A multi-stage vacuum pump may include first and second half-shell stator components defining a plurality of pumping chambers and for assembly together along respective longitudinally extending faces; first and second end stator components for assembly at respective longitudinal end faces of the first and second half-shell stator components; longitudinal seals for sealing between the first and second half-shell stator components when assembled together at the longitudinally extending faces; and annular seals for sealing between the first and second end stator components and the first and second half-shell stator components when assembled; the annular sealing members and the longitudinal sealing members forming a planar sealing interface therebetween.
VACUUM PUMP


TECHNICAL FIELD

[0002] The disclosure relates to a vacuum pump, in particular a multi-stage vacuum pump.

BACKGROUND

[0003] A vacuum pump may be formed by positive displacement pumps such as roots or claw pumps, having one or more pumping stages connected in series. Multi-stage pumps are desirable because they involve less manufacturing cost and assembly time compared to multiple single stage pumps in series.

SUMMARY

[0004] The present disclosure provides a multi-stage vacuum pump comprising: first and second half-shell stator components defining a plurality of pumping chambers for assembly together along respective pairs of mutually engaging longitudinally extending sealing faces; first and second end stator components for assembly at respective pairs of mutually engaging end sealing faces of the end stator components and the first and second half-shell stator components; longitudinal sealing members for sealing between each pair of mutually engaging longitudinally extending sealing faces; and annular sealing members for sealing between each pair of mutually engaging end sealing faces; wherein the sealing interfaces between the annular and the longitudinal sealing members are planar.

[0005] Other preferred and/or optional features of the disclosure are defined in the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] In order that the present disclosure may be well understood, some embodiments thereof will now be described in more detail, with reference to the accompanying drawings.

[0007] FIG. 1 shows generally the components of a clam shell stator.

[0008] FIG. 2 shows a section through a clam shell stator having a sealing arrangement according to an embodiment of the disclosure.

[0009] FIG. 2a shows an enlarged view of the sealing arrangement in FIG. 2.

[0010] FIG. 3 shows a modified sealing arrangement.

[0011] FIG. 4 shows a further modified sealing arrangement.

DETAILED DESCRIPTION

[0012] The present applicant has filed earlier patent applications (publication Numbers WO2012/127198 and GB2508405) covering sealing arrangements of a vacuum pump, the contents of which published applications are incorporated herein by reference. As with the earlier applications, the present application as shown in the embodiments described herein relates to a multi-stage vacuum pump comprising what is referred to in the art as a clamshell stator arrangement. This type of stator arrangement comprises two half shell stator components which are sealed along two pairs of mutually engaging longitudinally extending sealing faces for enclosing a plurality of pumping chambers. The pumping chambers are arranged one adjacent another in an axial dimension of the vacuum pump from a high vacuum chamber to a low vacuum chamber.

[0013] At each end of the half shell stator components are end stator components. The axial ends of one or more drive shafts extend into the end stator components and are supported by bearings for rotation by a motor and typically also a gear mechanism. The end stator components are sealed with the assembled half shell stator components at mutually engaging end sealing faces.

[0014] The sealing arrangement disclosed by the applicant’s earlier applications comprises two longitudinal, or axially extending, sealing members for sealing between each pair of mutually engaging longitudinally extending sealing faces. The sealing arrangement also comprises two annular sealing members extending around the axis or axes of the pump encircling the pumping chambers and sealing between each pair of mutually engaging end faces.

[0015] Each annular sealing member forms two sealing interfaces with the longitudinal sealing members at each end of the longitudinal sealing members. There are therefore four sealing interfaces in total and the sealing interfaces at each end of the stator are approximately diametrically opposed one from another. The interior of the vacuum pump is maintained in use at a pressure lower than ambient pressure which generates a pressure differential. The pressure differential induces gas to flow into the vacuum pump at the sealing interfaces. It is desirable to inhibit this gas flow.

[0016] A known alternative sealing arrangement is disclosed in US2002155014 providing a one piece sealing member comprising two longitudinal portions and two annular portions. The sealing member is however generally quite intricate to fit in place and expensive to manufacture.

[0017] Referring to FIG. 1 there is shown in more detail a stator of a multis stage vacuum pump. The view shown in FIG. 1 is common to both the prior art vacuum pump discussed in the introduction of this description and embodiments of the present disclosure. The vacuum pump comprises a rotor mechanism which for simplicity is not shown in FIG. 1, but may comprise for example a roots or claw mechanism. The stator 100 of the pump comprises first and second half-shell stator components 102, 104 which together define a plurality of pumping chambers 106, 108, 110, 112, 114, 116. Each of the half-shells has first and second longitudinally extending faces which mutually engage with the respective longitudinally extending faces of the other half-shell when the half-shells are fitted together. Only the two longitudinally extending faces 118, 120 of half-shell 102 are visible in the Figure. During assembly the two half shells are brought together in a generally radial direction shown by the arrows R.

[0018] The stator 100 further comprises first and second end stator components 122, 124. When the half-shells have been fitted together, the first and second end components are fitted to respective end faces 126, 128 of the joined half-shells in a generally axial, or longitudinal, direction shown
by arrows L. The inner faces 130, 132 of the end components mutually engage with respective end faces 126, 128 of the half-shells.

Each of the pumping chambers 106-116 is formed between transverse walls 134 of the half-shells. Only the transverse walls of half-shell 102 can be seen in FIG. 1. When the half-shells are assembled the transverse walls provide axial separation between one pumping chamber and an adjacent pumping chamber, or between the end pumping chambers 106, 116 and the end stator components. The present example shows a typical stator arrangement for a roots or claw pump having two longitudinally extending shafts (not shown) which are located in the apertures 136 formed in the transverse walls 134 when the half-shells are fitted together. Prior to assembly, rotors (not shown) are fitted to the shafts so that two rotors are located in each pumping chamber. Although not shown in this simplified drawing, the end components each have two apertures through which the shafts extend. The shafts are supported by bearings in the end components and driven by a motor and gear mechanism.

The multi-stage vacuum pump operates at pressures within the pumping chamber less than atmosphere and potentially as low as 10⁻³ mbar. Accordingly, there will be a pressure differential between atmosphere and the inside of the pump. Leakage of surrounding gas into the pump must therefore be prevented at the joints between the stator components, which are formed between the longitudinally extending surfaces 118, 120 of the half-shells and between the end faces 126, 128 of the half-shells and the inner faces 130, 132 of the end components. An adhesive is typically used to seal between the half-shells and between the half-shells and the end components, but the adhesive is particularly susceptible to damage by corrosive pumped gases, and is difficult and time consuming to apply consistently. It can also inhibit disassembly and maintenance.

FIG. 2 shows a plan view of the half-shell 102 and sections taken through end components 122, 124. Two longitudinal seal members 10 are located in channels 12 formed in the longitudinally extending faces 118, 120. The channels 12 locate the longitudinal seal members in the correct position during assembly and compression between the half shell components. The channels may be provided in only one half shell component or in both half shell components. Alternatively, one channel may be provided in one half shell component and another channel may be provided in the second half shell component, provided that each pair of mutually engaging longitudinally extending faces comprises at least one channel.

The channels 12 are counter-sunk in the longitudinal extending faces 118, 120 to a depth which is less than the depth of the longitudinal seal members so that when the half shell stator components are assembled together they compress the seal members to ensure a reliable seal. The seal members are resilient and undergo elastic deformation when compressed.

As shown in FIG. 2, two generally annular seal members 14 are located in respective generally annular channels 16 of the inner faces 130, 132 of the end components 122, 124. The channels 16 locate the seal members in the correct position during assembly and compression between the end stator components and the half shell stator components. The channels may be provided in the end stator components as shown in this figure and in FIG. 3 below or the seal members may be located in position in the half shell stator components prior to assembly as shown in FIG. 4 below. As shown in FIGS. 2 and 3 the channels 16 are counter-sunk in the end faces 130, 132 to a depth which is less than the depth of the seal members so that the seal members are compressed during assembly to provide a reliable seal. The annular seal members undergo elastic deformation during assembly.

The longitudinal seal members 10 prevent leakage of ambient gas into the pump along the length of the interface between the half shell components. The annular seal members encircle the axis or axes of the pump and prevent leakage of ambient gas in a generally inward radial direction at the interface between the end components and the half shell components.

In this example, the longitudinal channels 12 have a rectilinear, or rectangular, cross-section taken in a direction orthogonal to the axis or axes of the pump. The cross-section extends uniformly along the length of the half shell components from one end face 126, 128 to the other end face. The longitudinally extending seal members 10 have a complementary uniform cross-section which is sized to fit closely in the channels and to fill the channels completely on compression. The end surfaces of the seal members are planar and extend in a plane which is orthogonal to the length of the seal members. The length of the seal members is such that on compression between the half shell components their end surfaces engage the annular seal members to form a sealing connection for resisting leakage of gas between the seal members. In one example, the longitudinal seal members are compressed to protrude outwardly from the end faces to engage the annular seal members. The longitudinal seal members are made from plastics, rubber or metallic material (such as a gasket) which undergoes elastic, or resilient, deformation when compressed.

In this example, the annular channels 16 are circular and have a rectilinear or rectangular cross-section when taken in a direction generally radial to the axis or axes of the pump. The cross-section is uniform or generally uniform throughout the circumferential extent of the annular channels. The diameter of the channels is sized so that the annular channels intersect or coincide with the ends of the longitudinal channels 12 when assembled at two diametrically opposed positions of the annular channels. The annular seal members have a configuration complementary to the annular channels and have a cross section which is also rectilinear or rectangular. The annular seal members are sized to fit closely in the annular channels and to fill the channels on compression between the end stator components and the half shell stator components. The annular seals have a planar, or generally planar, annulus facing inwardly in an axial direction towards the half shell components. The annulus is the area between inner and outer concentric circles of the seal member and in this example protrudes outwardly from the end surfaces 130, 132 of the end stator components. Each annular seal member has two contact surfaces or portions of the annulus which engage with respective end surfaces of the longitudinal seal members when compressed at the intersections between the annular and longitudinal channels to form planar or generally planar sealing interfaces.

FIG. 2 is a view of the stator components with the seal members in position prior to final assembly and before
compression of the seal members. The location of the sealing interfaces is shown generally by numeral 18 in the Figure. FIG. 2a is an enlarged view of portion 11a in FIG. 2, in which one exemplary sealing interface 18 is shown after compression of the sealing members by bringing the stator components together in the directions shown by the arrows. As shown in FIG. 2a, compression causes the longitudinal seal members to deform and the other configurations of the seal members is selected so that sufficient force is applied from one seal member to the other to produce a reliable seal at the sealing interfaces. This force varies as the seal members thermally expand and contract during use of the pump and the arrangement ensures that a reliable seal is maintained throughout use.

[0028] In the applicant’s previous applications various solutions are disclosed to produce and maintain sufficient contact between the sealing members at the interfaces to resist leakage of gas. The disclosed annular sealing members comprise O-rings having a curved linear form in cross-section received in rectilinear annular channels in the end stator components. Ensuring a tight fit between the end of the longitudinal sealing members and the curved linear cross-section of the annular sealing members is problematic and in the earlier designs solutions include shaping the end of the longitudinal seal members to extend the sealing surface, such as the provision of a curvilinear end surface. It should also be noted that too much force between the seal members causes problems such as kinking and can also degrade the material of the seal members. For example, the longitudinal seal member is a metallic gasket too much force could potentially tear a rubber annular seal since the contact point between the seal members is small.

[0029] Therefore, in the present embodiment the interfaces between the sealing members are planar in order to increase the contact surface area available for sealing at the sealing interface. The increased surface area spreads the load over a greater area, which additionally extends the area over which gas can leak between the seal members. In the present example a planar sealing interface is formed between planar ends of the longitudinal sealing members and the planar annulus of the annular sealing members. In other arrangements, the annulus may be planar only at the intersections between the sealing members and may be shaped differently over the remainder of their circumferences. It is preferable as shown that annular sealing members have a rectilinear cross-section at the intersection and more preferably a uniform rectangular cross-section over the entire circumference of the sealing members complementary to the rectilinear cross-section of the annular channels 16.

[0030] When the longitudinal sealing members extend lengthwise during compression between the stator components and during thermal expansion there is a reactive force on the longitudinal sealing member produced by the annular sealing member. This reactive force can cause kinking of the longitudinal sealing member along its length and compromise reliable sealing. FIG. 3 shows a modified sealing arrangement similar to the view shown in FIG. 2a, in which the longitudinal sealing members are supported at their end portions. The other three sealing interfaces in this modified arrangement may have similar construction.

[0031] In FIG. 3, longitudinal channels 22 are formed in at least one longitudinally extending face 118, 120 of each pair of opposing faces of the half shell stator components 102, 104. Each longitudinal channel 22 comprises two parallel longitudinal channels portions 24 counter-sunk in the face 120 separated by a central land 26 planar with the remainder of the face. The end portion 28 of the channel connects the two channels at each end of the pump and provides a pair of outwardly directed shoulders 30.

[0032] Longitudinal seal members 32 are shaped to correspond with the shape of the channels 22 and comprise a pair of longitudinal portions 34 for location in channel portions 24 either side of land 26. Portions 34 are connected by an end portion 36. The end portion comprises a pair of outwardly directed shoulders 38. During compression and thermal expansion, the shoulders 30 of the channels act as a stop against which the shoulders 38 of the seal members press to resisting movement of the end of the longitudinal sealing members away from the annular sealing members. Resistance to movement maintains pressure between the planar sealing surfaces 40, 42 of the sealing members at the interfaces 18 and improves the reliability of the seal. Similarly, land 26 has an end wall 44 against which central portion 46 abuts to resist movement of the end of the longitudinal sealing members away from the annular sealing members to improve the reliability of the seal.

[0033] In FIG. 3, the annular sealing member 14 is received in an annular channel 16 in the end stator component 122. The channel locates the sealing member in position relative to the longitudinal sealing member and the annular sealing member protrude from the channel to engage an end surface of the longitudinal sealing member during compression to form a sealing interface 18. In a different configuration shown in FIG. 4, the annular channels are omitted in at least one and preferably both end stator components and instead the half-shell stator components together receive the annular sealing members.

[0034] FIG. 4 is a view similar to that shown in FIG. 3, which shows one sealing interface 18. The other three sealing interfaces of the arrangement may have similar construction. In more detail, part of an end stator component 122 is shown comprising an end face 130 for mutually engaging an end face 128 of the assembled half-shell components 102, 104. The end face 130 is planar and omits the annular channel 16 shown in FIGS. 2 and 3. Instead, the longitudinal channel 22 is arranged to receive the annular sealing member during assembly. The end portion 28 of the longitudinal channel forms part of an annular channel counter-sunk in the end faces of the assembled half-shell components (by two semi-circular channels in each half-shell component). The annular channels are rectilinear or rectangular in profile and shaped to complement the shape of the annular sealing members 14. In this way, the annular channels are similar to channels 16 in function and configuration and are arranged to receive the annular sealing members 14. In one example, as shown in FIG. 4 the central connecting part 36 of the longitudinal sealing member 32 is reduced in size compared to FIG. 3 to provide space for accommodating the annular sealing member. With the exception of the modification described above the FIG. 4 embodiment is similar to the FIG. 3 embodiment.
1. A multi-stage vacuum pump comprising:
first and second half-shell stator components defining a
plurality of pumping chambers for assembly together
along respective pairs of mutually engaging longitudi-
nally extending sealing faces;
first and second end stator components for assembly at
respective pairs of mutually engaging end sealing faces
of the end stator components and the first and second
half-shell stator components;
longitudinal sealing members for sealing between each
pair of mutually engaging longitudinally extending
sealing faces; and
annular sealing members for sealing between each pair of
mutually engaging end sealing faces;
wherein the sealing interfaces between the annular and the
longitudinal sealing members are planar.

2. The multi-stage vacuum pump as claimed in claim 1,
wherein the annular sealing members have respective gen-
erally planar sealing surface portions for sealing against
generally planar end sealing surfaces of the longitudinal
sealing members.

3. The multi-stage vacuum pump as claimed in claim 1,
wherein the profiles in cross-section of the generally planar
sealing surface portions are rectilinear.

4. The multi-stage vacuum pump as claimed in claim 3,
wherein the profiles in cross-section of the annular sealing
members are rectilinear throughout their circumference.

5. The multi-stage vacuum pump as claimed in claim 1,
wherein the end stator components each comprise an annular
channel in the end sealing face thereof for receiving one of
the annular sealing members.

6. The multi-stage vacuum pump as claimed in claim 1,
wherein the assembled half-shell stator components com-
prise at each end sealing face an annular channel for
receiving one of the annular sealing members.

7. The multi-stage vacuum pump as claimed in claim 5,
wherein the annular channels are shaped and sized to
complement the annular sealing members.

8. The multi-stage vacuum pump as claimed in claim 5,
wherein the annular channels are uniformly rectilinear in
profile throughout their circumference.

9. The multi-stage vacuum pump as claimed in claim 2,
wherein the profiles in cross-section of the generally planar
sealing surface portions are rectilinear.

10. The multi-stage vacuum pump as claimed in claim 9,
wherein the profiles in cross-section of the annular sealing
members are rectilinear throughout their circumference.

11. The multi-stage vacuum pump as claimed in claim 2,
wherein the end stator components each comprise an annular
channel in the end sealing face thereof for receiving one of
the annular sealing members.

12. The multi-stage vacuum pump as claimed in claim 3,
wherein the end stator components each comprise an annular
channel in the end sealing face thereof for receiving one of
the annular sealing members.

13. The multi-stage vacuum pump as claimed in claim 4,
wherein the end stator components each comprise an annular
channel in the end sealing face thereof for receiving one of
the annular sealing members.

14. The multi-stage vacuum pump as claimed in claim 2,
wherein the assembled half-shell stator components com-
prise at each end sealing face an annular channel for
receiving one of the annular sealing members.

15. The multi-stage vacuum pump as claimed in claim 3,
wherein the assembled half-shell stator components com-
prise at each end sealing face an annular channel for
receiving one of the annular sealing members.

16. The multi-stage vacuum pump as claimed in claim 4,
wherein the assembled half-shell stator components com-
prise at each end sealing face an annular channel for
receiving one of the annular sealing members.

17. The multi-stage vacuum pump as claimed in claim 5,
wherein the assembled half-shell stator components com-
prise at each end sealing face an annular channel for
receiving one of the annular sealing members.

18. The multi-stage vacuum pump as claimed in claim 6,
wherein the assembled half-shell stator components com-
prise at each end sealing face an annular channel for
receiving one of the annular sealing members.

19. The multi-stage vacuum pump as claimed in claim 6,
wherein the annular channels are uniformly rectilinear in
profile throughout their circumference.

20. The multi-stage vacuum pump as claimed in claim 7,
wherein the annular channels are uniformly rectilinear in
profile throughout their circumference.