

A Revolving Vane Compressor, Method of Manufacturing and Operating the Same

Description

Technical Field

The present invention generally relates to a revolving vane compressor, and method of manufacturing and operating the same.

Background Art

A compressor is a mechanical device that is capable of reducing the volume of a compressible fluid. An example of a compressible fluid is a refrigerant. Components within the compressor draw the compressible fluid from a low-pressure fluid inlet and compress the fluid to a higher pressure through volumetric reduction. The flow of the compressible fluid into the compressor is typically regulated by an intake assembly. The typical intake assembly generally comprises one or more reed valves which prevent the reverse flow of the fluid into the inlet as the fluid is compressed. A typical reed valve comprises a flexible reed plate covering a suction port on a valve plate. Fasteners typically secure one end of the reed plate to the valve plate while the other end is free. The intake of the compressible fluid begins when components within the compressor generate a pressure difference between the compressor and the fluid inlet. The pressure difference causes the reed plate to deflect and bend away from the valve plate, which opens the suction port, and allows the compressible fluid to flow into the compressor.

However, the use of reed valves in the intake assembly of revolving vane compressors comes with inherent disadvantages. The reed plates have a characteristic mass and introduce inertial resistance which causes a delay to the opening and closing of the reed valves. The delay in turn reduces volumetric and energy efficiencies of the compressor. Inertial resistance of the reed plates may also result in sub-optimal pressures within the compressor, which may in turn generate excessive vibrations and noise. While the characteristic mass of the reed plates can be reduced, lighter reed plates may become more sensitive to environmental vibrations and may flutter at high frequencies, which disrupts fluid flow and affects performance of the compressor. Moreover, durability of the reed valves is limited as repeated deflections and impact against the valve plate stress the reeds. Worn reed valves can affect the performance and efficiency of the compressor. If the reed valves break, chips from the broken reed valves may be lodged between the sliding/bearing

surfaces of the compressor. These chips can cause high friction wear within the compressor and result in compressor seizure. Further, considerable volume within the typical compressor is allocated to accommodate the deflection of the reed valves. Use of reed valves therefore hinders the development of more compact and space-efficient compressors which are used in, for example, automobile applications.

Accordingly, a need exists to provide a compressor that seeks to address some of the above problems. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

Summary of Invention

A first aspect of the present invention provides a revolving vane compressor comprising a first housing member connected to a compressor inlet, a flow regulator disposed downstream of the compressor inlet and a sleeve assembly comprising a sleeve cover. The sleeve assembly is configured to be received in the first housing member downstream of the flow regulator and to be rotatable relative to the first housing member about a rotational axis. The sleeve cover abuts the flow regulator and comprises one or more openings, each of the one or more openings being associated with a respective chamber of the sleeve assembly. The flow regulator is shaped such that, in a first rotational position of the sleeve assembly relative to the first housing member, a chamber of the sleeve assembly is in fluid communication with the compressor inlet for drawing a compressible fluid into said chamber, and in a second rotational position of the sleeve assembly relative to the first housing member, the flow regulator seals said chamber from the compressor inlet for compressing the fluid within said chamber.

The flow regulator may form a unitary construction with the first housing member.

The flow regulator may comprise a thrust washer configured to be received in the first housing member, the thrust washer being rotationally fixed relative to the first housing member.

The thrust washer may comprise a hollow portion disposed upstream of the opening associated with the chamber in the first rotational position and a solid portion disposed upstream of the opening associated with the chamber in the second rotational position.

The thrust washer may comprise an upstream face, the upstream face comprising a first attachment member configured to engage with a corresponding second attachment member

disposed in the first housing member for rotationally fixing the thrust washer relative to the first housing member.

The first attachment member may comprise at least one protruding tab and the corresponding second attachment member may comprise at least one corresponding depression.

The first attachment member may alternatively comprise at least one depression and the corresponding second attachment member may comprise at least one corresponding protruding tab.

The thrust washer may be fastened to the first housing member for rotationally fixing the thrust washer relative to the first housing member.

The size of each of the one or more openings of the sleeve cover may be determined based on a rotational speed of the sleeve assembly and a predetermined quantity of the compressible fluid to be drawn into the chamber.

The sleeve cover may comprise two openings disposed diagonally opposite each other.

The revolving vane compressor may further comprise a second housing member, the second housing member defining a flow channel upstream of a compressor outlet, wherein the flow channel is configured to separate a lubricating oil from the compressible fluid prior to the compressible fluid exiting the compressor outlet.

The second housing member may comprise a plurality of ribs extending from an inner surface of the second housing member, the plurality of ribs forming the flow channel.

The second housing member may further comprise an oil sump configured to collect the lubricating oil separated from the compressible fluid.

The revolving vane compressor may further comprise a plurality of oil channels in fluid communication with the oil sump, the oil channels configured to direct at least a portion of the collected oil to moving parts of the compressor based on pressure differences within the compressor.

A second aspect of the present invention provides a method of manufacturing a revolving vane compressor, the method comprising the steps of providing a first housing member such that the first housing member is connected to a compressor inlet, providing a flow regulator downstream of the compressor inlet, and mounting a sleeve assembly downstream of the flow regulator, the sleeve assembly comprising a sleeve cover, such that the sleeve assembly is rotatable relative to the first housing member about a rotational axis and the sleeve cover abuts the flow regulator. The sleeve cover comprises one or more openings, and each of the one or more openings being associated with a respective chamber of the sleeve assembly. The flow regulator is shaped such that, in a first rotational position of the sleeve assembly relative to the first housing member, a chamber of the sleeve assembly is in fluid communication with the compressor inlet for drawing a compressible fluid into said chamber, and in a second rotational position of the sleeve assembly relative to the first

housing member, the flow regulator seals said chamber from the compressor inlet for compressing the fluid within said chamber.

The step of providing the flow regulator may comprise forming the flow regulator as a unitary construction with the first housing member.

The step of providing the flow regulator may comprise mounting a thrust washer to the first housing member such that the thrust washer is rotationally fixed relative to the first housing member.

The step of mounting the thrust washer may comprise providing a thrust washer comprising a hollow portion and a solid portion, the hollow portion being disposed upstream of the opening associated with the chamber in the first rotational position, and the solid portion being disposed upstream of the opening associated with the chamber in the second rotational position.

The step of mounting the thrust washer may further comprise providing a first attachment member on an upstream face of the thrust washer, providing a corresponding second attachment member in the first housing member, and engaging the first attachment member with the corresponding second attachment member to rotationally fix the thrust washer relative to the first housing member.

The step of providing the first attachment member on the upstream face of the thrust washer may comprise providing at least one protruding tab on the upstream face of the thrust washer, and the step of providing the corresponding second attachment member in the first housing member may comprise providing at least one corresponding depression in the first housing member.

The step of providing the first attachment member on the upstream face of the thrust washer may alternatively comprise providing at least one depression on the upstream face of the thrust washer, and the step of providing the corresponding second attachment member in the first housing member may alternatively comprise providing at least one corresponding protruding tab in the first housing member.

The step of mounting a thrust washer to the first housing member may comprise fastening the thrust washer to the first housing member for rotationally fixing the thrust washer relative to the first housing member.

The size of each of the one or more openings may be determined based on a rotational speed of the sleeve assembly and a predetermined quantity of the compressible fluid to be drawn into the chamber.

The one or more openings may comprise two openings disposed diagonally opposite each other on the sleeve cover.

Brief Description of Drawings

Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Fig.1

Fig. 1 shows an exploded perspective view of a revolving vane compressor according to a first embodiment.

Fig.2

Fig. 2A shows a side cross-sectional view of the revolving vane compressor of Fig. 1 when assembled. Fig. 2B shows a side cross-section view of the revolving vane compressor according to a second embodiment.

Fig.3

Figs. 3A and 3B show perspective upstream and downstream views of a thrust washer of Fig. 1.

Fig.4

Fig. 4A shows a perspective view of a sleeve cover, and Fig. 4B shows a sectional perspective view of a thrust washer with the sleeve cover and sleeve according to the example embodiment of Fig. 1.

Fig.5

Figs. 5A and 5B show sectional perspective rear views of the front housing member of the revolving vane compressor in Figs. 2A and 2B respectively.

Fig.6

Figs. 6A to 6D show sectional views of the sleeve assembly of the revolving vane compressor of Fig. 1 rotated clockwise by various angles with respect to a reference line.

Fig.7

Figs. 7A to 7D show sectional views of the sleeve assembly of the revolving vane compressor of Fig. 1 with the thrust washer and the openings of the sleeve cover superimposed, the sleeve assembly being rotated clockwise through various angles with respect to a reference line during a first stage of an intake cycle.

Fig.8

Figs. 8A to 8D show sectional views of the sleeve assembly of the revolving vane compressor of Fig. 1 with the thrust washer and the openings of the sleeve cover superimposed, the sleeve assembly being rotated clockwise through various angles with respect to a reference line during a second stage of an intake cycle.

Fig.9

Fig. 9 shows a sectional view of a rear housing member of the revolving vane compressor of Fig. 1.

Fig.10

Fig. 10 shows a flowchart illustrating a method for operating a revolving vane compressor according to an example embodiment.

Fig.11

Fig. 11 shows a flowchart illustrating a method for manufacturing a revolving vane compressor according to an example embodiment.

Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been depicted to scale. For example, the dimensions of some of the elements in the illustrations, block diagrams or flowcharts may be exaggerated in respect to other elements to help to improve understanding of the present embodiments.

Description of Embodiments

The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention

to be bound by any theory presented in the preceding background of the invention or the following detailed description. Herein, an intake assembly of a revolving vane compressor, method of manufacturing and operating the same are presented in accordance with present embodiments having the advantages of compactness, improved durability, enhanced efficiency, greater performance and better noise and vibration characteristics.

Fig. 1 shows an exploded perspective view of a revolving vane compressor 100 according to a first example embodiment. The revolving vane compressor 100 comprises a first (e.g. front) housing member 102 having a compressor inlet, a sleeve assembly 103 and a flow regulator in the form of a thrust washer 104. The sleeve assembly 103 comprises a sleeve cover 106, and the sleeve assembly 103 is configured to be received in the first housing member 102 and rotatable relative to the first housing member 102 about a rotational axis 156. The thrust washer 104 is configured to be received in the first housing member 102 and is positioned upstream of the sleeve assembly. The thrust washer 104 is also configured to be rotationally fixed relative to the first housing member 102 while abutting the sleeve cover 106 when assembled. The intake assembly of the compressor 100 comprises the thrust washer 104 and the sleeve cover 106.

The compressor 100 also comprises a second (e.g. rear) housing member 108 having a compressor outlet and a third housing member 120. The respective housing members 102, 108, 120 are secured together by one or more fasteners 144. When assembled, the third housing member 120 is positioned between the first housing member 102 and the second housing member 108. Shim 136 may be optionally placed between the housing members 102, 120 to adjust the axial clearance between the housing members 102, 120 and sleeve assembly 103. A sealing element 134 is placed between the housing members 102, 120 to prevent leakage of compressible fluid from the compressor 100. Sealing element 142 is similarly placed between housing members 108, 120. Further, the sealing element and shim may be integrated into a single component, thus simplifying the manufacturing process of the compressor 100. In alternate embodiments, the housing may comprise two housing members instead of three. During operation, low-pressure compressible fluid is introduced into the compressor 100 through the inlet connected to the first housing member 102. The compressed, high-pressure compressible fluid exits the compressor 100 through the outlet connected to the second housing member 108.

The sleeve assembly 103 further comprises a sleeve 110 and a rear sleeve cover 132. The sleeve cover 106 is mounted to the sleeve 110 by one or more fasteners 128, and rear sleeve cover 132 is mounted to the sleeve by one or more fasteners 112. The sleeve assembly 103 is configured to be received in the first housing member 102. A drive shaft 101

extends from the sleeve cover 106 out of the first housing member 102 when the compressor is assembled. The drive shaft 101 is connected to a transmission assembly (not shown) which rotates the sleeve assembly 103 about the first rotational axis 156. The drive shaft 101 is supported by a drive shaft bearing 126 positioned within the first housing member 102. Sealing element 124 restricts fluid flow out of the first housing member 102. The sealing element 124 is positioned in front of the drive shaft bearing 126 and secured by snap ring 122. The sleeve cover 106 is part of the intake assembly of the revolving vane compressor 100. As will be described in detail in Fig. 4A, the sleeve cover 106 in the example embodiment comprises one or more openings.

The thrust washer 104 is configured to be received in the first housing member 102 and positioned upstream of the sleeve assembly. The thrust washer is configured to be rotationally fixed relative to the first housing member 102 while abutting the sleeve cover 106. The thrust washer 104 helps to distribute an axial force exerted by the sleeve assembly on the first housing member 102 due to pressure differences within the compressor during operation. The thrust washer 104 is also a component of the intake assembly of the compressor 100. The sliding surfaces of the thrust washer 104 and the sleeve cover 106 may be coated with anti-friction coatings which provide wear protection during operation of the compressor 100.

A rotor 152 is positioned within the sleeve assembly 103, and rotates about a second rotational axis 218 (shown in Fig. 2A) offset from the first rotational axis 156. The rotor 152 is supported by radial rotor bearing 138. Sealing element 140 is disposed within the third housing member 120. In the present embodiment, the rotor 152 has a substantially cylindrical external surface and the sleeve 110 has a cylindrical internal surface. The rotor 152 has a smaller diameter compared to the sleeve 110 such that a channel is formed in the space between the rotor 152 and the sleeve 110. The channel may be partitioned into a plurality of chambers by a primary vane 114 and at least one secondary vane 116. Each of the plurality of chambers is associated with each of the one or more openings on the sleeve cover 106. The primary vane 114 mechanically connects the rotor 152 to the sleeve 110 such that the sleeve 110 is operable to drive the rotor 152 about the second rotational axis. One end of the primary vane 114 is fixedly mounted to the sleeve 110 via one or more fasteners 130. The other end of the primary vane 114 is in sliding engagement with a shoe 118 positioned within the rotor 152. In alternate embodiments, a drive shaft may extend upstream from the rotor 152 towards the first housing member 102, and the rotor 152 drives the sleeve 110 instead. In the present embodiment, a rotating shaft extends downstream from the main body of the rotor 152. The rotating shaft is support by the radial rotor bearing

138. The rotating shaft of the rotor 152 is hollow, and comprises an outlet bore through which the compressed compressible fluid flows from the chambers.

The rotor 152 also comprises at least one discharge valve assembly positioned within recesses of the rotor 152. The discharge valve assembly controls the discharge flow of the high-pressure compressed fluid from the plurality of chambers to the outlet bore within the rotor. In the present embodiment, a ball check valve assembly is used to control the discharge flow. The ball check valve assembly of the present embodiment comprises a check valve casing 148, at least one ball 150, and sealing element 154. One or more fasteners 146 secures the ball check valve assembly to the rotor 152. In alternative embodiments, other types of check valves, such as diaphragm check valve, swing check valve, lift-check valve may be used. It will be appreciated by a person skilled in the art that different types and combinations of check valves may be used, and the above configuration are one of the examples.

Further, a person skilled in the art would also appreciate that different embodiments of the flow regulator may be used. For example, the thrust washer 104 and first housing member 102 may be substituted by an alternate first housing member with the flow regulator formed integrally. In other words, the flow regulator forms a unitary construction with the alternate first housing member, potentially simplifying the manufacturing process of the compressor 100.

Fig. 2A shows a side cross-sectional view of the revolving vane compressor 100 when assembled. The compressor 100 comprises the first housing member 102, the second housing member 108 and the third housing member 120. The first housing member 102 and the second housing member 108 include mounting brackets 204, 206 and mounting bracket 208 respectively for mounting the compressor 100 to a support structure such as one found in a vehicle. During operation of the compressor 100, compressible fluid is introduced into a cavity 202 within the compressor 100 via a compressor inlet 200 positioned on the first housing member 102. The cavity 202 is formed in the space between the sleeve assembly 103 (Fig. 1) and the housing assembly.

A portion of the cavity 202 is disposed upstream of the thrust washer 104 and the sleeve cover 106. As will be described in detail in Figs. 3 and 4, the sleeve cover 106 comprises one or more openings 220, 222 and each of the one or more openings 220, 222 is associated with a respective chamber of the sleeve assembly 103. In other words, the opening 220 is associated with chamber 212 of the sleeve assembly 103, and the opening 222 is associated with another chamber (not shown) of the sleeve assembly 103. The thrust washer 104 is shaped such that in a first rotational position of the sleeve assembly 103

relative to the first housing member 102, the chamber 212 of the sleeve assembly is in fluid communication with the compressor inlet 200 for drawing a compressible fluid into the chamber 212. In a second rotational position not illustrated in Fig. 2A, the thrust washer 104 seals the chamber 212 associated with the opening 220 from the compressor inlet 200 for compressing the fluid within the chamber 212. The thrust washer 104 and the sleeve cover 106 function as the intake assembly of the compressor 100, and replace the use of reed valves and associated short-comings.

The rotor 152 rotates about a second rotational axis 218 offset from the first rotational axis 156 of the sleeve assembly. The rotating shaft of the rotor 152 is hollow, and comprises an outlet bore 210 through which discharged compressed fluid flows. The outlet bore 210 is in fluid communication with the compressor outlet 216 positioned on the second housing member 108. The compressed fluid flows through outlet bore 210, passes through a flow channel formed from a plurality of ribs extending from the second housing member 108 and exits the compressor 100 via the compressor outlet 216. The flow channel, which will be described in detail in Fig. 9, is configured to separate a lubricating oil from the compressible fluid prior to the compressible fluid exiting the compressor outlet 216. The second housing member 108 also comprises an oil sump 214 configured to collect the lubricating oil separated from the compressible fluid. A plurality of oil channels is present in the compressor. Fig. 2A shows some of the oil channels 224, 226. The oil channels 224, 226 are in fluid communication with the oil sump 214. The oil channels 224, 226 are configured to direct at least a portion of the collected lubricating oil to moving parts of the compressor 100 based on pressure differences within the compressor 100.

Thus, the thrust washer 104 and the sleeve cover 106 advantageously eliminate the space within the compressor necessary to accommodate the deflection of reed valves used in a typical compressor. The cavity 202 within compressor 100 is more compact. Hence, less material is required to manufacture the housing required to accommodate cavity 202. The compressor 100 is smaller, space-efficient and easier to handle. The replacement of reed valves with the thrust washer 104 and the sleeve cover 106 beneficially increases volumetric and energy efficiencies of the compressor. The omission of reed valves also reduces the risk of compressor seizure which may be caused by chips of broken reed valves lodged between moving surfaces of the compressor.

Fig. 2B shows a side cross-sectional view of the revolving vane compressor 230 according to a second embodiment of the present invention. The compressor 230 is generally similar to compressor 100 of Fig. 2A. However, the first housing member 102 and the thrust washer 104 of compressor 100 are substituted by alternate first housing member 232 in compressor

230. The flow regulator is formed integrally with the alternate first housing member 232 and is disposed downstream of the compressor inlet 234. As with compressor 100, the compressor 230 comprises sleeve assembly 103 which includes sleeve cover 106. During operation of compressor 230, compressible fluid is introduced into cavity 236 within the compressor 230 via compressor inlet 234 connected to the housing member 232. The cavity 236 is formed in the space between the sleeve assembly 103 and the housing assembly. The alternate first housing member 232 is shaped such that in a first rotational position of the sleeve assembly 103 relative to the housing member 232, the chamber 212 is in fluid communication with the compressor inlet 234 for drawing a compressible fluid into the chamber 212. In a second rotational position not illustrated in Fig. 2B, the housing member 232 seals the chamber 212 associated with the opening 220 from the compressor inlet 234 for compressing the fluid within the chamber 212.

Figs. 3A and 3B show perspective upstream (front) and downstream (back) views of the thrust washer 104 of Fig. 1. The thrust washer 104 is part of the intake assembly of the revolving vane compressor 100 (Fig. 1). In the present embodiment, the thrust washer 104 comprises a solid portion 300 and a hollow portion 302. The thrust washer 104 is configured to be received in the first housing member 102 (Fig. 1) and positioned upstream of the sleeve assembly 103 (Fig. 1). The thrust washer 104 abuts the sleeve cover 106 (Fig. 1) of the sleeve assembly 103. As the sleeve assembly 103 rotates relative to the stationary thrust washer 104, the solid portion 300 prevents the openings of the sleeve cover 106 from fluidly communicating with the compressor inlet 200 (Fig. 2A). In other words, the solid portion 300 seals chambers of the sleeve assembly 103 during compression and discharge of the compressible fluid. The hollow portion 302 allows fluid communication between the compressor inlet 200 and the chambers of the sleeve assembly 103 as the sleeve assembly 103 rotates. For example, the hollow portion 302 permits intake of the compressible fluid via an opening of the sleeve cover 106 into chamber 212 (Fig. 2A) of the sleeve assembly 103.

Fig. 3A shows the upstream face 301 of the thrust washer 104. The upstream face 301 comprises an attachment member configured to engage with a corresponding attachment member disposed in the first housing member 102 for rotationally fixing the thrust washer 104 relative to the first housing member 102. Specifically, in the present embodiment, the attachment member comprises protruding tabs 304, 306 configured to be engaged with corresponding depressions on the first housing member 102. It will be appreciated that other ways of rotationally fixing the thrust washer 104 to the first housing member 102 may be used in alternate embodiments. For example, the first housing member 102 may comprise protruding tabs configured to be engaged with corresponding depressions or holes on the

thrust washer 104. Fastening elements or location pins may also be used to rotationally fix the thrust washer 104 to the first housing member 102.

Fig. 3B shows the downstream face 303 of the thrust washer 104. In the present embodiment, the downstream face 303 of the thrust washer 104 abuts the sleeve cover 106. The downstream face 303 of the thrust washer 104 is a flat, planar surface formed to minimize friction between the sleeve cover 106 as the sleeve assembly rotates relative to the stationary thrust washer 104. The thrust washer 104 may also be coated with anti-friction coatings to further reduce friction between the sliding surfaces. In addition to sealing the chambers of the rotating sleeve assembly downstream, the solid portion 300 also distributes the axial force exerted by the sleeve assembly on the first housing member 102 due to pressure differences within the compressor during operation. The solid portion 300 also comprises an annular section 308 which is configured to receive the drive shaft of sleeve cover 106.

Fig. 4A shows a perspective view of the sleeve cover 106 of Fig. 1. The sleeve cover 106 is a part of the sleeve assembly 103 (Fig. 1), and it abuts the thrust washer 104 (Fig. 1) positioned upstream. The sleeve cover 106 comprises openings 220, 222. Each of the opening 220, 222 is associated with a respective chamber of the sleeve assembly 103. For instance, the opening 220 is associated with chamber 212 (Fig. 2A). The sizes and shapes of the openings 220, 222 are individually optimized based on various factors. For example, the size of the openings 220, 222 are determined based on a rotational speed of the sleeve assembly and a predetermined quantity of the compressible fluid to be drawn into the chamber 212. In other words, the size of the openings 220, 222 are determined based on the expected performance of the compressor 100 and the size or capacity of the compressor 100. The shape of the openings 220, 222 are designed to facilitate intake of the compressible fluid as soon as the thrust washer 104 allows fluid communication between the compressor inlet 200 and the corresponding chamber in the sleeve assembly. Factors determining the shape of the openings 220, 222 include the shapes of both the solid portion 300 and the hollow portion 302 of the thrust washer 104, and the vanes of the sleeve assembly 103.

The openings 220, 222 on the sleeve cover 106 are disposed diagonally opposite to each other as the channel between the sleeve and the rotor is partitioned into two chambers by a primary vane 114 and a secondary vane 116. In alternative embodiments of the present invention, the sleeve cover may comprise one opening or more than two openings, and each of the openings is associated with a respective chamber of the sleeve assembly. For example, the channel between the sleeve and the rotor may be partitioned into three

chambers by a primary vane and two secondary vanes. The angular distance between the vanes may be substantially equal and the corresponding openings on the sleeve cover are also spaced substantially equally apart. In other words, the maximum volumes of the corresponding chambers are approximately equal. Further, a person skilled in the art may also appreciate that the maximum volumes of the respective chambers of the sleeve assembly may not be equal in alternative embodiments of the present invention. The primary and secondary vanes may be placed at different angular intervals along the radial direction of the rotor or at an angle to the radial direction. The openings of the sleeve cover may be spaced at different angular positions.

The sleeve cover 106 also comprises one or more fastener holes 400 for securing the front sleeve cover 106 to the sleeve 110. Through holes 402, 404 are provided on the sleeve cover 106 to direct the lubricating oil to the contact area between the sleeve cover 106 and the thrust washer 104. The lubricating oil reduces friction in the contact area as the sleeve assembly rotates relative to the stationary thrust washer 104.

Fig. 4B shows a sectional perspective view of the thrust washer 104 with the sleeve cover 106 and the sleeve 110. The sleeve cover 106 and the sleeve 110 are connected by one or more fasteners 128 which pass through fastener holes 400 shown in Fig. 4A. The thrust washer 104 is positioned upstream of the sleeve cover 106. In the present embodiment, the thrust washer 104 abuts the sleeve cover 106. The sleeve assembly 103 rotates relative to the stationary thrust washer 104 which is presented semi-transparent to show the positions of the openings 220, 222 behind the thrust washer 104. The opening 222 is shown in the first rotational position as mentioned in Fig. 2A before transiting to the second rotational position. The chamber of the sleeve assembly 103 associated with the opening 222 is in fluid communication with the compressor inlet 200 (Fig. 2A) via the hollow portion 302 (Fig. 3), allowing intake of the compressible fluid into the chamber. The solid portion 300 of the thrust washer 104 partially obscures the opening 222 as the sleeve assembly rotates the chamber into the second rotational position. The opening 220 is sealed by the thrust washer 104, wherein the thrust washer 104 prevents fluid communication between the compressor inlet 200 and the chamber associated with the opening 220. The thrust washer 104 blocks the opening 220 to allow compression and discharge of the compressible fluid to occur within the associated chamber of the sleeve assembly 103. Advantageously, the thrust washer 104 and sleeve cover 106 replace the typical reed valves used to control the intake of the compressible fluid into the compressor 100. The thrust washer 104 and sleeve cover 106 enable the development and production of smaller, more compact and energy-efficient compressors.

Fig. 5A shows a sectional perspective rear view of the first housing member 102. A section view of the compressor inlet 200 is also shown. The compressible fluid enters the cavity 202 formed between the sleeve assembly and the housing assembly through compressor inlet 200. The first housing member 102 includes corresponding depressions 500, 502 configured to be engaged with corresponding protruding tabs 304, 306 (Fig. 3) on the thrust washer 104. These attachment members are configured to rotationally fix the thrust washer within the first housing member 102. A projection 504 extends from the inner face of the first housing member 102. The shape and size of the projection 504 is similar to solid portion 300 of the thrust washer 102. The upstream face of the thrust washer 104 abuts the surface of the projection 504 and transfers the axial force exerted by the sleeve assembly to the first housing member 102. In alternative embodiments, the projection 504 may differ in shape or size compared to the upstream face of the thrust washer 104.

Fig. 5B shows a sectional perspective rear view of the alternate first housing member 232 and compressor inlet 234. Projection 506 extends from the inner face of the alternate first housing member 232 and is configured to be in sliding contact with the sleeve cover 106 of the sleeve assembly 103. The cavity 236 is formed as the projection 506 does not cover the entire inner face of the housing member 232. As described in Fig. 2B, the compressible fluid enters the cavity 236 formed between the sleeve assembly and the housing assembly through compressor inlet 234. The projection 506 has a flat planar surface, and may be coated with anti-friction coatings to reduce friction. In addition to sealing the chambers of the rotating sleeve assembly downstream during operation, the projection 506 also transfers the axial force exerted by the sleeve assembly to the housing assembly.

Fig. 6A to 6D show sectional views of the revolving vane compressor 100 rotated clockwise by various angles from a reference line. While Fig. 6A to 6D describe the operation of compressor 100, it is appreciated that the description can be similarly applied to compressor 230. In Fig. 6A, the primary vane 114 is aligned with a reference line 610 and the revolving vane compressor 100 is rotating in a clockwise direction. As mentioned in Fig. 2A, the sleeve 110 has the first rotational axis 156 while the rotor 152 has the second rotational axis 218 offset from the first rotational axis 156. In the present embodiment, the sleeve 110 has a cylindrical internal surface and the rotor 152 has a cylindrical external surface. The rotor 152 has a smaller diameter compared to the sleeve 110. A channel is formed in the space between the rotor 152 and the sleeve 110. The channel is partitioned into two chambers 600, 602 by the primary vane 114 and the secondary vane 116 at the current rotational position. Each of the chamber 600, 602 is substantially fluid tight from the adjacent chambers. As will be shown in Fig. 6B, the number of chambers may increase to three as the compressor 100 rotates into a different rotational position. In alternative embodiments,

the number of chambers may be increased by increasing the number of secondary vanes. For example, in a revolving vane compressor with a primary vane and two secondary vanes, the channel may be partitioned into either three or four chambers depending on the rotational position of the compressor.

During operation, the drive shaft extending from the sleeve cover 106 rotates the sleeve 110, which in turn rotates the rotor 152. The volumes occupied by the chambers 600, 602 vary accordingly due to the change in positions of the primary and secondary vanes 114, 116. The pressure within the chambers 600, 602 also varies due to the change in volume of the chambers 600, 602. As a result, the compressible fluid may be separately drawn into each of the chambers 600, 602, separately compressed to a predetermined volume within each of the chambers 600, 602 and separately discharged from the respective chambers 600, 602.

In the present embodiment, the primary vane 114 comprises a first end that is secured to the sleeve 110 by one or more fasteners 130 and a second end which is in sliding engagement with the shoe 118 positioned within the rotor 152. The shoe can swivel about a third rotational axis substantially parallel to the second rotational axis 218. During operation of the compressor 100, the shoe 118 can swivel back and forth about the third rotational axis, and the primary vane 114 can slide relative to the shoe 118. The primary vane 114 is sufficiently long to prevent dislodgement from the shoe 118 at any point during operation. The primary vane 114 therefore forms a fluid barrier between chambers 600, 602. In alternative embodiments, the primary vane 114 may be secured to the sleeve 110 and the rotor 152 via other mechanical means, as will be appreciated by a person skilled in the art.

The secondary vane 116 extends outward at an angle to the radial direction of the rotor 152. In alternative embodiments, the secondary vane 116 may extend outward radially from the rotor 152. The first end of the secondary vane 116 abuts the inner wall of the sleeve 110 while the second end is in sliding engagement with the rotor 152. During operation of compressor 100, the secondary vane 116 remains in abutment with the inner wall of the sleeve 110 by means of a centrifugal force generated by the rotational movement. In other words, the first end of the secondary vane abuts and slides along the inner wall of the sleeve 110 during operation of the compressor 100. The length of the secondary vane 116 is sufficient to prevent the secondary vane 116 from being dislodged from the rotor 152 during operation. The secondary vane 116 thus forms a fluid barrier between chambers 600, 602. In other embodiments, in addition to the centrifugal force, the contact between the secondary vane 116 and the sleeve 110 can be maintained by biasing means such as a spring disposed at the rotor end of the secondary vane 116 or by maintaining a pressure difference

within the space between the secondary vane 116 and the rotor 152 such that the secondary vane 116 is pushed outward from the rotor 152.

In Fig. 6A, the primary vane 114 is aligned with a reference line 610 and the revolving vane compressor 100 is rotating in a clockwise direction. At the current position, the chamber 602 is undergoing compression. The associated opening on the sleeve cover 106 and the ball check valve assembly 612 comprising one or more balls 150 and check valve casing 148 are sealed. In other words, the openings on the intake assembly and the discharge valve are closed, and the chamber 602 is sealed. The secondary vane 116 maintains fluid-tight separation between chambers 600, 602 by maintaining sliding abutment with the inner wall of the sleeve 110, and helps to compress the compressible fluid within chamber 602. In addition, the chamber 600 fluidly communicates with the compressor inlet 200, via the hollow section 302 of the thrust washer 104, allowing the compressible fluid to be drawn into the chamber 600. The ball check valve assembly 614 is sealed during the intake phase.

Fig. 6B shows a sectional view of the revolving vane compressor 100 as it is rotated clockwise by an angle of approximately 90 degrees from the reference line 610. At the current position, the channel is partitioned by the primary and secondary vanes 114, 116 into three chambers 600, 602, 606. The chambers 600, 602, 606 are substantially fluid-tight from each other. The chamber 602 is in a discharge phase, and the discharge phase is almost complete. The ball check valve assembly 612 is open to allow the compressed fluid to flow from the chamber 602 into the outlet bore 210 of the rotor 152. This is the first discharge by the compressor 100 from the initial position shown in Fig. 6A. The chamber 600 is at the onset of a compression phase, and the associated opening of the sleeve cover 106 is sealed by the solid portion 300 of the thrust washer 104. The corresponding ball check valve assembly 614 is also in a closed position. The compressible fluid within the chamber 600 is compressed into a predetermined volume. The chamber 606 is in an intake phase, the associated opening of the sleeve cover 106 is in fluid communication with the compressor inlet 200, and the chamber 606 draws the compressible fluid as the volume of the chamber 606 expands.

Fig. 6C shows a sectional view of the revolving vane compressor 100 as it is rotated clockwise by an angle of approximately 180 degrees from the reference line 610. At the current position, the channel is partitioned into the chambers 600, 606. The chamber 600 is undergoing compression. The associated opening on the sleeve cover 106 and the ball check valve assembly 614 are sealed. The primary vane 114 maintains fluid-tight separation between the chambers 600, 606 and helps to compress the compressible fluid within chamber 600. The chamber 606 is in the intake phase, and is in fluid communication with the

compressor inlet 200 via the hollow section 302 of the thrust washer 104 and the associated opening on the sleeve cover. The ball check valve assembly 612 is sealed and the compressible fluid is drawn into the chamber 606 during the intake phase.

Fig. 6D shows a sectional view of the revolving vane compressor 100 as it is rotated clockwise by an angle of approximately 270 degrees from the reference line 610. At the current position, the channel is partitioned into three chambers 600, 606, 608. The chambers 600, 606, 608 are substantially fluid-tight from each other. The chamber 600 is in a discharge phase, and the ball check valve assembly 614 is open to allow the compressed fluid to flow from the chamber 600 into outlet bore 210. This is the second discharge by the compressor 100 from the initial position shown in Fig. 6A. The chamber 606 is at the onset of the compression phase, wherein the compressible fluid will be compressed into the predetermined volume. The associated opening of the sleeve cover 106 is sealed by the solid portion 300 of the thrust washer 104. The ball check valve assembly 612 is also closed. The chamber 608 is in the intake phase, and the chamber 608 will draw the compressible fluid through the corresponding opening on the sleeve cover 106 as the volume of chamber 608 expands.

Figs. 7A to 7D show sectional views of the revolving vane compressor 100 with the thrust washer 104 and the openings 220, 222 of the sleeve cover 106 superimposed. While Figs. 7A to 7D describe the operation of compressor 100, it is appreciated that the description can be similarly applied to compressor 230, as the outline of the thrust washer 104 shown is similar to that of the flow regulator formed integrally within housing member 232 of the compressor 230. Figs. 7A to 7D show the intake cycle for a first chamber 700 of the compressor 100 as the compressor 100 is rotated clockwise through various angles from the reference line 610.

Fig. 7A shows a sectional view of the revolving vane compressor 100 when a center of the opening 220 is substantially aligned with a reference line 610 and the compressor 100 is rotating in a clockwise direction. At the current position, the intake cycle begins for chamber 700 which is defined between the primary vane 114, the rotor 152 and the sleeve 110. The chamber 700 is associated with the opening 220 on the sleeve cover 106, which is currently covered by the solid portion 300 of the thrust washer 104. The sealed chamber 700 contains high pressure compressible fluid carried forward from the previous discharge cycle which remains inside a volume often known as "dead volume". The chamber 700 starts to expand as the compressor rotates clockwise. Accordingly, the pressure within the chamber 700 decreases as the chamber 700 expands.

Fig 7B shows a sectional view of the revolving vane compressor 100 as it is rotated clockwise such that the center of the opening 220 forms an angle of approximately 30 degrees with respect to the reference line 610. Prior to the current position, the chamber 700 reaches a predetermined suction pressure. At the current position, the chamber 700 fluidly communicates with the compressor inlet 200 (Fig. 2A) through a portion of the opening 220 and the hollow portion 302 of the thrust washer 104, thus allowing the compressible fluid to enter the chamber 700.

Fig. 7C shows a sectional view of the revolving vane compressor 100 as it is rotated clockwise such that the center of the opening 220 forms an angle of approximately 120 degrees clockwise with respect to the reference line 610. At the current position, the opening 220 is substantially within the area defined by the hollow section 302 of the thrust washer 104. The chamber 700 fluidly communicates with the compressor inlet 200 through the opening 220 and draws compressible fluid into the chamber 700 as the volume defined by the sleeve 110, the rotor 152 and the primary vane 114 increases.

Fig. 7D shows a sectional view of the revolving vane compressor 100 as it is rotated clockwise such that the center of the opening 220 forms an angle of approximately 225 degrees clockwise with respect to the reference line 610. At the current position, the opening 220 is blocked by the solid portion 300 of the thrust washer 104. In other words, the chamber 700 is sealed by the thrust washer 104. At the current position, the chamber 700 has reached its maximum volume, and a predetermined quantity of compressible fluid to be compressed is contained within. As the compressor 100 further rotates from the current position, the volume of the chamber 700 decreases and the compressible fluid is compressed to a higher pressure.

Figs. 8A to 8D show sectional views of the revolving vane compressor 100 with the thrust washer 104 and the openings 220, 222 of the sleeve cover 106 superimposed. While Figs. 8A to 8D describe the operation of compressor 100, it is appreciated that the description can be similarly applied to compressor 230, as the outline of the thrust washer 104 shown is similar to that of the flow regulator formed integrally within housing member 232 of the compressor 230. Figs. 8A to 8D show the intake cycle for a second chamber 702 of the compressor 100 as the compressor 100 is rotated clockwise through various angles from the reference line 610.

Fig. 8A shows a sectional view of the revolving vane compressor 100 as it is rotated clockwise such that a center of the opening 222 forms an angle of approximately 30 degrees with respect to the reference line 610. At the current position, the intake cycle begins for chamber 702, which is defined by the secondary vane 116, the rotor 152 and the sleeve 110.

The chamber 702 is associated with the opening 222 on the sleeve cover 106. The opening 222 is currently sealed by the solid portion 300 of the thrust washer 104. The sealed chamber 702 contains high pressure compressible fluid carried forward from the previous discharge cycle which remains inside the dead volume. As the compressor 100 rotates clockwise, the volume of chamber 702 increases while the pressure within the chamber 702 drops.

Fig 8B shows a sectional view of the revolving vane compressor 100 as it is rotated clockwise such that the center of the opening 222 forms an angle of approximately 45 degrees clockwise with respect to the reference line 610. Prior to the current position, the chamber 702 reaches a predetermined suction pressure. At the current position, the chamber 702 fluidly communicates with the compressor inlet 200 (Fig. 2A) through a portion of the opening 222 and the hollow portion 302 of the thrust washer 104, thus allowing the compressible fluid to enter the chamber 702.

Fig. 8C shows a sectional view of the revolving vane compressor 100 as it is rotated clockwise such that the center of the opening 222 forms an angle of approximately 135 degrees clockwise with respect to the reference line 610. At the current position, the opening 222 is substantially within the area defined by the hollow section 302 of the thrust washer 104. The chamber 702 fluidly communicates with the compressor inlet 200 through the opening 222 and draws compressible fluid into the chamber 702 as the volume defined by the sleeve 110, the rotor 152 and the secondary vane 116 increases.

Fig. 8D shows a sectional view of the revolving vane compressor 100 as it is rotated clockwise such that the center of the opening 222 forms an angle of approximately 210 degrees clockwise with respect to the reference line 610. At the current position, the opening 222 is blocked by the solid portion 300 of the thrust washer 104. In other words, the chamber 702 is sealed. At the current position, chamber 702 has reached its maximum volume and the predetermined quantity of compressible fluid to be compressed is contained within. As the compressor 100 further rotates from the current position, the volume of the chamber 702 decreases and the compressible fluid is compressed to a higher pressure.

Fig. 9 shows a sectional view of the second (e.g. rear) housing member 108 of the compressor 100. The second housing member 108 comprises the compressor outlet 216, one or more fastener holes 900 and the mounting bracket 208 in a unitary construction to provide rigidity. The second housing member 108 also comprises a plurality of ribs 902, 904, 906, 908 extending from the inner surface of the second housing member 108 and forming a flow channel upstream of the compressor outlet 216. The flow channel is configured to separate a lubricating oil from the compressor fluid prior to the compressible fluid exiting the

compressor outlet 216. Specifically, when the compressor fluid exits the outlet bore 210 of the rotor 152, the rib 902 and the inner surface of the second housing member 108 direct the flow of the compressible fluid towards the ribs 904, 906, 908 where a portion of the oil impinges on the ribs 904, 906, 908 while the compressed fluid continues along the flow channel towards the compressor outlet 216. The ribs 904, 906, 908 are configured to guide the oil towards the oil sump 214. The design of ribs 902, 904, 906, 908 advantageously reduces the amount of oil carried out of the compressor 100, and ensures that there is sufficient lubricating oil within to grease the moving parts of the compressor 100. As mentioned in Fig. 2A, the oil collected at the oil sump 214 is directed by the plurality of oil channels in fluid communication with the oil sump 214 to moving parts of the compressor 100 based on pressure differences within the compressor 100. In other words, the collected oil in the oil sump 214 flows through the plurality of oil channels towards moving parts of the compressor 100 positioned upstream as the pressure within the second housing member 108 is higher.

Fig. 10 shows a flowchart 1000 illustrating a method for operating a revolving vane compressor in accordance with embodiments of the present invention. The method comprises, at step 1002, partitioning a fluid channel of the compressor into one or more chambers, and at step 1004, rotating a sleeve assembly of the compressor about a rotational axis into a first rotational position, wherein a chamber of the sleeve assembly fluidly communicates with a compressor inlet through a flow regulator and an opening disposed on a sleeve cover of the sleeve assembly. At step 1006, the method includes drawing a predetermined quantity of a compressible fluid into the chamber by rotating the sleeve assembly from the first rotational position to a second rotational position, wherein the flow regulator seals said chamber from the compressor inlet in the second rotational position. At step 1008, the method includes compressing the compressible fluid within said chamber by further rotating the sleeve assembly from the second rotational position into a third rotational position. At step 1010, the method includes discharging the compressible fluid from said chamber at the third rotational position.

Fig. 11 shows a flowchart 1100 illustrating a method for manufacturing a revolving vane compressor in accordance with embodiments of the present invention. The method comprises, at step 1102, providing a first housing member such that the first housing member is connected to a compressor inlet, and at step 1104, providing a flow regulator downstream of the compressor inlet. The flow regulator may be configured to be rotationally fixed relative to the first housing member. At step 1106, the method comprises mounting a sleeve assembly downstream of the flow regulator; the sleeve assembly comprising a sleeve cover, the sleeve assembly configured to be rotatable relative to the first housing member

about a rotational axis. The sleeve cover comprises one or more openings, and each of the one or more openings is associated with a respective chamber of the sleeve assembly. The flow regulator is shaped such that in a first rotational position of the sleeve assembly relative to the first housing member, a chamber of the sleeve assembly is in fluid communication with the compressor inlet for drawing a compressible fluid into said chamber, and in a second rotational position of the sleeve assembly relative to the first housing member, the flow regulator seals said chamber from the compressor inlet for compressing the fluid within said chamber.

Thus it can be seen that the compressor in accordance with the present embodiments have the advantages of compactness, improved durability, enhanced efficiency, greater performance and better noise and vibration characteristics. While exemplary embodiments have been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations exist.

It should further be appreciated that the exemplary embodiments are only examples, and are not intended to limit the scope, applicability, operation, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the invention, it being understood that various changes may be made in the function and arrangement of elements and method of operation described in an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims.

Claims

1. A revolving vane compressor comprising:
 - a first housing member connected to a compressor inlet;
 - a flow regulator disposed downstream of the compressor inlet;
 - a sleeve assembly comprising a sleeve cover, the sleeve assembly configured to be received in the first housing member downstream of the flow regulator and to be rotatable relative to the first housing member about a rotational axis;
 - wherein the sleeve cover abuts the flow regulator and comprises one or more openings, each of the one or more openings being associated with a respective chamber of the sleeve assembly; and
 - wherein the flow regulator is shaped such that, in a first rotational position of the sleeve assembly relative to the first housing member, a chamber of the sleeve assembly is in fluid communication with the compressor inlet for drawing a compressible fluid into said chamber, and in a second rotational position of the sleeve assembly relative to the first housing member, the flow regulator seals said chamber from the compressor inlet for compressing the fluid within said chamber.
2. The revolving vane compressor as claimed in claim 1, wherein the flow regulator forms a unitary construction with the first housing member.
3. The revolving vane compressor as claimed in claim 1, wherein the flow regulator comprises a thrust washer configured to be received in the first housing member, the thrust washer being rotationally fixed relative to the first housing member.
4. The revolving vane compressor as claimed in claim 3, wherein the thrust washer comprises a hollow portion disposed upstream of the opening associated with the chamber in the first rotational position and a solid portion disposed upstream of the opening associated with the chamber in the second rotational position.
5. The revolving vane compressor as claimed in claim 3 or 4, wherein the thrust washer comprises an upstream face, the upstream face comprising a first attachment member configured to engage with a corresponding second attachment member disposed in the first housing member for rotationally fixing the thrust washer relative to the first housing member.

6. The revolving vane compressor as claimed in claim 5, wherein the first attachment member comprises at least one protruding tab and the corresponding second attachment member comprises at least one corresponding depression.
7. The revolving vane compressor as claimed in claim 5, wherein the first attachment member comprises at least one depression and the corresponding second attachment member comprises at least one corresponding protruding tab.
8. The revolving vane compressor as claimed in claim 3 or 4, wherein the thrust washer is fastened to the first housing member for rotationally fixing the thrust washer relative to the first housing member.
9. The revolving vane compressor as claimed in any one of the preceding claims, wherein the size of each of the one or more openings of the sleeve cover is determined based on a rotational speed of the sleeve assembly and a predetermined quantity of the compressible fluid to be drawn into the chamber.
10. The revolving vane compressor as claimed in any one of the preceding claims, wherein the sleeve cover comprises two openings disposed diagonally opposite each other.
11. The revolving vane compressor as claimed in any one of the preceding claims, further comprising a second housing member, the second housing member defining a flow channel upstream of a compressor outlet, wherein the flow channel is configured to separate a lubricating oil from the compressible fluid prior to the compressible fluid exiting the compressor outlet.
12. The revolving vane compressor as claimed in claim 11, wherein the second housing member comprises a plurality of ribs extending from an inner surface of the second housing member, the plurality of ribs forming the flow channel.
13. The revolving vane compressor as claimed in claim 11 or 12, wherein the second housing member further comprises an oil sump configured to collect the lubricating oil separated from the compressible fluid.
14. The revolving vane compressor as claimed in claim 13, further comprising a plurality of oil channels in fluid communication with the oil sump, the oil channels configured to direct at least a portion of the collected oil to moving parts of the compressor based on pressure differences within the compressor.

15. A method of manufacturing a revolving vane compressor, the method comprising the steps of:
 - providing a first housing member such that the first housing member is connected to a compressor inlet;
 - providing a flow regulator downstream of the compressor inlet;
 - mounting a sleeve assembly downstream of the flow regulator, the sleeve assembly comprising a sleeve cover, such that the sleeve assembly is rotatable relative to the first housing member about a rotational axis and the sleeve cover abuts the flow regulator;
 - wherein the sleeve cover comprises one or more openings, each of the one or more openings being associated with a respective chamber of the sleeve assembly; and
 - wherein the flow regulator is shaped such that, in a first rotational position of the sleeve assembly relative to the first housing member, a chamber of the sleeve assembly is in fluid communication with the compressor inlet for drawing a compressible fluid into said chamber, and in a second rotational position of the sleeve assembly relative to the first housing member, the flow regulator seals said chamber from the compressor inlet for compressing the fluid within said chamber.
16. The method as claimed in claim 15, wherein the step of providing the flow regulator comprises forming the flow regulator as a unitary construction with the first housing member.
17. The method as claimed in claim 15, wherein the step of providing the flow regulator comprises mounting a thrust washer to the first housing member such that the thrust washer is rotationally fixed relative to the first housing member.
18. The method as claimed in claim 17, wherein mounting the thrust washer comprises providing a thrust washer comprising a hollow portion and a solid portion, the hollow portion being disposed upstream of the opening associated with the chamber in the first rotational position, and the solid portion being disposed upstream of the opening associated with the chamber in the second rotational position.
19. The method as claimed in claim 17 or 18, wherein mounting the thrust washer further comprises:
 - providing a first attachment member on an upstream face of the thrust washer;
 - providing a corresponding second attachment member in the first housing

member; and

engaging the first attachment member with the corresponding second attachment member to rotationally fix the thrust washer relative to the first housing member.

20. The method as claimed in claim 19, wherein the step of providing the first attachment member on the upstream face of the thrust washer comprises providing at least one protruding tab on the upstream face of the thrust washer, and wherein the step of providing the corresponding second attachment member in the first housing member comprises providing at least one corresponding depression in the first housing member.
21. The method as claimed in claim 19, wherein the step of providing the first attachment member on the upstream face of the thrust washer comprises providing at least one depression on the upstream face of the thrust washer, and wherein the step of providing the corresponding second attachment member in the first housing member comprises providing at least one corresponding protruding tab in the first housing member.
22. The method as claimed in claim 17 or 18, wherein the step of mounting a thrust washer to the first housing member comprises fastening the thrust washer to the first housing member for rotationally fixing the thrust washer relative to the first housing member.
23. The method as claimed in any one of claims 15 to 22, wherein the size of each of the one or more openings is determined based on a rotational speed of the sleeve assembly and a predetermined quantity of the compressible fluid to be drawn into the chamber.
24. The method as claimed in any one of claims 15 to 23, wherein the one or more openings comprise two openings disposed diagonally opposite each other on the sleeve cover.