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(71) Applicant: **Roper Pump Company LLC**
Commerce, GA 30529 (US)

(72) Inventors:
• **ANDERSON, Tyson Bentley**
Watkinsville, GA 30677 (US)
• **HAMPSON, Daniel Todd**
Athens, GA 30606 (US)

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(74) Representative: **Zacco Denmark A/S**
Arne Jacobsens Allé 15
2300 Copenhagen S (DK)

(54) **POSITIVE-DISPLACEMENT FLUID MACHINE WITH CONSTRAINED GEARSET**

(57) A positive-displacement fluid machine with a constrained gear set is provided. The positive-displacement fluid machine includes multiple shafts including a single drive shaft and multiple idler shafts. Multiple lobed rotors are provided with each mounted for rotation on one of the shafts. Each lobed rotor of the multiple of lobed rotors meshes with at least two other lobed rotors of the

multiple of lobed rotors. A constrained gear set includes multiple timing gears. Each of the multiple timing gears is mounted for rotation on one of the multiple shafts. Each timing gear of the multiple timing gears intermeshes with at least two other timing gears of the multiple timing gears.

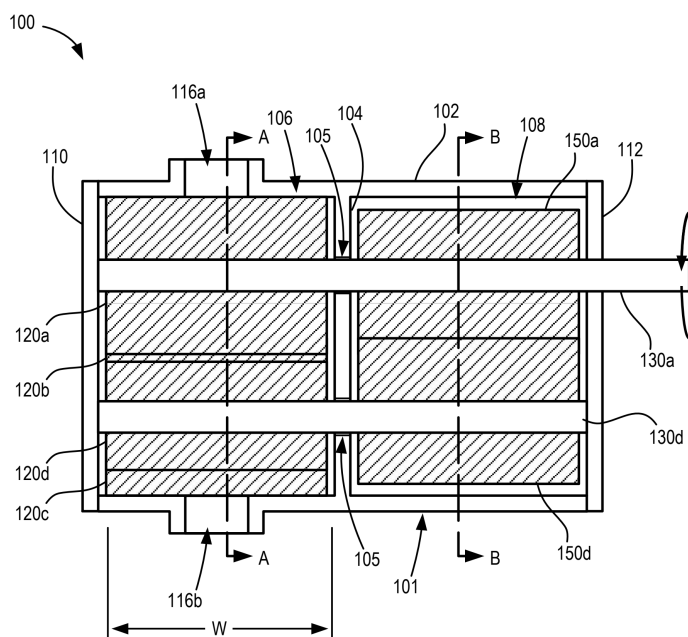


FIG. 1

Description

BACKGROUND

[0001] Some positive-displacement fluid machines use rotors for their superior sealing and solids-handling capabilities. These rotors, however, cannot facilitate power transfer, and so they are externally driven by timing gears. The timing gears typically reside in a separate compartment, which is sealed off from the flow volume where the rotors and fluid reside.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002]

Fig. 1 is a schematic cross-section of a positive-displacement fluid machine, according to implementations described herein;

Fig. 2 is a transverse cross-sectional view of a compressor chamber of a fluid machine, according to an implementation;

Fig. 3 is transverse a cross-sectional view of a gear chamber of a fluid machine, according to an implementation;

Figs. 4A-4C are perspective views of constrained gear sets according to different implementations;

Fig. 4D is a front view of a constrained gear set with different sized gears, according to another implementation;

Figs. 5A-5C are perspective views of different lobed rotor configurations driven by a four-gear constrained gear set, according to different implementations;

Fig. 6 is a transverse cross-sectional view of a compressor chamber of a fluid machine, according to another implementation;

Fig. 7 is a perspective view of circumferential-piston-style rotors driven by a four-gear constrained gear set, according to another implementation;

Fig. 8A is a perspective view of a constrained gear set according to another implementation; and

Fig. 8B is a perspective view of a lobed rotor configuration according to another implementation.

DETAILED DESCRIPTION

[0003] The following detailed description refers to the accompanying drawings. The same reference numbers in different drawings may identify the same or similar elements. Also, the following detailed description does not limit the invention.

[0004] Positive-displacement fluid machines may be used for displacing air (e.g., rotary lobe blowers) or liquids (e.g., rotary lobe pumps). In some applications, such as bulk transfer applications, positive-displacement blowers may be used for loading and unloading cargo. Transfer rates in such applications may be improved with higher

suction pressures. Additionally, smaller and more maneuverable blower units may improve efficiency during transfer setup. In other applications, positive-displacement blowers may be used for pneumatic conveying (e.g., pipeline transport), aeration in water treatment, air supply in combustion systems, and other vacuum systems. In conventional blowers, the number of rotors per stage is typically limited to two, which inherently limits the suction capabilities of these machines. To increase the pressure differential across these conventional blowers, multiple stages are typically used in series. Rotary lobe pumps are sometimes used for fluids with suspended solids, high viscosity fluids, or fluids that require gentle pumping action. Similar to rotary lobe blowers, multiple stages of conventional rotary lobe pumps may be needed to achieve required pressures. Thus, there is a need for a positive-displacement fluid machine that can achieve increased pressures in a single stage, while minimizing the overall size and weight of the unit.

[0005] Systems and methods described herein provide a positive-displacement machine (e.g., a rotary lobe blower or pump) with more than two rotors that are timed by a constrained gearset. In the constrained gearset, power is transmitted from a driving gear through other driven gears that connect in sequence back to the driving gear. In some aspects, there is no limit to the number of gears in the constrained system as long as the number of teeth and placement of the gears are properly matched.

[0006] According to one implementation, a positive-displacement fluid machine with a constrained gear set is provided. The positive-displacement fluid machine may include multiple shafts including a single drive shaft and multiple idler shafts. Multiple lobed rotors may be included in the positive-displacement fluid machine, with each rotor mounted for rotation on a different one of the shafts. Each lobed rotor of the multiple lobed rotors may mesh with at least two other lobed rotors of the multiple lobed rotors. A constrained gear set may also be included in the positive-displacement fluid machine. The constrained gearset may include multiple timing gears. Each of the multiple timing gears may be mounted for rotation on a different one of the shafts. Each timing gear of the multiple timing gears may intermesh with at least two other timing gears of the multiple timing gears.

[0007] According to implementations described herein, a positive-displacement fluid machine including a set of constrained gears and corresponding constrained rotors provides advantages of higher suction and pressure-building capabilities as compared to typical lobed blowers or pumps. The systems and methods can be applied in blowers or pumps for high suction lift and high discharge pressures, reducing the need for multiple stages in series. Embodiments of the positive-displacement fluid machine described herein can provide improved suction capability and load distribution in a more compact package than multi-stage units. These fluid machines may also provide a reduced overall weight

and provide increased performance over conventional blowers and pumps.

[0008] According to another embodiment, a positive-displacement fluid machine includes a compressor chamber with multiple fluid inlets and multiple fluid outlets, a gear chamber, multiple shafts spanning the compressor chamber and the gear chamber, multiple lobed rotors housed in the compressor chamber, and a constrained gear set housed in the gear chamber. The shafts include a drive shaft and multiple idler shafts. Each of the lobed rotors may be mounted for rotation on a different one of the shafts. The constrained gear set may include multiple timing gears, each of the timing gears being mounted for rotation on one of the plurality of shafts. Each timing gear may intermesh with at least two other timing gears.

[0009] According to one embodiment, each lobed rotor may mesh with at least two other lobed rotors. The lobed rotors may rotate within the compressor chamber without contacting each other. In another embodiment, each of the rotors may be identical and have at least two lobes. According to another embodiment, the multiple timing gears includes at least four timing gears. According to another embodiment, the number of fluid inlets is equal to the number of fluid outlets. According to still another embodiment, the amount of fluid inlets plus the amount of fluid outlets is equal to the number of lobed rotors. In still another embodiment, the multiple timing gears includes at least six timing gears and at least three fluid inlets.

[0010] According to one embodiment, the compressor chamber further includes an inset bar installed parallel to the shafts and through a center of the multiple lobed rotors. The inset bar may be a non-rotating member and fill a void in the center of the set of rotors. The inset bar may have a perimeter with a number of sides that is equal to the amount of the lobed rotors. In some embodiments, the timing gears may include straight spur teeth, or helically oriented teeth. In another embodiment, the lobe rotors may include a circumferential-piston-style rotor.

[0011] Fig. 1 is a schematic of a positive-displacement fluid machine 100 according to an implementation. Fluid machine 100 may correspond, for example, to a rotary lobe blower (e.g., for displacing air/gases) or a rotary lobe pump (e.g., for displacing liquids). As shown in Fig. 1, fluid machine 100 may include main case 101 with a peripheral wall 102, which may generally form a tubular structure with an internal wall 104 oriented generally orthogonally to peripheral wall 102. Internal wall 104 may divide main case 101 into a compressor chamber 106 and a gear chamber 108. On one end of peripheral wall 102, compressor chamber 106 may be enclosed by an end plate 110. On the other side of peripheral wall 102, gear chamber 108 may be enclosed by an end plate 112.

[0012] Each of end plate 110 and end plate 112 may include a structure to close off an end of main case 101, while supporting a set of shafts 130a, 130b, 130c, 130d

(all shown in Fig. 2, referred to collectively as shafts 130 or generically as shaft 130). In one implementation, end plates 110/112 may each include bores with a bearing to support each of shafts 130. Compressor chamber 106 may be closed on one side by end plate 110 with a fluid-tight seal. Gear chamber 108 may be closed on one side by end plate 112 with a fluid-tight seal. Main case 101 may include a set of connection holes opening at the exposed surfaces and extending at least partially into main case 101. End plates 110 and 112 may be secured to ends of peripheral wall 102 using, for example, bolts and tapped holes. Bolts inserted through the bolt holes into tapped holes (not shown) may connect end plates 110/112 to main case 101.

[0013] A set of shafts 130, including a drive shaft 130a and multiple idler shafts 130b, 130c, and 130d, may span compressor chamber 106 and gear chamber 108, passing through internal wall 104. Internal wall 104 may include openings 105, which may also accommodate seals and/or bearings (not shown), for the shafts to extend from gear chamber 108 into compressor chamber 106. Shafts 130 may be installed in parallel and supported by one or more of end plates 110/112. According to an implementation, shafts 130 may be supported on both sides of main case 101 by journal bearings, needle bearings, or any other type of bearing. This type of support allows for higher pressure capabilities and less wear on the bearings than traditional lobe pumps with cantilever (or overhung) arrangements. In other implementations, shafts 130 may be supported with bearings on one side of main case 101 and at internal wall 104 with an overhung arrangement. For example, shafts 150 may be supported for rotation by bearings (not shown) included in internal wall 104 and end plate 112 without support from endplate 110. As shown in Fig. 1, drive shaft 150a may extend beyond end plate 112, for example, to allow for coupling to an input shaft (e.g., powered by a motor). Shafts 150 may each be made of the same material, such as steel or another rigid material.

[0014] Fig. 2 is a transverse cross-sectional view of compressor chamber 106, taken along line A-A of Fig. 1. Fig. 3 is transverse a cross-sectional view of gear chamber 108, taken along line B-B of Fig. 1. Fluid machine 100 is described further herein in connection with Figs. 1-3.

[0015] A set of identical rotors 120 (individually referred to herein as rotors 120a, 120b, 120c, and 120d) may be disposed within compressor chamber 106. Each of rotors 120 may be attached to a corresponding shaft 130 and mounted for rotation on the shaft. When installed on shafts 130 in compressor chamber 106, lobes of rotors 120 may mesh but are configured to not contact each other (e.g., due to the use of timing gears 150 described below).

[0016] Compressor chamber 106 may include multiple fluid inlets 114a and 114b (e.g., shown in Fig. 2, referred to collectively as inlets 114 or generically as inlet 114) and multiple fluid outlets 116a and 116b (e.g., shown in Fig. 2, referred to collectively as outlets 116 or generically as

outlet 116). As described further herein, the number of inlets 114 and outlets 116 may correspond to the number and arrangement of rotors 120 included within compressor chamber 106. In some implementations, the number of inlets 114 may be equal to the number of outlets 116, and the combined number of inlets 114 and outlets 116 may equal the number of rotors 120. Inlets 114 and outlets 116 are not limited by their size or shape.

[0017] Compressor chamber 106 may have multiple rounded wall sections 140 (referred to individually as rounded wall sections 140a, 140b, 140c, and 140d). The rounded wall sections 140 may be generally located between each inlet 114/outlet 116 along the internal circumference of peripheral wall 102. Each rotor 120 may be mounted for rotation about a shaft 130 at the center of the rotor, which generally corresponds with a center of curvature of a corresponding rounded wall section 140. For example, rotor 120a may be mounted for rotation about drive shaft 130a (Fig. 2), which is disposed at center of curvature of rounded wall section 140a. In one implementation, rotors 120 may each have two lobes. In other implementations, rotors 120 may each have three or more lobes.

[0018] Main case 101 is configured to include a set of timing gears 150 (referred to individually as timing gears 150a, 150b, 150c, and 150d) journaled in gear chamber 108. Timing gears 150 may generally be isolated from rotors 120 via interior wall 104 (along with bearings and/or seals where shafts 130 pass through). Thus, gear chamber 108 may be separate from compression chamber 106 and have, for example, a dedicated oil bath or other lubrication source and seal set (not shown).

[0019] One gear 150a may be mounted to rotate with drive shaft 130a at its center. Similarly, driven gears 150b, 150c, and 150d may be mounted for rotation with idler shafts 130b, 130c, and 130d, respectively. Gears 150 may have peripheral teeth that intermesh with contact to teeth of other gears so that the rotation of one of the gears 150 (e.g., gear 150a attached to drive shaft 130a) may cause rotation of the other gears (e.g., gears 150a, 150b, and 150c). The teeth of gears 150 may have uniform sizes and may be machined to intermesh for all angular positions in a rotation of the gears 150.

[0020] In an exemplary implementation, one rotor 120 and one timing gear 150 may be affixed on each shaft 130. For example, rotor 120a may be fixed on drive shaft 130a with gear 150a (e.g., with interior wall 104 therebetween). Similarly, rotor 120b may be fixed on shaft 130b with gear 150b; rotor 120c may be fixed on shaft 130c with gear 150c; and rotor 120d may be fixed on shaft 130d with gear 150d. The axial length of rotors 120 may extend across a width (W) of chamber 106, as shown in Fig. 1.

[0021] Rotor 120a may be driven directly by drive shaft 130a. Thus, drive shaft 130a (e.g., when attached to a motor) simultaneously drives rotation of gear 150a and rotor 120a. Rotors 120b, 120c, and 120d may be driven by shafts 130b, 130c, and 130d, respectively. Each of

shafts 130b, 130c, and 130d may be driven by gears 150b, 150c, and 150d, respectively.

[0022] According to implementations herein, fluid machine 100 may include timing gears 150 arranged as a constrained gear set including a four or more (e.g., six, eight, etc.) timing gears in gear chamber 108. Timing gears 150 may have peripheral teeth that intermesh so that the rotation of one of the gears 150 causes rotation of the other gears. As a constrained gear set, each of the timing gears 150 in the constrained gear set may mesh with two other timing gears 150. Each of timing gears 150 may be mounted for rotation about one of the plurality of shafts 130. Each rotor 120 and gear 150 combination may be keyed to a respective shaft 130 to prevent rotation of rotor 120/gear 150 relative to shaft 130. In the example of Fig. 3, driving gear 150a may mesh with gears 150b and 150d; gear 150b may mesh with gears 150a and 150c; gear 150c may mesh with gear 150b and 150d; and gear 150d may mesh with gears 150c and 150a. In one implementation, the configuration of each gear 150 (e.g., pitch diameter, outside diameter, thickness, number of teeth, etc.) may be the same.

[0023] Figs. 4A-4C illustrate constrained timing gear arrangements for different numbers of timing gears. Fig. 4A is a perspective view of a four-gear constrained arrangement. Fig. 4B is a perspective view of a six-gear constrained arrangement. Fig. 4C is a perspective view of an eight-gear constrained arrangement. In each of Figs. 4A-4C, the number of gears 150 corresponds to the number of rotors 120 and shafts 130 used for fluid machine 100. Similarly, the number of rotors 120 used in compressor chamber 106 may define the number of inlets 114 and outlets 116 for compressor chamber 106. Furthermore, for each constrained gear arrangement, internal wall 104, end plate 110, and/or end plate 112 may be configured to support a corresponding number of shafts 130, with seals and bearings for each shaft 130.

[0024] Although Figs. 4A-4C illustrate basic timing gear arrangements, there are numerous other combinations with varying gear sizes, number of teeth, and number of gears that may be used in other implementations. In each constrained system, gears will include the same module (i.e., measure of tooth size) to function, and the total number of gears will be an even number (e.g., 4, 6, 8, 12, etc.). Additionally, the number of teeth/gears/centers can be manually matched. Thus, as shown in Fig. 4D, gears of different sizes (e.g., different pitch diameters, different outer diameters, different tooth counts, etc.) may be used. However, identical gears are generally more likely to be used to provide the same rate of rotation of gears 150 and rotors 120.

[0025] Rotors 120 may be configured with multiple lobes 160 (shown, for example, in Figs. 5A-5C). Generally, a lobe 160 refers to the sealing surface that meshes with lobes 160 of other rotors 120. The lobes 160 of rotors 120 are configured to mesh without contacting each other when rotors 120 rotate within compressor chamber 106

(e.g., due to the configuration of timing gears 150). Figs. 5A-5C are schematic illustrations of different rotor styles that may be used in implementation described herein. In the illustrations of Figs. 5A-5C, a constrained gear set with four gears 150 is shown immediately behind rotors 120 for alignment context. In an actual configuration, gears 150 and rotors 120 may be separated by interior wall 104.

[0026] Fig. 5A illustrates bi-lobed-style rotors 120 driven by a constrained gearset of gears 150 and shown in two different rotational orientations. Fig. 5B illustrates tri-lobed-style rotors 120 driven by a constrained gearset of gears 150 and shown in two different rotational orientations. Fig. 5C illustrates quad-lobed-style rotors 120 driven by a constrained gearset of gears 150 and shown in two different rotational orientations. While Figs. 5A-5C illustrate a constrained gearset with four gears 150, in other implementations, bi-lobed-style rotors 120, tri-lobed-style rotors 120, or quad-lobed-style rotors 120 may be used with other constrained gearsets (e.g., constrained gearsets with six gears 150, constrained gearset with eight gears 150, etc.). Thus, the number of lobes 160 on rotors 120 is not limited by any particular configuration of constrained gear set.

[0027] During operation, fluid is drawn from fluid inlets 114 into chamber 106. Referring to Fig. 2 particularly, rotors 120a and 120d may mesh during rotation, such that cavities between lobes of rotors 120a and 120d expand near inlet 114a to draw fluid into chamber 106. Similarly, rotors 120b and 120c may also mesh during rotation to similarly draw in fluid near inlet 114b. As rotors 120 rotate, fluid is trapped in cavities between the respective lobes 160 and rounded wall sections 140 of chamber 106. Each rotor 120 is aligned or otherwise configured to provide a continuous seal along the width, W, of chamber 106 to prevent slippage. Thus, fluid is transported from an inlet 114 to a respective outlet 116, where meshing of the rotors compresses the respective cavities and forces fluid out through the discharge port 116. More particularly, rotor 120a may generally move fluid from inlet 114a to outlet 116a, and rotor 120d may generally move fluid from inlet 114a to outlet 116b. Similarly, rotor 120b may generally move fluid from inlet 114b to outlet 116a, and rotor 120c may generally move fluid from inlet 114b to outlet 116b.

[0028] Fig. 6 is a simplified illustration of a cross-sectional view of compressor chamber 106 according to another implementation. Particularly, Fig. 6 illustrates a compressor chamber with a six bi-lobed-rotor arrangement. The total number of inlets 114 and outlets 116 in compressor chamber may be equal to the number of rotors (i.e., six), and the number of inlets 114 may be equal to the number of outlets 116. A rounded wall section 140 may be located between each inlet 114 and outlet 116 along the internal circumference of peripheral wall 102. Each rotor 120 may be mounted for rotation about a shaft 130 at the center of the rotor. The axis of a shaft 130 and the center of a rotor 120 generally correspond to a center

of curvature of a corresponding rounded wall section 140.

[0029] Similar to the four bi-lobed rotor arrangement of Fig. 2, during operation in the arrangement of Fig. 6, fluid is drawn from fluid inlets 114 into chamber 106. Referring to Fig. 6, rotors 120a and 120f may mesh during rotation, such that cavities between lobes of rotors 120a and 120f expand near inlet 114a to draw fluid into chamber 106. Similarly, rotors 120b and 120c and rotors 120d and 120e may also mesh during rotation to draw in fluid near inlet 114b and 114c, respectively. Each rotor 120 is aligned or otherwise configured to provide a continuous seal along the width, W, of chamber 106 to prevent slippage. Thus, fluid is transported from an inlet 114, along a respective rounded wall section 140, to a respective outlet 116, where meshing of the rotors compresses the respective cavities and forces fluid out through the discharge port 116. For example, rotor 120a may generally move fluid from inlet 114a to outlet 116a, rotor 120f may generally move fluid from inlet 114c to outlet 116a. Rotor 120b may generally move fluid from inlet 114a to outlet 116b, rotor 120c may generally move fluid from inlet 114b to outlet 116b. Rotor 120d may generally move fluid from inlet 114b to outlet 116c, and rotor 120e may generally move fluid from inlet 114c to outlet 116c.

[0030] As shown in Fig. 6, according to an implementation, chamber 106 may include an inset bar 180. Inset bar 180 may be installed, for example, parallel to shafts 130 across the width, W, of chamber 106. Inset bar 180 may be a fixed (e.g., non-rotating) member and fill at least a portion of a volume/void in a center region 184 or interior of the set of rotors 120. Inset bar 180 may prevent fluid from stagnating in center region 184 of the set of rotors 120. In one implementation, inset bar 180 may have a perimeter with a number of sides 182 equal to the number of rotors 120 in chamber 106. Each side 182 may have, for example, a radius of curvature that is the same or similar to the radius of curvature of rounded wall sections 140. In other implementations, inset bar 180 may have straight sides 182. In still other implementations, inset bar 180 may have a different number of sides than the number of rotors 120. For example, inset bar 180 may have a round perimeter.

[0031] Fig. 7 illustrates a set of circumferential-piston-style rotors 170 driven by a constrained gearset of gears 150 and shown in two different rotational orientations. In Fig. 7, a constrained gear set with four gears 150 is shown immediately behind rotors 170 for alignment context. In an actual configuration, gears 150 and rotors 170 may be separated by interior wall 104. Circumferential-piston-style rotors 170, also referred to as claw-type rotors, may be operated in a similar manner to the bi-lobed rotors described above (e.g., Fig. 5A). Particularly, rotors 170 may be mounted on shafts 130 (not shown in Fig. 7) and configured so that rotors 170 do not contact each other when the rotors 170 rotate within compressor chamber 106.

[0032] Rotors 170 may include wings 172 or pistons that function similarly to lobes 160 on rotors 120. The

shape of wings 172 and placement at opposite ends of each rotor 170 forms comparatively large cavities 174 (e.g., compared to those of bi-lobed rotors 120) that can minimize shear and bruising of solids during operation. According to an implementation, each circumferential-piston-style rotor 170 may be identical. In other configurations, rotors 170 with different shapes may be paired in a meshing arrangement. In the quad-rotor arrangement shown in Fig. 7 with a constrained gear set of four gears 150, rotors 170 may operate similarly to the arrangement described above in connection with Fig. 2.

[0033] Fig. 8A illustrates a constrained timing gear arrangement with helical gears 190. Helical gears 190 may have teeth that are angled along the axis of rotation (e.g., in contrast with straight gears that have teeth parallel to the axis of rotation) and may allow multiple teeth to from each gear 190 to intermesh simultaneously with teeth of an adjacent gear 190. Fig. 8A is a perspective view of a four-gear constrained arrangement. In Fig. 8A, the number of helical gears 190 corresponds to the number of rotors 120 and shafts 130 used for fluid machine 100. Helical gears 190 may provide improved wear and/or noise characteristics (e.g., over geared systems with spur gears). A constrained gear set of helical gears 190 may be used in conjunction with a corresponding set of straight rotors 120 (e.g., Fig. 5A) or a set of helical rotors (e.g., Fig. 8B).

[0034] Fig. 8B is a perspective view of a helical lobed rotor configuration for use with a four-gear constrained gear set. In Fig. 8B, the number of helical rotors 195 corresponds to the number of timing gears 150/190 and shafts 130 used for fluid machine 100. A set of helical rotors 195 may be used in conjunction with a corresponding constrained gear set of helical gears 190 (e.g., Fig. 8A) or a corresponding constrained gear set of straight timing gears 120 (e.g., Fig. 4A).

[0035] Systems, apparatuses, and methods described herein provide a positive-displacement fluid machine with more than two rotors that are timed by a constrained gearset. The fluid machine may include multiple shafts including a single drive shaft and multiple idler shafts. Multiple lobed rotors may be included in the fluid machine, with each rotor mounted for rotation on a different one of the shafts. Each lobed rotor of the multiple of lobed rotors may mesh with at least two other lobed rotors of the multiple of lobed rotors. A constrained gear set may also be included in the fluid machine. The constrained gearset may include multiple timing gears. Each of the multiple timing gears may be mounted for rotation on a different one of the shafts. Each timing gear of the multiple timing gears may intermesh with at least two other timing gears of the multiple timing gears.

[0036] Embodiments described herein may provide improved suction capability and load distribution in a more compact package than conventional multi-stage blowers or pumps. By eliminating the need for a series of different stages, embodiments described herein may also provide a reduced overall weight and increased

performance over conventional blowers and pumps.

[0037] The foregoing description of exemplary implementations provides illustration and description but is not intended to be exhaustive or to limit the embodiments described herein to the precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practice of the embodiments. Additionally, other processes described in this description may be modified and/or non-dependent operations may be performed in parallel.

[0038] Although the invention has been described in detail above, it is expressly understood that it will be apparent to persons skilled in the relevant art that the invention may be modified without departing from the spirit of the invention. Various changes of form, design, or arrangement may be made to the invention without departing from the spirit and scope of the invention. Therefore, the above-mentioned description is to be considered exemplary, rather than limiting, and the true scope of the invention is that defined in the following claims.

[0039] As set forth in this description and illustrated by the drawings, reference is made to "an exemplary embodiment," "an embodiment," "embodiments," etc., which may include a particular feature, structure or characteristic in connection with an embodiment(s). However, the use of the phrase or term "an embodiment," "embodiments," etc., in various places in the specification does not necessarily refer to all embodiments described, nor does it necessarily refer to the same embodiment, nor are separate or alternative embodiments necessarily mutually exclusive of other embodiment(s). The same applies to the term "implementation," "implementations," etc.

[0040] The terms "a," "an," and "the" are intended to be interpreted to include one or more items. The term "and/or" is intended to be interpreted to include any and all combinations of one or more of the associated items. The word "exemplary" is used herein to mean "serving as an example." Any embodiment or implementation described as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments or implementations.

[0041] Use of ordinal terms such as "first," "second," "third," etc., in the claims to modify a claim element does not by itself connote any priority, precedence, or order of one claim element over another, the temporal order in which acts of a method are performed, the temporal order in which instructions executed by a device are performed, etc., but are used merely as labels to distinguish one claim element having a certain name from another element having a same name (but for use of the ordinal term) to distinguish the claim elements.

[0042] No element, act, or instruction used in the description of the present application should be construed as critical or essential to the invention unless explicitly described as such.

[0043] Exemplary methods, devices, electronic devices, and non-transitory computer-readable storage

media are set out in the following items:

1. A positive-displacement fluid machine, comprising:

a compressor chamber including multiple fluid inlets and multiple fluid outlets;
a gear chamber;
a plurality of shafts spanning the compressor chamber and the gear chamber, wherein the plurality of shafts includes:

a drive shaft, and
multiple idler shafts;
a plurality of lobed rotors housed in the compressor chamber, each of the plurality of lobed rotors being mounted for rotation on one of the plurality of shafts; and
a constrained gear set housed in the gear chamber, the constrained gear set including a plurality of timing gears, each of the plurality of timing gears being mounted for rotation on one of the plurality of shafts, wherein each timing gear in the plurality of timing gears intermeshes with at least two other timing gears of the plurality of timing gears.

2. The positive-displacement fluid machine of item 1, wherein each of the lobed rotors is identical and includes at least two lobes.

3. The positive-displacement fluid machine of item 1, wherein the multiple timing gears includes at least four timing gears.

4. The positive-displacement fluid machine of item 1, wherein the number of multiple fluid inlets is equal to the number of multiple fluid outlets.

5. The positive-displacement fluid machine of item 3, wherein an amount of the fluid inlets plus an amount of the fluid outlets is equal to a number of the plurality of lobed rotors.

6. The positive-displacement fluid machine of item 1, wherein the plurality of timing gears includes at least six timing gears.

7. The positive-displacement fluid machine of item 6, wherein the multiple fluid inlets include three fluid inlets.

8. The positive-displacement fluid machine of item 1, wherein the compressor chamber further includes an inset bar installed parallel to the shafts and through a center region of the plurality of lobed rotors.

9. The positive-displacement fluid machine of item 8,

wherein the inset bar has a perimeter with a number of sides equal to a number of the plurality of lobed rotors.

10. The positive-displacement fluid machine of item 1, wherein each lobed rotor of the plurality of lobed rotors meshes with at least two other lobed rotors of the plurality of lobed rotors.

11. The positive-displacement fluid machine of item 10, wherein the plurality of lobed rotors do not contact each other when the plurality of lobed rotors rotate within the compressor chamber.

12. The positive-displacement fluid machine of item 1, further comprising:
an internal wall separating the compressor chamber and the gear chamber, wherein the internal wall includes openings for the plurality of shafts to extend from the gear chamber into the compressor chamber.

13. The positive-displacement fluid machine of item 1, wherein each of the plurality of lobed rotors includes a circumferential-piston-style rotor.

14. The positive-displacement fluid machine of item 1, wherein the positive-displacement fluid machine comprises a rotary-lobe blower.

15. The positive-displacement fluid machine of item 1, wherein each timing gear of the plurality of timing gears includes one of:

straight spur teeth, or
helically oriented teeth.

16. An assembly for a fluid machine, comprising:

a plurality of shafts including a drive shaft and multiple idler shafts;
a plurality of lobed rotors, each of the plurality of lobed rotors being mounted for rotation on one of the plurality of shafts, wherein each lobed rotor of the plurality of lobed rotors meshes with at least two other lobed rotors of the plurality of lobed rotors; and
a constrained gear set, the constrained gear set including a plurality of timing gears, each of the plurality of timing gears being mounted for rotation on one of the plurality of shafts, wherein each timing gear of the plurality of timing gears intermeshes with at least two other timing gears of the plurality of timing gears.

17. The assembly of item 16, wherein the drive shaft is configured to drive rotation of a first gear of the plurality of timing gears and a first rotor of the plurality

of lobed rotors, and wherein the first gear is configured to drive rotation of at least a second gear and a third gear of the plurality of timing gears.

18. The assembly of item 16, wherein the assembly is configured to prevent contact between the plurality of lobed rotors when the plurality of lobed rotors are installed within a compression chamber.

19. The assembly of item 16, further comprising: an inset bar aligned parallel to the plurality of shafts and through a center region of the plurality of lobed rotors.

20. The assembly of item 16, wherein each timing gear of the plurality of timing gears includes one of:

straight spur teeth, or
helically oriented teeth.

Claims

1. A positive-displacement fluid machine, comprising:

a compressor chamber including multiple fluid inlets and multiple fluid outlets;
a gear chamber;
a plurality of shafts spanning the compressor chamber and the gear chamber, wherein the plurality of shafts includes:

a drive shaft, and
multiple idler shafts;

a plurality of lobed rotors housed in the compressor chamber, each of the plurality of lobed rotors being mounted for rotation on one of the plurality of shafts; and
a constrained gear set housed in the gear chamber, the constrained gear set including a plurality of timing gears, each of the plurality of timing gears being mounted for rotation on one of the plurality of shafts, wherein each timing gear in the plurality of timing gears intermeshes with at least two other timing gears of the plurality of timing gears.

2. The positive-displacement fluid machine of claim 1, wherein each of the lobed rotors is identical and includes at least two lobes.

3. The positive-displacement fluid machine of claim 1 or 2, wherein the multiple timing gears includes at least four timing gears.

4. The positive-displacement fluid machine of any of the preceding claims, wherein the number of multiple

fluid inlets is equal to the number of multiple fluid outlets.

5. The positive-displacement fluid machine of claim 3, wherein an amount of the fluid inlets plus an amount of the fluid outlets is equal to a number of the plurality of lobed rotors.

6. The positive-displacement fluid machine of any of the preceding claims, wherein the plurality of timing gears includes at least six timing gears.

7. The positive-displacement fluid machine of claim 6, wherein the multiple fluid inlets include three fluid inlets.

8. The positive-displacement fluid machine of any of the preceding claims, wherein the compressor chamber further includes an inset bar installed parallel to the shafts and through a center region of the plurality of lobed rotors.

9. The positive-displacement fluid machine of claim 8, wherein the inset bar has a perimeter with a number of sides equal to a number of the plurality of lobed rotors.

10. The positive-displacement fluid machine of any of the preceding claims, wherein each lobed rotor of the plurality of lobed rotors meshes with at least two other lobed rotors of the plurality of lobed rotors.

11. The positive-displacement fluid machine of claim 10, wherein the plurality of lobed rotors do not contact each other when the plurality of lobed rotors rotate within the compressor chamber.

12. The positive-displacement fluid machine of any of the preceding claims, further comprising: an internal wall separating the compressor chamber and the gear chamber, wherein the internal wall includes openings for the plurality of shafts to extend from the gear chamber into the compressor chamber.

13. The positive-displacement fluid machine of any of the preceding claims, wherein each of the plurality of lobed rotors includes a circumferential-piston-style rotor.

14. The positive-displacement fluid machine of any of the preceding claims, wherein the positive-displacement fluid machine comprises a rotary-lobe blower.

15. The positive-displacement fluid machine of any of the preceding claims, wherein each timing gear of the plurality of timing gears includes one of:

straight spur teeth, or
helically oriented teeth.

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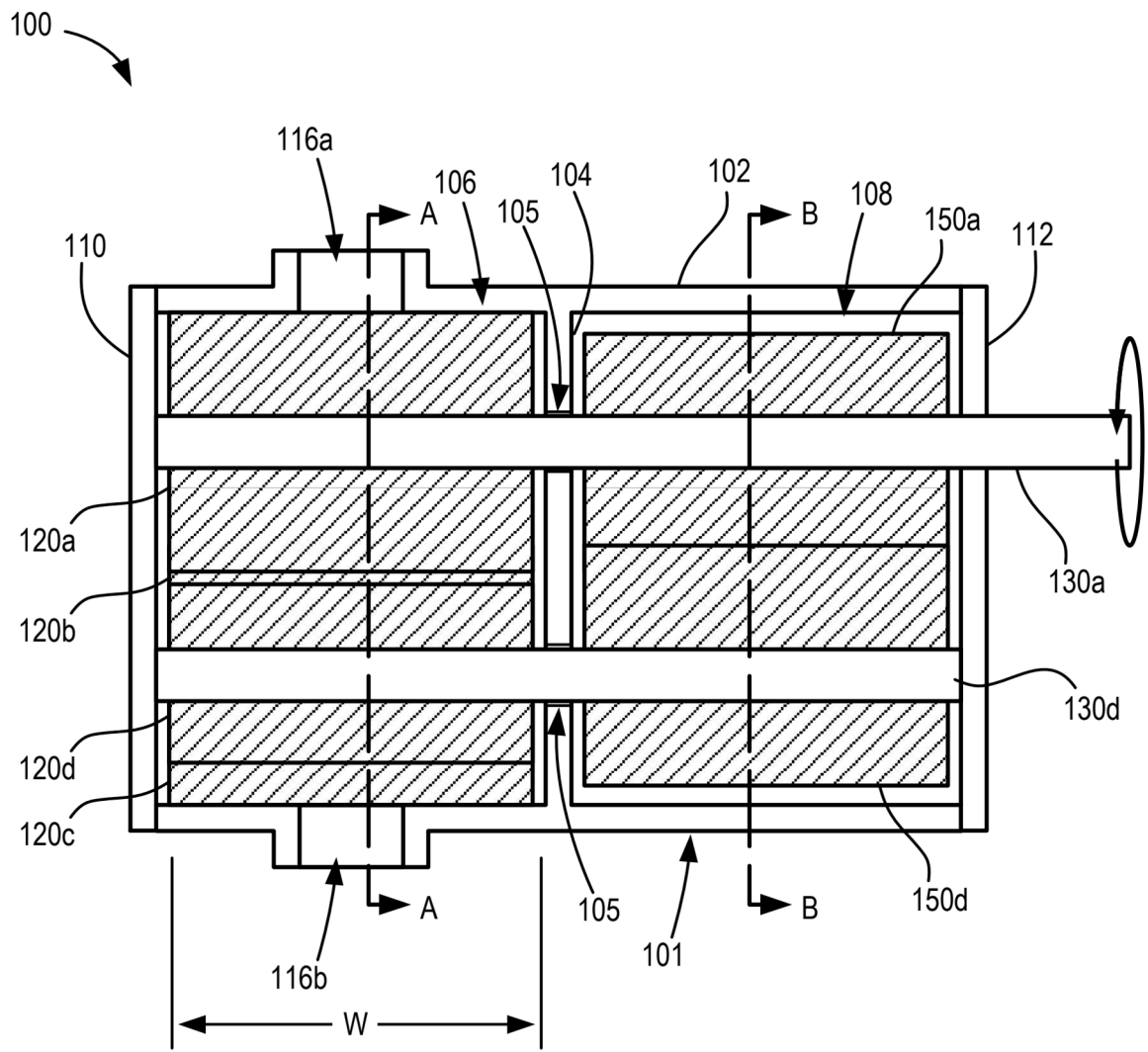


FIG. 1

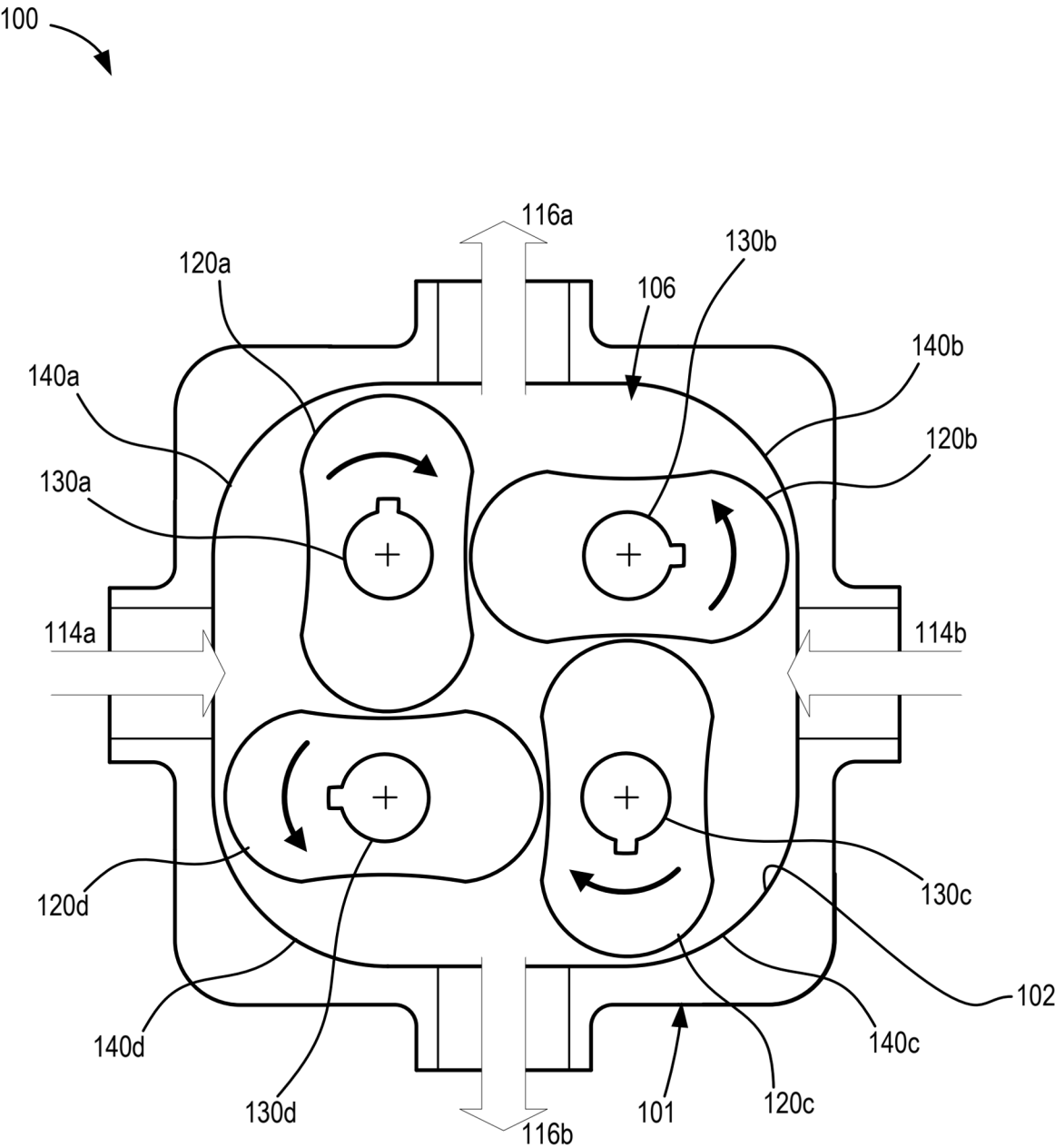


FIG. 2

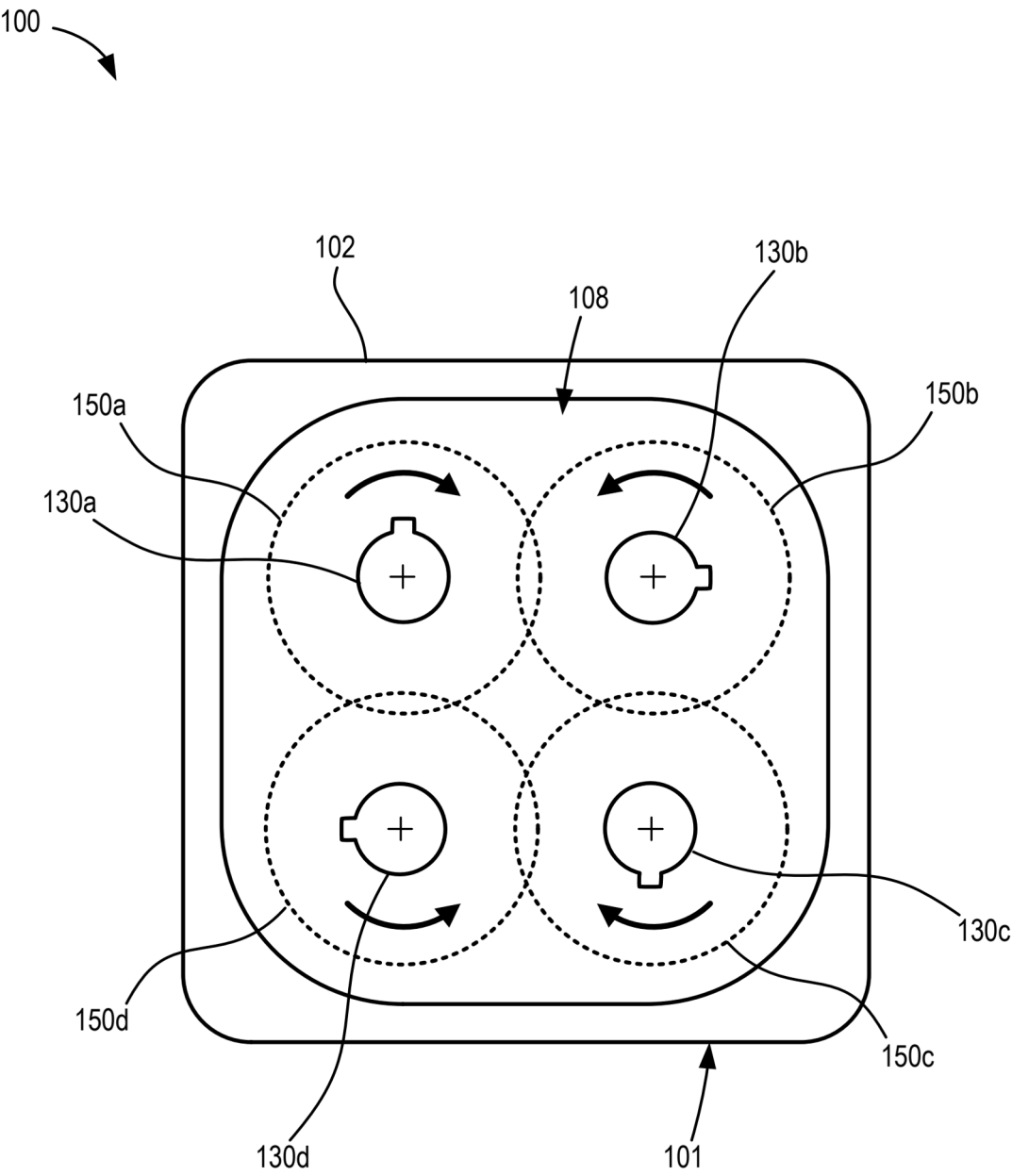


FIG. 3

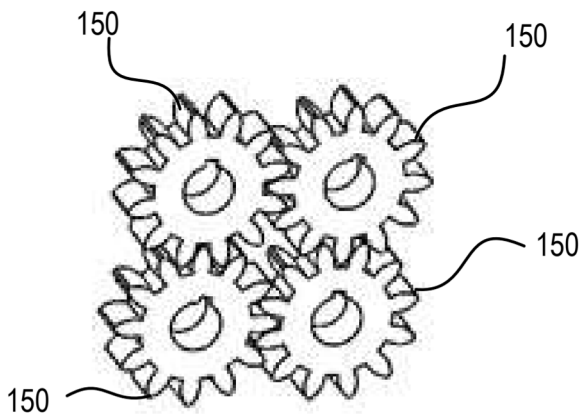


FIG. 4A

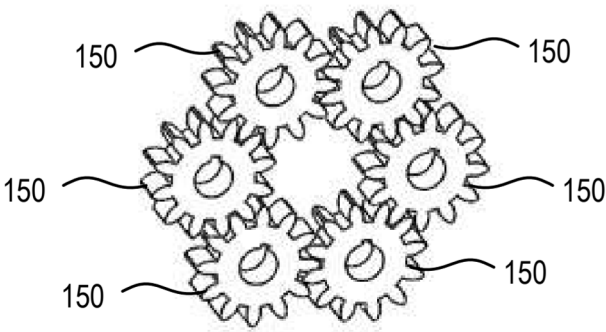


FIG. 4B

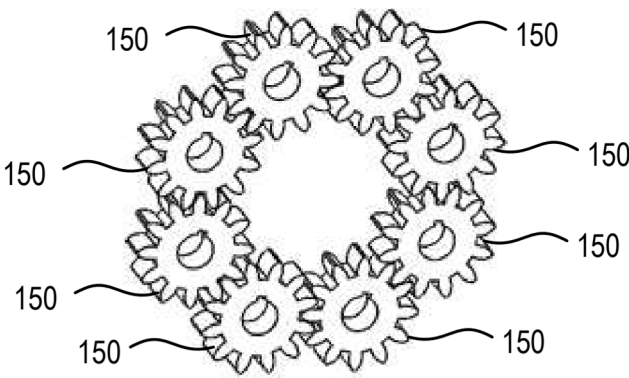


FIG. 4C

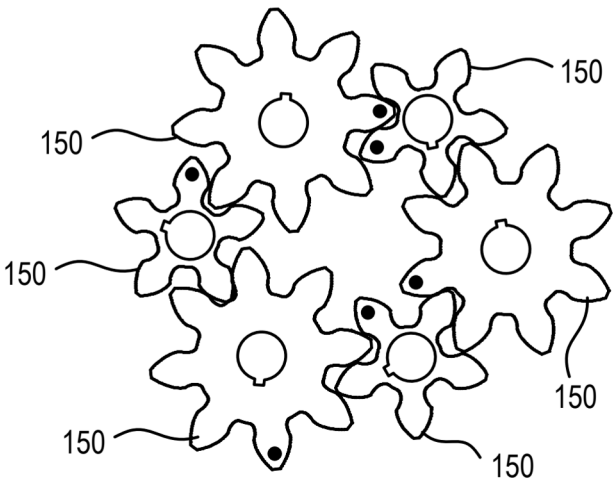
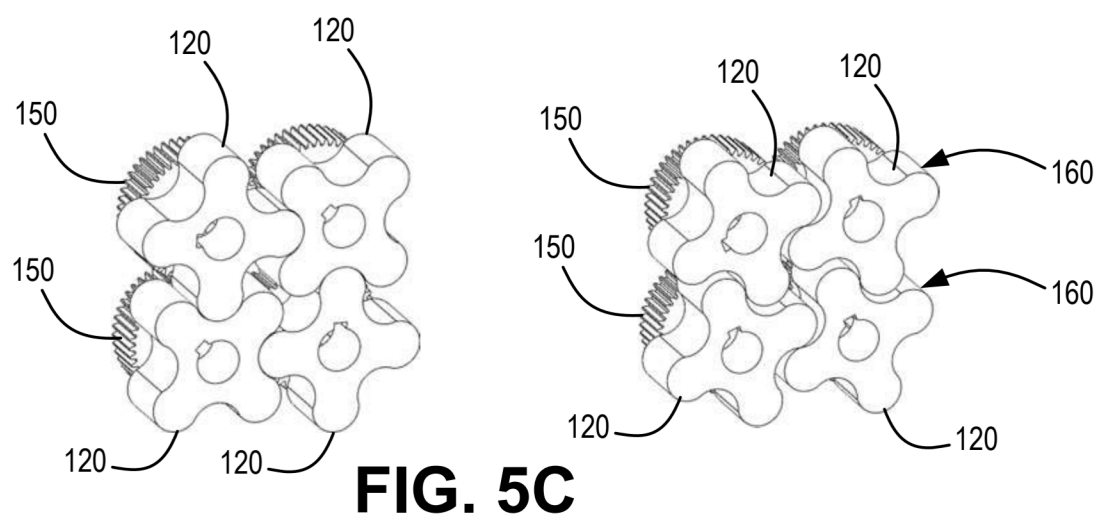
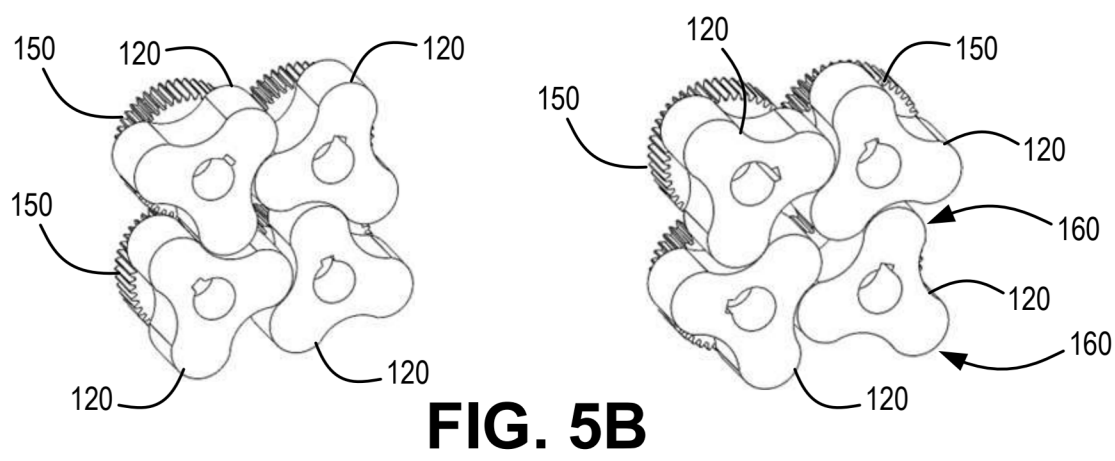
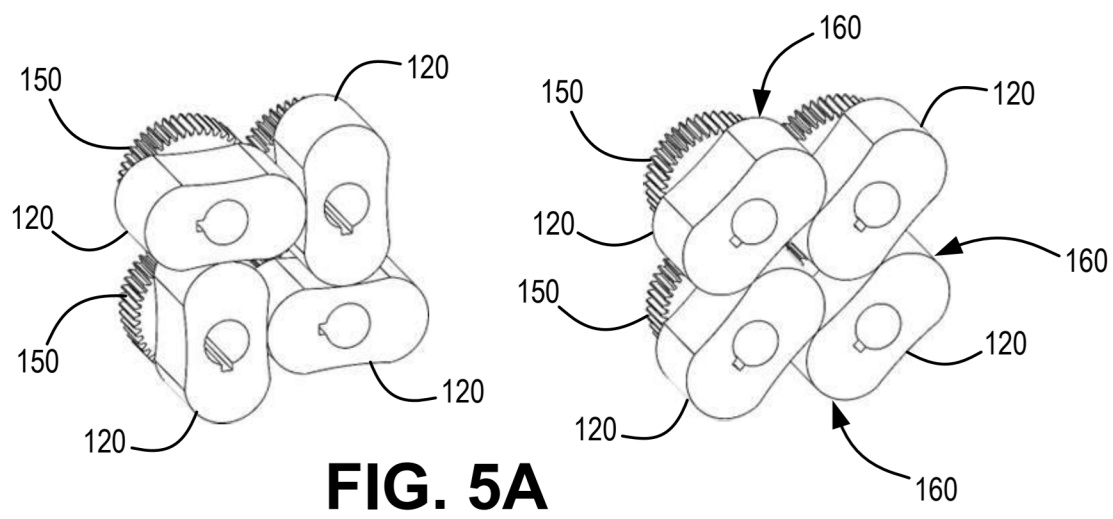


FIG. 4D



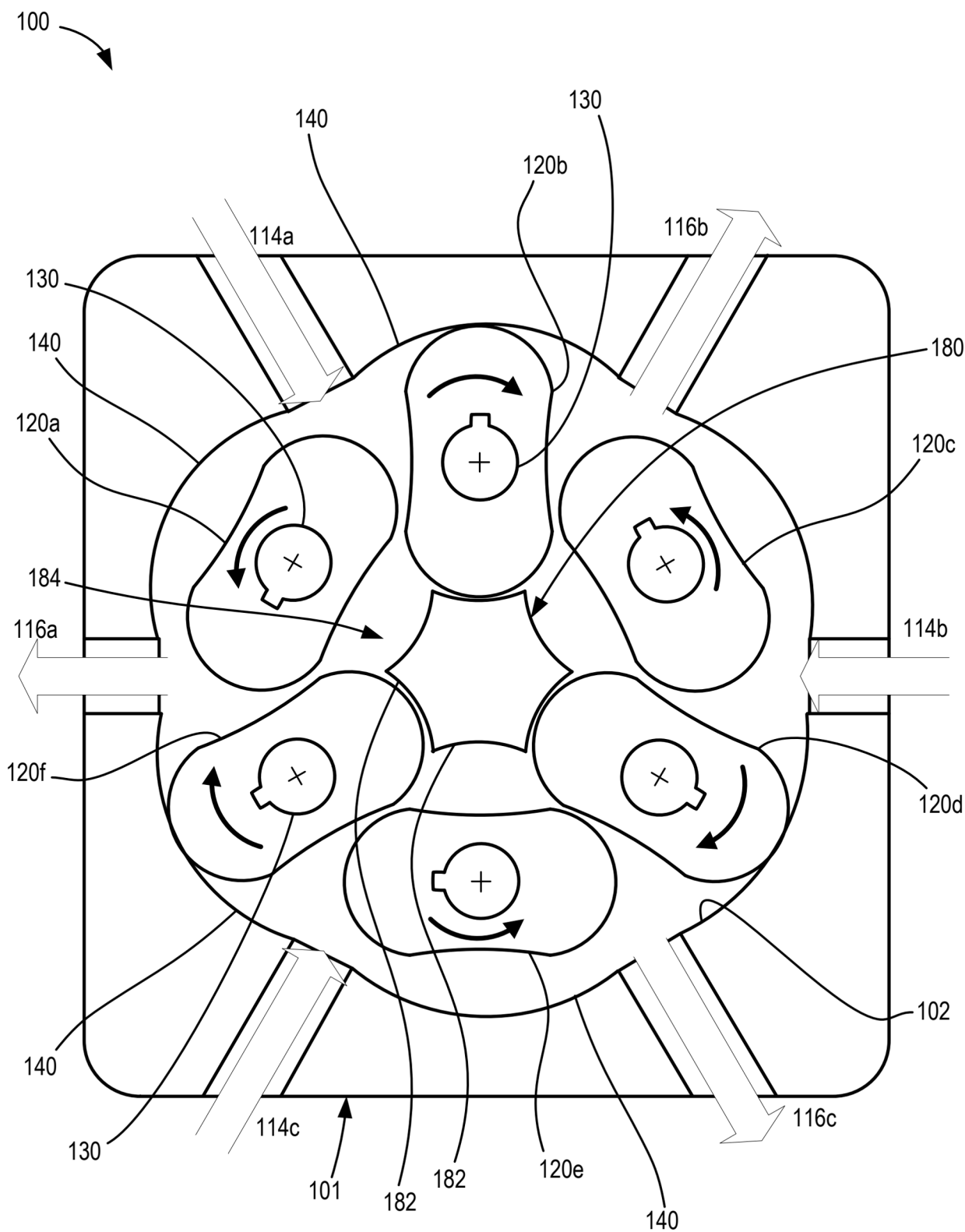


FIG. 6

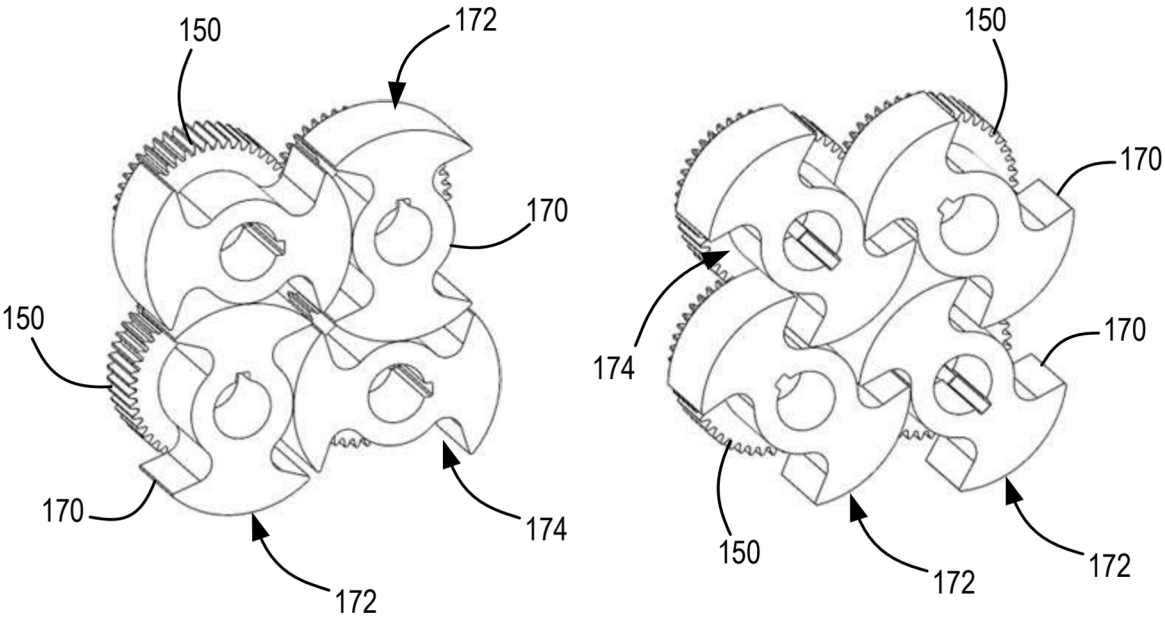


FIG. 7

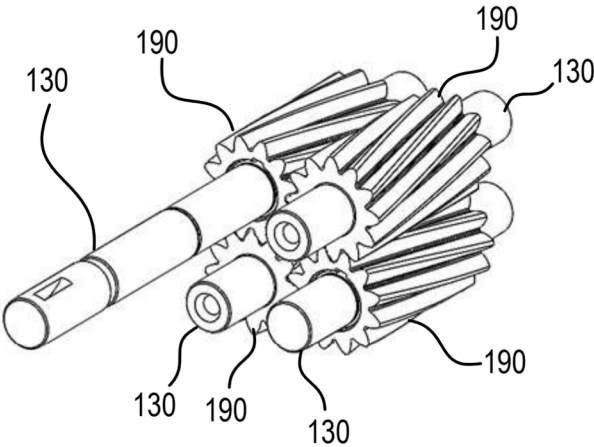


FIG. 8A

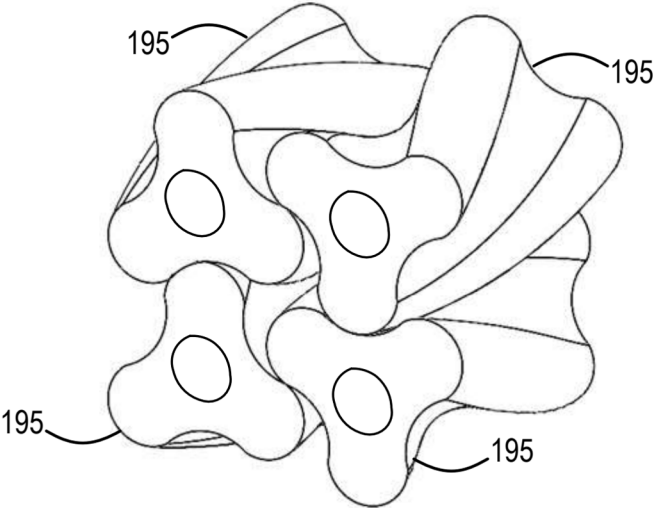


FIG. 8B



EUROPEAN SEARCH REPORT

Application Number

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		19 February 2026	Durante, Andrea
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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