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Dreifert et al.(10) **Pub. No.: US 2009/0148284 A1**(43) **Pub. Date: Jun. 11, 2009**(54) **VACUUM PUMP**(76) Inventors: **Thomas Dreifert**, Kerpen (DE);
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F04D 29/10 (2006.01)(52) **U.S. Cl.** **415/230**(57) **ABSTRACT**

A vacuum pump for producing a vacuum in a space which is to be evacuated comprises a housing (10) having a cylindrical inner space (22). An expeller (26) is arranged eccentrically in the inner space (22). A helical sealing element (34) is provided between the expeller (26) and an inner wall (38) of the housing (10) for forming at least one crescent-shaped conveying space. The housing (10) or the expeller (26) are connected to a drive device (44) for producing a relative rotary movement between the housing (10) and the expeller (26). The vacuum pump is configured as a dry-running vacuum pump.

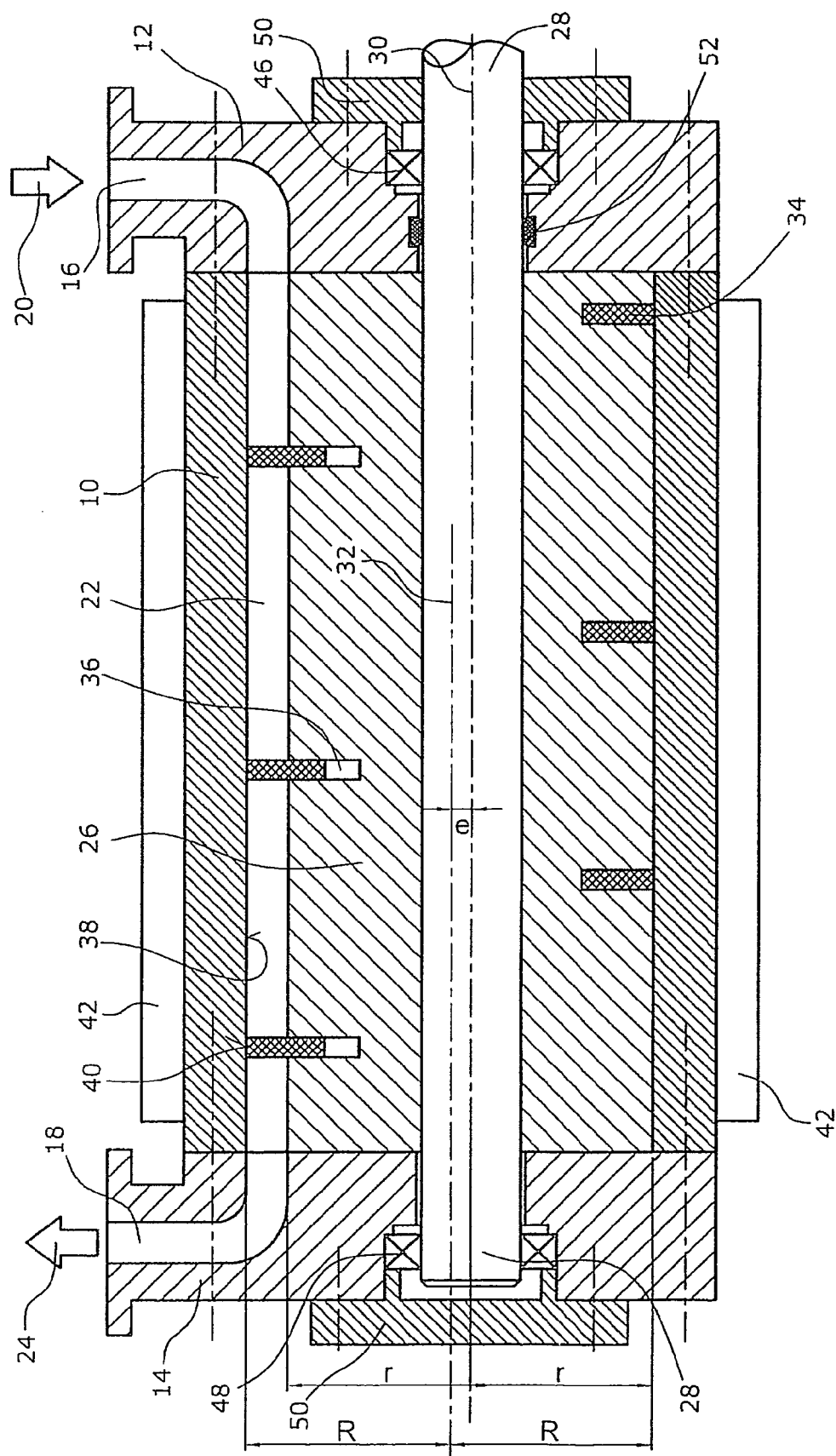


Fig.1

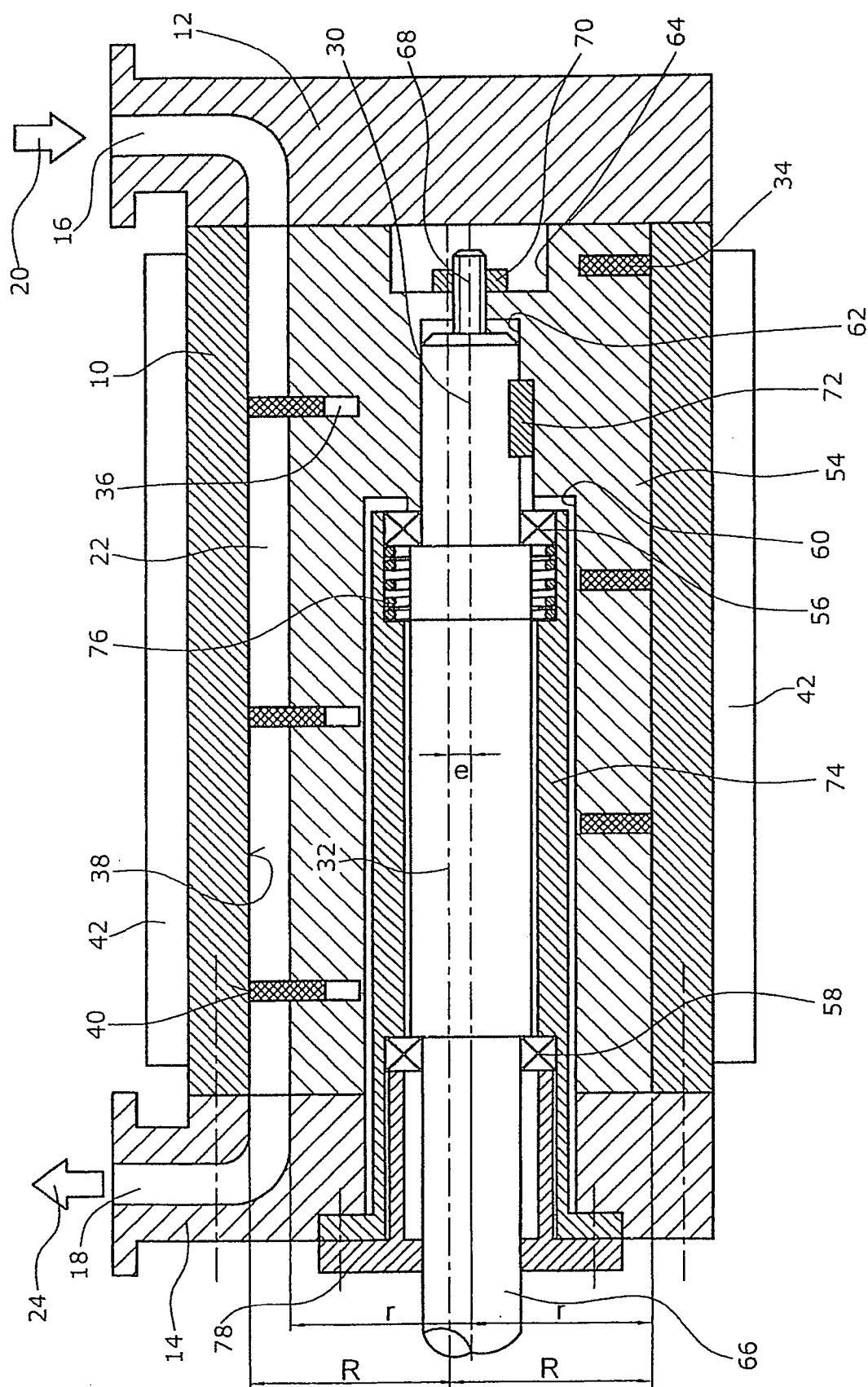


Fig. 2

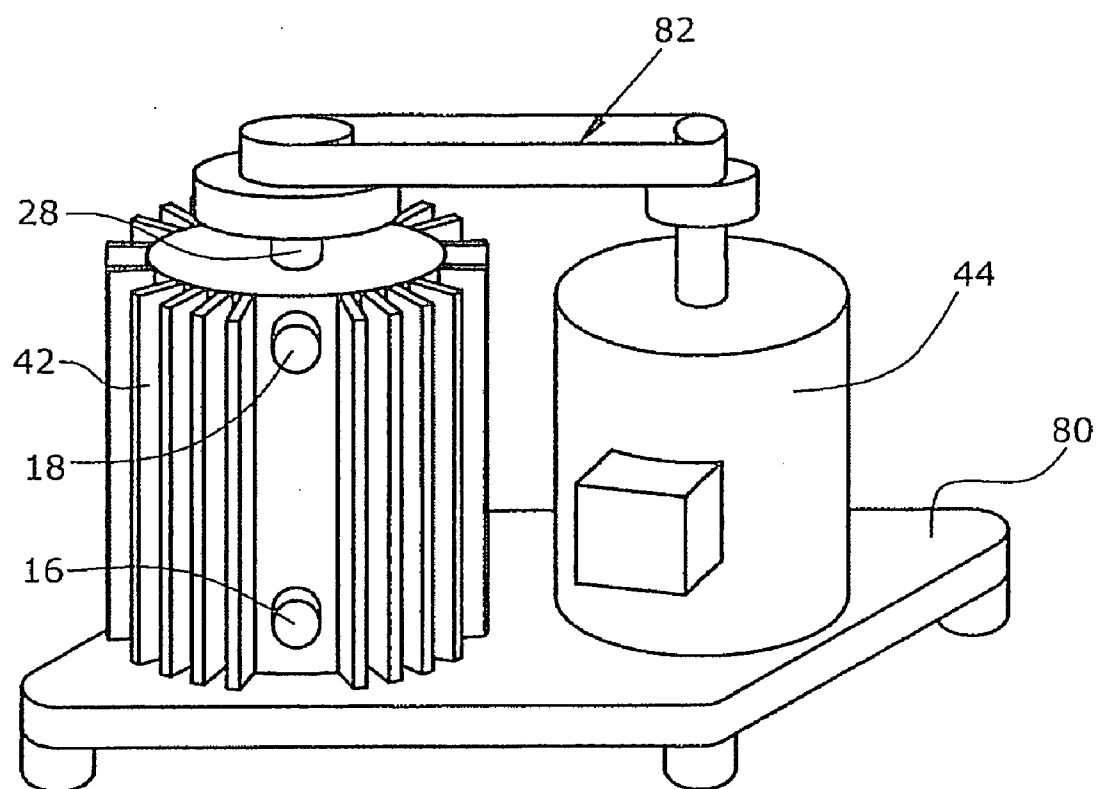


Fig.3

VACUUM PUMP

BACKGROUND

[0001] The invention relates to a vacuum pump for producing a vacuum in a space.

[0002] Vacuum pumps are used for evacuation of spaces in which processes are performed which would be critically affected particularly by particles. Such processes are performed especially in semiconductor production, in vapor-deposition processes, in chemical processes etc. To avoid an intrusion of lubricant substances from the vacuum pump into the space which is to be evacuated, it is required to use dry-running pumps.

[0003] There are already known, for instance, rotary slide valve vacuum pumps of the dry-running type which, however, suffer from the disadvantage of high relative speeds occurring on the frictional components, i.e. between the slide and the inner wall of the pumping chamber. Since high relative speeds are inevitable for acceptable volume flows, the lifespan of rotary slide valve vacuum pumps is relatively short.

[0004] A further variety of vacuum pumps of the dry-running type is a scroll pump. Scroll pumps comprise one stationary component and one orbiting component, which components are provided with spirally shaped conveying means arranged in mutual engagement. Scroll pumps, however, are expensive in manufacture and need frequent maintenance work in order to safeguard a reliable continuous operation.

[0005] Piston vacuum pumps of the dry-running type have the disadvantage that the production costs are high and, further, their constructional volume is large. In such pumps, also the noise development and the occurring vibrations are disadvantageous.

[0006] From US 2005/0163632, there is known a dry-running vacuum pump comprising an eccentrically supported expeller. A helical sealing element is arranged in a spirally shaped groove of the cylindrical expeller. Internally of the hollow cylinder, a crank is arranged eccentrically to the rotational axis of the cylinder. The system consisting of the rotating crank and the orbiting expeller is arranged in a cylindrical housing. The vacuum pump described in US 2005/0163632 is well-suited for high conveying capacities but has a complicated design.

SUMMARY

[0007] It is an object of the invention to provide a vacuum pump which can be reliably operated in an economical manner also in dry running conditions, particularly also in case of a low suction capacity.

[0008] The vacuum pump of the invention comprises a housing having a cylindrical inner space. Within said inner space, an expeller is arranged eccentrically. Between the expeller and the inner wall of the housing, a helical sealing element is arranged for forming at least one crescent-shaped conveying space. The expeller and/or the housing are directly connected to a drive device wherein, depending on the given design, either the housing or the expeller is preferably stationary. Due to said eccentricity, a simple rotational movement of the housing or the expeller will effect a conveyance, e.g. of a gas, from a to-be-evacuated space through an inlet of the vacuum pump to an outlet of the vacuum pump.

[0009] An aspect of the invention in this regard resides in that the expeller is supported centrally, i.e. that the shaft of the expeller which, depending on whether or not the expeller is

driven, forms the drive shaft or the support shaft—is arranged concentrically to the cylindrical expeller. Thus, the expeller will not perform an orbiting movement but a rotating movement. According to the invention, the expeller is supported concentrically.

[0010] According to the invention, the vacuum pump is configured as a dry-running vacuum pump. The vacuum pump of the invention offers the particular advantage of being a vacuum pump of a simple constructional design wherein only the housing or the expeller has to be driven. This can be realized by a simple connection of the expeller or the housing to an electric motor, which connection is realized e.g. via a belt drive or an intermediate transmission, or also directly. The vacuum pump of the invention is particularly suited as a slow-running vacuum pump which has rotational numbers of preferably less than 300 l/min and most preferably 200 l/min. Because of the configuration and the geometry of the vacuum pump of the invention, a good conveying flow can be obtained in spite of the low rotational numbers.

[0011] To be able to operate the inventive dry-running vacuum pump in a reliable manner and with easy maintenance, it is of particular advantage to realize a suitable material pairing between the helical sealing element and the sliding surface having the sealing element sliding thereon. Depending on the design of the vacuum pump, the sealing element, if provided in a vacuum pump with outer-friction sealing element, will slide on the inner wall of the cylindrical inner space of the housing in cases where the sealing element is connected to the expeller for common rotation therewith. In a vacuum pump with inner-friction sealing element, the sealing element is connected to the housing for common rotation therewith and will slide on an outer surface of the cylindrical expeller. Particularly preferred material pairings between the sealing element and a sliding surface, i.e. between the inner wall of the housing and the outer surface of the expeller, consist of a sealing element made of a PTFE compound or PEEK in combination with a sliding surface of smoothed, particularly anodized aluminum. Further, the sealing element can be made of spring steel, particularly coated spring steel. The coating preferably comprises any one of PTFE compounds (PTFE with fillers), PEEK and PEEK compounds, PI (polyimides) and PI compounds, PPS (poly-phenylene sulfide) and PPS compounds or epoxy resins with fillers. Plastics highly resistive to mechanical and thermal stresses are generally of good use. For such a tribological system, relative speeds of up to 5 m/s can be realized. Suitable materials for the sliding surface are, apart from the anodized and thereby preferably hardened aluminum, grey cast iron, spheroidal cast iron, annealed cast iron, as well as steels, particularly stainless steels. These materials are preferably coated with wear-protection layer, particularly CrN or TiN. For reducing the friction between the sealing element and the sliding surface, it is further advantageous to provide coatings or sliding lacquers. These can be ceramic coatings as well as TiN, CrN, AlCrN and CrC.

[0012] In respect to the above, the roughness R_z of the sliding surface is preferably lower than 5, more preferably lower than 2 and most preferably lower than 0.5.

[0013] Due to the eccentricity between the expeller and the cylindrical inner space of the housing, the sealing element is arranged in a groove and is radially displaceable therein. Said groove is formed either in the expeller or in the housing. Although the relative speeds within the sealing element and a groove wall are distinctly lower, it would be advantageous to

provide also the inner wall of the groove with a coating, for instance, thus reducing the friction.

[0014] The width and the depth of the groove are selected to the effect that, in the operative condition of the vacuum pump, there is guaranteed a good radial displacement of the sealing element, one the one hand, and the gap between the sealing element and the groove is as small as possible, on the other hand, in order to avoid leakage flows which would reduce the pumping capacity of the vacuum pump. In this respect, it is to be considered, particularly in dependence on the given selection of materials, that the expansion coefficients and therefore also the thermal expansion of the constructional components, may differ from each other. This holds true particularly for a sealing element made of plastic.

[0015] According to a particularly preferred embodiment of the invention, a cooling element is provided for dissipation of the heat generated at the sliding surface of the sealing element. This allows for a considerable reduction of the wear development, particularly of the sealing element. In a vacuum pump of the type with inner sliding movement, wherein the sealing element is arranged to slide on the inner wall of the cylindrical inner space of the housing, the cooling element, preferably provided in the form of cooling ribs, is preferably connected to the housing. For safeguarding a good cooling effect, it is possible to direct an air flow against the cooling ribs. This onflow can be controlled in dependence on the temperature so that the vacuum pump will quickly reach its operating temperature at the beginning of the operation and then will be operated within a narrow temperature range. This particularly offers the advantage that the sealing element can be produced from a material having a high thermal expansion coefficient and thus will only with relatively narrow temperature ranges be capable to guarantee a reliable sealing effect along with good sliding properties.

[0016] In a vacuum pump having a sealing element for inner sliding movement, it is particularly advantageous if the expeller is cooled. For this purpose, one can provide e.g. a hollow expeller wherein, also in this case, cooling ribs can be arranged in the hollow space, with air flowing around the cooling ribs for cooling.

[0017] With particular preference, the support of the housing or the expeller can be provided on the outlet side. In this case, the supports are arranged in such a manner that no connection exists to the underpressure side of the vacuum pump. Thereby, it is safeguarded that no lubricant from the bearings which are formed particularly as roller bearings, will enter the space that is to be evacuated. Particularly preferred is an overhung support of the expeller. A further improvement of the overhung support of the expeller, which is effective to reduce the tilting moments acting on the bearings, resides in the preferred configurations of internally arranged bearings. For instance, it is possible to provide the expeller in the form of a hollow cylinder and to arrange the drive shaft for the expeller within the hollow cylinder, with the drive shaft connected to the cylinder. To make it possible that the drive shaft arranged in the cavity is supported internally and the supports are nonetheless arranged on the outlet side, the drive shaft can be surrounded by a hollow axis which, if required, is arranged within the cavity of the expeller. The hollow axis is stationary and carries the bearings for support of the drive shaft.

[0018] The helical sealing element preferably comprises a plurality of windings or turns. In correspondence thereto, also the spirally shaped groove comprises a plurality of thread turns. To keep the power input of the vacuum pump as low as

possible and—while at the same time maintaining a small construction space—to keep the compression temperatures low, an internal compression is to be preferred. Such an internal compression of the medium which is to be conveyed can be obtained in that the pitch of the groove or sealing element is reduced in the conveying direction. Compression ratios of 1/3 to 1/10 between the internal compression and the external compression are preferred. Preferably, a bypass valve is provided for preventing an over-compression in the compression region.

[0019] A mathematical analysis of the kinematics of the inventive vacuum pump shows that the relative speed will influence, to the extent of its third power, the maximum obtainable sectional performance. Said relative speed is the relative speed between the sealing element and the sliding element. The maximum obtainable relative speed substantially depends on the material pairing, the surface quality and the temperatures occurring at the contact sites.

[0020] The number of rotations, on the other hand, has a reciprocal quadratic effect on the possible sectional performance when the maximum relative speed is kept constant. Thus, it is possible to realize pumps which in comparison with known vacuum pumps have extraordinarily low rotational numbers of less than 500 l/min or 200 l/min. while still reaching a high suction performance. Due to the inventive constructional design of the vacuum pump, it is thus possible to reach a high suction performance at low rotational numbers. Because of the required low rotational numbers, the vacuum pump can be designed as a dry-running vacuum pump. Higher rotational numbers would cause maximum relative speeds at the contact sites that would result in faster wear effects. Thus, using the inventive dry-running vacuum pump, there can be obtained suction performances of about 0.1 m³/h-30 m³/h. Further, the simple configuration of the vacuum pump allows for an inexpensive construction. Due to the low number of constructional components, maintenance will be very convenient. Further, a long useful life will be guaranteed, particularly due to the low rotational numbers. Still further, the demands posed to the impact resistance are low. A further advantage resides in the occurrence of merely slight vibrations and the low noise development.

[0021] According to a preferred embodiment of the invention, the sealing element is installed with a radial bias. This will entail a good sealing effect. Further, this provision will bring about a balancing of the thermal expansion and allow for convenient replaceability. A radial bias can be generated e.g. by an elastomeric material at the bottom of the groove. Further, the sealing element can be tangentially tensioned by providing a spring.

[0022] The following is a detailed description of an embodiment of the invention with reference to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] In the drawings:

[0024] FIG. 1 is a schematic lateral view of a first preferred embodiment of a vacuum pump;

[0025] FIG. 2 is a schematic lateral view of a second preferred embodiment of a vacuum pump;

[0026] FIG. 3 is a schematic perspective view of a vacuum pump with electromotoric drive.

DETAILED DESCRIPTION

[0027] According to a first preferred embodiment of the invention (FIG. 1), the vacuum pump comprises a stationary

housing 10. Housing 10 is closed by an inlet cover 12 and an outlet cover 14. Inlet cover 12 includes an inlet 16 connected to the space which is to be evacuated. Outlet cover 14 is provided with a connection 18 for discharge of the gases suctioned from the space which is to be evacuated. Thus, the gas will move from the to-be-evacuated space in the direction of arrow 20 via inlet 16 into a cylindrical inner space 22 of housing 10 and will leave said space in the direction of arrow 24 via said outlet connection 18 arranged in outlet cover 14.

[0028] Internally of said cylindrical space 22, a cylindrical expeller 26 is located. Expeller 26 is arranged centrically to a shaft 28. Thus, the central axis 30 of the expeller corresponds to the central axis of shaft 28. Shaft 28 is arranged eccentrically in the cylindrical inner space 22. Consequently, the central axis 32 of inner space 22 has an eccentricity e relative to the central axis 30 of expeller 26 and shaft 28, respectively. In the illustrated exemplary embodiment, shaft 28 is guided through the cover 50 fastened to inlet cover 12.

[0029] Expeller 26 is provided with a helically or spirally shaped sealing element 34. The sealing element 34 is arranged in a corresponding helically or spirally shaped groove 36. Sealing element 34 is connected to expeller 26 for common rotation therewith and for radial displacement relative thereto. By rotation of expeller 26, sealing element 34 will be rotated relative to an inner wall 38 of housing 10. At the same time, expeller 26 will be radially displaced, resulting in the conveyance of gas in the direction of arrows 20, 24. The conveyance of gas is performed in that crescent-shaped conveying spaces, formed between adjacent helical passages of sealing element 34, will convey the medium towards the right-hand side in FIG. 1. The distance between adjacent helical passages of sealing element 34 can decrease in the direction of conveyance so that the medium will be compressed or condensed.

[0030] In the exemplary embodiment illustrated in FIG. 1, the relative movement takes place between the inner wall 38 of inner space 22 and an outer face 40 of sealing element 34. This movement causes both the housing 10 and the sealing element 34 to heat up. Therefore, it is imperative in this embodiment that the housing 10 has a good thermal conductivity and is provided with cooling ribs 42 on the outside. Further, for enhancing the cooling effect, an air flow can be directed towards the cooling ribs 42.

[0031] The shaft 28 connected to expeller 26 is connected to a drive means 44 (FIG. 3) which preferably consists of an electric motor. In the illustrated exemplary embodiment, the support of the shaft is preferably provided by bearings 46, 48, preferably formed as roller bearings, which are arranged in the inlet cover 12 and the outlet cover 14, respectively. Said bearings 46, 48 are held by covers 50 and are preferably formed as roller bearings, and further are greased and are sealed or provided with lids. Particularly on the outlet side, it is of advantage to arrange a sealing 52 with good sealing properties between inlet cover 12 and shaft 28 so as to avoid a gas exchange between the surroundings and the space which is to be evacuated. Such an occurrence would be disadvantageous particularly if the space to be evacuated is a space wherein semiconductor processes or the like are carried out. The contacting shaft sealings can be of the dry-running or of the lubricated type. In case of small pressure differences, also gap sealings can be provided. Also the inlet-side bearing 48 can be separated from the process medium in the pumping chamber by a contacting shaft sealing.

[0032] Further, it is possible to arrange the sealing element 34 in a groove formed in housing 10; in this case, the generated relative speeds will occur between the sealing element and an outer side of expeller 26. The dissipation of the heat caused by such an arrangement will however be more difficult. For heat dissipation, one could use e.g. a hollow expeller.

[0033] As a further option, there could be provided a stationary expeller and a rotating housing. In this case, the bore in the housing would be arranged eccentrically to the rotational axis of the rotation of the housing.

[0034] In connection with a further preferred embodiment (FIG. 2), similar or identical components to those in FIG. 1 are provided with the same reference numerals.

[0035] Housing 10 is configured in correspondence with the embodiment shown in FIG. 1 and is closed by housing covers 12, 14. Housing 10 again comprises a cylindrical opening accommodating an expeller 54. In the same manner as depicted in FIG. 1, expeller 54 has a cylindrical outer contour wherein grooves 36 have a helical sealing element 34 arranged therein so that the functioning of the second embodiment (FIG. 2) corresponds to that of the embodiment of FIG. 1.

[0036] In order to avoid the occurrence of a connection between the bearings of expeller 54 and the to-be-evacuated space and the inlet opening 16, respectively, the bearings in the illustrated embodiment are arranged within the expeller 54. For this purpose, expeller 54 is formed with a cylindrical opening 60 connecting to a cylindrical opening 62 having a smaller diameter. The cylindrical opening 60, 62 is arranged with rotational symmetry relative to expeller 54 and thus is located on the central axis of expeller 54. Provided in concentric arrangement opposite to opening 62 is a cylindrical opening 64, said openings 62, 64 being connected to each other via a further concentric opening.

[0037] A drive shaft 66 formed with a plurality of steps is arranged in the cylindrical openings 60, 62 and comprises a threaded pin 68 extending into opening 64. To connect the shaft 66 to the expeller 54 for common rotation therewith, threaded pin 68 is fixed in position by means of a nut 70, and there is provided an adjusting spring 72. Within the cylindrical hollow space 60 of expeller 54, the bearings 56, 58 are arranged on the outer side of shaft 66. Further, the cylindrical opening 60 has arranged therein a hollow axis 74 carrying the bearings 56, 58. Hollow axis 64 is connected to cover 14 for common rotation therewith. For position definition, bearing 56 is biased by means of a spring 76. Bearing 58 is held by a cover 78.

[0038] Since the bearings are arranged internally and on the outlet side, respectively, no connection exists to the space which is to be evacuated, thereby precluding the possibility that, due to the existing underpressure, lubricant could be sucked out from the bearings and could possibly intrude into the space which is to be evacuated.

[0039] Apart from the supports as depicted in FIGS. 1-2 for the expellers 26, 54, the expellers can also be supported in an overhung manner externally of the housing.

[0040] The two-sided support illustrated in FIG. 1 is advantageous particularly if a double-flow system is provided. In a double-flow vacuum pump, the suctional intake is performed by a centrally arranged suction nozzle; then, using a suitably configured expeller, the gas will be conveyed in both directions towards the side and be laterally discharged from the two outlet openings. An expeller of this type comprises two sealing elements which again have a helical shape and will

transport the medium from the central inlet nozzle respectively to the outside. In a double-flow system with two-sided support, the bearings are arranged respectively on the outlet side, thus avoiding also in this case that lubricant of the bearings can intrude into the space which is to be evacuated.

[0041] Depending on the arrangement of the bearings, the bearings are sealed towards the conveying space by shaft bearings or other sealing elements.

[0042] The perspective view of FIG. 3 shows a fully assembled vacuum pump comprising a drive element **44** formed as an electric motor. The Figure clearly shows the housing **10** provided with the circumferentially distributed, substantially radially arranged cooling ribs **42**. Further shown are the inlet **16** and the outlet **18**. The shaft **28** fastened to expeller **26** is connected to electric motor **44** via a belt drive **82**.

[0043] The two components are arranged on a base plate **80**. The arrangement depicted in FIG. 3 is an extremely compact and thus space-saving arrangement.

[0044] Concerning the kinematics of the various possible embodiments of the vacuum pump of the invention, it is to be noted that the rotational axis preferably is the axis of the component comprising the groove. Both the bore and the expeller are always circular in cross section. The central line of the cylindrical expeller corresponds to the central line of the axis, particularly the rotational axis of the expeller. Preferably, in the various embodiments, the bottom of the groove is always concentric with the component comprising the groove.

[0045] A sealing effect can also be obtained by providing a decrease of the pitch of the groove in the conveying direction. Further, also a two-stepped configuration of the vacuum pump is possible.

[0046] The invention has been described with reference to the preferred embodiments. Modifications and alterations may occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

1. A vacuum pump for producing a vacuum in a space, comprising

- a housing having a cylindrical inner space,
- an expeller arranged eccentrically in the inner space,
- a helical sealing element arranged between the expeller and an inner wall of the housing for forming at least one crescent-shaped conveying space, and
- a drive device, connected to the housing or the expeller for producing a relative rotary movement between the housing and the expeller, the vacuum pump being configured as a dry-running vacuum pump.

2. The vacuum pump according to claim 1, wherein the expeller is supported concentrically.

3. The vacuum pump according to claim 1, wherein the dry-running operation is realized by suitable material pairings between the sealing element and a sliding surface with good sliding properties, particularly by use of material pairings of PTFE and/or PEEK and/or smoothed anodized aluminum.

4. The vacuum pump according to claim 1, wherein an inner wall of the inner space has a roughness Rz of 0.1 to 5, preferably of 0.5 to 2.

5. The vacuum pump according to claim 1, wherein the sealing element is held in a groove for radial displacement therein, said groove being arranged in the housing or in the expeller.

6. The vacuum pump according to claim 5, wherein said groove is coated.

7. The vacuum pump according to claim 1, characterized by a cooling element, connected to the housing, for cooling the housing inner wall.

8. The vacuum pump according to claim 1, wherein said cooling element comprises cooling ribs arranged on an outer side of the housing.

9. The vacuum pump according to claim 1, wherein bearings are arranged for rotatable support of the housing or the expeller.

10. The vacuum pump according to claim 1, wherein the expeller is supported in an overhung manner.

11. The vacuum pump according to claim 1, wherein the expeller is provided with inner bearings.

12. The vacuum pump according to claim 11, wherein the expeller comprises a hollow space having arranged therein a drive shaft connected to the expeller.

13. The vacuum pump according to claim 12, wherein said hollow space has provided therein a hollow axis surrounding the drive shaft and serving to accommodate the bearings.

14. The vacuum pump according to claim 1, wherein the rotational number of the housing or of the expeller is delimited to 500 l/min, preferably to 200 l/min.

15. A vacuum pump comprising:

- a cylindrical rotor having a rotor central axis, the cylindrical rotor defining a helical channel along an outer surface thereof;
- a sealing element received in the helical channel;
- a housing defining a cylindrical chamber having housing central axis;
- a bearing assembly which mounts the cylindrical rotor and the housing for relative rotational movement around an axis of rotation, the axis of rotation being aligned with the rotor axis and radially offset from the housing axis.

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