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SCROLL COMPRESSOR WITH ROLLING ELEMENT BEARINGS

Abstract

A scroll compressor includes a housing and a rotatable drive shaft disposed within the housing and having an eccentric end portion. First and second support bearings rotatably couple the drive shaft with the housing and each includes a plurality of rolling elements, at least one of which is ceramic, and an annular cage formed of a polymeric material. A scroll member is disposed within the housing chamber and a drive bearing rotatably couples the shaft eccentric portion with the scroll member such that the scroll member orbits about the central axis. The drive bearing includes a plurality of rolling elements, at least one of which is ceramic, and an annular cage formed of a polymeric material. Further, a solution formed of refrigerant and oil is directed to each one of the drive bearing and the first and second support bearings so as to lubricate the rolling elements.

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Background/Summary

BACKGROUND OF THE INVENTION

[0001] The present invention relates to compressors, and more particularly to bearings for scroll compressors.

[0002] Scroll compressors are known and generally include an orbital scroll member with a spiral wall engaged with a mating spiral wall of a fixed scroll member. During compressor operation, the orbital scroll member is driven to orbit about an axis such that the two engaged spiral walls interact to compress a vapor, such as refrigerant, directed between the mating walls. Typically, the orbital scroll member is mounted to an eccentric portion of a shaft that is driven to rotate about an axis, usually by means of an electric motor.

[0003] In many applications, such as heat pumps, air conditioning systems, superchargers, etc., a scroll compressor are typically sized relatively small or compact. Such size limitations make the use of conventional lubrication systems complicated and difficult to incorporate. Therefore, in particular with refrigerant compressors, a portion of the refrigerant flowing through the scroll compressor is mixed with oil and directed into components, such as bearings, to provide the necessary lubrication.

SUMMARY OF THE INVENTION

[0004] In one aspect, the present invention is a scroll compressor comprising a housing having an interior chamber and a drive shaft disposed within the housing chamber and rotatable about a central axis. The shaft has an eccentric end portion with a centerline spaced from and extending parallel to the central axis. A scroll member is disposed within the housing chamber and a drive bearing is configured to rotatably couple the drive shaft with the scroll member such that the scroll member orbits about the central axis. The drive bearing includes at least one row of rolling elements disposed between the shaft eccentric end portion and the scroll member, at least one of the rolling elements being formed of a ceramic material. Further, a quantity of a solution formed of refrigerant and oil is disposed within the housing chamber, the solution being directed into the drive bearing to lubricate the at least one ceramic rolling element.

[0005] In another aspect, the present invention is again a scroll compressor, the compressor comprising a housing having an interior chamber and a drive shaft disposed within the housing chamber, rotatable about a central axis, and having an eccentric end portion with a centerline spaced from and extending parallel to the central axis. A first support bearing and a second support bearing are spaced apart along the central axis, the first and second support bearings rotatably coupling the drive shaft with the housing. Each one of the first and second support bearings includes at least one row of rolling elements and an annular cage having a plurality of pockets, each pocket retaining a separate one of the rolling elements. Each cage is preferably formed of a polymeric material due to low viscosity lubricant providing relatively poor lubrication, but may be formed of other materials such as a coated metal, brass, etc. A scroll member is disposed within the housing chamber and a drive bearing rotatably couples the drive shaft with the scroll member such that the scroll member orbits about the central axis. The drive bearing includes at least one row of rolling elements and an annular cage, which is preferably formed of a polymeric material as discussed above, and has a plurality of pockets, each pocket retaining a separate one of the rolling elements Further, a quantity of a solution formed of refrigerant and oil is disposed within the housing chamber, the solution being directed to each one of the drive bearing and the first and second support bearings so as to lubricate the rolling elements.

Description

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0006] The foregoing summary, as well as the detailed description of the preferred embodiments of the present invention, will be better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, there is shown in the drawings, which are diagrammatic, embodiments that are presently preferred. It should be understood, however, that the present invention is not limited to the precise arrangements and instrumentalities shown. In the drawings:

[0007] FIG. **1** is an axial cross-sectional view of a simplified version of a scroll compressor in accordance with the present invention;

[0008] FIG. **2** is a broken-away, axial cross-sectional view of an upper portion of the scroll compressor, showing details of two engaged scroll members;

[0009] FIG. **3** is an enlarged, broken-away view of a portion of FIG. **2**, showing a first construction of a drive bearing;

[0010] FIG. **4** is another enlarged, broken-away view of a portion of FIG. **2**, showing a second construction of the drive bearing;

[0011] FIG. **5** is a broken-away, perspective view of the drive bearing, shown without an inner ring; and

[0012] FIG. **6** is a broken-away, enlarged view of a portion of FIG. **1**, showing the structure of one support bearing.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Certain terminology is used in the following description for convenience only and is not limiting. The words “inner”, “inwardly” and “outer” refer to directions toward and away from, respectively, a designated centerline or a geometric center of an element being described, the particular meaning being readily apparent from the context of the description. Further, as used herein, the words “connected” and “coupled” are each intended to include direct connections between two members without any other members interposed therebetween and indirect connections between members in which one or more other members are interposed therebetween. The terminology includes the words specifically mentioned above, derivatives thereof, and words of similar import.

[0014] Referring now to the drawings in detail, wherein like numbers are used to indicate like elements throughout, there is shown in FIGS. **1-6** a scroll compressor **10** and its constituent parts, which basically comprises a housing **12** having an interior chamber C.sub.H, a motor **13** disposed within the chamber C.sub.H, a drive shaft **14** connected to or incorporated into the motor **13**, a movable scroll member **16** coupled with the shaft **14** and a fixed scroll member **18**. The motor **13** drives the shaft **14** to rotate about a central axis A.sub.C, the shaft **14** being rotatably coupled with the housing **12** by first and second rolling element “support” bearings **20**A, **20**B. The shaft **14** has an eccentric end portion **15** with a centerline L.sub.C spaced from and extending parallel to the central axis A.sub.C, the eccentric portion **15** being coupled with the movable scroll member **16** by a rolling element “drive” bearing **22**.

[0015] As such, rotation of the shaft **14** about the central axis A.sub.C drives the movable scroll member **16** to orbit about the central axis A.sub.C and interact with the fixed scroll member **18** so as to compress a vapor, preferably a refrigerant, which is directed between the two members **16**, **18**. Further, due to preferred applications in which the compressor **10** is sized relatively small or compact, lubrication of the various compressor components, in particular the bearings **20**A, **20**B and **22**, is achieved by a solution S.sub.L of refrigerant and oil, and preferably about five percent oil in a bulk solution, contained within the housing **12**, as schematically depicted in FIG. **1**. The refrigerant-oil solution S.sub.L, which may consist “locally” (i.e., in the vicinity of the bearings) of a substantially higher percentage of oil, is directed into the drive bearing **22** and the support bearings **20**A, **20**B by appropriate ducts or fluid lines (none depicted), the solution S.sub.L thus

providing relatively low viscosity lubrication.
[0016] Referring to FIGS. **1** and **2**, the movable scroll member **16** has first and second axial ends **16***a*, **16***b*, the first axial end **16***a* being engaged with the fixed scroll member **18**, and a cylindrical bore **24** extending axially inwardly from the second axial end **16***b*, the bore **24** receiving the shaft eccentric end portion **15**. Preferably, the movable scroll member **16** includes a baseplate **26** with opposing first and second axial ends **26***a*, **26***b*, respectively, a spiral wall **28** extending axially from the plate first axial end **26***a* and engageable with a mating wall **19** of the fixed scroll member **18**, and a cylindrical hub **29** extending axially from the plate second axial end **26***b* and having an inner circumferential surface **29***a* defining the cylindrical bore **24**, as depicted in FIG. **2**. The eccentric end portion **15** of the shaft **14** has an outer circumferential surface **15***a* and is disposed within the bore **24** of the scroll member hub **28**. Further, the drive bearing **22** is disposed within the hub bore **24** and is configured to rotatably couple the shaft eccentric end portion **15** with the movable scroll member **16**, as discussed below.
[0017] Referring to FIGS. **3**-**5**, the drive bearing **22** includes at least one row of rolling elements **30** spaced circumferentially about the centerline L.sub.C of the shaft eccentric portion **15**. Each rolling element **30** is preferably a cylinder, and in a presently preferred application, the cylinders are formed and/or sized as needles (i.e., with a length substantially greater than an outer diameter). Preferably, the drive bearing **22** also includes an annular cage **32** having a plurality of circumferentially spaced pockets **34**, as best shown in FIG. **5**, which is preferably formed of a polymeric material but may alternatively be formed of another appropriate material (e.g., brass, a polymer-coated metal, etc.). Each one of the plurality of rolling elements **30** is disposed within a separate one of the pockets **34** so as to circumferentially space the elements **30**. The cage **32** is preferably formed of polyetheretherketone (“PEEK”) or polyamide (“PA”), but may alternatively be formed of any other appropriate polymeric material.
[0018] Further, the specific structure of the drive bearing **22** and the type of rolling elements **30**, i.e., standard cylinders or needles, may vary due to the specific dimensions of the annular space SA between the outer circumferential surface **15***a* of the shaft eccentric portion **15** and the inner circumferential surface **29***a* of the hub bore **24**. That is, in a presently preferred compressor **10**, the bore **24** of the cylindrical hub **24** has an inside diameter IDB with a value of between nineteen millimeters (19 mm) and eighty millimeters (80 mm) and the eccentric portion **15** of the shaft **14** has an outside diameter ODE with a value of between twelve millimeters (12 mm) and sixty millimeters (60 mm), as indicated in FIG. **3**. As the hub **24** is preferably sized to accommodate the size of the shaft eccentric portion **15**, i.e., a lesser hub inside diameter IDB with a lesser shaft outside diameter hub ODE and vice-versa, a radial width W.sub.R of the annular space SA has a value of between three and one-half millimeters (3.5 mm) and twenty five millimeters (25 mm).
[0019] Furthermore, the drive bearing **22** may include both an inner ring **36** and an outer ring **38**, as depicted in FIG. **3**. The inner ring **36** is disposed about the shaft eccentric portion **15** and has an inner race **37** and the outer ring **38** is disposed within the scroll member bore **24** and has an outer race **39**. With both inner and outer rings **36**, **38**, the rolling elements **30**, and preferably also the cage **32**, are disposed between the rings **36**, **38** such that each rolling element **30** rolls simultaneously along the inner and outer races **37**, **39**.
[0020] In certain applications in which the radial width W.sub.R is substantially less than the maximum value, the drive bearing **22** may include only the outer ring **38** disposed within the scroll member bore **24** and the rolling elements **30** roll simultaneously against the outer race **39** and directly against the outer circumferential surface **15***a* of the eccentric end portion **15** of the shaft **14**, as depicted in FIG. **4**. However, either of these constructions of the drive bearing **22** may be used regardless of the specific radial width W.sub.R of a particular application. Further, it is within the scope of the present invention to use any other appropriate construction of the drive bearing **22**, such as for example, including only an inner ring **36** and with the rolling elements **30** rolling against the bore surface **29***a*, etc.

[0021] Furthermore, to optimize lubrication of the cage **32**, it is preferred to guide an outer circumferential surface **32***a* of the cage **32** against the bearing outer ring **38**. Specifically, due to the orbiting motion of the movable scroll member **16** and the rotation of the shaft **14**, centrifugal forces cause the lubricating solution S.sub.L to collect in greater quantities on the outer ring **38** as compared with the inner ring **36**. As such, the outer ring **38** has an inner circumferential guide surface **38***a*, preferably two inner circumferential guide surfaces **38***a* on opposing axial sides of the outer race **39**, and the cage **32** correspondingly has at least one and preferably two outer circumferential surfaces **32***a* slidable against the guide surface(s) **38***a*. Thereby, the outer ring **38** supports radial loads applied to the cage **32** and ensures that an inner circumferential surface **32***b* of the cage **32** remains radially spaced from the inner ring **36** or the eccentric end portion **15** of the shaft **14**.

[0022] Additionally, with the relative sizing of the drive bearing **22**, in particular the mean diameter D.sub.M (FIG. **3**), in relation to the intended rotational speed of the shaft **14** during compressor operation, the bearing **22** has an "ndm" value of no greater than three hundred thousand millimeters×rotations per minute, i.e., ndm≤300,000 mm×rpm. Specifically, as is known in the art of rolling element bearings, the ndm value of a bearing is the mean diameter of the bearing in millimeters multiplied by the rotational speed of the bearing in rotations per minute. With such a relatively low ndm value and low viscosity lubrication conditions, the lubrication film thickness at the point of contact between each rolling element **30** and the raceways **37**/**39** or **15***a*/**39** tends to be relatively small, making it challenging to adequately lubricant the drive bearing **22**. Such reduced quality of the lubrication conditions can lead to reduced bearing life, especially due to the effects of wear and surface initiated fatigue.

[0023] Therefore, to increase the robustness of the drive bearing **22** against the effects of poor lubrication, at least one of the rolling elements **30** is formed of a ceramic material, preferably silicon nitride but may alternatively be formed of zirconia or any other appropriate material. In certain applications, a plurality of the rolling elements **30** or even the entire row of rolling elements **30** are formed of ceramic. In addition to reducing friction even under poor lubrication conditions, such as low speed and low viscosity, ceramic rollers also mitigate the effects of contamination. Specifically, contaminate particles produce dents with raised material around them on the bearing raceways that become stress raisers. Due to the fact that ceramic rollers are harder than steel rollers, a ceramic roller will plastically deform the raised edges around the dents to result in a "finer" raceway surface. Such a finer surface is beneficial for better utilizing available lubrication and the elimination of raised material removes stress raisers that may lead to fatigue cracks. Even a single ceramic rolling element **30** will mitigate the effects of contaminants and will also improve lubrication conditions for the remaining rolling elements **30** that are formed of steel.

[0024] To further improve lubrication and increase bearing life, the races **37**/**39** or **15***a*/**39** of the drive bearing **22** are preferably finished to a greater degree or extent as compared to the surface finish of a typical rolling bearing. More specifically, when the drive bearing **22** has both inner and outer rings **36**, **38**, the surface **37***a* of the inner race **37** and the surface **39***a* of the outer race **39** each have a surface roughness with an Ra value of no greater than one tenth of a micrometer (0.1 μm) and preferably less than fifty thousandths of a micrometer (0.050 μm). Similarly, when the drive bearing **22** includes only the outer ring **38** and the rolling elements **30**, the surface **39***a* of the outer race **39** and at least a section of the outer surface **15***a* of the shaft eccentric end portion **15** each have a surface roughness with an Ra value of no greater than one tenth of a micrometer (0.1 μm) and preferably less than fifty thousandths of a micrometer (0.050 μm). Thus, the combination of one or more of the rolling elements **30** being ceramic and the relatively fine surface finish of the races **37**/**39** or **15***a*/**39** substantially improves the lubrication conditions and potentially also reduces friction within the drive bearing **22**.

[0025] Referring now to FIGS. **1** and **5**, the first and second support bearings **20**A, **20**B each includes at least one row of rolling elements **40** and may include two or more rows (only a single row depicted). Preferably, each rolling element **40** is a ball and each support bearing **20**A, **20**B is formed as a deep groove ball bearing. More specifically, each support bearing **20**A, **20**B includes an inner ring **42** mounted about the shaft **14** and having an inner race **43** and an outer ring **44** connected with the housing **12** and having an outer race **45**.

[0026] Further, each support bearing **20**A, **20**B preferably further includes an annular cage **46** formed of a polymeric material and having a plurality of pockets **48**. Each pocket **48** retains a separate one of the rolling elements/balls **40** such that the balls **40** are spaced circumferentially about the central axis A.sub.C. Preferably, each cage **46** is formed of polyetheretherketone ("PEEK") or polyamide ("PA"), but may be formed of another appropriate polymeric material.

[0027] As with the drive bearing **22**, the low viscosity lubrication provided by the refrigerant-oil solution S.sub.L tends to be disadvantageous compared to pure oil or grease for bearing lubrication and fatigue life. However, more oil or higher viscosity potentially reduces compressor efficiency. As such, at least one of the rolling elements **40** is formed of a ceramic material, preferably silicon nitride, and in certain applications, a plurality or even the entire row of rolling elements **40** is formed of ceramic. As a result, the one or more ceramic rolling element **40** improves the fatigue life of each one of the support bearings **20**A, **20**B against poor lubrication effects from the low viscosity lubrication and potentially improves the efficiency of the compressor **10**. The ceramic rolling element(s) **40** also mitigate the potential detrimental effects of contaminants, as discussed above in connection with the drive bearing **22**.

[0028] Representative, non-limiting examples of the present invention were described above in detail with reference to the attached drawings. This detailed description is merely intended to teach a person of skill in the art further details for practicing preferred aspects of the present teachings and is not intended to limit the scope of the invention.

[0029] Moreover, combinations of features and steps disclosed in the above detailed description may not be necessary to practice the invention in the broadest sense, and are instead taught merely to particularly describe representative examples of the invention. Furthermore, various features of the above-described representative examples, as well as the various independent and dependent claims below, may be combined in ways that are not specifically and explicitly enumerated in order to provide additional useful embodiments of the present teachings.

[0030] All features disclosed in the description and/or the claims are intended to be disclosed separately and independently from each other for the purpose of original written disclosure, as well as for the purpose of restricting the claimed subject matter, independent of the compositions of the features in the embodiments and/or the claims. In addition, all value ranges or indications of groups of entities are intended to disclose every possible intermediate value or intermediate entity for the purpose of original written disclosure, as well as for the purpose of restricting the claimed subject matter. The invention is not restricted to the above-described embodiments, and may be varied within the scope of the following claims.

Claims

1. A scroll compressor comprising: a housing having an interior chamber; a drive shaft disposed within the housing chamber, rotatable about a central axis, and having an eccentric end portion with a centerline spaced from and extending parallel to the central axis; a movable scroll member disposed within the housing chamber; a rolling element drive bearing configured to rotatably couple the drive shaft with the movable scroll member such that the scroll member orbits about the central axis, the drive bearing including at least one row of rolling elements disposed between the shaft eccentric end portion and the scroll member, at least one of the rolling elements being formed of a ceramic material; and a quantity of a solution formed of refrigerant and oil disposed within the housing, the solution being directed into the drive bearing to lubricate the at least one row of rolling elements.

2. The compressor as recited in claim 1, wherein the at least one row of rolling elements includes a plurality of rolling elements formed of a ceramic material.
3. The compressor as recited in claim 1, wherein the movable scroll member includes first and second axial ends, the first axial end being engageable with a mating fixed scroll, and a cylindrical bore extending axially inwardly from the second axial end, the drive bearing being disposed within the cylindrical bore.
4. The compressor as recited in claim 3, wherein the cylindrical bore of the movable scroll member has an inside diameter with a value of between nineteen millimeters and eighty millimeters and the eccentric portion of the shaft has an outside diameter with a value of between twelve millimeters and sixty millimeters.
5. The compressor as recited in claim 3, wherein one of: the drive bearing includes an inner ring disposed about the eccentric portion of the shaft and an outer ring disposed within the bore of the cylindrical hub, the at least one row of rolling elements being disposed between the inner ring and the outer ring; and the drive bearing includes an outer ring disposed within the bore of the cylindrical hub and the at least one row of rolling elements roll directly against an outer circumferential surface of the eccentric portion of the shaft.
6. The compressor as recited in claim 1, wherein each one of the row of rolling elements of the drive bearing is a cylinder.
7. The compressor as recited in claim 6, wherein each one of the cylinders is a needle.
8. The compressor as recited in claim 1, wherein the drive bearing includes at least one of: an inner ring disposed about the eccentric end portion of the shaft and having an inner race surface, the inner race surface having a surface roughness with an Ra value of no greater than one tenth of a micrometer (0.1 μm); and an outer ring connected with the scroll member and having an outer race surface, the outer race surface having a surface roughness with an Ra value of no greater than one tenth of a micrometer (0.1 μm).
9. The compressor as recited in claim 1, wherein the drive bearing further includes an annular cage formed of a polymeric material, the cage having a plurality of circumferentially spaced pockets and each one of the row of rolling elements is disposed within a separate one of the pockets.
10. The compressor as recited in claim 9, wherein the polymeric material is polyetheretherketone or polyamide.
11. The compressor as recited in claim 10, wherein the drive bearing includes an outer ring connected with the scroll member and having an inner circumferential guide surface, the cage having an outer circumferential surface slidable against the guide surface of the outer ring.
12. The compressor as recited in claim 1, further comprising a first support bearing and a second support bearing spaced apart from the first support bearing along the central axis, the first and second support bearings rotatably coupling the drive shaft with the housing and each one of the first and second support bearings including at least one row of rolling elements, at least one of the rolling elements of each one of the support bearings being formed of a ceramic material.
13. The compressor as recited in claim 12, wherein each one of the first and second support bearings is a deep groove ball bearing.
14. The compressor as recited in claim 12, wherein a portion of the solution of refrigerant and oil is directed into each one of the first and second support bearings to lubricate the at least one row of rolling elements.
15. The compressor as recited in claim 1, wherein the shaft rotates at an angular speed and the drive bearing has a mean diameter sized such that the ndm factor of the bearing is no greater than three hundred thousand.
16. A scroll compressor comprising: a housing having an interior chamber; a drive shaft disposed within the housing chamber, rotatable about a central axis, and having an eccentric end portion with a centerline spaced from and extending parallel to the central axis; a first support bearing and a second support bearing spaced apart from the first support bearing along the central axis, the first

and second support bearings rotatably coupling the drive shaft with the housing and each one of the first and second support bearings including at least one row of rolling elements and an annular cage formed of a polymeric material and having a plurality of pockets, each pocket retaining a separate one of the rolling elements; a scroll member disposed within the housing chamber; a drive bearing rotatably coupling the drive shaft with the scroll member such that the scroll member orbits about the central axis, the drive bearing including at least one row of rolling elements and an annular cage formed of a polymeric material and having a plurality of pockets, each pocket retaining a separate one of the rolling elements; and a quantity of a solution formed of refrigerant and oil disposed within the housing, the solution being directed to each one of the drive bearing and the first and second support bearings so as to lubricate the rolling elements.

17. The compressor as recited in claim 16, wherein the polymeric material of each annular cage is polyetheretherketone or polyamide.

18. The compressor as recited in claim 16, wherein the drive bearing includes an outer ring connected with the scroll member and having an inner circumferential guide surface, the annular cage of the drive bearing having an outer circumferential surface slidable against the guide surface of the outer ring.

19. The compressor as recited in claim 16, wherein the scroll member includes first and second axial ends, the first axial end being engageable with a mating fixed scroll, and a cylindrical bore extending axially inwardly from the second axial end, the drive bearing being disposed within the cylindrical bore.

20. The compressor as recited in claim 19, wherein the cylindrical bore of the movable scroll member has an inside diameter with a value of between sixty millimeters and eighty millimeters and the and the eccentric portion of the shaft has an outside diameter with a value of between twelve millimeters and twenty-four millimeters.

21. The compressor as recited in claim 16, wherein one of: the drive bearing includes an inner ring disposed about the eccentric portion of the shaft and an outer ring disposed within the bore of the cylindrical hub, the at least one row of rolling elements being disposed between the inner ring and the outer ring; the drive bearing includes an outer ring disposed within the bore of the cylindrical hub and the at least one row of rolling elements roll directly against an outer circumferential surface of the eccentric portion of the shaft.

22. The compressor as recited in claim 16, wherein each rolling element of the drive bearing is a cylinder and each rolling element of the first and second support bearings is a ball.

23. The compressor as recited in claim 22, wherein each cylinder of the drive bearing is a needle.

24. The compressor as recited in claim 16, wherein the drive bearing includes at least one of: an inner ring disposed about the eccentric end portion of the shaft and having an inner race surface, the inner race surface having a surface roughness with an Ra value of no greater than one tenth of a micrometer (0.1 μm); and an outer ring connected with the scroll member and having an outer race surface, the outer race surface having a surface roughness with an Ra value of no greater than one tenth of a micrometer (0.1 μm).

25. The compressor as recited in claim 16, wherein the shaft rotates at an angular speed and the drive bearing has a mean diameter sized such that the ndm factor of the drive bearing is no greater than three hundred thousand.