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TWO-STAGE COMPRESSOR

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2 Claims

ABSTRACT OF THE DISCLOSURE

Two-stage screw compressor having a housing providing two separate working spaces, each composed of intersecting bores, the axis of each bore of one working space being coaxial with the axis of a bore of the other working space, pairs of intermeshing male and female rotor elements in each working space, a pair of coaxial rotor elements being axially and torsionally fixed to each other and provided with a thrust bearing in the end plate of the second stage, and the high pressure port of each stage being located at the end plate of the housing limiting the working space.

The present invention relates to a two-stage compressor of the meshing screw rotor type. Such a compressor comprises a housing composed of two barrel members separated by a partition, and two end plate members. Each barrel member provides a working space composed of two intersecting, cylindrical bores with parallel axes and axially limited by high pressure and low pressure end wall surfaces, provided by the partition and the adjacent end plate member. At least one bore of one working space is coaxial with a bore of the other working space and separated therefrom by the partition. In each of the working spaces intermeshing male and female rotor elements are located for rotation around axes coinciding with those of the bores. Each rotor element is provided with helical lands and grooves having an effective wrap angle of less than 350 degrees. The lands and grooves of a male rotor element are located mainly outside the pitch circle of the rotor element and are provided with generally convex flanks, whereas the lands and grooves of a female rotor element are located mainly inside the pitch circle of the rotor element and are provided with generally concave flanks. A male rotor element and a female rotor element cooperate with each other and with the wall surfaces of the working space to form chevron-shaped compression chambers, each comprising communicating groove portions of the cooperating rotor elements. The base ends of the chevron-shaped chambers are located at the high pressure end wall surface of the working space, whereas the apices of the chevron-shaped chambers move axially towards the base ends thereof, as the rotors revolve, whereby the volume of each chevron-shaped chamber decreases. One rotor element in one working space is connected with an aligned rotor element in other working space by a form a torsionally and axially rigid rotor unit extending through the partition and provided with radial bearings in the end plate members of the housing and with a thrust bearing in one of the end plate members only, whereas the other axial end of the axially rigid rotor unit must be axially free. The lands and grooves of the rotor elements of the rotor unit are directed oppositely to each other, whereby the apices of the chevron-shaped compression chambers in the two sections move in opposite directions, so that the axial forces acting on the two rotor elements of the rotor unit are counterdirected and partially balance each other. One working space and the two cooperating rotor elements enclosed therein constitute a first compression stage. This first stage is provided with an inlet port communicating with an inlet channel to the compressor which port has at least its major portion located at the low pressure end wall surface of the working space or within an area adjacent thereto, and an outlet port communicating with an overflow channel between the two stages which overflow port has at least its major portion located at the high pressure end wall surface of the working space or within an area adjacent thereto. The second working space and the two cooperating rotor elements enclosed therein constitute a second compression stage. This second stage is provided with an inflow port communicating with the overflow channel which inflow port has at least its major portion located at the low pressure end wall surface of the working space or within an area adjacent thereto, and an outlet port communicating with an outlet channel from the compressor which outlet port has at least its major portion located at the high pressure end wall surface of the working space or within an area adjacent thereto. Hitherto it has been common practice to locate the overflow port of the first compression stage and the outlet port of the second compression stage at the end walls of the working spaces provided by the partition. Even though this location of the ports is favorable with regard to the possibilities to keep the clearances between each of the high pressure end wall surfaces of the working spaces and the confronting high pressure ends of the rotor elements within a very small range, which is essential with regard to the internal leakage and thus to the efficiency of the compressor, this location of the ports means that the radial forces acting upon the rotor elements and trying to deflect them and to separate them from each other are largest in the area adjacent to the partition and smallest in the areas adjacent to the end plate members in which the bearings are located. For high pressures in the compressor the clearances between the rotor elements at the high pressure ends thereof will thus owing to the deflection be so large that the internal leakage within the compressor will decrease the efficiency more than is tolerable.

The object of the present invention is to reduce the separation of the rotor elements without noticeable deterioration of the compressor in other respects. In order to bring about the desired results the high pressure ports of the two stages, i.e., the overflow port of the first stage and the outlet port of the second stage, in accordance to the invention are located adjacent to the end plate members of the housing and the radial bearings for the rigid rotor unit have to be located in those members in the way already known per se. In this way the largest radial forces will act upon the rotor elements adjacent to the radial bearings thus reducing the deflection of the rotor elements and consequently reducing the separation thereof. However, this location of the ports is not enough to produce a practically useful compressor as it is also necessary to hold the axial clearances within a small range. As the rotor unit is not only rotatably rigid in order to convey the required power to the different compression stages, but also axially rigid in order to provide the largest possible balancing of the axial forces deriving from the different stages, the rotor unit can be axially journalled only in one single thrust bearing. As the most essential axial clearance in the compressor is the one between the high pressure end wall surface and the high pressure ends of the rotor elements of the second compression stage the thrust bearing for the rigid rotor unit...
is in accordance to the invention located in the housing in the end plate member thereof facing the working space of the first compression stage. Furthermore in order to keep the axial clearance between the high pressure end wall surface and the high pressure ends of the rotor elements of the first compression stage at a small value, which clearance is located at the end plate member of the housing facing the working space of the first compression stage, it is necessary to hold the thermally deformations of the housing and the rotor elements within a very low range. It is, however, not sufficient that the variations of the axial distance between the end plate members of the housing and of the axial distance between the remote rotor ends of the rigid rotor unit are the same, but it is also necessary to hold the housing within a very low temperature range in order to avoid warping thereof in dependence on the complicated form of the housing which warping except for increased dimensions results in curved end wall surfaces and in disalignment of the rotor bearings. In order to reduce such thermal deformations to acceptable values a compressor according to the invention is provided with means for injection of liquid into the working spaces of the different stages, whereby the working fluid is effectively cooled and thus the heat transferred to the compressor structure is so limited that the temperature rise will fall within an acceptable range.

As the female rotor elements are subjected to larger radial forces than the cooperating male rotor elements and as the female rotor elements normally have a smaller moment of inertia, so that the deflection of each female rotor element is considerably larger than the deflection of the cooperating male rotor element, a further improvement in a compressor of the actual type can be obtained by composing the rigid rotor unit of two male rotor elements and by making the two female rotor elements separate from each other. In this case the female rotor elements must be journalled also in the partition and provided with separate thrust bearings. However, as the axial forces acting on each of those female rotor elements are much smaller than those acting upon the male rotor elements separate thrust bearings do not mean a problem. As at least the thrust bearing of the female rotor element of the first compression stage is located on a considerable axial distance from the thrust bearing of the rigid male rotor unit the female rotor element of the first compression stage can not be connected with the male rotor unit by means of a synchronizing gear but has to be driven by direct flank contact between the flanks of the meshing lands and grooves of the cooperating rotor elements. Normally there will be such a flank contact between the cooperating rotor elements also in the second compression stage.

The invention will now be described more in detail with reference to the embodiment thereof shown in the accompanying drawings, in which:

FIG. 1 is a top view of the two-stage compressor generally taken through the common plane of the rotor axes.

FIG. 2 is a cross section taken along line II-—II in FIG. 4.

FIG. 3 is a section taken along line III-—III in FIG. 2.

FIG. 4 is a section taken along line IV—IV in FIG. 2.

The compressor shown comprises a housing composed of a first barrel member 10, a second barrel member 12 integral with an end plate member 14, a partition 16 located between the barrel members 10, 12 and an end plate member 18 secured to the end of the barrel member 10 remote from the partition 16.

Each of the two barrel members 10, 12 forms a working space 20 and 22 respectively, generally composed of two cylindrical, intersecting bores with parallel axes and axially closed by the partition 16 and the adjacent end plate member 14, 18. All four bores have the same diameter and each bore in one barrel member is in alignment with one bore in the other barrel member.

The working space 20 in the barrel member 10 is provided with an inlet port 24 having an axial section in the wall of the partition 16 and a radial section in the portions of the barrel wall adjacent thereto and communicating with an inlet channel 26 provided in the barrel member 10, in which inlet channel a splash plate 28 is located. The working space 20 is further provided with an outflow port 30 having an axial section in the wall of the end plate member 18 and a radial section in the portions of the barrel wall adjacent thereto and communicating with an overflow channel 32 provided in the barrel member 10, the partition 16 and the barrel member 12. The working space 22 is correspondingly provided with an inflow port 34 having an axial section in the wall of the partition 16 and a radial section in the portions of the barrel wall adjacent thereto and communicating with the overflow channel 32. The working space 22 is further provided with an outflow port 36 having an axial section in the wall of the end plate member 14 and a radial section in the portions of the barrel wall adjacent thereto and communicating with an outlet channel 38 located in the barrel member 12.

A male rotor element 40 provided with four helical lands and interring grooves, mainly located outside the pitch circle of the element and provided with generally convex flanks, and a female rotor element 42 intermeshing therewith and provided with six helical lands and interring grooves, mainly located inside the pitch circle of the element and provided with generally concave flanks, are provided within the working space 20 and located in coaxial alignment with the bores thereof. A correspondingly shaped pair of intermeshing male and female rotor elements 44 and 46, respectively, are provided within the working space 22. The male rotor element 40 is provided with a shaft 48 projecting therefrom and extending through the partition 16, the working space 22 and the end plate member 14 to form the driving shaft of the compressor. The shaft is within the working space 22 provided with two annular interference surfaces 50, 52 separated by a shallow and relatively wide valley 54. The male rotor element 44 is provided with a central bore having correspondingly formed interference surfaces and is shrunk on the shaft 48. The rotor element 44 is further nonrotatably fixed to the shaft 48 by a pin 56. The two male rotor elements 40, 44 form thus an axially and torsionally rigid rotor unit. In order to make it possible for the rotor element 44 from the shaft 48 the interference surface 52 adjacent to the rotor element 40 has a slightly larger diameter than the surface 50 and the shaft is provided with a central channel 58 communicating with the valley 54 through a radial channel 60 for introduction of a high pressure liquid between the shaft 48 and the rotor element 44 in order to nullify the interference therebetween.

The rigid male rotor unit 40, 44 is mounted in bearings in the end plate members 14 and 18. The bearing in the end plate member 18 is a radial bearing only and comprises a bushing 62 held in position by a cover 64 fixed to the end plate member 18 by means of bolts 74 not shown. The bearing in the end plate member 14 is a combined radial and thrust bearing and comprises a bushing 66 having an end member 68 nonrotatably but slightly tiltably fixed thereto. The bushing is held in an axial position determined by the thickness of a washer 70 by means of a ring member 72. The shaft 48 of the rotor unit 40, 44 is provided with a ring member 74 nonrotatably and axially fixed thereto which ring member 74 cooperates with the end member 68 to form a thrust bearing for axial forces trying to move the rotor unit 40, 44 towards the end plate member 18. The bushing 66 is further provided with an end surface facing the rotor element 44 and cooperating therewith to form a bearing for axial forces trying to move the rotor unit 40, 44 towards the end plate member 12. The end plate member 14 is covered by a cap 76 and a sealing device 78 is
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provided at the opening through which the shaft 48 projects.

A bore in the partition is located in alignment with the shaft 48 projecting therethrough and provided with a sealing device 80 of labyrinth type cooperating with the shaft 48.

Shims are inserted between the barrel member 12 and the partition 16, between the partition 16 and the barrel member 10, and between the barrel member 10 and the end plate member 18 in order to adjust the axial clearances between the rotor element 44 and the partition 16, between the partition 16 and the rotor element 40, and between the rotor element 40 and the end plate member 18, respectively.

The two female rotor elements 42, 46 are completely free from each other. Each of them is mounted correspondingly to the male rotor unit by means of a radial bearing in the partition 16 and in a combined radial and thrust bearing in the adjacent end plate member 18, 44.

The partition 16 is provided with an inlet channel 82 for supply of pressure oil from a source, not shown. From the channel 82 the oil is distributed to the working spaces 20, 22 through injection openings 84 and 86 respectively, to the sealing device 78 and to bearings for the female rotor element 42, 46 located in the partition 16. Pressure oil is further supplied to the space between the cover of and the confronting end of the male rotor unit 40, 44 for partial balancing of the axial forces acting on the unit. Oil is also supplied to the bearings not specifically mentioned above. The oil injected into the working spaces 20, 22 serves except for as a lubricant between the cooperating flanks of the rotor elements 40, 42, 44, 46 and as a sealing agent for the clearances between the intermeshing rotor elements and between the rotor elements and the walls of the working spaces also as a cooling agent for the working fluid during the compression thereof resulting in a much lower temperature of the working fluid and thus in a small transfer of heat to the structure of the compressor which means so low a temperature of the housing and the rotor elements that the thermal expansion thereof results in negligible deformations only.

The compressor shown acts in the following way. Working fluid is supplied to the inlet channel 26 and passes through the inlet port 24 to the working space 20, where it enters the grooves of the rotor elements 40 and 42.

The fluid then during the rotation of the rotor elements 40, 42 transferred to the compression phase of the first stage and compressed therein and delivered thereof from the first stage and passed through the overflow channel 26.

During the compression, oil is injected into the working space 20 through the injection opening 84 for cooling, sealing and lubricating purposes. Most of the oil injected flows with the working fluid to the overflow channel but a certain amount thereof passes between the rotor elements 40, 42, is intercepted by the splash plate 28 and returned to the working space 20 without mingling with the heat transfer to the non-compressed working fluid. The working fluid passes through the overflow channel 32 to the inflow port 34 of the second stage and further compressed therein and delivered therefrom through the outlet port 36 to the outlet channel 38 through which it is discharged from the compressor. During the compression, oil is injected into the second working space 22 through the injection openings 86 for cooling, sealing and lubricating purposes.

The forces acting between the rotor elements 40, 42, 44, 46 and the working fluid are directed and distributed in such a way that the axial forces acting upon the elements 40, 44 of the male rotor unit counteract each other, which together with the axial force acting on the rotor unit by the pressure oil enclosed by the cover 64 reduces the load on the thrust bearing 68, 74 to such an extent that the radial forces acting upon the rotor elements 40, 42, 44, 46 have their maximum values close to the end plate members 14, 18 where the radial bearings are located which means that the deflections of the rotor elements 40, 42, 44, 46 are reduced to a minimum.

However, it is a fact that owing to the shape of the rotor profiles the radial forces acting on the female rotor elements 42, 46 are larger than those acting on the male rotor elements 40, 44 as well as to torque of inertia and thus the resistance to bending is smaller for the female rotor element 42, 46 than for the cooperating male rotor element 40, 44. For this reason the female rotor elements 42, 46 are provided with bearings also in the partition thus still more reducing the deflections of the female rotor elements 42, 46 and consequently reducing the clearances between the rotor elements 40, 42, 44, 46 to a minimum.

The small deflections of the rotor elements and the negligible thermal deformations thereof and of the housing means that the clearances in the compressor necessary with respect to the mechanical reliability can be kept smaller than those otherwise necessary which means that the internal leakage will be further reduced resulting in a still higher efficiency of the compressor.

The invention is thus not limited to the shown embodiment but encloses everything falling within the scope of the following claims.

What is claimed is:

1. Two-stage compressor of the meshing screw rotor type comprising a housing composed of two barrel members, a partition and two end plate members, providing a working space in each of said barrel members, each working space being generally composed of intersecting cylindrical bores with parallel axes and axially limited by the partition and the adjacent end plate member, at least one bore of one working space being in coaxial alignment with a bore of the other working space, intermeshing male and female rotor elements being mounted in the housing for rotation in each of said working spaces, each rotor element being provided with helical lands and intervening grooves having an effective wrap angle of less than 360°, one rotor element in one working space being connected with a coaxially aligned rotor element in the other working space to form a torsionally and axially rigid rotor unit, the lands and grooves of each male rotor element being located mainly outside the pitch circle of the element and provided with generally convex flanks, the lands and grooves of each female rotor element being located mainly inside the pitch circle of the element and provided with generally concave flanks, said intermeshing rotor elements cooperating with each other and the walls of the working space to form chevron-shaped compression chambers, said compression chambers varying in volume when the apices thereof move axially as the rotor elements rotate, the directions of movement of said apices being opposite to each other in the two working spaces, one working space constituting together with the rotor elements enclosed therein a first compression stage and being provided with an inlet port generally located at one end thereof and with an outlet port generally located at the other end thereof, the other working space constituting together with the rotor elements enclosed therein a second compression stage and being provided with an inflow port generally located at one end thereof and an outlet port generally located at the other end thereof, characterized in that said outflow port of the first stage and said outlet...
port of the second stage are located at the respective end plate member, that said rigid rotor unit is mounted in a radial bearing in the end plate member adjacent to said outflow port and in a combined radial and thrust bearing in the end plate member adjacent to said outlet port, and that means are provided for injection of liquid into said working spaces.

2. Compressor as defined in claim 1, in which said rigid rotor unit is composed of two male rotor elements and said female rotor elements are completely free from each other, each of said female rotor elements being mounted in the partition and in the adjacent end plate member.

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