

REVOLVING VANE COMPRESSOR

FIELD OF THE INVENTION

[0001] This invention relates to compressors, and more particularly to revolving vane compressors with enhanced efficiency.

BACKGROUND OF THE INVENTION

[0002] Revolving vane compressors have a rotor, one or more vanes extending from the rotor and inserted in corresponding radial channels in the rotor. The rotor is mounted offset in a larger housing which can be circular or have a more complex shape. As the rotor turns, blades slide along slots keeping contact with the outer wall of the housing. Thus, rotation of the rotor decreases available volume within the housing, thereby compressing fluid in the housing.

[0003] Generally, as an amount of fluid introduced to the compressor increases, the capacity of the compressor also increases. Therefore it would be desirable to provide a revolving vane compressor which can induce an increased mass flow rate. Further, it would be desirable to reduce pressure loss through the compressor suction and discharge ports, as this will also help increase overall compressor efficiency.

SUMMARY OF THE INVENTION

1 [0004] In accordance with a first aspect, a revolving vane compressor comprises a
2 cylinder rotatable about an axis of rotation, a vane rotatable with the cylinder, a rotor
3 is operatively connected to the vane such that rotation of the cylinder causes rotation
4 of the rotor, a drive shaft, and a front cylinder cover rotatable with the cylinder by the
5 drive shaft, comprising at least one fluid inlet positioned circumferentially around the
6 drive shaft, and adapted to receive a compressible fluid. Rotation of the cylinder
7 urges the compressible fluid through the fluid inlet and into the compression
8 chamber through the rotor.

9
10 [0005] From the foregoing disclosure and the following more detailed description of
11 various embodiments it will be apparent to those skilled in the art that the present
12 invention provides a significant advance in the technology of compressors.
13 Particularly significant in this regard is the potential the invention affords for providing
14 a revolving vane compressor with increased efficiency. Additional features and
15 advantages of various embodiments will be better understood in view of the detailed
16 description provided below.

17 18 BRIEF DESCRIPTION OF THE DRAWINGS

19
20 [0006] Fig. 1 is an isometric view of a revolving vane compressor in accordance with
21 one embodiment.

22
23 [0007] Fig. 2 is an exploded isometric view of a revolving vane compressor in
24 accordance with the embodiment of Fig. 1.

1 [0008] Fig. 3 is a cross section view showing a flow of fluid through the compressor.

2
3 [0009] Figs. 4-7 show cross section views taken along line 4-4 in Fig. 3 (through the
4 vane) showing positions of a rotor with respect to the vane during rotation of the rotor
5 with respect to a cylinder.

6
7 [0010] Figs. 8 and 9 are isolated isometric views of a front cylinder cover.

8
9 [0011] Fig. 10 is an isolated isometric view of an alternate embodiment of the front
10 cylinder cover.

11
12 [0012] Fig. 11 is an isolated isometric view of a rotor, showing a fluid travel path and
13 a discharge valve assembly channel.

14
15 [0013] Fig. 12 is an isolated isometric view of the discharge valve assembly, partially
16 cut away, showing a discharge casing and a discharge plate.

17
18 [0014] Fig. 13 shows underside view of the discharge casing showing reinforcement
19 ribs.

20
21 [0015] Figs. 14-15 are views of another embodiment of a discharge valve assembly.

22
23 [0016] Fig. 16 is a side view of the interior of the main housing, showing an oil sump
24 adapted to receive part of a rear plate.

1 [0017] Figs. 17 and 18 are front and back isolated isometric views of the rear plate.

2
3 [0018] It should be understood that the appended drawings are not necessarily to
4 scale, presenting a somewhat simplified representation of various features illustrative
5 of the basic principles of the invention. The specific design features of the revolving
6 vane compressor as disclosed here, including, for example, the specific dimensions
7 of the rotor will be determined in part by the particular intended application and use
8 environment. Certain features of the illustrated embodiments have been enlarged or
9 distorted relative to others to help provide clear understanding. In particular, thin
10 features may be thickened, for example, for clarity of illustration. All references to
11 direction and position, unless otherwise indicated, refer to the orientation illustrated
12 in the drawings.

13 14 DETAILED DESCRIPTION OF CERTAIN EMBODIMENTS

15
16 [0019] It will be apparent to those skilled in the art, that is, to those who have
17 knowledge or experience in this area of technology, that many uses and design
18 variations are possible for the revolving vane compressor disclosed here. The
19 following detailed discussion of various alternate features and embodiments will
20 illustrate the general principles of the invention with reference to a revolving vane
21 compressor suitable for use in an automotive air conditioner. Other embodiments
22 suitable for other applications will be apparent to those skilled in the art given the
23 benefit of this disclosure.

[0020] Turning now to the drawings, Fig. 1 shows an isometric view of a revolving vane compressor 17. A drive shaft 20 is connected to a clutch assembly (not shown) which rotates the drive shaft 20. A housing comprises a main housing 40 connected to front housing 30 by one or more fasteners 18. Compressible fluid is introduced into the compressor 17 at suction port 32 of the front housing. After the fluid is compressed, the fluid exits at discharge port 41. Fig. 2 shows an exploded isometric view of an embodiment of the compressor. The fluid suction port 32 may be capped with a suction filter 31. Drive shaft 20 is operatively connected to a front cylinder cover 50 such that the pair rotate together about an axis of rotation. Front cover 30 receives the drive shaft 20, and may be provided with a drive shaft bearing 34 which permits relative rotation, and a sealing element which restricts fluid flow such as radial shaft seal 33. A thrust washer 110 is positioned between the front housing 30 and the front cylinder cover 50. The thrust washer 110 helps absorb a net axial force biasing the cylinder 60 toward the front housing 30 during operation resulting from the pressure differential of the fluid across the compressor.

[0021] A rotor 80 is positioned within the cylinder 60. A vane 25 connects the rotor 80 and cylinder 60 together and is positioned in vane channel 62 in the cylinder 60 and rotor vane channel 82 in the rotor 80. Front cylinder cover 50 cooperates with the cylinder 60 and rear cylinder cover 70 to define a space which receives the rotor 80 and the vane 25. Front cylinder cover 50 also defines a recess 54 adapted to receive front bearing 55. The front cylinder cover 50, cylinder 60 and rear cylinder cover 70 are connected by a plurality of fasteners or bolts 19 through bolt channels 64 and all rotate together. Front bearing 55 is positioned between the front cylinder cover 50 and the rotor 80, defines a fluid path channel 56, and has a front cylinder

cover bearing 57 and a rotor bearing 58. Rear bearing 91, which is shown here formed as a unitary extension of a rear plate 90, has bearings which engage the rotor 80 at outlet bore 86 and also engages rear cylinder cover 70. A discharge valve assembly 100 comprising, for example, a discharge valve casing 102 and a discharge valve plate 104, is optionally positioned in a discharge valve assembly channel 84 formed in the rotor 80. An end face plug 103 may be provided which is used to reduce abrasive wear of discharge valve casing 102 when sliding on the surface of the rear cylinder cover 70. An oil separation plate 93 may be affixed to or positioned on the rear plate 90. The rear plate 90 may also be provided with ribs 94 which cooperate with the main housing 40. The channel 84 may be provided with an undercut, as shown in Fig. 11.

[0022] Also shown in Fig. 2, front cylinder cover 50 and rear cylinder cover 70 have balancing holes 59, and the cylinder has holes 69. These holes 59 and 69 are adapted to receive balancing pins 106 to help rotational balance of the cylinder and rotor during operation.

[0023] Fig. 3 shows a cross section view which illustrates fluid passageways in the rotor 80. In response to rotation of the drive shaft 20, the front cylinder cover 50, cylinder 60 and rear cylinder cover 70 rotate with respect to the front housing 30 and main housing 40. The rotor 80 rotates about a rotor axis offset from an axis of rotation of the cylinder 80. As shown in Fig. 3, the cylinder's axis of rotation is generally coaxial with shaft 20, while the rotors axis of rotation is offset. Bearing assemblies 55 and 91 maintain this offset. The fluid travel path of the compressible fluid is shown in part by the large arrows from suction port 32 to inlet channel 36 to

fluid channels 52 in the front cylinder cover 50 to fluid path channel 56. The rotor 80 and housing cooperate to define a compression chamber 65 (shown in Figs. 4-7). From the fluid path channel, the fluid continues to inlet bore 81, then to inlet passageway 83 to compression chamber 65, where the fluid is compressed during rotation of the cylinder, through the discharge valve plate assembly channel 84 to outlet passageway 85 to outlet bore 86. From there, the compressed fluid exits through rear channel 92 formed in rear bearing 91 to expanded channel 95 and finally through discharge port 41. Each of these openings and channels cooperates to define part of the fluid travel path. The flow path of the compressible fluid is serpentine through the rotor. Fig. 3 also shows the oil separation plate 93 positioned in the fluid flow path. Some oil mist may be present in the compressed fluid. The oil separation plate 93 may be positioned generally perpendicular to the expanded channel 95, as shown in Fig. 3. When the combination of the oil mist and compressed fluid reaches the oil separation plate 93, advantageously there will be some impingement of the oil mist on the oil separation plate. The oil tends to accumulate at the plate while the refrigerant continues to the discharge port 41. This helps separate the refrigerant/compressed fluid from the oil.

[0024] During operation, the drive shaft 20 rotates the cylinder 60 about the axis of rotation, while the rotor rotates about a separate rotor axis of rotation which is offset from the axis of rotation. The rotor is offset with respect to the cylinder. This relative movement is shown in Figs. 4-7 illustrate this rotation of the rotor 80, showing relative change of position of the vane 25 within the vane channel 82 and with respect to the rotor 80 during rotation of the rotor 80. Vane 25 can have a larger end which is operatively received in vane channel 62 such that the vane 25 rotates

1 with the cylinder. As shown, the end is rounded and fits within the vane channel 62
2 to restrict separation but allow for some relative movement of the vane 25 with
3 respect to the housing 60.

4
5 [0025] During the operation, a compression chamber formed between the cylinder
6 and the rotor (as well as expanded channel 95 of rear plate 90 and portions of the
7 fluid path downstream of the compression chamber) is filled with a pressurized
8 compressible fluid. Fluid path upstream from the rotor, including the inlet channel 36
9 to a front housing chamber contain fluid at a lower pressure. Due to the resulting
10 pressure differential, there is a net axial force biasing the cylinder 60 towards the
11 front housing 30. Thrust washer 110 shown in Figs. 2 and 3 is positioned between
12 the front cylinder cover 50 and the front housing 30 and helps to compensate for
13 such axial loading, as well as continuous sealing between portions of the fluid path.

14
15 [0026] In accordance with a highly advantageous feature, the front cylinder cover 50,
16 shown in isolated isometric views of Figs. 8 and 9, acts as a supercharger,
17 increasing the pressure of the fluid as it is delivered to the rotor 80. Drive shaft 20 is
18 operatively connected to the front cylinder cover 50 so that they rotate together. At
19 least one fluid channel 52 is positioned circumferentially around the drive shaft 20.
20 Compressible fluid/refrigerant flows from the inlet channel 36 to each fluid inlet 120
21 of the front cylinder cover. As shown in the embodiment of the front cylinder cover
22 50 of Fig. 8, the fluid inlets each connect to a passageway 130, and an exit 140 from
23 the passageway 130. Optionally each fluid inlet 120 may be provided with a
24 corresponding ramped surface 53. Since during operation the front cylinder cover 50

rotates, the inlets and ramped surfaces act as a fan-like mechanism, advantageously increasing the rate of fluid flow through the fluid channel 52 and into the rotor 80.

[0027] In the embodiment of Figs. 8-9 there are four fluid channels 52 and the entrance 120 to the passageway 130 is generally perpendicular to the axis of rotation of the drive shaft 20 and cylinder 60. As best seen in Fig. 9, front cylinder cover 50 defines a recess or opening 54 adapted to receive the front bearing 55. The front bearing 55 has a fluid path 56 which is in fluid communication with the exits 140 of each fluid channel 52. Compressible fluid flows from the exits 140 of the fluid channels into the fluid path 56 inside the front bearing 55, and from there to the rotor 80. The exits 140 can be generally parallel to the axis of rotation, as best shown in Fig. 9.

[0028] Fig. 8 shows openings 111 which cooperate with the bolt channels 64 on the cylinder 60. Corresponding openings are also present on the rear cylinder cover and cooperate with bolt channels and openings on the front cylinder cover to receive corresponding bolts 19. The bolts 19 connect the cylinder covers 50, 70 and the cylinder 60 together. In accordance with a highly advantageous feature, to counter imbalance in the cylinder due to the presence of vane 25, balancing holes 59 are provided on the front cylinder cover 50 and rear cylinder cover 70 which cooperate with holes 69 to allow the insertion of one or more balancing pins 106. The balancing holes (and therefore the balancing pins 106) are positioned on a side of a circumference of the cylinder which is generally opposite of the vane 25. By inserting suitable weight of balancing pins 106, the inherent imbalance during

rotation can be reduced, thereby reducing the overall offset forces generated during the rotation of the cylinder.

[0029] Fig. 10 shows an alternate embodiment of a front cover 150. Whereas in the embodiment of Figs. 8-9 the entrances of each fluid channel are perpendicular to the axis of rotation of the cylinder and drive shaft, in this embodiment the entrances of the fluid channels 152 are parallel to the axis of rotation. Corresponding ramped surfaces 153 guide the compressible fluid into each inlet and direct the fluid towards the rotor. In response to rotation, the ramped surfaces act as fan, effectively increasing pressure of the compressible fluid delivered to the rotor 80.

[0030] Fig. 11 shows one embodiment of a rotor 80. In this embodiment, the rotor is considered to be shaftless, to contrast it with conventional rotors with two protruding shafts extending from each end of the rotor. Advantageously, the shafts are replaced with an inlet bore 81 and an outlet bore 86, which significantly reduces overall weight of the compressor, as well as material costs of the rotor. Inlet bore 81 and outlet bore 86 may be coaxial, as shown. Inlet bore 81 is adapted to receive front bearing 55, and outlet bore is adapted to receive rear bearing 91 (which, in the embodiment shown in the Figs., is a unitary extension of the rear plate 90). These bearings 55, 91 operatively engage the rotor 80 such that the rotor 80 is rotatable with respect to both bearings. Since material in the rotor is not symmetrical about the rotor axis of rotation, holes 105, 108 may be added to shift a center of mass back to the rotor axis of rotation. Optionally, rotor balancing holes 105, 108 may have openings with a diameter larger at both ends than in a diameter of the middle, akin to a funnel shape. This can help reduce oil accumulation in the rotor balancing holes

1 105 and 108 and thereby help maintain rotational balance of the rotor during
2 operation. A through hole 107 for oil circulation may also be provided, as shown.

3
4 [0031] Compressible fluid is directed from inlet bore 81 through inlet passageway 83
5 to the compression chamber 65, which is the space between the cylinder 60 and the
6 rotor 80 as the two move with respect to one another. As there is a pressure
7 differential, the fluid is typically sucked into the compression chamber 65. The rotor
8 80 defines a vane channel 82 which receives the vane 25. As noted above, the rotor
9 80 and cylinder 60 rotate about separate axes of rotation, separated by an offset
10 maintained by the front bearing 55 and rear bearing 91.

11
12 [0032] The rotor 80 also defines a discharge valve plate assembly channel 84.
13 Compressed fluid enters this channel and is routed to outlet passageway 85 and
14 from there to outlet bore 86. Thus, the outlet passageway 85 operatively connects
15 the compression chamber 65 to the outlet bore. Rotation of the cylinder urges the
16 compressible fluid to flow through the inlet bore 81 to the outlet bore 86. Optionally
17 the vane channel 82 may be positioned circumferentially between the inlet
18 passageway 83 and outlet passageway 85, as shown in Fig. 11. That is, along the
19 circumference of the bore, the vane channel is positioned between the inlet
20 passageway 83 and outlet passageway 85.

21
22 [0033] Figs. 12 and 13 show one embodiment where a discharge valve assembly
23 100 is used and positioned within the channel 84. The discharge valve assembly
24 100 acts as a check valve, helping to reduce pressure losses. The discharge valve
25 assembly 100 is moveable from a closed position restricting flow of the compressible

1 fluid back from the rear channel to the compression chamber 65, to an open position
2 which allows flow of the compressible fluid from the compression chamber 65 to the
3 rear channel. The discharge valve assembly 100 can comprise, for example, a
4 discharge valve casing 102 and a discharge valve plate 104. The valve plate 104
5 floats in response to pressure differentials for ease in valve opening.

6
7 [0034] During normal operation fluid flow the plate 104 is urged downward allowing
8 fluid flow between the casing 102 and the plate 104. Ribs may be provided to help
9 hold the plate 104 within the casing while allowing fluid flow. If there is a
10 backpressure, the plate 104 is forced upward into contact with the casing 102,
11 effectively blocking fluid flow back into the compression chamber 65. Further, the
12 discharge valve assembly 100 shown in the drawings advantageously takes
13 advantage of the centrifugal force generated during operation, helping to enhance
14 sealing. This design advantageously eliminates the need for a separate component
15 such as a spring to help seal the plate 104 against the casing 102. The discharge
16 valve plate 104 of Fig. 12 has a protrusion which extends up into the casing 102
17 which serves to reduce dead volume at the end of the discharge process, and
18 thereby ensure most of the intake fluid will be discharged. A top of the casing 102
19 may be shaped to further help reduce dead volume. Reducing dead volume
20 advantageously reduces power consumption and improves efficiency of the
21 compressor.

22
23 [0035] Figs. 14-15 show an alternate embodiment of the discharge valve assembly
24 200, where a discharge valve casing 202 has a plurality of openings which are
25 closed by corresponding balls 204. The balls may be inserted into an underside of

1 the casing 202 and float within the casing in response to pressure differential in the
2 same manner as valve plate 104 in the previous embodiment.

3
4 [0036] Fig. 16 is a side view of the main housing 40 looking toward the back of the
5 housing. The main housing 40 has landings 44 and rib 42 which help to define an oil
6 sump 43. The landings 44 also cooperate with ribs 94 on the rear plate 90 (shown in
7 Fig. 18) to help with alignment of these two parts with respect to one another. Figs.
8 17-18 show front and back isometric views of the rear plate 90. The front side of
9 rear plate 90 has a rotor bearing 98 which operatively engages outlet bore 86 of the
10 rotor. The front side also has a rear cylinder cover bearing 97 which operatively
11 engages the rear cylinder cover 70 such that the cylinder 60 and cylinder covers
12 rotate with respect to the rear plate 90. Rear channel 92 is part of the fluid travel
13 path. Compressed fluid exits the rotor 80 and enters rear channel 92. In
14 accordance with one embodiment, prior to reaching the discharge port 41, the fluid
15 contacts the oil separation plate 93, shown in Fig. 16, positioned in expanded
16 channel 95. The fluid comprises the compressible fluid but also some oil. The oil
17 contacts the oil separation plate and tends to impinge on the oil separation plate 93
18 while the compressed fluid continues past ribs 42 to the discharge port 41. The ribs
19 42 help guide the oil to the oil sump 43. This design advantageously helps reduce
20 the amount of oil which is carried out of the compressor.

21
22 [0037] From the foregoing disclosure and detailed description of certain
23 embodiments, it will be apparent that various modifications, additions and other
24 alternative embodiments are possible without departing from the true scope and
25 spirit of the invention. The embodiments discussed were chosen and described to

1 provide the best illustration of the principles of the invention and its practical
2 application to thereby enable one of ordinary skill in the art to use the invention in
3 various embodiments and with various modifications as are suited to the particular
4 use contemplated. All such modifications and variations are within the scope of the
5 invention as determined by the appended claims when interpreted in accordance
6 with the breadth to which they are fairly, legally, and equitably entitled.

CLAIMS

What is claimed is:

1. A revolving vane compressor comprising, in combination:
 - a cylinder rotatable about an axis of rotation;
 - a vane rotatable with the cylinder;
 - a rotor is operatively connected to the vane such that rotation of the cylinder causes rotation of the rotor;
 - a drive shaft; and
 - a front cylinder cover rotatable with the cylinder by the drive shaft, comprising at least one fluid inlet positioned circumferentially around the drive shaft, and adapted to receive a compressible fluid, wherein rotation of the cylinder urges the compressible fluid through the fluid inlet and into the rotor.
2. The revolving vane compressor of claim 1 wherein the at least one fluid inlet has a passageway, an entrance to the passageway and an exit from the passageway.
3. The revolving vane compressor of claim 1 further comprising a ramped surface corresponding to each at least one fluid inlet.
4. The revolving vane compressor of claim 1 wherein the rotor rotates about a rotor axis of rotation which is offset from the axis of rotation of the cylinder.

1 5. The revolving vane compressor of claim 1 further comprising a housing
2 having an suction port and a discharge port for the compressible fluid, wherein the
3 cylinder is positioned within the housing.

4
5 6. The revolving vane compressor of claim 5 further comprising a thrust washer
6 positioned between the housing and the front cylinder cover.

7
8 7. The revolving vane compressor of claim 1 wherein the rotor defines a vane
9 channel, the cylinder has a vane groove, and the vane is received in both the vane
10 channel and the vane groove; and
11 balancing pins are positioned on the cylinder opposite the vane groove.

12
13 8. The revolving vane compressor of claim 5 wherein the rotor further comprises
14 an outlet bore and an oil separator plate is positioned between the outlet bore of the
15 rotor and the discharge port of the housing.

16
17 9. The revolving vane compressor of claim 5 further comprising a rear cylinder
18 cover, a rear bearing operatively engaging an outlet bore of the rotor, and a rear
19 cylinder cover bearing operatively engaging the rear cylinder cover; and
20 the rear plate defines a rear channel in fluid connection with the outlet bore
21 and the discharge port.

22
23 10. The revolving vane compressor of claim 9 wherein the rear bearing is formed
24 as a unitary extension of a rear plate.

1 11. The revolving vane compressor of claim 10 wherein the oil separator plate is
2 positioned on the rear plate.

3
4 12. The revolving vane compressor of claim 5 wherein the housing has a rib and
5 defines an oil sump; and
6 a rear plate defines a rear channel;
7 wherein the rib is positioned between the discharge port and the rear channel.

8
9 13. The revolving vane compressor of claim 1 wherein the drive shaft is
10 positioned in a central bore of the front cylinder cover.

11
12 14. The revolving vane compressor of claim 1 further comprising
13 a front bearing and a rear bearing cooperating with the rotor and the
14 compression chamber to define a fluid path channel of a compressible fluid, and the
15 rear bearing further defines a rear channel in fluid communication with a
16 compression chamber defined by the rotor and the cylinder, wherein the front
17 bearing and the rear bearing each operatively engage the rotor such that the rotor is
18 rotatable with respect to both the front bearing and the rear bearing; and

19 a discharge valve assembly moveable
20 from a closed position restricting flow of the compressible fluid back
21 from the rear channel to the compression chamber,
22 to an open position which allows flow of the compressible fluid from the
23 compression chamber to the rear channel.

24
25 15. The revolving vane compressor of claim 14 wherein the rotor further defines

1 an inlet bore;
2 an inlet passageway operatively connecting the inlet bore and the
3 compression chamber;
4 an outlet bore; and
5 an outlet passageway operatively connecting the compression chamber to the
6 outlet bore;
7 wherein rotation of the cylinder urges the compressible fluid to flow through
8 the inlet bore to the outlet bore.

9
10 16. The revolving vane compressor of claim 15 wherein the discharge valve
11 assembly is positioned in a discharge valve assembly channel defined by the rotor.

12
13 17. The revolving vane compressor of claim 15 wherein the discharge valve
14 assembly comprises a discharge valve casing adapted to receive one of a discharge
15 valve plate and a plurality of balls.

16
17 18. The revolving vane compressor of claim 15 wherein the inlet bore and outlet
18 bore are coaxial.

19
20 19. The revolving vane compressor of claim 15 wherein the rotor further defines
21 at least one rotor balancing hole, wherein each rotor balancing hole has a pair of
22 ends and a middle, and openings at the ends have a larger diameter than a diameter
23 of the middle.