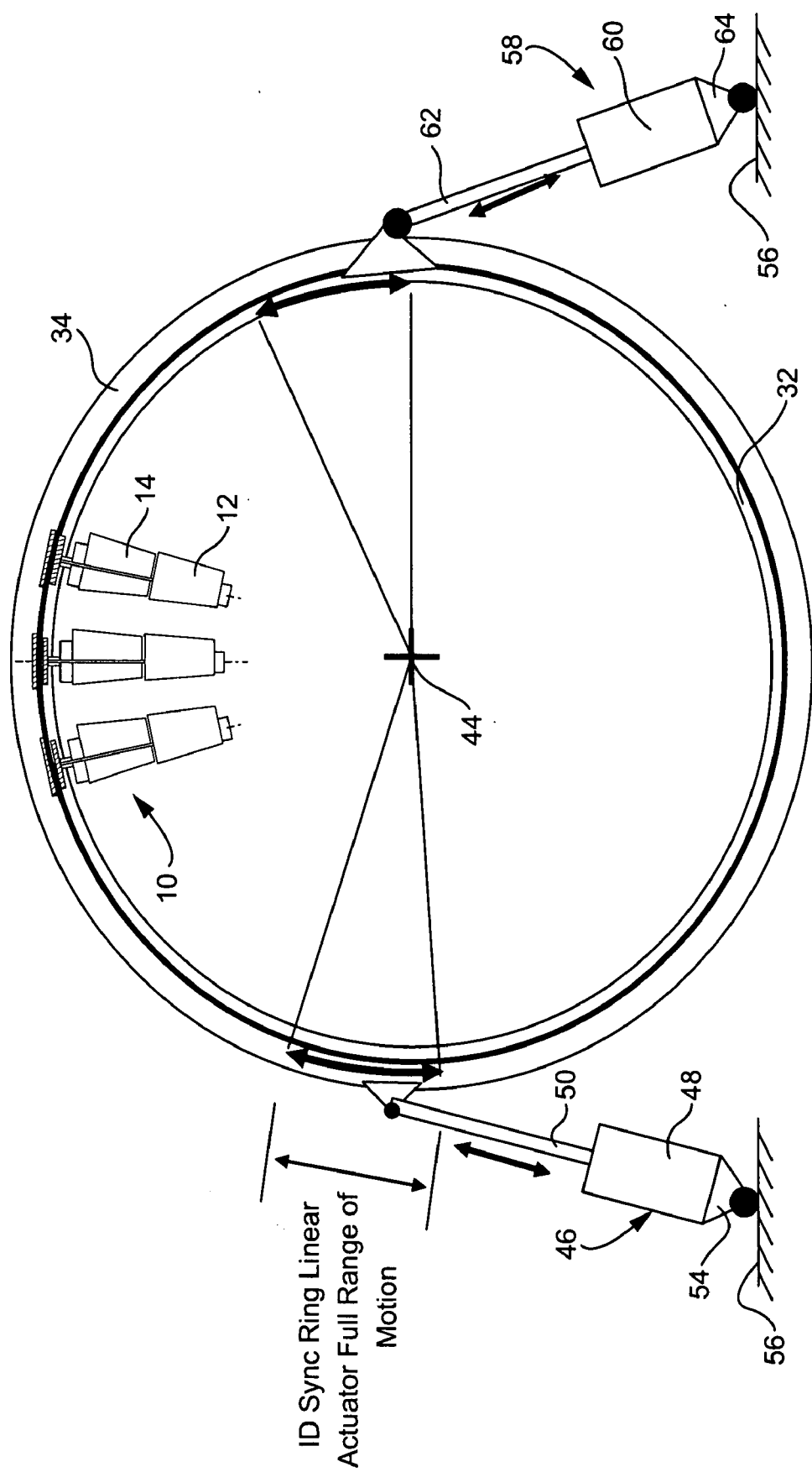
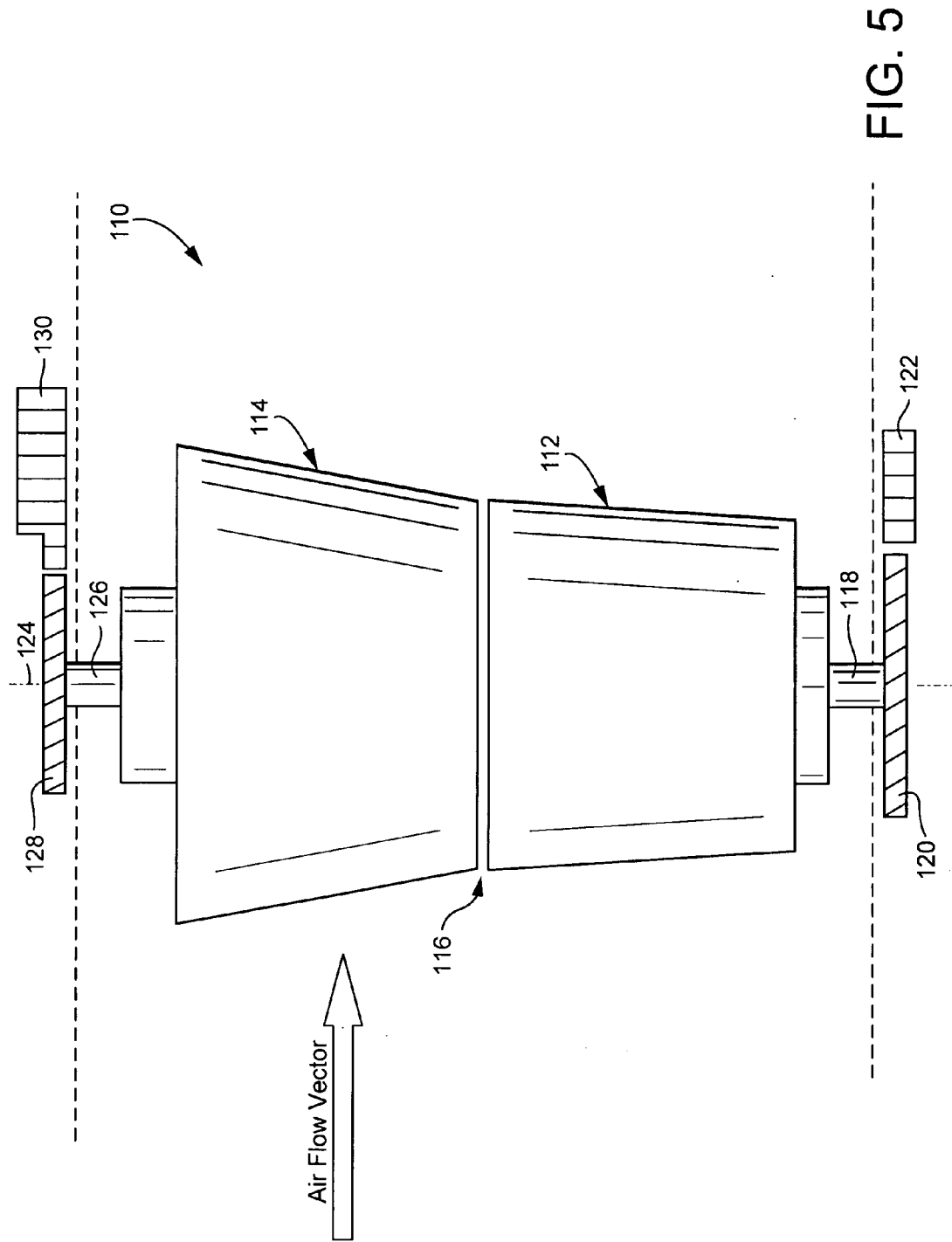


FIG. 4



SPANWISE SPLIT VARIABLE GUIDE VANE AND RELATED METHOD

[0001] This invention relates to gas turbine machines and, more specifically, to turbine compressor variable guide vane constructions.

BACKGROUND OF THE INVENTION

[0002] Power generation axial flow gas turbines are designed to optimally operate at a fixed rotational speed and output. In addition, axial flow gas turbine compressors have limited variable stage geometry and limited air extractions. These factors lead to significant off-design aerodynamic conditions, such as the rotating stall phenomenon, during startup and shutdown operations.

[0003] Rotating stall manifests itself as local stall cells that rotate at about half the wheel or rotor speed. These cells provide coherent unsteady aerodynamic loads on both the rotor and stator blades. As the rotor changes speed, the stall cell count changes, thereby setting up different orders of excitation or nodal diameters. The vibratory response on the rotor and stator blades from the rotating stall aerodynamic loads may lead to increased sensitivity to normal blade damage and premature failures.

BRIEF SUMMARY OF THE INVENTION

[0004] Recent investigations have revealed that during off-speed operation (such as at start-up and shut-down), fixed speed, multi-staged axial flow compressors with a single stage of variable geometry vanes, VSV, called Inlet Guide Vanes (IGVs), exhibit separated flow at the inner diameter (ID) flow path while the outer diameter (OD) flow path zone is more stable. This part-speed, ID-located stall effect is predicted in computational fluid dynamics (CFD) analysis of a typical fixed speed, multi-staged axial flow compressor.

[0005] Traditionally, the one-piece variable IGV stage manages the compressor flow uniformly from the ID to OD. Therefore it is not possible to separate the flow control to the ID zone from the remainder of the flow path.

BRIEF DESCRIPTION OF THE INVENTION

[0006] In accordance with an exemplary but non-limiting embodiment of the invention, the IGVs are split and independently controllable to manage especially the ID flow path where rotating stall occurs. This spanwise split of the individual IGVs improves axial flow compressor rotor and stator blade durability by eliminating the aerodynamic excitation on axial flow compressor rotor and stator blades, thus also eliminating rotating stall, especially during start-up and shut-down operations. Stated differently, spanwise separation of the compressor flow management provides a method of preventing axial flow compressor rotating stall aerodynamics from forming coherent unsteady loads by separately managing the compressor flow in the ID and OD flow path zones. This reduces the ID stall strength and weakens the ability of the rotating stall to form a coherent unsteady vibratory force on the compressor airfoils. Under normal operating conditions, the ID and OD flow path zones can be merged by adjusting the inner and outer vane sections to establish a single airfoil profile, i.e., with no differential angle between the sections.

[0007] Accordingly, in one aspect, the invention relates to a variable guide vane for an axial flow compressor comprising: a first radially outer vane section; and a second radially inner vane section; the first and second vane sections angularly adjustable relative to each other about a longitudinal radial axis of the vane.

[0008] In another aspect, the invention relates to a variable guide vane for an axial flow compressor comprising: a first radially outer vane section; a second radially inner vane section; the first and second vane sections angularly adjustable relative to each other about a longitudinal radial axis of the vane; and wherein the first and second vane sections are secured to respective shafts lying on the radial axis, each of the shafts being independently rotatable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a schematic side elevation of a split IGV in accordance with an exemplary but non-limiting embodiment of the invention;

[0010] FIG. 2 is a schematic front elevation of the IGV shown in FIG. 1;

[0011] FIG. 3 is a schematic plan view of the IGV shown in FIGS. 1 and 2;

[0012] FIG. 4 is a schematic front view of an actuator mechanism for adjusting the IGVs of a compressor stator; and

[0013] FIG. 5 is a schematic view similar to FIG. 1 but showing an alternative drive embodiment for split IGVs.

DETAILED DESCRIPTION OF THE DRAWINGS

[0014] With reference now to FIGS. 1-3, a turbine compressor stator IGV 10 is spanwise split into two sections, a radially inner section 12 and a radially outer section 14, each pivotable about a common radial axis 16.

[0015] A radial view of the spanwise split is best seen in FIG. 3. From this standpoint, it is clear that the IGV ID and OD sections 12, 14, respectively, are positioned at different angles relative to the incoming axial flow, referenced by flow arrow 18. FIG. 3 also shows the radially-oriented axis of rotation 16 that extends through the IGV sections 12, 14 and that is common to both. In the illustrated example of FIG. 1, the OD IGV section 14 has a leading edge 20 and a trailing edge 22, while the ID IGV section 12 has a leading edge 24 and a trailing edge 26.

[0016] With reference again to FIGS. 1 and 2, concentric shafts 28, 30 are employed to rotate the IGV sections 12, relative to each other about the axis 16. More specifically, the radially outer end of shaft 28 is fixed to an ID IGV section first gear 32. The shaft 28 extends through the OD IGV section 14 (and is rotatable relative thereto), and is fixed to the ID IGV section 12. The gear 32 is engaged by a first sync gear 34 (FIG. 2), rotation of the latter causing the ID IGV section 12 to pivot about the axis 16 on a stub or other suitable bearing 36.

[0017] At the same time, the OD IGV section 14 is provided with a bushing 38 through which shaft 28 passes, and shaft 30 is telescoped over the shaft 28 and extends between OD IGV 14 and a second gear 40. Gear 40 is engaged with a second sync ring gear 42 (FIG. 2). Independent rotation of the sync ring gears 34, 42 will cause differential rotation of IGV sections 12, 14, such that the IGV ID and OD sections become angularly offset as shown in FIG. 3.

[0018] FIG. 4 illustrates one exemplary but non-limiting manner in which the first and second sync ring gears 32, can be rotated, as well as engagement of the rings with multiple IGVs 10 that surround a rotor shaft (not shown), the axis of which is shown at 44. In this example, a first linear actuator 46 having a cylinder 48 and piston 50 may be arranged such that the remote end 52 of the piston 50 is pivotably attached to the second ring 34, and the base 54 of the cylinder 48 is pivotably

attached to a stationary support **56** (e.g., the compressor casing). Extension (or retraction) of the piston **50** causes rotational movement of the sync ring gear **34** and movement of the IGV ID section **12** of each IGV **10**. Similarly, a second actuator **58** having a cylinder **60** and piston **62** is pivotally attached to the first ring **32**, and the base **64** of the cylinder **60** is pivotally attached to the casing **56**. Actuation of the linear actuators may be coordinated by, for example, computer program or other suitable control means, to achieve the desired movement of the ID and OD vane sections **12**, **14**. Under start-up and shut-down operations, for example, the ID and OD sections of the IGVs will be offset as shown in FIG. **3**. When the turbine is operating under normal full-load conditions, the ID and OD IGV sections **12**, **14** will be adjusted to eliminate the offset, i.e., reducing the differential angle between the ID and OD IGV sections substantially to zero.

[0019] It will be appreciated that any suitable mechanical, pneumatic or hydraulic actuators may be employed to rotate the IGV ID and OD sections.

[0020] It will be understood that the ID and OD IGV spanwise lengths (i.e., radial lengths) are variable, based upon either CFD predictions or measured data. The only requirement on blade span is that the sum of the ID and OD radial blade lengths together span the entire flow path.

[0021] FIG. **5** illustrates another exemplary and non-limiting embodiment where each IGV section of the IGV **110** is actuated by its own sync ring. More specifically, the IGV **110** is split to include an ID IGV section **112** and an OD IGV section **114**, with a slight radial gap **58** at the interface. The ID IGV section **112** is provided with a shaft **60** secured to a gear **62**. The gear **62** is engaged by a first sync ring gear **64**, the rotation of which causes ID IGV section **112** to rotate about a radial axis of rotation **116**.

[0022] The OD IGV section **114** likewise is provided with a shaft **66** to which is fixed a second gear **68** engaged by a second sync ring gear **70**.

[0023] It will be appreciated that by using separate linear actuators similar to those shown in FIG. **4**, sync ring gears **64** and **70** may be rotated independently to fix the ID IGV and OD IGV sections at the desired angles relative to the incoming air flow vector.

[0024] In general application, the ID and OD airfoil sections do not need to have the same configuration at the ID-OD interface location. Additionally, the interface section need not be parallel to the engine center line as displayed in the figures, but may have a generally defined section.

[0025] Splitting the IGVs into ID and OD sections as described above has a number of benefits and advantages. For example, this spanwise split IGV invention improves axial flow compressor rotor and stator blade durability by eliminating aerodynamic excitation. By spanwise separation of the compressor flow management, a method to reduce the axial flow compressor rotating stall aerodynamics is provided by preventing the formation of coherent unsteady loads. The spanwise split IGV also provides a method for separately managing the compressor flow in the ID and OD flow path zones. This reduces the ID stall zone and weakens the ability of the rotating stall to form a coherent unsteady vibratory force on the compressor airfoils.

[0026] Another benefit of separate spanwise management of compressor flows is improved power turn-down capability. Fixed speed axial flow compressors provide power turn-down by reducing compressor flow. This flow reduction is provided

by IGV closure. Optimal management of the split spanwise IGV improves turn-down performance and turn-down magnitude.

[0027] While the invention has been described in connection with what is presently considered to be the most practical and preferred IGV 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 VSV modifications and equivalent arrangements included within the spirit and scope of the appended claims.

What is claimed is:

1. A variable guide vane for an axial flow compressor comprising:

a first radially outer vane section; and

a second radially inner vane section; said first and second vane sections angularly adjustable relative to each other about a longitudinal radial axis of said vane.

2. The variable guide vane of claim **1** wherein said first and second vane sections interface along a horizontal split line substantially perpendicular to said longitudinal axis.

3. The variable guide vane of claim **2** wherein said horizontal split line is located about mid-way along a radial length dimension of said vane.

4. The variable guide vane of claim **1** wherein said first and second vane sections are secured to respective shafts lying, on said radial axis, each of said shafts being independently rotatable.

5. The variable guide vane of claim **4** wherein each of said shafts has a gear secured at a respective end thereof, engageable with a respective sync ring gear.

6. The variable guide vane of claim **1** wherein said first and second vane sections are mounted on a common shaft lying on said longitudinal axis, one of said vane sections fixed to said shaft, and the other of said vane sections rotatable relative to said shaft.

7. The variable guide vane of claim **1** wherein said first and second vane sections are mounted to respective shafts, each fixed to a gear at respective opposite ends of the guide vane.

8. The variable guide vane of claim **5** wherein said respective sync gears are each rotatable by a hydraulic actuator.

9. A variable guide vane for an axial flow compressor comprising:

a first radially outer vane section;

a second radially inner vane section; said first and second vane sections angularly adjustable relative to each other about a longitudinal radial axis of said vane; and

wherein said first and second vane sections are secured to respective shafts lying on said radial axis, each of said shafts being independently rotatable.

10. The variable guide vane of claim **9** wherein said first and second vane sections interface along a horizontal split line substantially perpendicular to said longitudinal axis.

11. The variable guide vane of claim **9** wherein said horizontal split line is located about mid-way along a radial length dimension of said vane.

12. The variable guide vane of claim **9** wherein said first and second vane sections are secured to respective shafts lying on said radial axis, each of said shafts being independently rotatable.

13. A method of eliminating rotating stall aerodynamic excitation associated with axial flow turbine compressor inlet guide vanes comprising:

- (a) splitting each variable guide vane in a row of such inlet guide vanes to form a radially inner section and a radially outer section; and
- (b) adjusting relative angular positions of said radially inner and radially outer sections relative to a direction of flow of air across said guide vanes.

14. The method of claim **13** wherein said radially inner and radially outer sections are adjusted by separate ring gears.

15. The method of claim **13** including selecting a radial length for each section based on computational fluid dynamics predictions.

16. The method of claim **13** comprising angularly offsetting said radially inner and radially outer sections during start-up and shut-down.

17. The method of claim **16** comprising reducing the angular offset between said radially inner and radially outer sections substantially to zero during normal full load operation.

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