

SCROLL PUMP

FIELD OF THE INVENTION

- 5 The present invention relates to scroll pumps.

BACKGROUND

- 10 Scroll pumps are a known type of pump used in various different industries to pump fluid. Scroll pumps operate by using the relative motion of two intermeshed scrolls (known as a fixed scroll and an orbiting scroll) to pump fluid. Each of the fixed and orbiting scrolls includes a spiral wall extending from a base.
- 15 One type of scroll pump is a non-contacting scroll pump. In a non-contacting scroll pump, there is no contact between the tip (i.e. the end of the spiral wall) of each of the fixed and orbiting scrolls and the other scroll. Furthermore, in a non-contacting scroll pump, there is no tip seal between the tip of each of the fixed and orbiting scrolls and the other scroll. Therefore, in non-contacting scrolls
- 20 pumps, there is a small gap (or clearance), e.g. of 10-20 microns, between the tip of each of the fixed and orbiting scrolls and the other scroll. In order to maintain said gap, non-contacting scroll pumps typically include a thrust bearing assembly engaged with one of the scrolls to keep the scroll in the correct axial position relative to the other scroll.

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SUMMARY OF INVENTION

- In an aspect of the invention, there is provided a non-contacting scroll pump, the non-contacting scroll pump comprising a housing, an orbiting scroll located
- 30 within the housing, and a thrust bearing assembly located within the housing for axially supporting the orbiting scroll. The thrust bearing assembly comprises a first plate fixed to the orbiting scroll, a second plate spaced apart from the first plate, and a ball bearing located between the first plate and the second plate, the ball bearing being configured to roll against the first and second plates

during orbiting of the orbiting scroll. The thrust bearing assembly further comprises a coupling structure extending axially between the housing and the second plate to couple the housing to the second plate, wherein the coupling structure is engaged with the second plate, and wherein the coupling structure
5 comprises a spring arranged to push the coupling structure against the second plate.

The coupling structure may comprise a nut, wherein the nut is arranged such that loosening the nut causes the spring to push the coupling structure towards
10 the second plate, and tightening the nut pulls the coupling structure in a direction away from the second plate.

The spring may be arranged to push the coupling structure against the second plate with a force between 500 N and 2000 N.

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The non-contacting scroll pump may comprise three thrust bearing assemblies. Each of the three thrust bearing assemblies comprises a first plate fixed to the orbiting scroll, a second plate spaced apart from the first plate, and a ball bearing located between the first plate and the second plate, the ball bearing
20 being configured to roll against the first and second plates during orbiting of the orbiting scroll. Each of the three thrust bearing assemblies further comprises a coupling structure extending axially between the housing and the second plate to couple the housing to the second plate, wherein the coupling structure is engaged with the second plate, and wherein the coupling structure comprises a
25 spring arranged to push the coupling structure against the second plate. The three thrust bearing assemblies may be evenly angularly distributed around the rotation axis of the orbiting scroll in a triangular formation.

The non-contacting scroll pump may further comprise a first ball bearing cage sandwiched between the first plate and the second plate, and a second ball
30 bearing cage sandwiched between the first plate and the second plate, wherein the first and second ball bearing cages house the ball bearing to constrain movement of the ball bearing.

The first ball bearing cage may be fixed to the first plate and the second ball bearing cage may be fixed to the second plate.

5 The first and second ball bearing cages may each comprise a hole, the hole of the first ball bearing cage overlapping with the hole of the second ball bearing cage, and wherein the ball bearing is accommodated within the overlapped holes of the ball bearing cages.

10 The coupling structure may be a pin.

The coupling structure may be for adjusting the axial position of the orbiting scroll.

15 In another aspect of the invention, there is provided a vacuum pumping system comprising a plurality of vacuum pumps, wherein one of the vacuum pumps is the non-contacting scroll pump of the above aspect.

20 In yet another aspect of the invention, there is provided the use of the non-contacting scroll pump of any of the above aspects to pump fluid.

In yet another aspect of the invention, there is provided a method performed by a user on the non-contacting scroll pump of any of the above aspects, the method comprising loosening a nut of the coupling structure to cause the spring to push a spiral wall of the orbiting scroll into contact with a fixed scroll of the non-contacting scroll pump, tightening the nut to pull the coupling structure away from the fixed scroll, thereby causing the orbiting scroll to be moved axially away from the fixed scroll, while tightening the nut, using a sensor to track an amount of axial distance moved, and stopping the tightening of the nut once a desired amount of axial distance has been reached.

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BRIEF DESCRIPTION OF DRAWINGS

Figure 1 is a schematic illustration (not to scale) showing a cross-sectional view of a non-contacting scroll pump;

Figure 2 is a schematic illustration (not to scale) showing a close-up cross-sectional view of a thrust bearing assembly of the non-contacting scroll pump;

- 5 Figure 3 is a schematic illustration (not to scale) showing a perspective view of a plurality of thrust bearing assemblies of the non-contacting scroll pump; and

Figure 4 is a schematic illustration (not to scale) showing a close-up perspective view of part of a thrust bearing assembly of the non-contacting scroll pump.

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DETAILED DESCRIPTION

Figure 1 is a schematic illustration (not to scale) showing a cross-sectional view of a non-contacting scroll pump 100.

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The scroll pump 100 comprises housing portions 110, a fixed scroll 120, an orbiting scroll 130, a drive shaft 140, an actuator 150, a main bearing assembly 160, and a plurality of thrust bearing assemblies 170.

- 20 In this embodiment, the housing portions 110 and the fixed scroll 120 together define an overall housing of the scroll pump 100 within which other components of the scroll pump 100 are located. However, it will be appreciated that, in other embodiments, the fixed scroll 120 may not define any of the overall housing of the scroll pump 100 and instead may be located entirely within an overall
25 housing. In this embodiment, the orbiting scroll 130 is located within the overall housing of the scroll pump 100.

- The orbiting scroll 130 is intermeshed with the fixed scroll 120 to define a space (or channel) which is used by the scroll pump 100 during operation to pump
30 fluid (e.g. a gas). The orbiting scroll 130 is configured to orbit relative to the fixed scroll 120 to pump fluid from an inlet (not shown) of the scroll pump 100 to an outlet (not shown) of the scroll pump 100. The precise physical mechanism by which fluid is pumped by the orbiting of the orbiting scroll 130 relative to the

fixed scroll 120 is well understood and will not be described herein for the sake of brevity.

5 The fixed scroll 120 comprises a first base 122 and a first spiral wall 124. The orbiting scroll 130 comprises a second base 132 and a second spiral wall 134. The first spiral wall 124 and second spiral wall 134 are intermeshed with each other. Furthermore, the first spiral wall 124 extends perpendicularly from the first base 122 towards the second base 132 such that an end surface (also known as the tip) of the first spiral wall 124 is proximate to (e.g. 10-20 microns away) but not in contact with an opposing surface of the second base 132. The 10 second spiral wall 134 extends perpendicularly from the second base 132 towards the first base 122 such that an end surface (or tip) of the second spiral wall 134 is proximate to (e.g. 10-20 microns away) but not in contact with an opposing surface of the first base 122. Thus, there is a gap or clearance (e.g. of 15 10-20 microns) between the end surfaces of the first and second spiral walls 124, 134 the respective opposing surfaces of the first and second bases 122, 132. The distance between the end surface of the first spiral wall 124 and the opposing surface of the second base 132 is the same as the distance between the second spiral wall 134 and the opposing surface of the first base 122. The 20 gaps are empty in the sense that there are no objects or other scroll pump parts located within the gaps. For example, there are no tip seals within the gaps. Accordingly, the end surfaces of the first and second spiral walls 124, 134 are not in contact with any objects or other scroll pump parts.

25 In this embodiment, the first base 122 and first spiral wall 124 are integrally formed with each other, and the second base 132 and second spiral wall 134 are integrally formed with each other. However, in other embodiments, one or both of the spiral walls 124, 134 are not integrally formed with their respective bases 122, 132.

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The drive shaft 140 is coupled to the orbiting scroll 130 and configured to rotate to drive the orbiting of the orbiting scroll 130. The drive shaft 140 is located within the overall housing of the scroll pump 100 and mounted via the main bearing assembly 160 which facilitates rotation of the drive shaft 140. In this

embodiment, the draft shaft 140 extends through both the fixed scroll 120 and the orbiting scroll 130, and the orbiting scroll 130 is mounted at an end of the draft shaft 140.

- 5 The actuator 150 (e.g. an electric motor) is coupled to the drive shaft 140 and configured to actuate the drive shaft 140 to cause the drive shaft 140 to rotate to drive the orbiting of the orbiting scroll 130. The actuator 150 is located within the overall housing of the scroll pump 100 and mounted around the drive shaft 140.

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The main bearing assembly 160 mechanically couples the drive shaft 140 to the orbiting scroll 130 and the overall housing of the scroll pump 100 such that the drive shaft 140 is able to rotate within the scroll pump 100 to drive the orbiting scroll 130. In this embodiment, the main bearing assembly 160 comprises a
15 bearing located between (and mechanically coupling) a first end of the drive shaft 140 and the overall housing of the scroll pump 100, a bearing located between (and mechanically coupling) the orbiting scroll 130 and a second end of the drive shaft 140 opposite to the first end, and a bearing located between (and mechanically coupling) the fixed scroll 120 and the drive shaft 140.

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The plurality of thrust bearing assemblies 170 are each located between the orbiting scroll 130 and a housing portion 110 which is axially spaced apart from the orbiting scroll 130. Each thrust bearing assembly 170 is coupled to (and engaged with) the orbiting scroll 130 to constrain and/or control the axial
25 position of the orbiting scroll 130 relative to the fixed scroll 120. In this embodiment, there are three thrust bearing assemblies 170 evenly angularly distributed around the central rotation axis of the orbiting scroll in a triangular formation to provide a stable axial force on the orbiting scroll 130 (this is illustrated further in Figure 3). The precise structure of each of the thrust
30 bearing assemblies will be described in more detail with reference to Figure 2.

Figure 2 is a schematic illustration (not to scale) showing a close-up cross-sectional view of a thrust bearing assembly 170 of the non-contacting scroll pump 100.

The thrust bearing assembly 170 comprises a first plate 171, a second plate 172, a first ball bearing cage 173a, a second ball bearing cage 173b, a plurality of ball bearings 174, an adjustment pin 175, and a casing 176. Via these
5 structures, the thrust bearing assembly 170 provides axial support to the orbiting scroll 130 while also facilitating the orbiting of the orbiting scroll 130 during operation, as will be described in more detail below.

The first and second plates 171, 172 each have a first side facing towards the
10 orbiting scroll 130 and a second side opposite to the first side facing away from the orbiting scroll 130. The first and second ball bearing cages 173a, 173b also each have a first side facing towards the orbiting scroll 130 and a second side opposite to the first side facing away from the orbiting scroll 130. The first side of the first plate 171 is fixed to a back surface of the orbiting scroll 130, and the
15 second side of the first plate 171 is fixed to the first side of the first ball bearing cage 173a. The second side of the first ball bearing cage 173a is spaced apart from the first side of the second ball bearing cage 173b by the ball bearings 174, thereby allowing relative motion of the first and second ball bearing cages 173a, 173b. The second side of the second ball bearing cage 173b is fixed to
20 the first side of the second plate 172. The second side of the second plate 172 is engaged with an end of the adjustment pin 175.

The first and second ball bearing cages 173a, 173b each comprise a plurality of
holes within which the plurality of ball bearings 174 are located. Each hole of
25 the first ball bearing cage 173a partially overlaps with a corresponding hole of the second ball bearing cage 173b to form a plurality of hole pairs. Each hole pair houses a single ball bearing 174. The partial overlap of the holes enables the first and second bearing cages 173a, 173b to accommodate the orbiting motion of the orbiting scroll 130 during operation while constraining the
30 movement of the ball bearings 174. This is illustrated further in Figure 4.

The plurality of ball bearings 174 are sandwiched between the first and second plates 171, 172 such that each of the first and second plates 171, 172 are in contact with the ball bearings 174. Each ball bearing 174 of the plurality of ball

bearings 174 is housed within a respective hole pair of the first and second ball bearing cages 173a, 173b. The plurality of ball bearings 174 may be formed from steel or ceramic.

- 5 During operation, to facilitate the orbiting of the orbiting scroll 130, the plurality of ball bearings 174 roll against the first and second plates 171, 172 within the hole pairs of the first and second ball bearing cages 173a, 173b. During operation of the scroll pump 100, the first plate 171 and first ball bearing cage 173a, which are fixed to each other and to the orbiting scroll 130, move together
- 10 with the orbiting scroll 130. Thus, during operation, the first plate 171, first ball bearing cage 173a and orbiting scroll 130 all move together relative to the second plate 172 and the second ball bearing cage 173b on the plurality of ball bearings 174.
- 15 The adjustment pin 175 extends axially between a housing portion 110 of the scroll pump 100 and the second plate 172. A first end 175a of the adjustment pin 175 is attached to the housing portion 110, and a second end 175b opposite to the first end 175a of the adjustment pin 175 is engaged with the second side of the second plate 172. The first end 175a of the adjustment pin 175 is
- 20 threaded and coupled to the housing portion 110 via a corresponding threaded nut 175c. The threaded nut 175c is at the first end 175a of the adjustment pin 175 and is rotatable on the threading of the first end 175a to adjust the axial position of the adjustment pin 175, thereby facilitating control of the axial position of the orbiting scroll 130 via the rest of the thrust bearing assembly 170.
- 25 The adjustment pin 175 further comprises a spring 175d which acts to push the adjustment pin 175 against the second plate 172. To push the adjustment pin 175 against the second plate 172, the spring 175d extends between a surface of the housing portion 110 facing towards the second plate 172 and a surface of the adjustment pin 175 facing away from the second plate 172. One end of the
- 30 spring 175d presses against the surface of the housing portion 110 facing towards the second plate 172 and the other end of the spring 175d presses against the surface of the adjustment pin 175 facing away from the second plate 172. This arrangement allows a user to set the axial position of the orbiting scroll 130 relative to the fixed scroll 120 in a simple and repeatable way, in

order to control the clearance between the tips of the fixed and orbiting scrolls 120, 130 and the other scroll, as described below.

- The second end 175b of the adjustment pin 175 sits in a tapered recess 172a in the second side of the second plate 172. The tapered recess 172a has a generally conical shape. More specifically, the second end 175b of the adjustment pin 175 comprises a rounded surface which is engaged with a surface of the second side of the second plate 172 which defines the tapered recess 172a. In this way, the rounded surface of the second end 175b of the adjustment pin 175 and the surface defining the tapered recess 172a together form a ball and socket joint, which enables the second plate 172 and second ball bearing cage 173b to articulate/rotate on the first end 175b of the adjusting pin 175.
- 15 The casing 176 surrounds the adjustment pin 175 and acts as a barrier to prevent escape of lubricant (e.g. oil or grease) used for the ball bearings 174, the first and second bearing cages 173a, 173b, and the first and second plates 171, 172. In this embodiment, the casing 176 has a bellows shape.
- 20 In order to set the axial position of the orbiting scroll 130 relative to the fixed scroll 120, the user first loosens the nut 175c which causes the spring 175d to push the tips of the orbiting scroll 130 into contact with the fixed scroll 120 with a consistent force (i.e. the same force each time it is done). The user then places a depth gauge through ports (not shown) in the overall housing 110 of the scroll pump 100. The user then uses the depth gauge to measure the axial distance between the housing portion 110 where the first end 175a of the adjustment pin 175 is attached and the orbiting scroll 130. The user then zeros the depth gauge. The user then tightens the nut 175c which pulls the adjustment pin 175 axially away from the fixed scroll 120, which in turn causes the orbiting scroll 130 to be moved away from the fixed scroll by the pre-load forces from the main bearing assembly 160. While tightening the nut 175c, the user tracks the amount of distance moved using the depth gauge and stops tightening the nut 175c once a desired axial distance has been reached. The above procedure is repeated for all the other thrust bearing assemblies 170 in

the scroll pump 100 in order to set a uniform axial distance across the orbiting scroll 130.

5 The operating force of the springs 175d is chosen to be significantly greater than the force from the combination of the gas pressure on the orbiting scroll 130 and pre-load forces from the main bearing assembly 160. This ensures that the adjustment pins 175 are not pushed away during operation of the scroll pump 100. The spring 175d operating force is also chosen to be below that which would cause any damage to the main bearing system 160 during the
10 setting operation. For example, the spring operating force may be between 500 N and 2000 N (e.g. 1000 N). Advantageously, the spring 175d allows a consistent known force to be used during the setting of the axial distance, which tends to reduce the risk of a user accidentally exerting too much force and damaging other components of the scroll pump 100. Also, the consistent force
15 of the spring 175d tends to provide a consistent zero position for the depth gauge used during the setting process.

Figure 3 is a schematic illustration (not to scale) showing a perspective view of the plurality of thrust bearing assemblies 170 of the non-contacting scroll pump
20 100. As shown, in this embodiment, the scroll pump 100 comprises three thrust bearing assemblies 170 which evenly angularly distributed around the central rotation axis of the orbiting scroll in a triangular formation to provide a stable axial force on the orbiting scroll 130.

25 Figure 4 is a schematic illustration (not to scale) showing a close-up perspective view of part of a thrust bearing assembly 170 of the non-contacting scroll pump 100. Specifically, Figure 4 illustrates a close-up view of the first and second bearing cages 173a, 173b of the thrust bearing assembly 170. As shown, each hole of the first ball bearing cage 173a partially overlaps with a corresponding
30 hole of the second ball bearing cage 173b to form a plurality of hole pairs. The ball bearings 174 are each located within a respective hole pair (only one is labelled in Figure 4).

The above-described non-contacting scroll pump 100 may be used as part of a vacuum pumping system including multiple pumps and/or other components.

5 It will be appreciated that various modifications/deviations may be made to the above described embodiments without departing from the scope of the invention.

10 In the above-described embodiments, a depth gauge is used to measure the axial distance during the setting process. However, in other embodiments, a different type of appropriate distance measuring sensor is used.

In the above-described embodiments, the scroll pump comprises three separate thrust bearing assemblies. However, in other embodiments, the scroll pump comprises a different number of thrust bearing assemblies, e.g. only one, two or more than 3.

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In the above-described embodiments, the thrust bearing assembly comprises a plurality of ball bearings. However, in other embodiments, the thrust bearing assembly comprises only one ball bearing.

20 In the above-described embodiments, the thrust bearing assembly comprises ball bearing cages to constrain the movement of the ball bearings. However, in other embodiments, the ball bearing cages are omitted.

25 In the above-described embodiments, an elongate adjustment pin is used to couple the housing to the second plate. However, in other embodiments, a different type of coupling structure may be used, e.g. a different type of elongate member.

REFERENCE NUMERAL LIST

- 100: non-contacting scroll pump
- 5 110: housing
- 120: fixed scroll
- 122: base of fixed scroll
- 124: spiral wall of fixed scroll
- 130: orbiting scroll
- 10 132: base of orbiting scroll
- 134: spiral wall of orbiting scroll
- 140: drive shaft
- 150: actuator
- 160: main bearing assembly
- 15 170: thrust bearing assembly
- 171: first plate
- 172: second plate
- 172a: recess
- 173a: first ball bearing cage
- 20 173b: second ball bearing cage
- 174: ball bearing
- 175: adjustment pin
- 175a: first end of adjustment pin
- 175b: second end of adjustment pin
- 25 175c: nut
- 175d: spring
- 176: casing

CLAIMS

1. A non-contacting scroll pump, the non-contacting scroll pump comprising:
- 5 a housing;
- an orbiting scroll located within the housing; and
- a thrust bearing assembly located within the housing for axially supporting the orbiting scroll, wherein the thrust bearing assembly comprises:
- a first plate fixed to the orbiting scroll;
- 10 a second plate spaced apart from the first plate;
- a ball bearing located between the first plate and the second plate, the ball bearing being configured to roll against the first and second plates during orbiting of the orbiting scroll; and
- a coupling structure extending axially between the housing and
- 15 the second plate to couple the housing to the second plate, wherein the coupling structure is engaged with the second plate, and wherein the coupling structure comprises a spring arranged to push the coupling structure against the second plate.
- 20 2. The non-contacting scroll pump of claim 1, wherein the coupling structure comprises a nut, wherein the nut is arranged such that loosening the nut causes the spring to push the coupling structure towards the second plate, and tightening the nut pulls the coupling structure in a direction away from the second plate.
- 25 3. The non-contacting scroll pump of any preceding claim, wherein the spring is arranged to push the coupling structure against the second plate with a force between 500 N and 2000 N.

4. The non-contacting scroll pump of any preceding claim, wherein the non-contacting scroll pump comprises three thrust bearing assemblies,

wherein each of the three thrust bearing assemblies comprises:

a first plate fixed to the orbiting scroll;

5 a second plate spaced apart from the first plate;

a ball bearing located between the first plate and the second plate, the ball bearing being configured to roll against the first and second plates during orbiting of the orbiting scroll; and

a coupling structure extending axially between the housing and the
10 second plate to couple the housing to the second plate, wherein the coupling structure is engaged with the second plate, and wherein the coupling structure comprises a spring arranged to push the coupling structure against the second plate,

wherein the three thrust bearing assemblies are evenly angularly
15 distributed around the rotation axis of the orbiting scroll in a triangular formation.

5. The non-contacting scroll pump of any preceding claim, further comprising:

a first ball bearing cage sandwiched between the first plate and
20 the second plate; and

a second ball bearing cage sandwiched between the first plate and the second plate,

wherein the first and second ball bearing cages house the ball bearing to constrain movement of the ball bearing.
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6. The non-contacting scroll pump of claim 5, wherein the first ball bearing cage is fixed to the first plate and the second ball bearing cage is fixed to the second plate.

30 7. The non-contacting scroll pump of claim 5 or 6, wherein the first and

second ball bearing cages each comprise a hole, the hole of the first ball bearing cage overlapping with the hole of the second ball bearing cage, and

wherein the ball bearing is accommodated within the overlapped holes of the ball bearing cages.

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8. The non-contacting scroll pump of any preceding claim, wherein the coupling structure is a pin.

9. The non-contacting scroll pump of any preceding claim, wherein the coupling structure is for adjusting the axial position of the orbiting scroll.

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10. A vacuum pumping system comprising a plurality of vacuum pumps, wherein one of the vacuum pumps is the non-contacting scroll pump of any preceding claim.

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11. Use of the non-contacting scroll pump of any of claims 1 to 9 to pump fluid.

12. A method performed by a user on the non-contacting scroll pump of any of claims 1 to 9, the method comprising:

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loosening a nut of the coupling structure to cause the spring to push a spiral wall of the orbiting scroll into contact with a fixed scroll of the non-contacting scroll pump;

tightening the nut to pull the coupling structure away from the fixed scroll, thereby causing the orbiting scroll to be moved axially away from the fixed scroll;

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while tightening the nut, using a sensor to track an amount of axial distance moved; and

stopping the tightening of the nut once a desired amount of axial distance has been reached.

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