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(54) **CENTRIFUGAL COMPRESSOR HAVING  
VARIABLE GEOMETRY DIFFUSER AND  
METHOD THEREOF**

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(57) **ABSTRACT**

A centrifugal compressor is provided. The centrifugal compressor includes a plurality of diffuser vanes arranged in a circumferentially spaced array about a machine axis. Each diffuser vane is mounted on a respective shaft. Each of the shafts is coupled to a ring that is rotatable about the machine axis. A worm drive is provided that includes a worm that meshes with a worm gear or a segment of a worm gear mounted along a portion of the circumference of the ring. A step motor is coupled to the worm. The step motor is operable to rotate the worm about a worm axis perpendicular to the machine axis, such that the worm drive transmits rotational torque from the step motor to the ring, to resultantly vary the position of the diffuser vanes.

(76) Inventors: **Claus Smits HANSEN**,  
Helsingborg (SE); **Joergen**  
**LYQUIST**, Alsgarde (DK)

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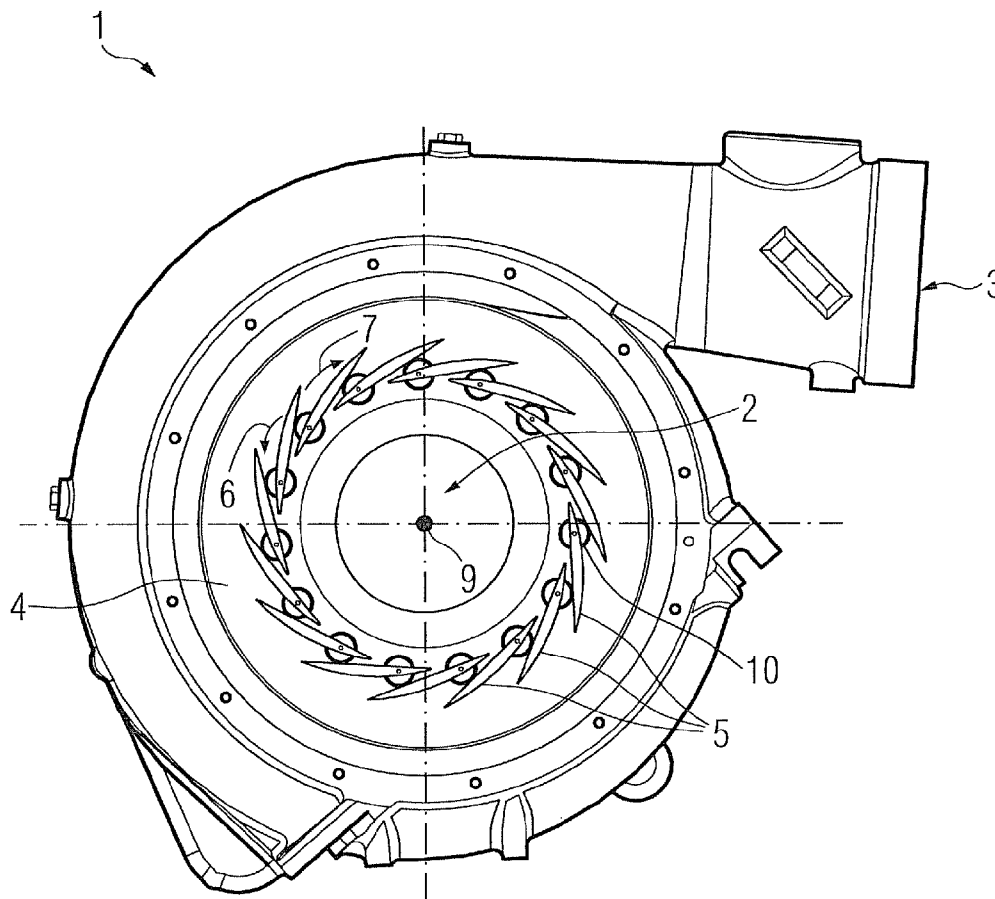


FIG 1

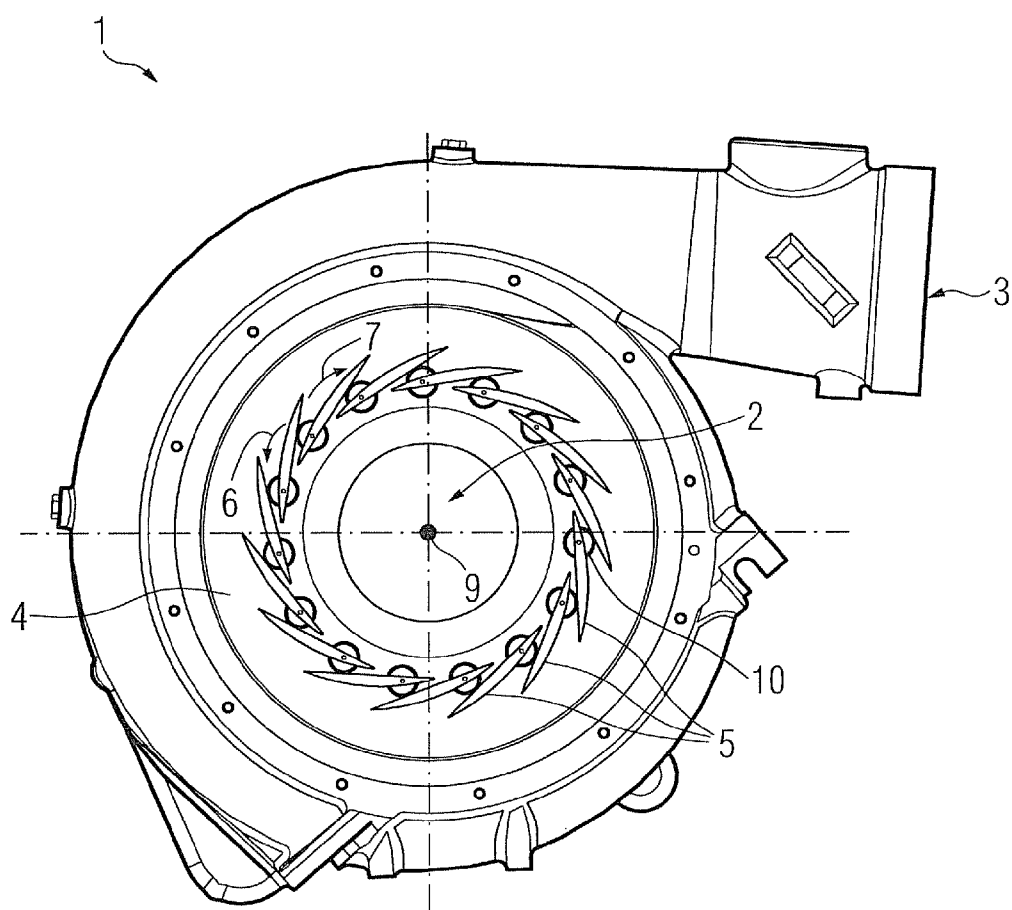


FIG 2

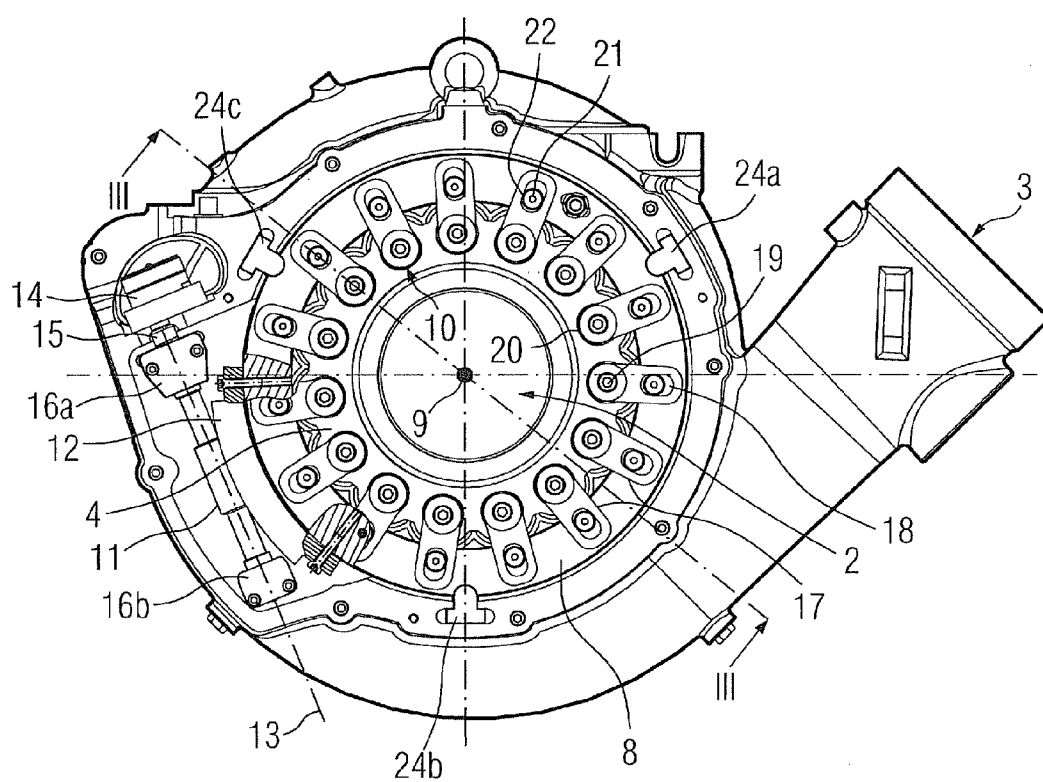
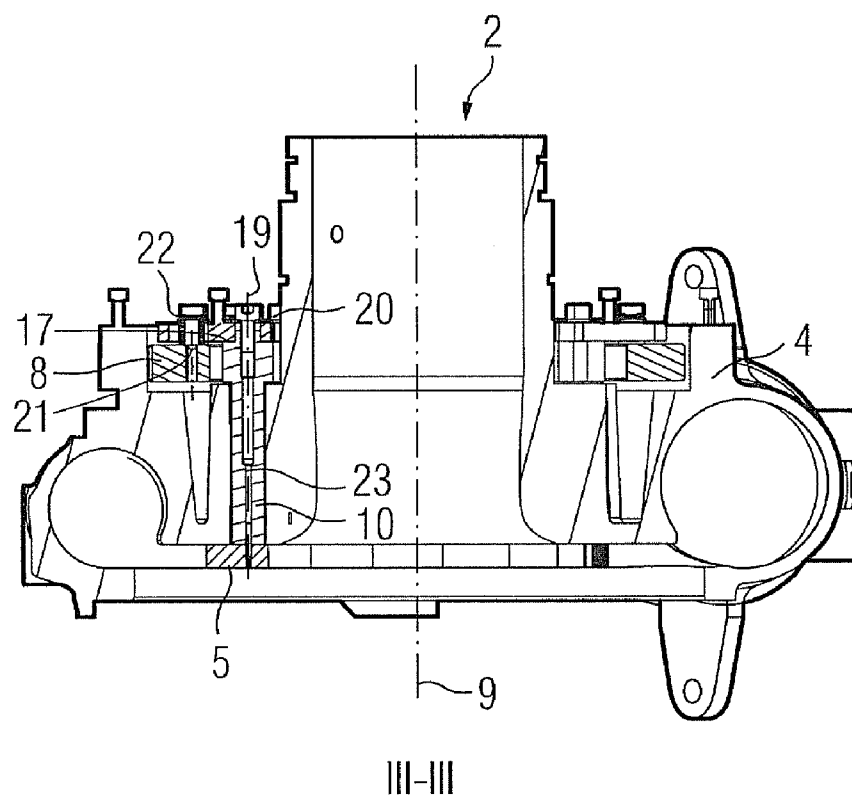


FIG 3



# **CENTRIFUGAL COMPRESSOR HAVING VARIABLE GEOMETRY DIFFUSER AND METHOD THEREOF**

## **CROSS REFERENCE TO RELATED APPLICATIONS**

**[0001]** This application claims priority of European Patent Office application No. 11153299.0 EP filed Feb. 4, 2011. All of the applications are incorporated by reference herein in their entirety.

## **FIELD OF INVENTION**

**[0002]** The present invention relates to centrifugal compressors and, in particular, to centrifugal compressors having variable geometry vane-type diffusers.

## **BACKGROUND OF INVENTION**

**[0003]** It is well known in the art of rotary compressors that most applications call for a reduction in the relatively high velocities of the gases exiting from such compressor apparatus for subsequent utilization, such as in power producing gas turbine engines. To achieve the conversion of the kinetic energy of the high velocity gases to a pressure increase in the gas, diffusers are currently employed downstream of the compressors to achieve the conversion via a diffusion process.

**[0004]** Variable geometry diffusers for centrifugal compressors have been considered in the past to provide a wide operating range. Variable geometry is achieved by pivoting the diffuser vanes to match the exit angle of the flow from the impeller and by adjusting the mechanical diffuser throat area. These adjustments make it possible to increase compressor efficiency, for example, by permitting greater flow under choke conditions while reducing the flow at which surge occurs.

**[0005]** In existing variable geometry vane-type diffusers, each diffuser vane is mounted on a respective crank shaft and these crank shafts are supported on a ring. The ring is actuated by a crank shaft that is coupled to a linear actuator via an arm. When the actuator is activated, the crank shaft is rotated, which rotates the ring. The ring, in turn, rotates the individual crank shafts on which the respective diffuser vanes are mounted. Thus the position of the diffuser vanes is varied between a maximum and a minimum flow setting. The disadvantage of the above arrangement is that it employs a linear actuator which makes it difficult to accurately control the diffuser vane position.

## **SUMMARY OF INVENTION**

**[0006]** The object of the present invention is to improve the accuracy in controlling variable diffuser vanes in a centrifugal compressor.

**[0007]** The above object is achieved by the centrifugal compressor of the claims and the method of the claims.

**[0008]** The underlying idea of the present invention is to provide an apparatus and method for accurately regulating volume flow through a centrifugal compressor by controlling the position of diffuser vanes by means of a step motor and a worm drive. The use of a step motor advantageously allows the position of the diffuser vanes to be controlled more accurately with easy feedback to the compressor control system, thus obviating the above-mentioned difficulties with the above-mentioned state of the art involving linear actuators and crank-shafts. The purpose of the worm drive is to transmit

rotational torque from the step motor to the ring, and in turn, to the diffuser shafts to which the diffuser vanes are mounted. The arrangement proposed ensures that the diffuser geometry is compact.

**[0009]** In one embodiment, each shaft is coupled to the ring by a radial arm that transmits rotational torque from the ring to the respective shaft, and resultantly, to the respective diffuser vane mounted thereon. In this way, angular displacement of the ring is translated into angular displacement of the shafts, to control the positions of the diffuser vanes mounted thereon.

**[0010]** In a further embodiment, a plurality of first bearings are provided along the circumference of the ring, wherein each radial arm are flexibly coupled to a respective first bearing by means of a slot provided on the respective arm. This gives an easy link between the radial arm and the bearing, which also gives a minimum play on the diffuser vanes.

**[0011]** In a preferred embodiment, the step motor is coupled to the worm by means of a flexible coupling. The Flexible coupling allows the step motor and worm gear to have a relative displacement.

**[0012]** In one embodiment, the compressor includes a volute casing, wherein the ring is supported on the volute casing by means a plurality of second bearings disposed circumferentially around the volute casing.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0013]** The present invention is further described hereinafter with reference to illustrated embodiments shown in the accompanying drawings, in which:

**[0014]** FIG. 1 illustrates a rear end view of a centrifugal compressor showing variable diffuser vanes,

**[0015]** FIG. 2 illustrates a front end view of the centrifugal compressor showing the worm drive and the step motor,

**[0016]** FIG. 3 illustrates a cross-sectional view of the compressor along the section in FIG. 2.

## **DETAILED DESCRIPTION OF INVENTION**

**[0017]** Referring now to FIG. 1 is illustrated a rear end view of a centrifugal compressor 1. In operation, the compressor 1 receives a gas axially through an inlet 2. The gas flowing through the inlet 2 is accelerated by an impeller mounted on a rotor (not shown for clarity), which increases the kinetic energy of the gas. The kinetic energy of the gas is then converted into a pressure increase by means of diffuser vanes 5 disposed downstream of the impellers. The impellers and the diffuser vanes are housed in a volute casing 4, which directs the gas flowing out of the diffuser tangentially toward a compressor outlet 3.

**[0018]** The diffuser vanes 5 are arranged in a circumferentially spaced array about a machine axis 9. To provide a wide operating range, the position of the diffuser vanes 5 is variable between a maximum and a minimum volumetric flow setting. Variable geometry is achieved by pivoting the diffuser vanes 5 to match the exit angle of the flow from the impeller and by adjusting the mechanical diffuser throat area. In the illustrated embodiment, each of the diffuser vanes 5 is mounted on a respective shaft 10. The shafts 10, also referred to herein as diffuser shafts 10, are rotatable to move the diffuser vanes 5 along a direction 6 to provide increased volumetric flow-rate and along a direction 7 to provide decreased volumetric flow-rate.

[0019] The mechanism for regulating the position of the diffuser vanes 5 is illustrated referring to the front end view of the compressor 1 as shown in FIG. 2. As shown, the proposed diffuser assembly includes a ring 8 that is rotatable about the axis 9. That is, the ring 8 is capable of angular displacement about the axis 9. Each of the diffuser shafts 10 is coupled to the ring 8 in a manner such that rotation (i.e., angular displacement) of the ring 8 causes rotation (i.e., angular displacement) of the shafts 10. In the illustrated embodiment, each diffuser shaft 10 is coupled to the ring 8 by means of a radial arm 17.

[0020] FIG. 3 shows a cross-sectional view along the section in FIG. 2. Referring jointly to FIG. 2 and FIG. 3, the radial arm 17 is rigidly fixed on one end to the diffuser shaft 10 by means of a screw 19 and a washer 20. The other end of the radial arm 17 includes a slot 18, which fits on to a bearing 22 disposed on the ring 8. Several such bearings 22 are disposed circumferentially spaced apart on the ring 8 on each of which a respective radial arm 17 is flexibly coupled by the respective slots 18. Referring to FIG. 3, each diffuser shaft 10 is rigidly coupled to a diffuser vane 5 by means of a screw 23, such that the rotation (i.e., angular displacement) of the shaft 10 in either direction results in a change in position of the respective diffuser vane 5 as indicated by the directional arrows 6 and 7 in FIG. 1.

[0021] Referring back to FIG. 2, the ring 8 is actuated by means of a step motor 14 and a worm drive 11, 12 that transmits rotational torque from the step motor 14 to the ring 8. The worm drive includes a worm 11 that meshes with a worm gear 12 rigidly mounted along the circumference of the ring 8, for example by means of a screw. In the illustrated embodiment, the worm gear 12 includes only segment of a worm gear mounted along only a portion of the circumference of the ring 8. The segment should be of sufficient arc-length so as to accommodate the entire range of angular displacement of the worm 11. This arrangement provides a compact assembly. However, alternately, the worm gear 14 may be mounted along the entire circumference of the ring 8. In the illustrated embodiment, for fifteen diffuser vanes, a gear ratio of 218:1 may be chosen for the worm drive.

[0022] The worm 11 is rotatable about a worm axis 13 that is perpendicular to the machine axis 9. The worm 11 is supported on the volute casing 4 by bearings 16a and 16b and is coupled to the step motor 14 by means of a flexible coupling 15. The step motor 14 is capable of dividing rotational motion into a sufficiently large number of discrete angular displacements. In the illustrated example, the step motor is combined with a gear which has a gear ratio of 30:1.

[0023] The worm drive 11, 12 transmits rotational torque from the step motor 14 to the ring 9. The ring 8 is axially and radially supported on the volute casing 4 by means of a plurality of bearing assemblies 24a, 24b, 24c disposed circumferentially around the volute casing 4. In operation, the rotation, i.e., angular displacement of the step motor 14 results in rotation, i.e., discrete angular displacement of the ring 8. The radial arms 17 transmit rotational torque from the ring 9 to the diffuser shafts 10, to resultantly vary the angular positions of the diffuser vanes 5 mounted thereon, as clearly shown in FIG. 1. Advantageously, using a step motor 14 allows the angular position of the diffuser vanes 5 to be controlled more accurately and positioned by the compressor control system, which therefore knows the exact position of the diffuser vanes. Further advantageously, the angular position of the diffuser vanes 5 may be precisely controlled with-

out any feedback mechanism as long as the step motor is carefully sized to the application.

[0024] While this invention has been described in detail with reference to certain preferred embodiments, it should be appreciated that the present invention is not limited to those precise embodiments. Rather, in view of the present disclosure which describes the current best mode for practicing the invention, many modifications and variations would present themselves, to those of skilled in the art without departing from the scope and spirit of this invention. The scope of the invention is, therefore, indicated by the following claims rather than by the foregoing description. All changes, modifications, and variations coming within the meaning and range of equivalency of the claims are to be considered within their scope.

We claim:

1. A centrifugal compressor, comprising:
  - a plurality of diffuser vanes arranged in a circumferentially spaced array about a machine axis, each diffuser vane being mounted on a respective shaft;
  - a ring to which each of the shafts is coupled to, the ring being rotatable about the machine axis;
  - a worm drive including a worm that meshes with a won't gear or a segment of a worm gear mounted along at least a portion of the circumference of the ring; and
  - a step motor coupled to the worm and operable to rotate the worm about a worm axis perpendicular to the machine axis, such that the worm drive transmits rotational torque from the step motor to the ring, to resultantly vary the position of the diffuser vanes.
2. The centrifugal compressor according to claim 1, wherein each shaft is coupled to the ring by a radial arm that transmits rotational torque from the ring to the respective shaft, and resultantly, to the respective diffuser vane mounted thereon.
3. The centrifugal compressor according to claim 2, wherein a plurality of bearings are provided along the circumference of the ring, wherein each radial arm is flexibly coupled to a respective bearing by means of a slot provided on the respective arm.
4. The centrifugal compressor according to claim 1, wherein the step motor is coupled to the worm by means of a flexible coupling.
5. The centrifugal compressor according to claim 1, further comprising a volute casing, wherein the ring is axially and radially supported on the volute casing by means a plurality of bearing assemblies disposed circumferentially around the volute casing.
6. A method for providing variable geometry of diffuser vanes of a centrifugal compressor, comprising:
  - mounting each of a plurality of diffuser vanes on a respective shaft, such that the diffuser vanes are arranged in a circumferentially spaced array about a machine axis;
  - coupling each of the shafts to a ring that is rotatable about the machine axis;
  - disposing a worm drive including a worm that meshes with a worm gear or a segment of a worm gear mounted along a portion of the circumference of the ring; and
  - coupling a step motor to the worm, the step motor being operable motor to rotate the worm about a worm axis perpendicular to the machine axis, such that the worm drive transmits rotational torque from the step motor to the ring, to resultantly vary the position of the diffuser vanes.

7. The method according to claim 6, further comprising coupling each shaft to the ring by a radial arm that transmits rotational torque from the ring to the respective shaft, and resultantly, to the respective diffuser vane mounted thereon.

8. The method according to claim 7, further comprising:  
disposing a plurality of bearings along the circumference of the ring, and  
flexibly coupling each radial arm to a respective bearing by means of a slot provided on the respective arm.

9. The method according to claim 6, further comprising coupling the step motor to the worm by means of a flexible coupling.

10. The method according to claim 6, further comprising disposing a plurality of bearing assemblies circumferentially around a volute casing of the compressor, and axially and radially supporting the ring on the volute casing by means of the plurality of bearings.

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