CENTRIFUGAL COMPRESSOR HAVING ADJUSTABLE INLET GUIDE VANES

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ABSTRACT
An apparatus for adjustment of inlet guide vanes of a compressor includes a ring having a plurality of slots spaced around a circumference thereof; a plurality of lever arm assemblies each having a pin that includes a body with a first end and a second end and a lever arm extending perpendicularly from the second end of the body of the pin; a plurality of vanes each coupled to an end of one of the plurality of lever arms by a shaft; and a rack and pinion drive mechanism. The pin of each of the lever arm assemblies is configured to be positioned within each of the plurality of slots such that the first end of the pin extends into the slot. The rack and pinion drive mechanism includes a pinion coupled to the shaft of one of the plurality of vanes, thereby creating a drive vane; and a driven rack operationally coupled to the pinion. The drive vane is configured to rotate the ring via the rack and pinion drive mechanism, thereby adjusting an angular position of the plurality of vanes.
CENTRIFUGAL COMPRESSOR HAVING ADJUSTABLE INLET GUIDE VANES

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 60/922,713 entitled "Centrifugal Compressor Having Adjustable Inlet Guide Vanes" filed Apr. 10, 2007, which is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention
[0003] The present invention relates to the field of compressors and, more particularly, to an apparatus for the adjustment of inlet guide vanes to the compressor.
[0004] 2. Description of Related Art
[0005] Centrifugal compressors are commonly used in the liquefied natural gas industry. This application requires a large range of compressor performance characteristics due to the nature of the liquefaction process. In order to achieve all the variations of performance needed, it is common industry practice to use a compressor that is able to vary the angle of its vanes near the inlet stage. The ability to change the angle of the inlet vanes for various processes allows a user to achieve a broader range of performance characteristics.
[0006] U.S. Pat. No. 6,679,057 (the '057 patent) to Arnold discloses a turbocharger guide vane arrangement including a plurality of vanes coupled to a unison ring. The unison ring is rotated by rotation of an actuator crank, which causes an actuating lever arm to move around a longitudinal axis of the actuator crank, which in turn effects rotation of the unison ring via an actuating pin. The actuating mechanism in the '057 patent is shown in further detail in U.S. Pat. Nos. 6,269,642 to Arnold et al.
[0007] The prior art shows how it is possible to rotate the unison ring using gearing engaging an outer periphery of the unison ring or to use a crank arm engaged with a unison ring to rotate the ring. U.S. Pat. Nos. 6,269,642 and 6,679,057 disclose using such a crank arm to effect rotation of a unison ring with the crank arm being actuated by a rack and pinion arrangement.
[0008] However, the crank arm of the prior art is not coupled to any of the guide vanes, especially in the context of a rack and pinion gear driven master vane. Accordingly, the mechanisms for moving vanes may be improved upon.

SUMMARY OF THE INVENTION

[0009] The present invention is directed to an apparatus for adjustment of inlet guide vanes of a compressor. The apparatus includes a ring having a plurality of slots spaced around a circumference thereof; a plurality of lever arm assemblies each having a pin that includes a body with a first end and a second end and a lever arm extending perpendicularly from the second end of the body of the pin; a plurality of vanes each coupled to an end of one of the plurality of lever arms by a shaft; and a rack and pinion drive mechanism. The pin of each of the lever arm assemblies is configured to be positioned within each of the plurality of slots such that the first end of the pin extends into the slot. The rack and pinion drive mechanism includes a pinion coupled to the shaft of one of the plurality of vanes, thereby creating a drive vane; and a driven rack operationally coupled to the pinion. The drive vane is configured to rotate the ring via the rack and pinion drive mechanism, thereby adjusting an angular position of the plurality of vanes.

[0010] The driven rack may be coupled to a drive shaft that is powered by a hydraulic cylinder located externally from the compressor. The apparatus may be positioned such that it is isolated from a flow path of the compressor by an endwall cover plate. The ring may be constrained axially in the compressor by an end wall and the end wall cover plate. The plurality of vanes may be each rotated to the same angle when the drive vane rotates the ring via the rack and pinion drive mechanism, thereby adjusting the angular position of the plurality of vanes.

[0011] The present invention is also directed to a compressor including a casing; a rotor having a shaft and an impeller positioned within the casing; and a vane adjustment mechanism positioned within the casing and surrounding the rotor. The Vane adjustment mechanism includes a ring having a plurality of slots spaced around a circumference thereof; a plurality of lever arm assemblies each having a pin that includes a body with a first end and a second end and a lever arm extending perpendicularly from the second end of the body of the pin; a plurality of vanes each coupled to an end of the plurality of lever arms by a shaft; and a rack and pinion drive mechanism. The pin of each of the lever arm assemblies is configured to be positioned within each of the plurality of slots such that the first end of the pin extends into the slot. The rack and pinion drive mechanism includes a pinion coupled to the shaft of one of the plurality of vanes, thereby creating a drive vane; and a driven rack operationally coupled to the pinion. The drive vane is configured to rotate the ring via the rack and pinion drive mechanism, thereby adjusting an angular position of the plurality of vanes.

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[0013] In addition, the present invention is directed to a vane adjustment mechanism for a compressor. The vane adjustment mechanism includes a ring; and a plurality of vanes pivotally attached around a circumference of the ring. One of the plurality of vanes is a drive vane configured to rotate the ring via a rack and pinion drive mechanism, thereby adjusting an angular position of the plurality of vanes.

[0014] The ring may include a plurality of slots spaced around a circumference thereof. The vane adjustment mechanism may further include a plurality of lever arm assemblies each including a pin having a body with a first end and a second end and a lever arm extending perpendicularly from the second end of the body of the pin. The pin of each of the lever arm assemblies may be configured to be positioned within each of the plurality of slots such that the first end of the pin extends into the slot. The plurality of vanes may be each coupled to an end of one of the plurality of lever arms by a shaft.

[0015] The rack and pinion drive mechanism may include a pinion coupled to the shaft of one of the plurality of vanes, thereby creating a drive vane; and a driven rack operationally
coupled to the pinion. The driven rack may be coupled to a drive shaft and a hydraulic cylinder may be provided to power the drive shaft to drive the driven rack.

These and other features and characteristics of the present invention, as well as the methods of operation and functions of the related elements of structures, and the combination of parts and details of manufacture, will become more apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form a part of this specification, wherein like reference numerals designate corresponding parts in the various figures. As used in the specification and the claims, the singular form of "a", "an", and "the" include plural referents unless the context clearly dictates otherwise.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cutaway perspective view of an apparatus for adjusting an angular position of a plurality of inlet guide vanes situated within a compressor in accordance with the present invention;

FIG. 2 is a perspective view of the apparatus for adjusting the angular position of a plurality of inlet guide vanes for a compressor, in accordance with the present invention;

FIG. 3 is a front plan view of the apparatus shown in FIG. 2;

FIG. 4 is a cross-sectional view of the apparatus taken along lines 4-4 of FIG. 3;

FIG. 5 is a perspective view of a rotating ring of the apparatus;

FIG. 6 is a perspective view of a vane with a lever arm of the apparatus;

FIG. 7 is a perspective view of a plurality of vanes secured within the ring via the corresponding lever arms thereof;

FIG. 8 is a partial front plan view of the ring with a rack and pinion mechanism of the apparatus;

FIG. 9 is a partial rear plan view of the ring with the rack and pinion mechanism of the apparatus;

FIG. 10 is a front perspective view of the apparatus showing the rack;

FIG. 11 is a rear perspective view of the apparatus showing the rack and pinion mechanism;

FIG. 12 is a perspective view of the apparatus showing the ring centered on an endwall.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

For purposes of the description hereinafter, the terms "upper", "lower", "right", "left", "vertical", "horizontal", "top", "bottom", "lateral", "longitudinal" and derivatives thereof shall relate to the invention as it is oriented in the drawing figures. However, it is to be understood that the invention may assume various alternative variations, except where expressly specified to the contrary. It is also to be understood that the specific devices illustrated in the attached drawings, and described in the following specification, are simply exemplary embodiments of the invention. Hence, specific dimensions and other physical characteristics related to the embodiments disclosed herein are not to be considered as limiting.

With reference to FIG. 1, a centrifugal compressor, denoted generally as reference numeral 1, includes a casing 3 with a rotor positioned therein. The rotor includes an impeller 5 and a shaft 7. An apparatus, or vane adjustment mechanism, denoted generally as reference numeral 9, for adjusting an angular position of a plurality of inlet guide vanes 11 is positioned within casing 3 and surrounds shaft 7 of the rotor. Compressor 1 further includes a bearing housing 29 coupled to endwall 17.

Vane adjustment mechanism 9 includes a rotating ring 13 with the plurality of inlet guide vanes 11 positioned around a circumference thereof as will be described in greater detail hereinafter. Vane adjustment mechanism 9 is positioned within casing 3 of compressor 1, such that it is isolated from a flow path of compressor 1 by an endwall cover plate 15. By keeping the vane rotation mechanism 9 out of the flow path, aerodynamic efficiency and performance of the inlet stage may be maintained. Additionally, rotating ring 13 constrained axially in compressor 1 by an endwall 17 and endwall cover plate 15. Rotating ring 13 should also be aligned with the centerline of compressor 1 to ensure that vanes 11 rotate at the same angle. This is achieved by centering rotating ring 13 on a surface of endwall 17, as shown in FIG. 12, for instance. Vane adjustment mechanism 9 also includes a rack and pinion drive mechanism 21 as will be discussed in greater detail hereinafter. Rack and pinion drive mechanism 21 is coupled to a drive shaft 23 that is powered by a hydraulic cylinder 25 located in a housing 27 positioned externally from compressor 1.

With reference to FIGS. 2-6, and with continuing reference to FIG. 1, vane adjustment mechanism 9 includes a plurality of adjustable inlet guide vanes 11 positioned around the circumference of rotating ring 13. While vane adjustment mechanism 9 illustrated in the figures includes sixteen adjustable inlet guide vanes 11, this is not to be construed as limiting the present invention as any suitable number of vanes may be utilized. Generally, in order for the aerodynamic design of the adjustable inlet guide vanes 11 to be effective, each vane 11 in the inlet section of compressor 1 should be rotated at the same angle. As shown in FIG. 5, vane adjustment mechanism 9 achieves the aforementioned design criteria by using a rotating ring 13 that can accommodate each vane 11 within an elongated slot 31 thereof via a lever arm assembly 33.

With specific reference to FIG. 6, each lever arm assembly 33 includes a pin 35 having a body 37 with a first end 39 and a second end 41 and a lever arm 43 extending perpendicularly from second end 41 of body 37 of pin 35. Vanes 11 are each coupled to an end of one of the plurality of lever arms 43 by a shaft 45. Body 37 of pin 35 of each lever arm assembly 33 is configured to be positioned within elongated slots 31 of rotating ring 13, such that first end 39 of pin 35 extends into elongated slot 31. As rotating ring 13 rotates, each vane 11 is rotated by the same angle.

With reference to FIGS. 7 through 12, and with continuing reference to FIGS. 1-6, vane adjustment mechanism 9 also includes a rack and pinion drive mechanism 21 configured to drive one of the plurality of vanes 11, thereby creating a drive vane 47. Rack and pinion drive mechanism 9 includes a pinion 53 coupled to an elongated shaft 55 (see FIG. 4) of drive vane 47 and a driven rack 57. Driven rack 57 includes a plurality of teeth 59 that are configured to engage a plurality of teeth 61 on the pinion 53, thereby operationally coupling driven rack 57 to pinion 53. An end of driven rack 57
The apparatus for adjustment of inlet guide vanes of a compressor comprising:

1. A ring having a plurality of slots spaced around a circumference thereof;
2. A plurality of lever arm assemblies each comprising a pin having a body with a first end and a second end and a lever arm extending perpendicularly from the second end of the body of the pin, the pin of each of the lever arm assemblies configured to be positioned within each of the plurality of slots, such that the first end of the pin extends into the slot;
3. A plurality of vanes each coupled to an end of one of the plurality of lever arms by a shaft; and
4. A rack and pinion drive mechanism comprising:
   a pinion coupled to the shaft of one of the plurality of vanes, thereby creating a drive vane; and
   a driven rack operationally coupled to the pinion, wherein the drive vane is configured to rotate the ring via the rack and pinion drive mechanism, thereby adjusting an angular position of the plurality of vanes.

5. The apparatus for adjustment of inlet guide vanes of a compressor of claim 2, wherein a hydraulic cylinder powers the drive shaft to drive the driven rack.
6. The apparatus for adjustment of inlet guide vanes of a compressor of claim 1, wherein the hydraulic cylinder is located external to the compressor.
7. The apparatus for adjustment of inlet guide vanes of a compressor of claim 1, wherein the plurality of vanes are each rotated to the same angle when the drive vane rotates the ring via the rack and pinion drive mechanism, thereby adjusting the angular position of the plurality of vanes.
8. A compressor comprising:
   a casing;
   a rotor comprising a shaft and an impeller positioned within the casing; and
   a vane adjustment mechanism positioned within the casing and surrounding the rotor, the vane adjustment mechanism comprising:
   a ring having a plurality of slots spaced around a circumference thereof;
   a plurality of lever arm assemblies each comprising a pin having a body with a first end and a second end and a lever arm extending perpendicularly from the second end of the body of the pin, the pin of each of the lever arm assemblies configured to be positioned within each of the plurality of slots, such that the first end of the pin extends into the slot;
   a plurality of vanes each coupled to an end of one of the plurality of lever arms by a shaft; and
   a rack and pinion drive mechanism comprising:
   a pinion coupled to the shaft of one of the plurality of vanes, thereby creating a drive vane; and
   a driven rack operationally coupled to the pinion, wherein the drive vane is configured to rotate the ring via the rack and pinion drive mechanism, thereby adjusting an angular position of the plurality of vanes.
wherein one of the plurality of vanes is a drive vane configured to rotate the ring via a rack and pinion drive mechanism, thereby adjusting an angular position of the plurality of vanes.

16. The vane adjustment mechanism of claim 15, wherein the ring includes a plurality of slots spaced around a circumference thereof.

17. The vane adjustment mechanism of claim 16, further comprising a plurality of lever arm assemblies each comprising a pin having a body with a first end and a second end and a lever arm extending perpendicularly from the second end of the body of the pin, the pin of each of the lever arm assemblies configured to be positioned within each of the plurality of slots such that the first end of the pin extends into the slot.

18. The vane adjustment mechanism of claim 17, wherein the plurality of vanes are each coupled to an end of one of the plurality of lever arms by a shaft.

19. The vane adjustment mechanism of claim 15, wherein the rack and pinion drive mechanism comprises:

   a pinion coupled to the shaft of one of the plurality of vanes, thereby creating a drive vane; and

   a driven rack operationally coupled to the pinion.

20. The vane adjustment mechanism of claim 8, wherein the driven rack is coupled to a drive shaft and a hydraulic cylinder powers the drive shaft to drive the driven rack.

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