

Roots Pump Rotor with Pneumatic Sealing Grooves and Roots Pump

The present disclosure claims the priority of the Chinese patent application filed on March 31, 2023 before the CNIPA, China National Intellectual Property Administration with the application number of 202310338837.6 and the title of “Roots Pump Rotor with Pneumatic Sealing Grooves and Roots Pump”, which is incorporated herein in its entirety by reference.

Technical Field

The present disclosure relates to the technical field of vacuum pumps, and more particularly relates to a Roots pump rotor with pneumatic sealing grooves and a Roots pump.

Background Art

The function of a vacuum pump is to extract gas molecules from a vacuum chamber, thereby reducing gas pressure in the vacuum chamber to achieve the required vacuum degree. The vacuum pump is mainly applied in the industries such as pharmaceuticals and chemicals, vacuum coating, vacuum drying, surface treatment, vacuum smelting, ceramic manufacturing, food packaging, milking, and beverages.

With the vigorous development and continuous innovation of science and technology and economic soft power, the application of vacuum technology is more and more extensive, and the demand for the vacuum pump is also increasing in the fields of national economy such as semiconductors, petrochemical engineering, medical facilities, food and pharmaceuticals, and metallurgy. The vacuum pumps include a Roots vacuum pump, a screw pump, a turbine-type oil-free pump, and the like, wherein the Roots vacuum pump has been favored by the semiconductor industry due to the characteristics such as a relatively high pumping speed, fast start-up, small vibration, no internal compression process, and small friction loss thereof.

Two axes of rotors of the Roots vacuum pump are parallel to each other, the rotor is formed by combining impellers with a shaft, and there are tiny clearances between the impellers, as well as between the impeller and a casing and a bearing plate to prevent mutual contact. With the continuous development and improvement of the Roots pump technology, leakage through a clearance between the rotor and a housing of the Roots pump has gradually become the bottleneck problem which restricts the performance of the Roots pump. In the prior art, the Chinese patent application CN110741165A discloses a double-shaft pump and a pumping method. In the technical solution of the application, a rotor is constructed to have a dimension cooperating with a stator hole, so that during rotation in at least part of an outer portion, and an outer edge of each rotor away from the other rotor is sealed with the stator hole. This method has the problem of

having no obvious effect on mitigating the tip clearance leakage of the rotor and having insufficient pertinence. In addition, the Chinese patent application CN105649980A discloses a Roots vacuum pump which is convenient for measuring a clearance between end surfaces and adjusting a clearance between rotors. In the technical solution of the application, a sealing sliding block is mounted on an end surface of a casing, and a radial measuring groove is provided to facilitate the measurement of the clearance between the rotor and the end surface. This method has the problem that contact sealing is adopted, so that the requirement for a machining process is relatively high, and has the deficiency that energy consumption may be increased.

In the prior art, the leakage amount still cannot be further reduced and the pumping speed of the Roots vacuum pump cannot be increased due to the restriction of the machining accuracy and the contact between the rotor and a pump housing caused by thermal deformation during a running process of the rotor.

Therefore, how to overcome the deficiencies of the existing technical solutions mentioned above and reduce the pressure difference of clearance leakage airflow so as to reduce leakage flow has become an urgent technical problem to be solved in this technical field.

Summary of the Invention

In order to overcome the deficiencies of the prior art mentioned above, the present disclosure provides a Roots pump rotor with pneumatic sealing grooves and a Roots pump. The following technical solutions are specifically adopted in the present disclosure.

A Roots pump rotor with pneumatic sealing grooves is provided, wherein the pneumatic sealing groove includes an outer layer groove which is positioned in an edge area of the Roots pump rotor and is parallel to a contour of the Roots pump rotor; and during rotation of the Roots pump rotor, airflow flows into the pneumatic sealing groove along a Roots pump housing and a side wall of the rotor to form a streamwise vortex; and the Roots pump rotor rotates at a high speed to form a tangential vortex, and the streamwise vortex and the tangential vortex form an pneumatic sealing structure.

Optionally, a cross section of the Roots pump rotor perpendicular to an axis of rotation thereof exhibits a figure-8 leaf-shaped contour.

Optionally, the outer layer groove comprises two first grooves adjacent and parallel to each other.

Optionally, the pneumatic sealing groove further comprises an inner layer groove which is positioned in the side wall surface of the Roots pump rotor and is parallel to a rotor shaft hole.

Optionally, the inner layer groove comprises two second grooves adjacent and parallel to each other.

Optionally, the first groove and the second groove have a depth of 5 mm, and the rotor is not in

contact with an inner wall of the Roots pump housing during working.

Optionally, spacing between the two first grooves adjacent and parallel to each other is 0.3 mm; and/or

spacing between the two second grooves adjacent and parallel to each other is 0.3 mm.

The present disclosure further relates to a Roots pump including the Roots pump rotor with pneumatic sealing grooves as described above. The Roots pump includes: a Roots pump housing, and a left rotor and a right rotor which are accommodated in the Roots pump housing; wherein the left rotor and the right rotor are the Roots pump rotors with pneumatic sealing grooves as described above;

the left rotor and the right rotor respectively rotate around respective rotation shafts along opposite directions; and axes of the rotation shafts of the left rotor and the right rotor are provided parallel to each other;

when one of the rotors is provided vertically, the other rotor is provided horizontally; and

during rotation of the rotors, an pneumatic sealing structure is formed when airflow flows through passages formed by side walls of the left rotor and the right rotor and an inner wall of the Roots pump housing.

Optionally, an upper side wall of the Roots pump housing is provided with an air inlet which is close to a front side of the Roots pump housing; and a lower side wall of the Roots pump housing is provided with an air outlet which is close to a rear side of the Roots pump housing; and an opening area of the air inlet is greater than or equal to an opening area of the air outlet.

Optionally, the Roots pump housing, the left rotor, and the right rotor are made of a high-nickel alloy material.

The technical solutions of the present disclosure achieves the following beneficial effects: by providing a series of pneumatic sealing grooves in a side wall surface of the Roots pump rotor, a flow vortex structure is utilized to reduce a flow passage area of a gas flowing from a high pressure side to a low pressure side along the clearance between the Roots pump housing and the side wall surface of the rotor; a cavity structure inside the pneumatic sealing groove is utilized to reduce the pressure difference between two ends of an air leakage cross section; and backflow loss and air leakage loss in the clearance between the Roots pump housing and the side wall surface of the rotor are mitigated, thereby effectively suppressing the clearance leakage flow between the Roots pump housing and the side wall surface of the rotor in the pump, and enhancing the overall pumping speed. In addition, the rotor mass is effectively decreased, and the energy consumption is reduced.

Brief Description of the Drawings

FIG. 1 is a schematic structural view of a Roots pump rotor with pneumatic sealing grooves according to the present disclosure.

FIG. 2 is a front view of the Roots pump rotor with pneumatic sealing grooves according to the present disclosure.

FIG. 3 is a cross-sectional view taken along a plane A-A in FIG. 2.

FIG. 4 is a cross-sectional view taken along a plane B-B in FIG. 2.

FIG. 5 is a cross-sectional view taken along a plane C-C in FIG. 2.

FIG. 6 is a schematic view of a vortex structure in the pneumatic groove of the Roots pump rotor with pneumatic sealing grooves according to the present disclosure.

FIG. 7 is a schematic structural view of a Roots pump according to the present disclosure.

FIG. 8 is a top view of the Roots pump according to the present disclosure.

FIG. 9 is a cross-sectional view taken along a plane A-A in FIG. 8.

FIG. 10 is a cross-sectional view taken along a plane B-B in FIG. 8.

Detailed Description of the Invention

Hereinafter, the present disclosure will be further described with reference to the accompanying drawings. The example implementations described herein are only intended for illustrating the technical solutions of the present disclosure more clearly, not intended for limiting the scope of protection of the present disclosure. It is noted that, the detailed description is only exemplary, intended for further explaining the present disclosure.

Unless otherwise indicated, all technological and scientific terms referred to herein have same meanings as generally understood by a person of normal skill in the art. It is noted that, the terms referred to therein are only intended for describing specific implementations, not intended for limiting the example implementations of the present disclosure. unless otherwise explicitly indicated, a single form of a term referred to herein is also intended for covering its plural form. In addition, the terms “comprise” and/or “include” referred to herein indicate presence of features, steps, operations, devices, components and/or combinations thereof.

The terms “longitudinal”, “transverse”, “upper”, “lower”, “front”, “rear”, “left”, “right”, “vertical”, “horizontal”, “top”, “bottom”, “inner”, “outer”, and the like indicate orientations or positional relationships based on the orientations or positional relationships shown in the accompanying drawings, which are merely for convenience of description, do not indicate or imply that the devices or elements referred to must have a particular orientation or be constructed and operated in a particular orientation, and thus are not to be construed as limiting the present disclosure.

As shown in FIG. 1 and FIG. 2, a specific example 1 of the present disclosure relates to a Roots

pump rotor with pneumatic sealing grooves. A cross section of the Roots pump rotor with pneumatic sealing grooves perpendicular to an axis of rotation thereof exhibits a figure-8 leaf-shaped contour. The pneumatic sealing groove 6 includes an outer layer groove 61 which is positioned in an edge area of a side wall surface of the Roots pump rotor and is parallel to the figure-8 leaf-shaped contour, that is, the edge area of the side wall surface of the Roots pump rotor is provided with the outer layer groove 61, and a cross section of the outer layer groove 61 also exhibits the figure-8 leaf-shaped contour. Based on the pneumatic sealing groove, during rotation of the rotor, a pneumatic sealing structure is formed when airflow flows through a passage formed by a side wall of the rotor and an inner wall of a housing.

It should be noted that based on the pneumatic sealing groove, airflow flows into the pneumatic sealing groove along the Roots pump housing and the side wall of the rotor to form a streamwise vortex; and the Roots pump rotor rotates at a high speed to form a tangential vortex, and the streamwise vortex and the tangential vortex form the pneumatic sealing structure, namely, the leakage through the side wall of the rotor is reduced under the combined action of the streamwise vortex and the tangential vortex.

It should be understood that the interior of the pneumatic sealing groove is of a cavity structure, so that the pressure difference between two ends of an air leakage cross section may be reduced based on the cavity structure; and backflow loss and air leakage loss in the clearance between the Roots pump housing and the side wall surface of the rotor are mitigated, thereby effectively suppressing the clearance leakage flow between the Roots pump housing and the side wall surface of the rotor in the pump, and enhancing the overall pumping speed.

It should be further noted that the Roots pump rotor has two side wall surfaces provided opposite to each other, and the pneumatic sealing grooves may be respectively provided in the above two side wall surfaces, namely, the two side wall surfaces of the Roots pump rotor are both provided with the pneumatic sealing grooves 6, as shown in FIG. 3 to FIG. 5.

As shown in FIG. 3, FIG. 4 and FIG. 5, the pneumatic sealing groove 6 provided in the side wall surface of the Roots pump rotor is in the form of multi-layer nesting, and includes the outer layer groove 61 parallel to the figure-8 leaf shape, the outer layer groove 61 includes two first grooves adjacent and parallel to each other, that is, the two first grooves included in the outer layer groove 61 are of figure-8 annular structures, and the two first grooves of the figure-8 annular structures are provided in an edge area of the Roots pump rotor in a nesting manner.

Further, as shown in FIG. 1 to FIG. 5, the pneumatic sealing groove 6 of the present disclosure further includes an inner layer groove 62 which is positioned in the side wall surface of the Roots pump rotor and is parallel to a rotor shaft hole. It should be noted that being parallel to the rotor shaft hole herein should be understood in a broad sense. The inner layer groove may be provided

in a parallel relationship with the rotor shaft hole by being sleeved on the rotor shaft hole, and may also be provided in the parallel relationship with the rotor shaft hole by being spaced apart from the rotor shaft hole.

In some preferred examples, the inner layer groove 62 is sleeved on an outer side of the rotor shaft hole, namely, the inner layer groove may include two second grooves adjacent and parallel to each other, and may also be one second groove provided in the outer side of the shaft hole of the Roots pump rotor or three second grooves parallel to each other, and the like, which is not specifically limited. The second groove included in the inner layer groove is of an annular structure, and when two or three second grooves are included, a plurality of second grooves of the annular structures are provided in the outer side of the rotor shaft hole of the Roots pump rotor in a nesting manner.

In other preferred examples, the inner layer groove 62 further includes a second groove positioned in an outer side of a figure-8 leaf-shaped through hole, that is, the inner layer groove may be positioned in a figure-8 leaf-shaped structure on one or two sides which is provided adjacent to the rotor shaft hole. Of course, the second groove may also be of an annular structure, so that the second groove of the annular structure forms a parallel relationship with the rotor shaft hole by being spaced apart from the rotor shaft hole.

It should be understood that the number of grooves included in the outer layer groove and the inner layer groove described above needs to be adjusted according to the size of the rotor, and when the size of the rotor is relatively large, the number of groove layers needs to be increased to improve the sealing effect.

The first groove and the second groove included in the pneumatic sealing groove have a depth of 5 mm, and the Roots pump rotor is not in contact with an inner wall of the housing during working. Spacing between the two grooves adjacent and parallel to each other included in the outer layer groove and the inner layer groove is 0.3 mm, namely, the spacing between the two first grooves adjacent and parallel to each other may be 0.3 mm, and the spacing between the two second grooves adjacent and parallel to each other may also be 0.3 mm.

As shown in FIG. 6, in the present disclosure, by providing the pneumatic sealing groove in the Roots pump rotor, airflow may flow into the pneumatic sealing groove along the Roots pump housing and the side wall of the rotor to form a streamwise vortex; and the rotor rotates at a high speed to form a tangential vortex, and the leakage through the side wall of the rotor is reduced under the combined action of the streamwise vortex and the tangential vortex.

As shown in FIG. 7, a specific example 2 of the present disclosure relates to a Roots pump including a Roots pump rotor with annular pneumatic sealing grooves. The Roots pump includes a Roots pump housing 1, a left rotor 2, and a right rotor 3, wherein the left rotor 2 and the right rotor 3 are the Roots pump rotors described above, and reference may be made to the above description

for a specific structure. The left rotor 2 and the right rotor 3 are accommodated in the Roots pump housing 1, a corresponding left rotary shaft 7 is provided in the left rotor 2 in a penetrating manner, a corresponding right rotary shaft 8 is provided in the right rotor 3 in a penetrating manner, axes of the left rotary shaft 7 and the right rotary shaft 8 are provided parallel to each other, and the left rotor 2 and the right rotor 3 respectively rotate around respective rotation shafts along opposite directions, for example, the left rotor 2 rotates clockwise, and accordingly, the right rotor 3 rotates counterclockwise; or the left rotor 2 rotates counterclockwise, and accordingly, the right rotor 3 rotates clockwise.

It should be noted that being provided parallel to each other herein should be understood in a broad sense. In consideration of manufacturing and mounting errors, the axis of the left rotary shaft and the axis of the right rotary shaft are allowed to exhibit an inclination of a certain angle within an error range, and such an inclination is also allowed.

As shown in FIG. 8 and FIG. 9, cross sections of the left rotor 2 and the right rotor 3 perpendicular to an axis of rotation both exhibit a figure-8 leaf-shaped contour, when one of the rotors is provided vertically, the other rotor is provided horizontally, for example, when the left rotor 2 is provided vertically, the right rotor 3 is provided horizontally; and when the right rotor 3 is provided vertically, the left rotor 2 is provided horizontally. Moreover, during rotation of the rotors, an pneumatic sealing structure is formed when airflow flows through passages formed by the side walls of the rotors and the inner wall of the housing.

As shown in FIG. 7 to FIG. 10, an upper side wall of the Roots pump housing 1 is provided with an air inlet 5 which is close to a front side of the Roots pump housing 1; and a lower side wall of the Roots pump housing 1 is provided with an air outlet 4 which is close to a rear side of the Roots pump housing 1. An opening area of the air inlet 5 is greater than or equal to an opening area of the air outlet 4.

It should be understood that the upper side wall, the lower side wall, the front side, and the rear side of the Roots pump housing are not specifically limited, two sides of the Roots pump housing along a length direction of the rotary shaft may be taken as the front side and the rear side, and two sides of the Roots pump housing along a direction perpendicular to a connecting line of the two rotary shafts may be taken as the upper side wall and the lower side wall.

In the present disclosure, the Roots pump housing 1, the left rotor 2, and the right rotor 3 are made of a high-nickel alloy material.

In the present disclosure, after adding the pneumatic sealing groove, a flow vortex structure is utilized to reduce a flow passage area of a gas flowing from a high pressure side to a low pressure side along the clearance between the Roots pump housing and the side wall surface of the rotor; a cavity structure inside the pneumatic sealing groove is utilized to reduce the pressure difference

between two ends of an air leakage cross section; and backflow loss and air leakage loss in the clearance between the Roots pump housing and the side wall surface of the rotor are mitigated, thereby effectively suppressing the clearance leakage flow between the Roots pump housing and the side wall surface of the rotor in the pump, and enhancing the overall pumping speed under the premise of not changing the thickness dimension of the rotor, so that the rotor mass is decreased, and the energy consumption is reduced.

The foregoing is merely the preferred embodiments of the present disclosure. It should be pointed out that for those ordinarily skilled in the art, several improvements and variations may also be made without departing from the technical principles of the present disclosure, and these improvements and variations should also be regarded as falling within the protection scope of the present disclosure.

Claims

1. A Roots pump rotor with pneumatic sealing grooves, wherein the pneumatic sealing groove comprises an outer layer groove which is positioned in an edge area of a side wall surface of the Roots pump rotor and is parallel to a contour of the Roots pump rotor; and during rotation of the Roots pump rotor, airflow flows into the pneumatic sealing groove along a Roots pump housing and a side wall of the rotor to form a streamwise vortex; and the Roots pump rotor rotates at a high speed to form a tangential vortex, and the streamwise vortex and the tangential vortex form an pneumatic sealing structure.
2. The Roots pump rotor with pneumatic sealing grooves according to claim 1, wherein a cross section of the Roots pump rotor perpendicular to an axis of rotation thereof exhibits a figure-8 leaf-shaped contour.
3. The Roots pump rotor with pneumatic sealing grooves according to claim 1, wherein the outer layer groove comprises two first grooves adjacent and parallel to each other.
4. The Roots pump rotor with pneumatic sealing grooves according to claim 3, wherein the pneumatic sealing groove further comprises an inner layer groove which is positioned in the side wall surface of the Roots pump rotor and is parallel to a rotor shaft hole.
5. The Roots pump rotor with pneumatic sealing grooves according to claim 4, wherein the inner layer groove comprises two second grooves adjacent and parallel to each other.
6. The Roots pump rotor with pneumatic sealing grooves according to claim 5, wherein the first groove and the second groove have a depth of 5 mm, and the rotor is not in contact with an inner wall of the Roots pump housing during working.
7. The Roots pump rotor with pneumatic sealing grooves according to claim 5, wherein spacing between the two first grooves adjacent and parallel to each other is 0.3 mm; and/or spacing between the two second grooves adjacent and parallel to each other is 0.3 mm.
8. A Roots pump, comprising: a Roots pump housing, and a left rotor and a right rotor which are accommodated in the Roots pump housing; wherein the left rotor and the right rotor are the Roots pump rotors with pneumatic sealing grooves according to any one of claims 1 to 7; and the left rotor and the right rotor respectively rotate around respective rotation shafts along opposite directions; and axes of the rotation shafts of the left rotor and the right rotor are provided parallel to each other; when one of the rotors is provided vertically, the other rotor is provided horizontally; and during rotation of the rotors, an pneumatic sealing structure is formed when airflow flows through passages formed by side walls of the left rotor and the right rotor and the inner wall of the Roots pump housing.
9. The Roots pump according to claim 8, wherein an upper side wall of the Roots pump housing is

provided with an air inlet which is close to a front side of the Roots pump housing; and a lower side wall of the Roots pump housing is provided with an air outlet which is close to a rear side of the Roots pump housing; and

an opening area of the air inlet is greater than or equal to an opening area of the air outlet.

10. The Roots pump according to claim 8, wherein the Roots pump housing, the left rotor, and the right rotor are made of a high-nickel alloy material.