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Manther et al.

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(54) **MULTI-POSITION CAMSHAFT PHASER WITH TWO ONE-WAY WEDGE CLUTCHES AND VISCOUS DAMPING**

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F01L 1/344 (2006.01)

(52) **U.S. Cl.**
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(58) **Field of Classification Search**
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USPC 123/90.15, 90.17
See application file for complete search history.

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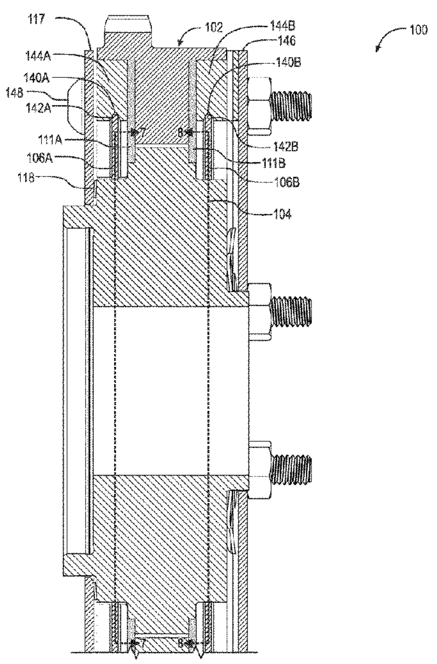
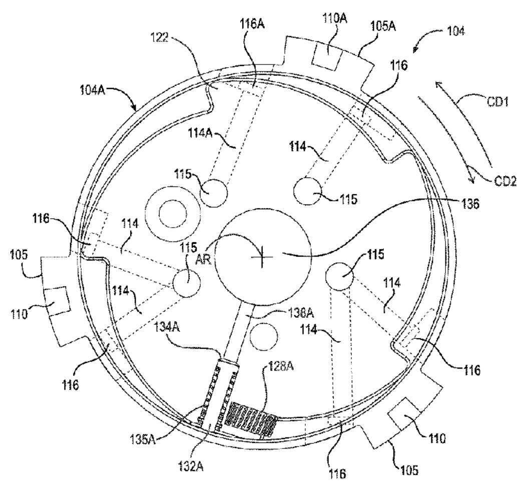
(57) **ABSTRACT**

A camshaft phaser, including: a stator including radially inwardly extending protrusions with radially outermost ends; a rotor including radially outwardly extending protrusions radially outermost ends; chambers at least partially bounded by a inwardly extending protrusion and an outwardly extending protrusion; first seals disposed in the radially innermost ends and facing the rotor; second seals disposed in the radially outermost ends and facing the stator; first and second wedge plates radially disposed between the rotor and the stator; and a displacement assembly arranged to for an advance mode, displace the first wedge plate to enable rotation of the rotor, with respect to the stator, in the first circumferential direction and for a retard mode, displace the second wedge plate to enable rotation of the rotor, with respect to the stator, in a second circumferential direction opposite the first circumferential direction.

20 Claims, 11 Drawing Sheets





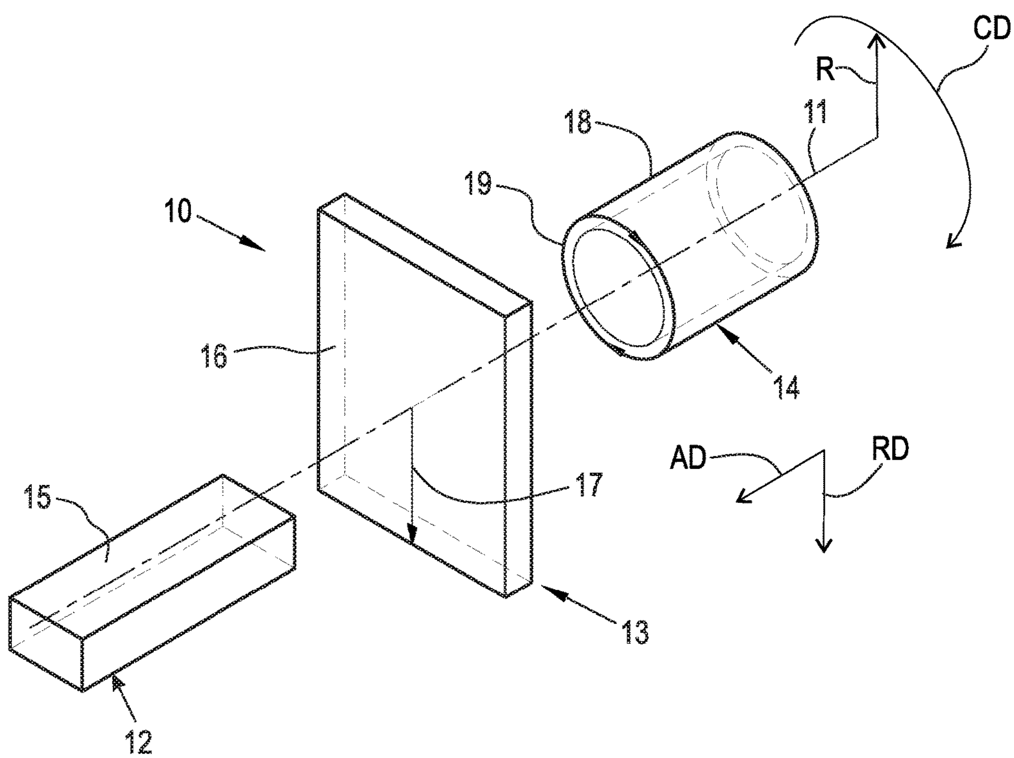
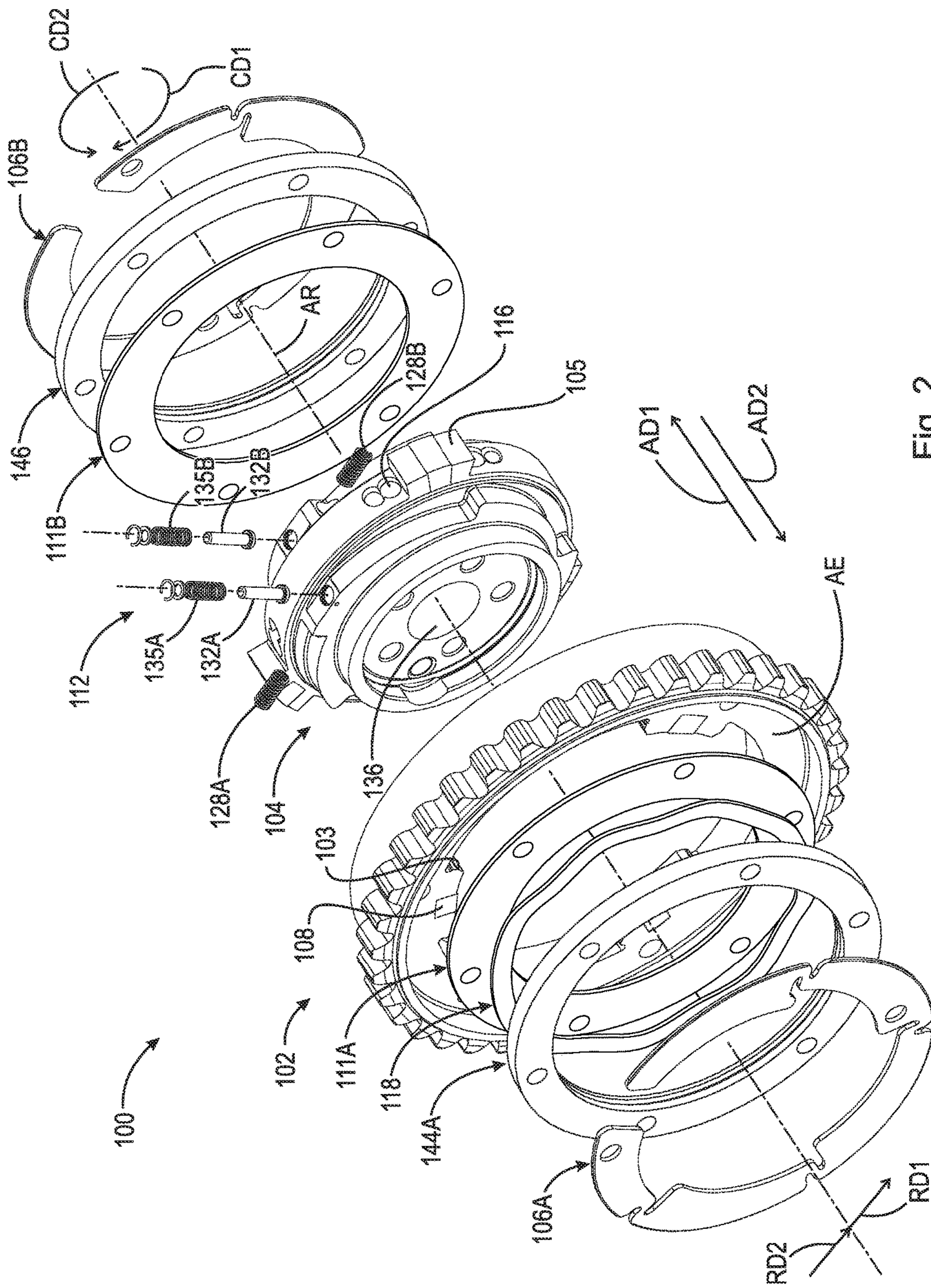
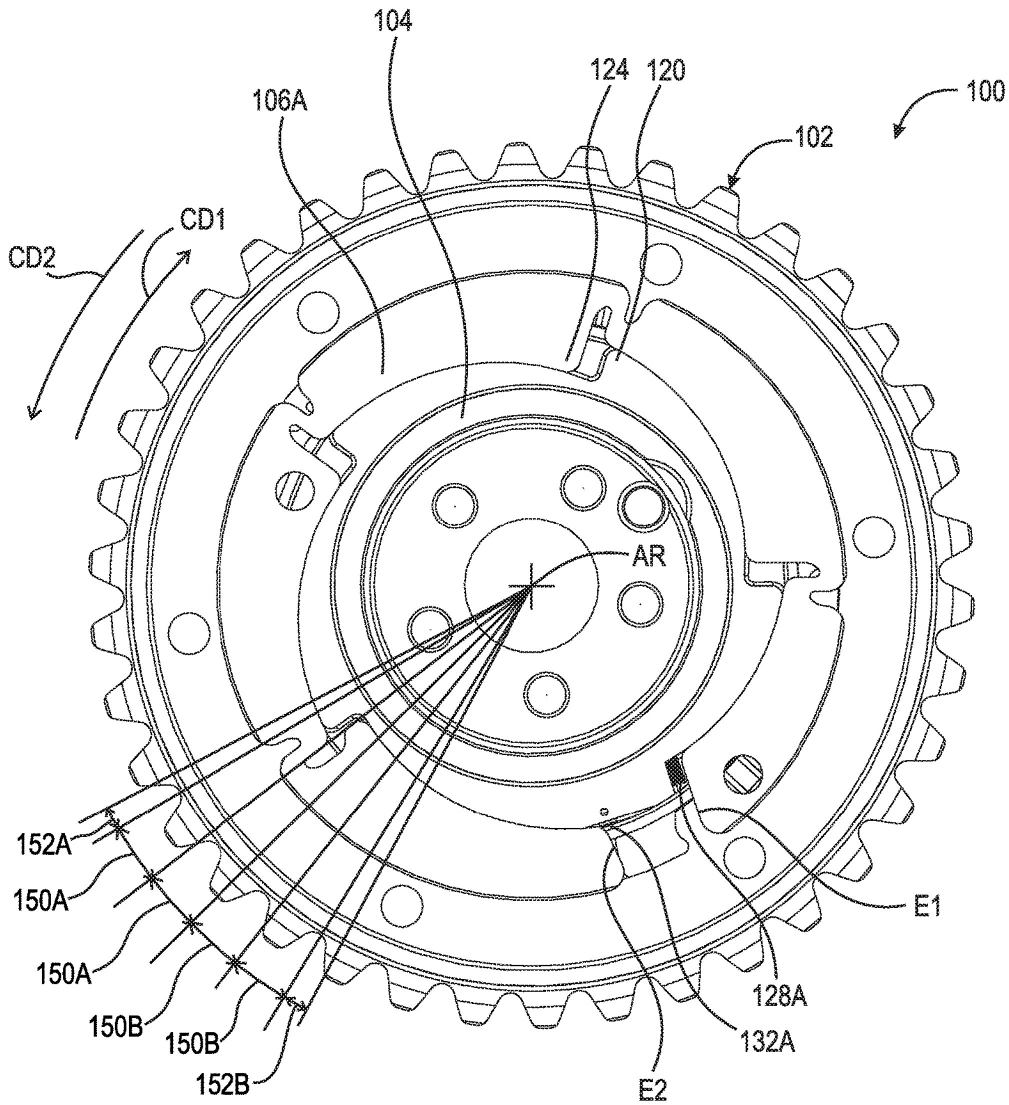


Fig. 1



CD2
CD1
106B
AR
116
105
128B
146
111B
135B
132B
AD1
AD2
112
135A
132A
AE
136
128A
104
103
108
102
111A
118
144A
100
106A
RD1
RD2

Fig. 2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124
120
100
106A
102
CD1
CD2
AR
152A
150A
150A
150B
150B
152B
E1
128A
132A
E2

Fig. 3

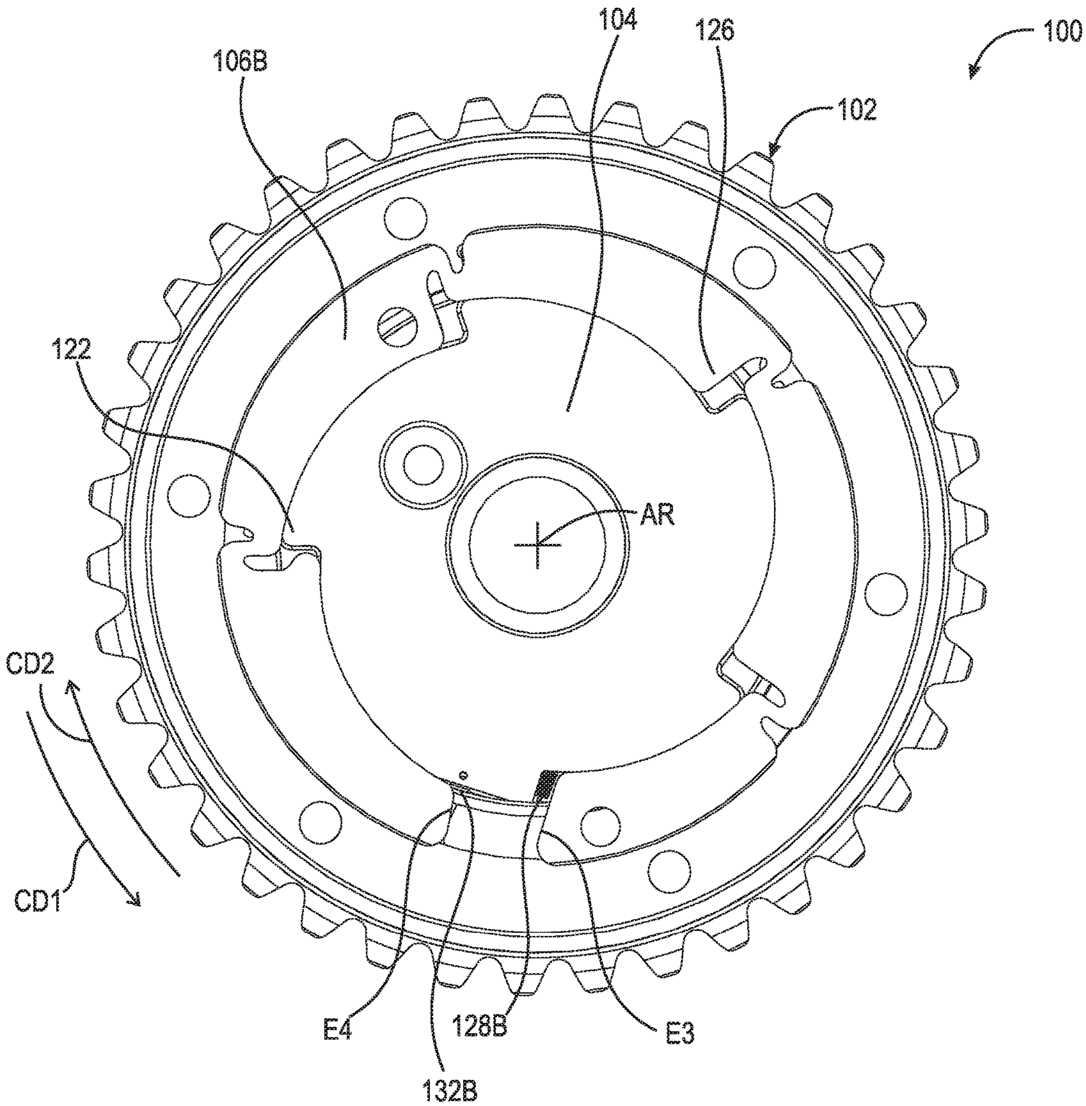


Fig. 4

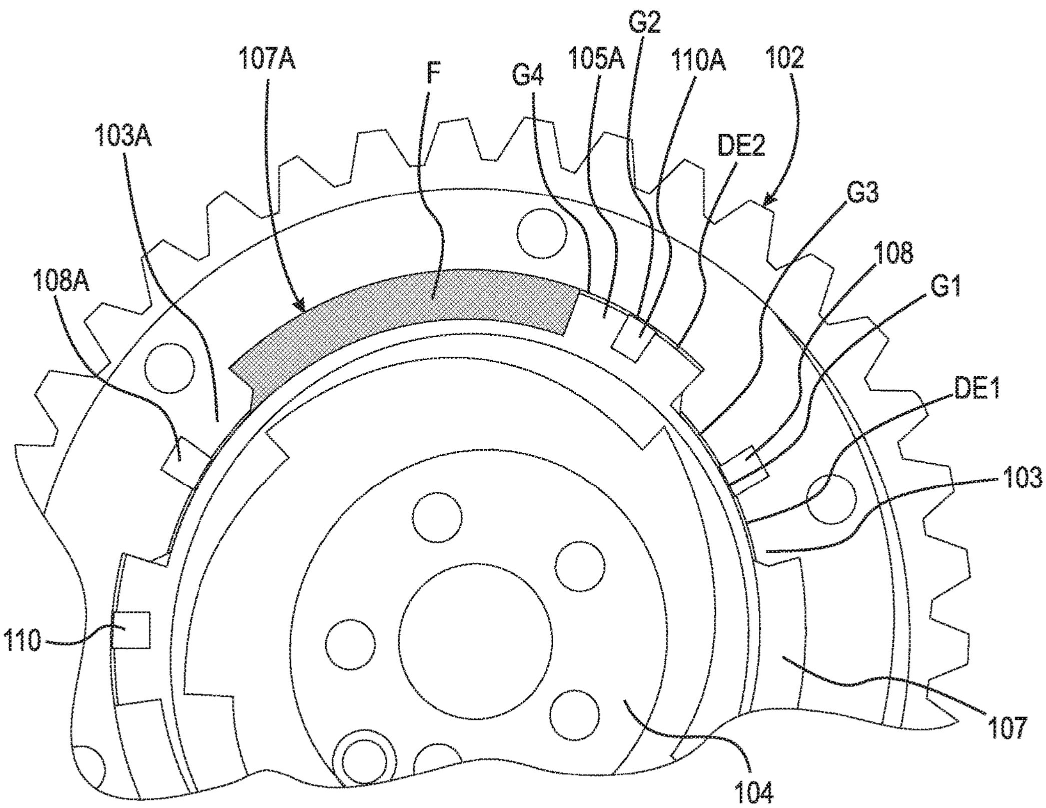
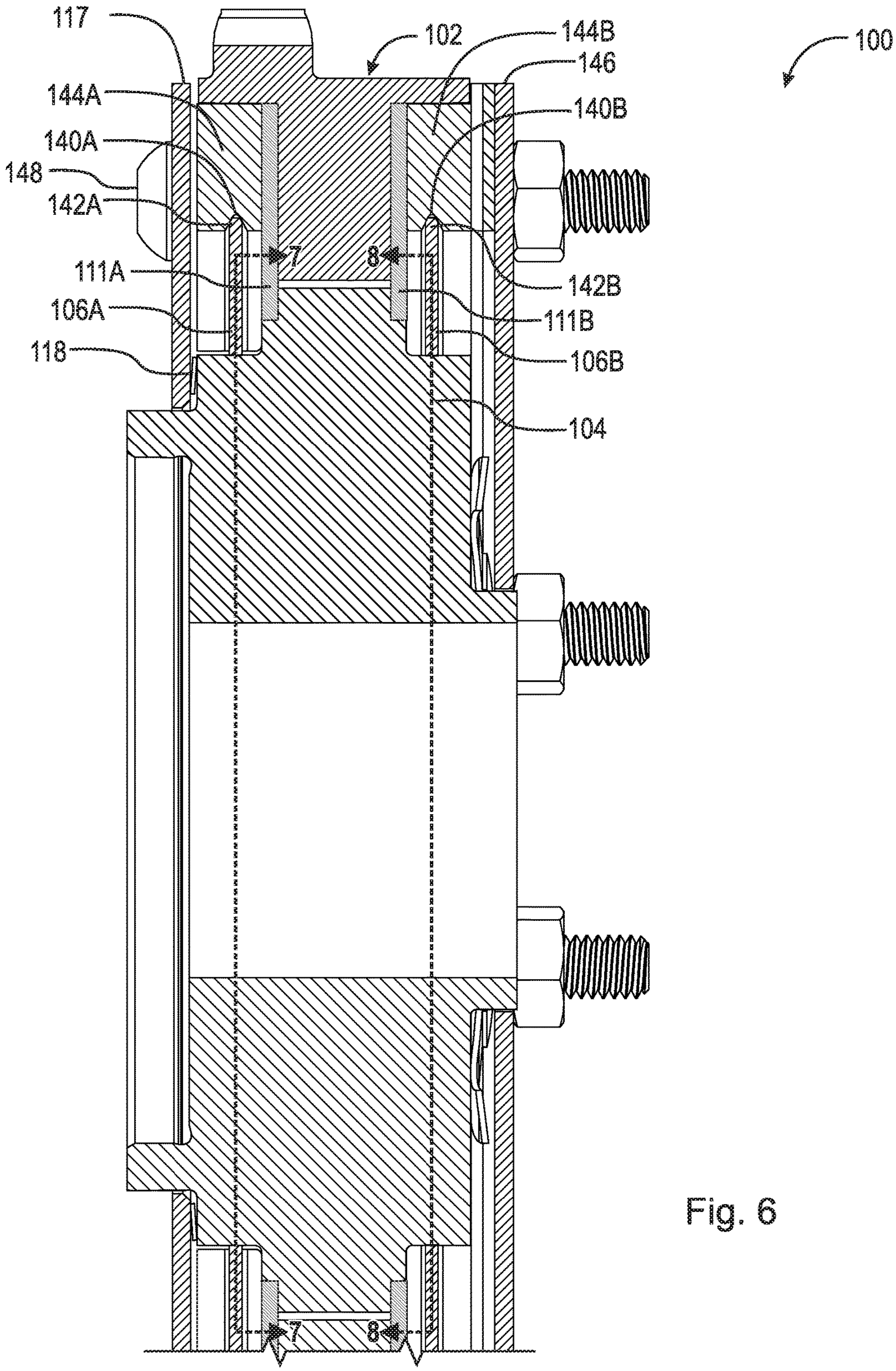

107A
F
G4
105A
G2
110A
102
103A
DE2
G3
108A
108
G1
DE1
103
110
107
104

Fig. 5


117
102
144B
100
146
144A
140B
140A
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142A
7
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111A
142B
106A
111B
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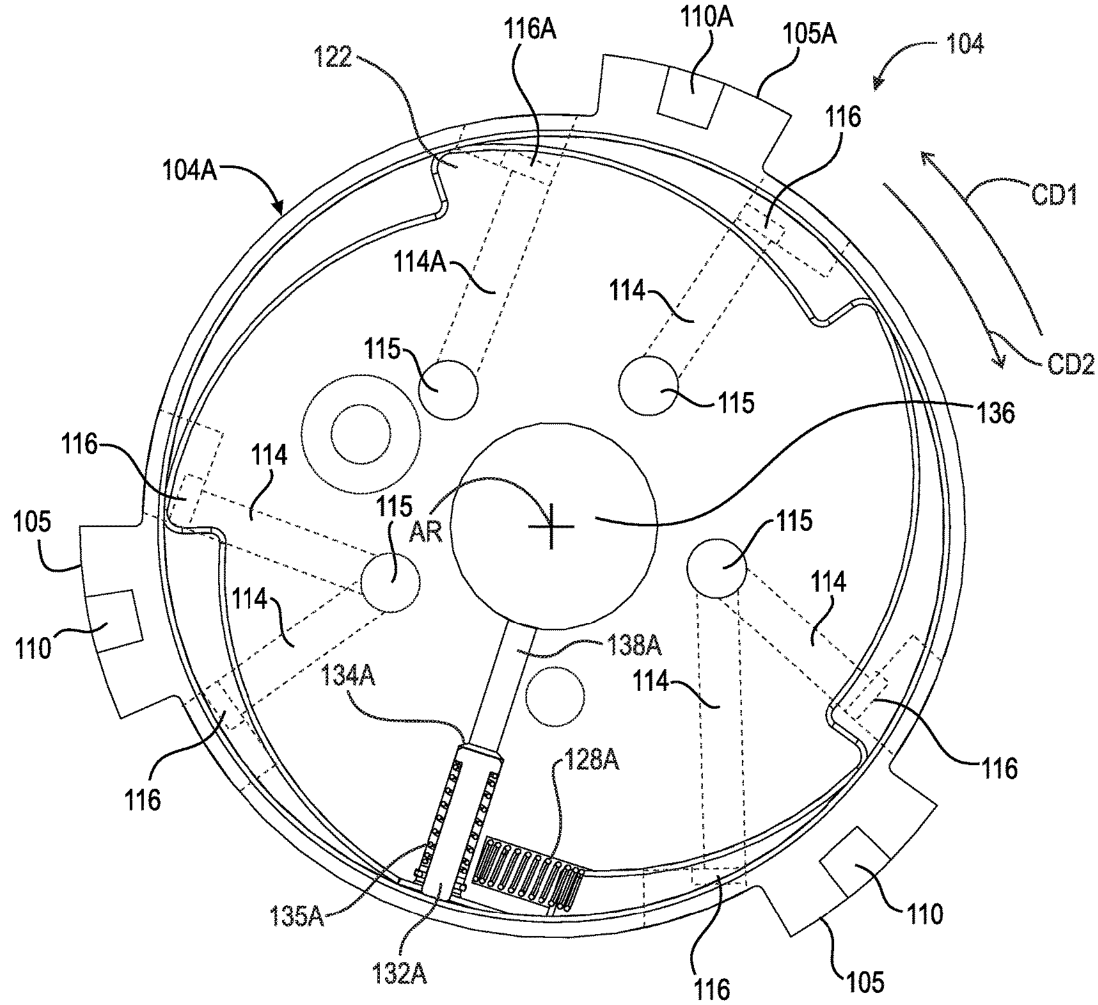
106B
104
7
8

Fig. 6


110A
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116A
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104A
CD1
114A
114
CD2
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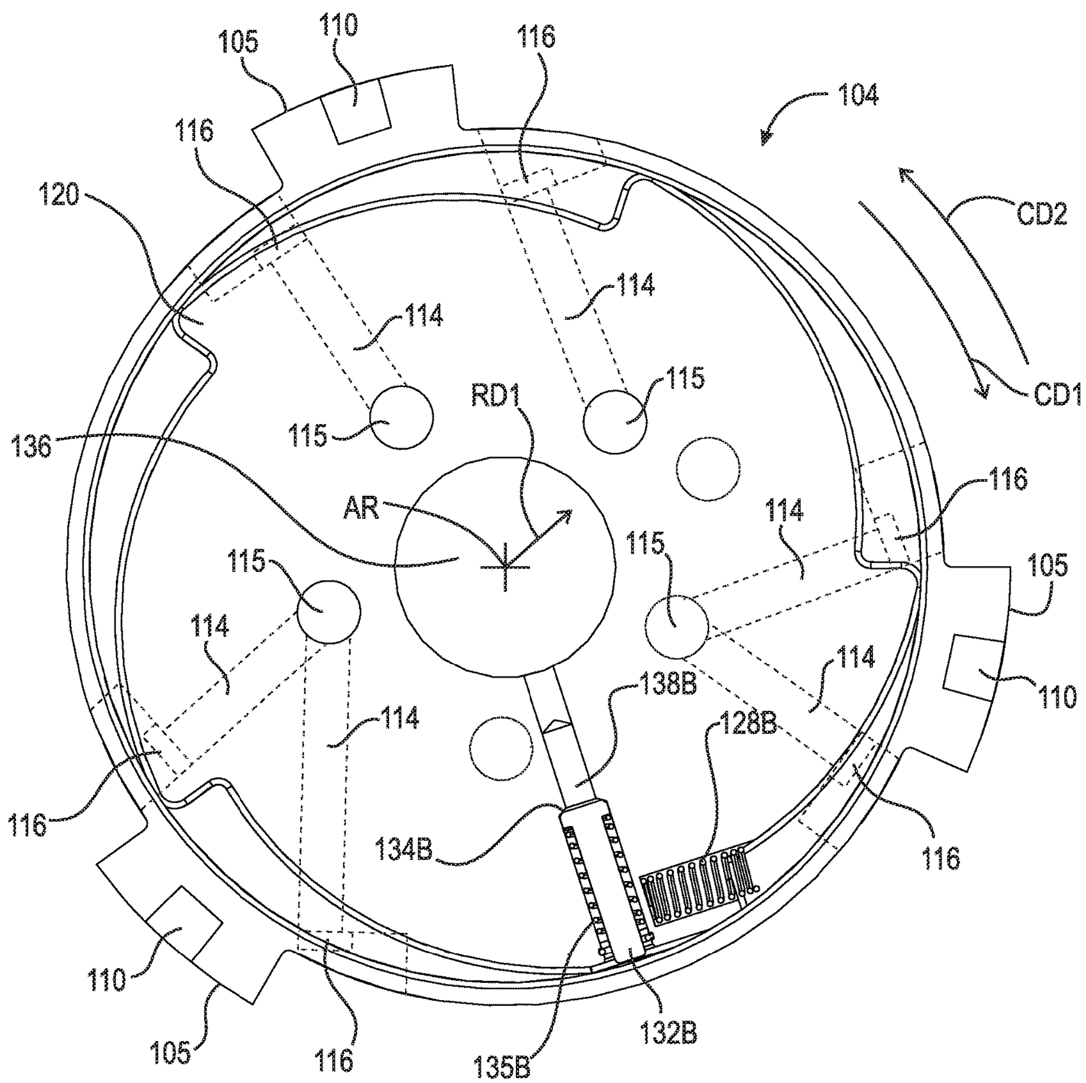
115
136
116
114
105
115
AR
115
114
110
114
138A
114
134A
116
128A
116
135A
132A
116
110
105

Fig. 7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110
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104
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120
114
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CD2
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RD1
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CD1
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116
AR
114
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128B
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134B
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110
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116
135B
132B

Fig. 8

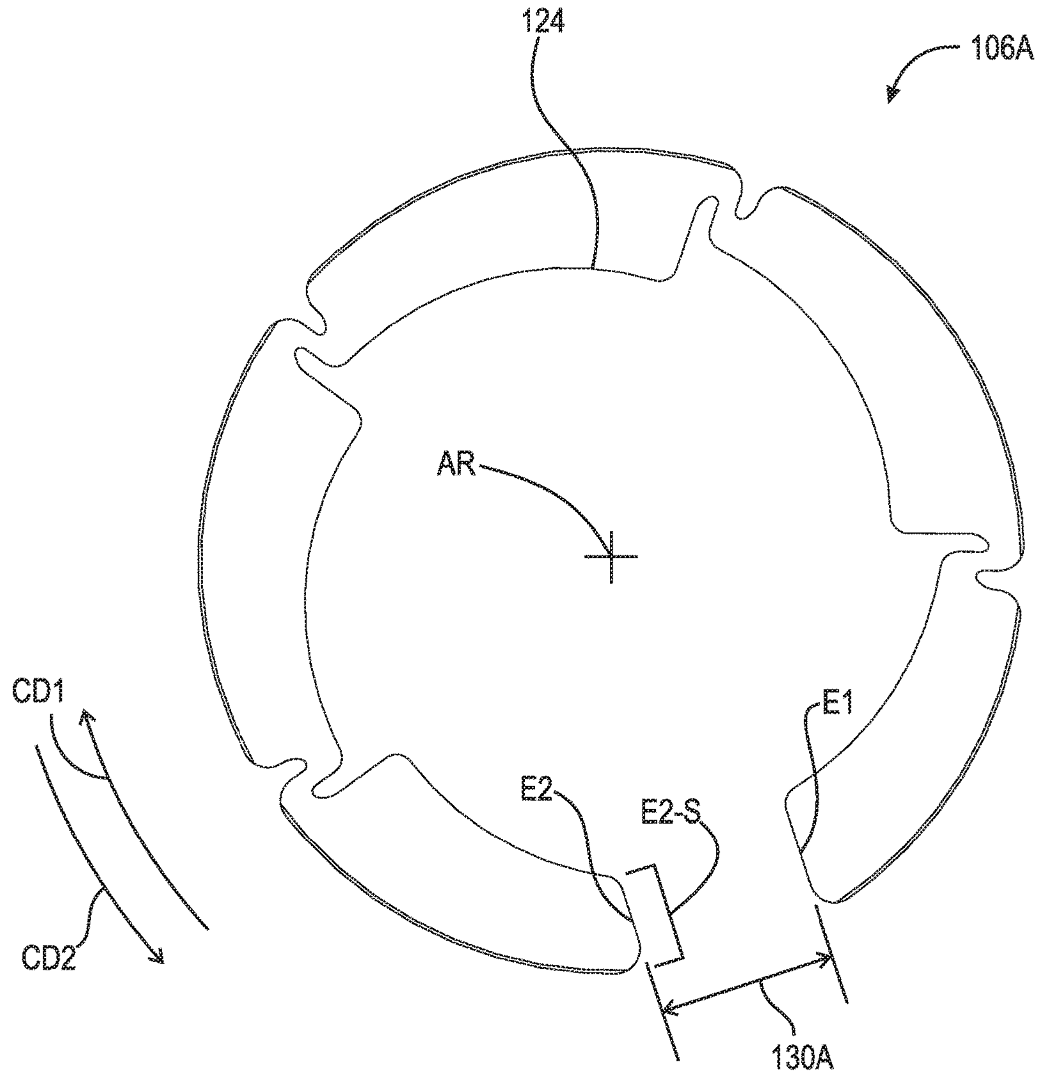

Fig. 9

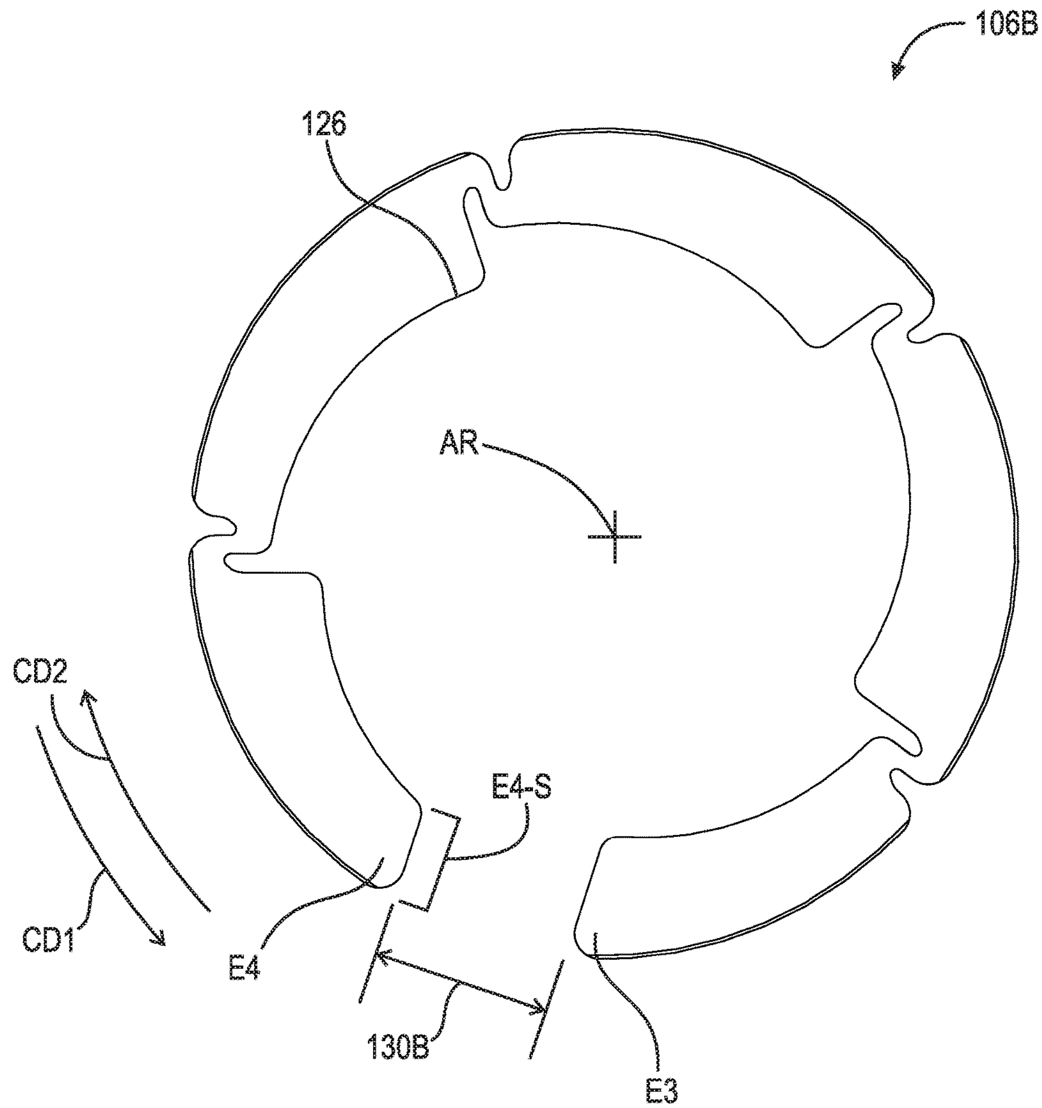

Fig. 10

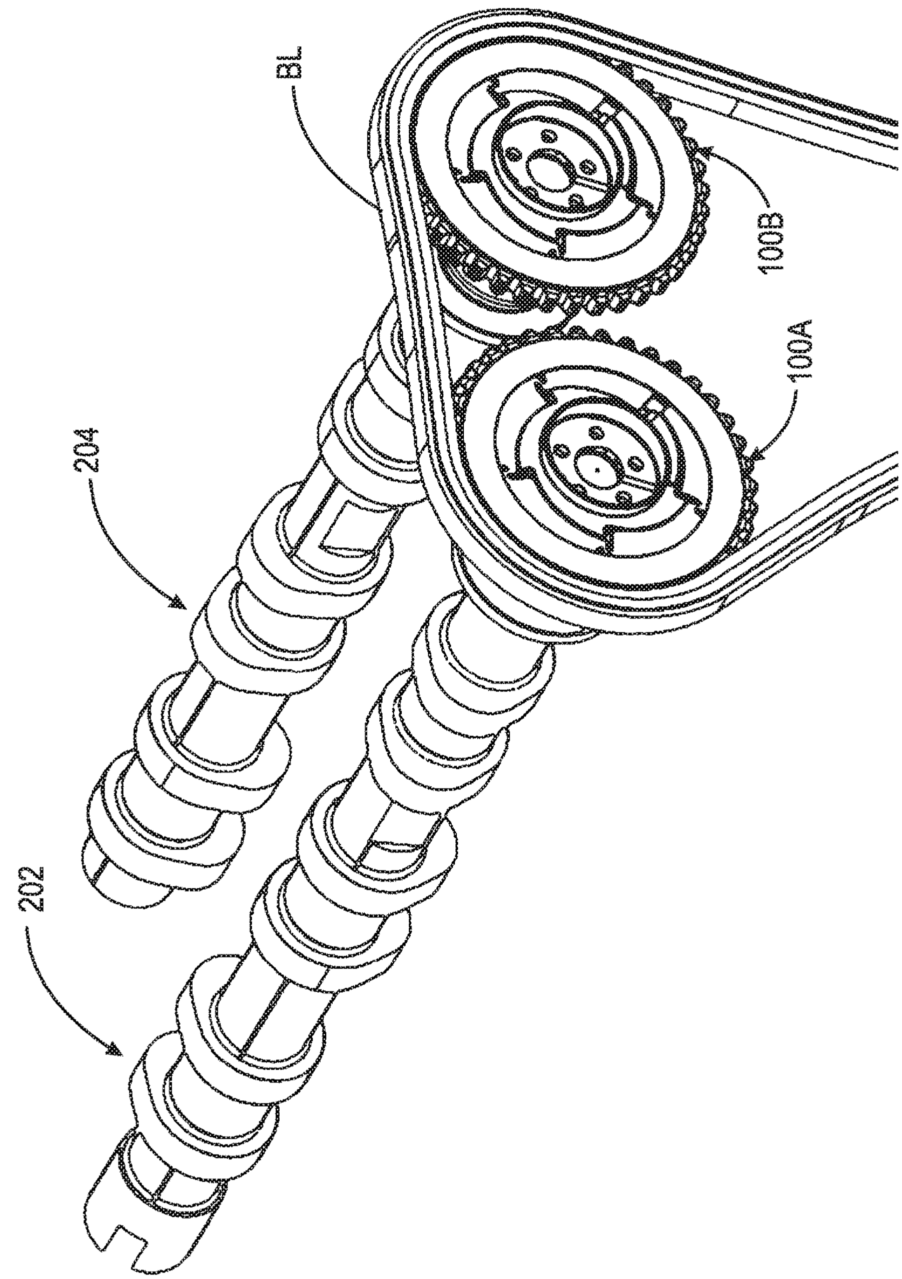

Fig. 11

MULTI-POSITION CAMSHAFT PHASER WITH TWO ONE-WAY WEDGE CLUTCHES AND VISCOUS DAMPING

TECHNICAL FIELD

The present disclosure relates to a multi-position camshaft phaser with two one-way wedge clutches including viscous and coulomb damping. The two one-way wedge clutches are used to advance and retard the phase of the rotor with respect to the stator.

BACKGROUND

A camshaft phaser using two one-way wedge clutches to control phasing of a rotor with respect to a stator is known. However, the rotor can shift with respect to the stator at rotational speeds that are excessive; high enough to create problems with respect to positioning the rotor.

SUMMARY

According to aspects illustrated herein, there is provided a camshaft phaser, including:

a stator arranged to receive torque from an engine and including a plurality of radially inwardly extending protrusions, each radially inwardly extending protrusion including a radially outermost end; a rotor arranged to be non-rotatably connected to a camshaft and including a plurality of radially outwardly extending protrusions, each radially outwardly extending protrusion including a radially outermost end; a plurality of chambers, each chamber at least partially bounded by a respective radially inwardly extending protrusion and a respective radially outwardly extending protrusion circumferentially adjacent to the radially inwardly extending protrusion; a first plurality of seals, each seal in the first plurality of seals disposed in a respective radially innermost end and facing the rotor in a first radial direction; a second plurality of seals, each seal in the second plurality of seals disposed in a respective radially outermost end and facing the stator in a second radial direction opposite the first radial direction; first and second wedge plates radially disposed between the rotor and the stator; and a displacement assembly arranged to for an advance mode, displace the first wedge plate to enable rotation of the rotor, with respect to the stator, in the first circumferential direction and for a retard mode, displace the second wedge plate to enable rotation of the rotor, with respect to the stator, in a second circumferential direction opposite the first circumferential direction.

According to aspects illustrated herein, there is provided a camshaft assembly, including: a stator arranged to receive torque from an engine and including a plurality of radially inwardly extending protrusions; a rotor arranged to be non-rotatably connected to a camshaft and including a plurality of radially outwardly extending protrusions; a plurality of chambers, each chamber at least partially bounded by a respective radially inwardly extending protrusion and a respective radially outwardly extending protrusion circumferentially adjacent to the radially inwardly extending protrusion; a plurality of channels through the rotor, each channel leading to a respective chamber; a respective check valve between said each channel and the respective chamber; a first plurality of seals, each seal in the first plurality of seals radially disposed between the rotor and a respective radially inwardly extending protrusion; a second plurality of seals, each seal in the second plurality of seals radially disposed between the stator and a respective radially outwardly extending protrusion; first and second wedge plates radially disposed between the rotor and the stator; and a displacement assembly arranged to for an advance mode, displace the first wedge plate to enable rotation of the rotor, with respect to the stator, in a first circumferential direction and for a retard mode, displace the second wedge plate to enable rotation of the rotor, with respect to the stator, in a second circumferential direction opposite the first circumferential direction.

According to aspects illustrated herein, there is provided a method of operating a camshaft phaser including: a stator including a plurality of radially inwardly extending protrusions, each radially inwardly extending protrusion including a radially outermost end; a rotor including a plurality of radially outwardly extending protrusions; a plurality of chambers, each chamber at least partially bounded by a respective radially inwardly extending protrusion and a respective radially outwardly extending protrusion circumferentially adjacent to the radially inwardly extending protrusion; and a plurality of seals, each seal in the plurality of seals disposed in a respective radially innermost end and facing the rotor in a first radial direction, the method including: for each chamber in the plurality of pairs of chambers, flowing pressurized fluid, through a respective channel in the rotor, to said each chamber; receiving, with the stator, first torque in a first circumferential direction from an engine; and for an advance mode: receiving, with the rotor, second torque in the first circumferential direction; displacing a first wedge plate, radially disposed between the stator and the rotor, in the first circumferential direction; rotating the rotor, with respect to the stator, in the first circumferential direction; for a first chamber included in each pair of chambers, opposing the rotation of the rotor in the first circumferential direction with the pressurized fluid; and restricting flow, in the second circumferential direction, of the pressurized fluid out of the first chamber radially between a seal included in the plurality of seals and the rotor.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments are disclosed, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, in which:

FIG. **1** is a perspective view of a cylindrical coordinate system demonstrating spatial terminology used in the present application;

FIG. **2** is a perspective exploded view of a camshaft phaser with two-way wedge clutches and viscous damping;

FIG. **3** is a front view of the camshaft phaser in FIG. **2**;

FIG. **4** is a rear view of the camshaft phaser in FIG. **2**;

FIG. **5** is a front view of the rotor and stator in FIG. **2** showing chambers;

FIG. **6** is a cross-sectional view of the camshaft phaser in FIG. **2**;

FIG. **7** is a cross-sectional view generally along line **7-7** in FIG. **6**;

FIG. **8** is a cross-sectional view generally along line **8-8** in FIG. **6**;

FIG. **9** is a front view of the wedge plate shown in FIG. **3**;

FIG. **10** is a rear view of the wedge plate shown in FIG. **4**; and, FIG. **11** is a perspective view of camshaft phasers connected to respective cam shafts.

DETAILED DESCRIPTION

At the outset, it should be appreciated that like drawing numbers on different drawing views identify identical, or functionally similar, structural elements of the disclosure. It is to be understood that the disclosure as claimed is not limited to the disclosed aspects.

Furthermore, it is understood that this disclosure is not limited to the particular methodology, materials and modifications described and as such may, of course, vary. It is also understood that the terminology used herein is for the purpose of describing particular aspects only, and is not intended to limit the scope of the present disclosure.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this disclosure belongs. It should be understood that any methods, devices or materials similar or equivalent to those described herein can be used in the practice or testing of the disclosure.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this present disclosure belongs. It should be appreciated that the term "substantially" is synonymous with terms such as "nearly", "very nearly", "about", "approximately", "around", "bordering on", "close to", "essentially", "in the neighborhood of", "in the vicinity of", etc., and such terms may be used interchangeably as appearing in the specification and claims. It should be appreciated that the term "proximate" is synonymous with terms such as "nearby", "close", "adjacent", "neighboring", "immediate", "adjoining", etc., and such terms may be used interchangeably as appearing in the specification and claims.

FIG. **1** is a perspective view of cylindrical coordinate system **10** demonstrating spatial terminology used in the present application. The present application is at least partially described within the context of a cylindrical coordinate system. System **10** includes longitudinal axis **11**, used as the reference for the directional and spatial terms that follow. Axial direction AD is parallel to axis **11**. Radial direction RD is orthogonal to axis **11**. Circumferential direction CD is defined by an endpoint of radius R (orthogonal to axis **11**) rotated about axis **11**.

To clarify the spatial terminology, objects **12**, **13**, and **14** are used. An axial surface, such as surface **15** of object **12**, is formed by a plane co-planar with axis **11**. Axis **11** passes through planar surface **15**; however any planar surface co-planar with axis **11** is an axial surface. A radial surface, such as surface **16** of object **13**, is formed by a plane orthogonal to axis **11** and co-planar with a radius, for example, radius **17**. Radius **17** passes through planar surface **16**; however any planar surface co-planar with radius **17** is a radial surface. Surface **18** of object **14** forms a circumferential, or cylindrical, surface. For example, circumference **19** is passes through surface **18**. As a further example, axial movement is parallel to axis **11**, radial movement is orthogonal to axis **11**, and circumferential movement is parallel to circumference **19**. Rotational movement is with respect to axis **11**. The adverbs "axially," "radially," and "circumferentially" refer to orientations parallel to axis **11**, radius **17**, and circumference **19**, respectively. For example, an axially disposed surface or edge extends in direction AD, a radially disposed surface or edge extends in direction R, and a circumferentially disposed surface or edge extends in direction CD.

FIG. **2** is a perspective exploded view of camshaft phaser **100** with two-way wedge clutches and viscous damping.

FIG. **3** is a front view of camshaft phaser **100** in FIG. **2**.

FIG. **4** is a rear view of camshaft phaser **100** in FIG. **2**.

FIG. **5** is a front view of the rotor and stator in FIG. **2** showing chambers. The following should be viewed in light of FIGS. **2** through **5**. Camshaft phaser **100** includes: axis of rotation AR; stator **102** arranged to receive torque from an engine (not shown) and including radially inwardly extending protrusions **103**; rotor **104** arranged to be non-rotatably connect to a camshaft (not shown) and including radially outwardly extending protrusions **105**; wedge plates **106**A and **106**B radially disposed between stator **102** and rotor **104**; chambers **107**; seals **108**; and seals **110**. Each chamber **107** is at least partially bounded by a protrusion **103** and a respective protrusion **105** circumferentially adjacent to the protrusion **103**. For example, chamber **107**A is bounded by protrusions **103**A and **105**A in opposite circumferential directions CD**1** and CD**2**.

Each protrusion **103** includes radially inmost (distal) end DE**1** and each protrusion **105** includes radially outermost (distal) end DE**2**. Each seal **108**: is disposed in a respective end DE**1**; is radially located between end DE**1** and rotor **104**; and faces rotor **104** in radial direction RD**2**. Each seal **110**: is disposed in a respective end DE**2**; is radially located between end DE**2** and stator **102**; and faces stator **102** in radial direction RD**1**. In an example embodiment, camshaft phaser **100** includes plates **111**A and **111**B bounding chambers **107** in axial directions AD**1** and AD**2**. In an example embodiment, seals **108** are separated from rotor **104**, in direction RD**2**, by gaps G**1**. In an example embodiment, seals **110** are separated from stator **102**, in direction RD, by gaps G**2**. In an example embodiment (not shown), seals **108** are in contact rotor **102** and/or seals **110** are in contact with stator **102**. Ends E**1** are separated, in radial direction RD**2**, from rotor **104** by gaps G**3**. Ends E**2** are separated, in radial direction RD**1**, from stator **102** by gaps G**4**.

Camshaft phaser **100** includes displacement assembly **112**. For an advance mode, displacement assembly **112** is arranged to displace wedge plate **106**A to enable rotation of rotor **104**, with respect to stator **102**, in circumferential direction CD**1**. For a retard mode, displacement assembly **112** is arranged to displace wedge plate **106**B to enable rotation of rotor **104**, with respect to stator **106**, in circumferential direction CD**2**.

During use, fluid F, for example pressurized fluid F, is provided in chambers **107**. To simplify presentation, fluid F is shown only in chamber **107**A. However, it should be understood that all of chambers **107** can be provided with fluid F. Each seal **108** restricts leakage, in circumferential directions CD**1** and CD**2**, of fluid F radially between a respective protrusion **103** and rotor **104**. That is, seals **108** restrict flow through gaps G**1** and G**3**. Each seal **110** restricts leakage, in circumferential directions CD**1** and CD**2**, of fluid F radially between a respective protrusion **105** and stator **102**. That is, seals **110** restrict flow through gaps G**2** and G**4**. For example: seal **108**A restricts leakage, in circumferential directions CD**1** and CD**2**, of fluid F, from chamber **107**A, radially between protrusion **103**A and rotor **104**; and seal **110**A prevents leakage, in circumferential directions CD**1** and CD**2**, of fluid F, from chamber **107**A, radially between protrusion **105**A and stator **102**. In an example embodiment (not shown): each seal **108** blocks leakage, in circumferential directions CD**1** and CD**2**, of fluid F radially between a respective protrusion **103** and rotor **104**; and each seal **110** blocks leakage, in circumferential directions CD**1** and CD**2**, of fluid F radially between a respective protrusion **105** and stator **102**.

FIG. **6** is a cross-sectional view of camshaft phaser **100** in FIG. **2**.

FIG. **7** is a cross-sectional view generally along line **7-7** in FIG. **6**.

FIG. **8** is a cross-sectional view generally along line **8-8** in FIG. **6**. The following should be viewed in light of FIGS. **2** through **8**. Phaser **100** includes channels **114** and check valves **116**. Channels **114** are in rotor **104** and pass through rotor **104**. Each channel **114** leads to a respective chamber **107**. For example, channel **114**A leads to chamber **107**A. A respective check valve **116** is located between each chamber **107** and the channel **114** leading to the chamber **107**. For example, check valve **116**A is located between channel **114**A and chamber **107**A. Check valves **116** enable flow of fluid F into chambers **107** and prevent the flow of fluid F from chambers **107** through channels **114**. Check valves **116** can be any check valve known in the art, for example, reed valves.

Channels **114** are arranged to receive fluid F, for example through channels **115** connected to a source of pressurized fluid, at a first pressure. Note that a channel **115** can be connected to one channel **114** or to multiple channels **114**. Check valves **116** are arranged to open to enable flow of pressurized fluid F into chambers **107** for pressure of fluid F in chambers **107** less than the first pressure. As noted above, fluid F can leak out of chambers **107** through gaps G**1** and G**2**. Thus, if the leakage results in the lowering of fluid pressure in the chambers to a level below a desired level (the first pressure noted above), channels **114** replenish pressurized fluid F in chambers **107**.

In an example embodiment, camshaft phaser **100** includes cover plate **117** and resilient element **118**. Cover plate **117** is fixedly secured to axial end AE of stator **102**. Resilient element **118** is axially disposed between cover plate **117** and rotor **104** and is in contact with cover plate **117** and rotor **104**. Resilient element **118** reacts against cover plate **117** and rotor **104** to oppose rotation of rotor **104** with respect to stator **102**. That is, element **118** provides coulomb, or frictional, damping between rotor **104** and stator **102**.

For the advance mode, displacement assembly **112** is arranged to displace wedge plate **106**A in circumferential direction CD**1** to enable rotation of rotor **104**, with respect to stator **102**, in circumferential direction CD**1**. For the retard mode, displacement assembly **112** is arranged to displace wedge plate **106**B in circumferential direction CD**2** to enable rotation of rotor **104**, with respect to stator **102**, in circumferential direction CD**2**. To block rotation of rotor **104**, with respect to stator **102**, in circumferential direction CD**2**, for example during the advance mode, displacement assembly **112** is arranged to non-rotatably connect rotor **104**, wedge plate **106**B, and stator **102**. To block rotation of rotor **104**, with respect to stator **102**, in circumferential direction CD**1**, for example during the retard mode, displacement assembly **112** is arranged to non-rotatably connect rotor **104**, wedge plate **106**A, and stator **102**.

FIG. **9** is a front view of wedge plate **106**A shown in FIG. **3**.

FIG. **10** is a rear view of wedge plate **106**B shown in FIG. **4**. The following should be viewed in light of FIGS. **2** through **10**. In an example embodiment, rotor **104** includes ramps **120** and **122** and wedge plates **106**A and **106**B includes ramps **124** and **126**, respectively. Ramps **120** are engaged with ramps **124** and ramps **122** are engaged with ramps **126**. In an example embodiment, for the advance mode: ramps **120** are arranged to slide along ramps **124** in circumferential direction CD**1**; and displacement assembly **112** is arranged to slide ramps **126** along ramps **122** in circumferential direction CD**1**. In an example embodiment, for the retard mode: ramps **122** are arranged to slide along ramps **126** in circumferential direction CD**2**; and displacement assembly **112** is arranged to slide ramps **124** along ramps **120** in circumferential direction CD**2**.

The following provides further detail regarding an example embodiment of phaser **100** and displacement assembly **112**. Displacement assembly **112** includes resilient elements **128**A and **1218**B. Resilient element **128**A is circumferentially disposed between rotor **104** and wedge plate **106**A and is arranged to displace wedge plate **106**A in circumferential direction CD**2** with respect to the rotor. Resilient element **128**B is circumferentially disposed between rotor **104** and wedge plate **106**B and is arranged to displace wedge plate **106**B in circumferential direction CD**1** with respect to the rotor.

For the advance mode, resilient element **128**B is arranged to displace wedge plate **106**B in circumferential direction CD**1** to block rotation of rotor **104**, with respect to stator **102**, circumferential direction CD**2** and eliminate back lash. For the retard mode, resilient element **128**A is arranged to displace wedge plate **106**A in circumferential direction CD**2** to block rotation of rotor **104**, with respect to stator **102**, circumferential direction CD**1** and eliminate back lash.

In an example embodiment: wedge plate **106**A includes circumferential ends E**1** and E**2** separated by gap **130**A in circumferential direction CD**1**; and wedge plate **106**B includes circumferential ends E**3** and E**4** separated by gap **130**B in circumferential direction CD**1**. Resilient elements **128**A and **128**B are engaged with circumferential ends E**1** and E**3**, respectively.

Displacement assembly **112** includes pins **132**A and **132**B in chambers **134**A and **134**B, respectively, in rotor **104**. Pins **132**A and **132**B are at least partially located in chambers **134**A and **134**B, respectively. Springs **135**A and **135**B, respectively, urge pins **132**A and **132**B in radially inward direction RD**2**. Further, rotor **104** includes: central opening **136** through which axis of rotation AR for camshaft phaser **100** passes. Assembly **112** includes: channel **138**A in rotor **104** connecting opening **136** and chamber **134**A; and channel **138**B in rotor **104** connecting opening **136** and **134**B.

Channels **138**A and **138**B are arranged to receive pressurized fluid. For the advance mode, the pressurized fluid is arranged to displace pin **132**A in radially outward direction RD**1** to displace end E**2** in circumferential direction CD**1**. For the retard mode, the pressurized fluid is arranged to displace pin **132**B in radially outward direction RD**1** to displace end E**4** in circumferential direction CD**2**. Springs **135**A and **135**B urge pins out of contact with ends E**2** and E**4**, respectively, in the absence of pressurized fluid in channels **138**A and **138**B. Thus, in the absence of the pressurized fluid, pins **132**A and **132**B do not interfere with rotation of wedge plates **106**A and **106**B, respectively.

Ends E**2** and E**4** include slopes, or sloped portions, E**2**-S and E**4**-S, respectively. In an example embodiment, sloped portions E**2**-S and E**4**-S include all of E**2**-S and E**4**-S, respectively. Along radially outward direction RD**1**, slope E**2**-S extends further in circumferential direction CD**2**. Along radially outward direction RD**1**, slope E**4**-S extends further in circumferential direction CD**1**. Thus: as pin **132**A extends in direction RD**1**, pin **132**A slides along slope E**2**-S, pushing wedge plate **106**A in direction CD**1**; as pin **132**B extends in direction RD**1**, pin **132**B slides along slope E**4**-S, pushing wedge plate **106**B in direction CD**2**.

FIG. **11** is a cross-sectional view generally along line **11-11** in FIG. **3** with side plates added. The following should be viewed in light of FIGS. **2** through **11**. In an example embodiment, phaser **100** includes circumferentially disposed grooves **140**A and **140**B and wedge plates **106**A and **106**B include chamfered radially outer portions **142**A and **142**B. In an example embodiment, phaser **100** includes groove plates **144**A and **144**B with grooves **140**A and **140**B, respectively. Plates **144**A and **144**B are fixedly connected to stator **102**, for example by side plates **117** and **146**, respectively, and bolts **148**. Portions **142**A and **142**B are frictionally engaged with grooves **140**A and **140**B so that wedge plates **106**A and **106**B rotate with stator **102** except as noted above and below. As wedge plate **106**A is displaced radially outward as described above, portion **142**A compressively engages groove **140**A, non-rotatably connecting stator **102** and wedge plate **106**A. As wedge plate **106**B is displaced radially outward as described above, portion **142**B compressively engages groove **140**B, non-rotatably connecting stator **102** and wedge plate **106**B.

FIG. **12** is a perspective view of camshaft phasers **100**A and **100**B connected to cam shafts **202** and **204**, respectively. The discussion regarding phaser **100** is applicable to phasers **100**A and **100**B. Typically, one of cam shafts **202** and **204** is for an intake valve train and the other of cam shafts **202** and **204** is for an exhaust valve train. Phasers **100**A and **100**B are rotated by chain (simplified chain model—chain sprockets are shown) BL, typically driven by a crankshaft for an engine of which the camshafts and phasers are a part. The following discussion is directed to phaser **100**A; however, it should be understood that the discussion is applicable to phaser **100**B as well.

In the discussion that follows, stator **102** rotates in direction CD**1** in response to torque from chain BL. As is known in the art, torsional forces T**1** and T**2** are transmitted from camshaft **202**, in directions CD**1** and CD**2**, respectively, to rotor **104** during operation of phaser **100**. The torsional force forces are due to interaction of cam lobes (not shown) on camshaft **202** with various components of a valve train (not shown) of which camshaft **202** is a part. Torsional forces T**1** and T**2** are transmitted in a repeating cycle. Rotor **104** rotates in direction CD**1**; however, torsional force T**1** urges rotor **104** in direction CD**1** with respect to the stator and torsional force T**2** urges rotor **104** in direction CD**2** with respect to the stator.

The following describes the advance mode. Assume stator **102** is rotating in direction CD**1** and phaser **100**A receives torsional force T**1**. Fluid PF in channel **138**A urges pin **132**A in direction CD**1** to displace wedge plate **106**A is direction CD**1**. Ramps **124** slide down ramps **120**, and rotor **104** displaces distance **150**A in direction CD**1**. At the same time, the rotation of rotor **104** causes ramps **122** to slide down ramps **126**, that is, wedge plate **106**B does not block the rotation of the rotor.

The rotor then receives torque T**2** and the pressurized fluid is drained from channel **138**A. Torque T**2** on rotor **104** urges the rotor in direction CD**2**. At the same time, wedge plate **106**B is urged in direction CD**1** by resilient element **128**B. As a result, as soon as the rotor receives torque T**2**, ramps **126** slide up ramps **122** to non-rotatably connect the rotor and the stator. That is, resilient element **128**B eliminates backlash in the transition from torque T**1** to torque T**2**. Thus, rotor **104** is prevented from rotating back in direction CD**2**, which would cancel the displacement in distance **150**A. Therefore, in the advance mode, for each cycle of torques T**1** and T**2**, rotor **104** rotates distance **150**A in direction CD**1**. For successive cycles of T**1** and T**2** in the advance mode, rotor **104** displaces distance **150**A, with respect to stator **102**, in direction CD**1**. That is, this process is repeatable via successive cycles of torsional forces T**1** and T**2** to attain a desired shift of rotor **104**.

The following describes the retard mode. Assume stator **102** is rotating in direction CD**1** and phaser **100**A receives torsional force T**2**. Fluid PF in channel **138**B urges pin **132**B in direction CD**2** to displace wedge plate **106**B is direction CD**2**. Ramps **122** slide down ramps **126**, and rotor **104** displaces distance **150**B in direction CD**2**. At the same time, the rotation of rotor **104** causes ramps **120** to slide down ramps **124**, that is, wedge plate **106**A does not block the rotation of the rotor.

The rotor then receives torque T**1** and the pressurized fluid is drained from channel **138**B. Torque T**1** on rotor **104** urges the rotor in direction CD**1**. At the same time, wedge plate **106**A is urged in direction CD**2** by resilient element **128**A. As a result, as soon as the rotor receives torque T**1**, ramps **124** slide up ramps **120** to non-rotatably connect the rotor and the stator. That is, resilient element **128**A eliminates backlash in the transition from torque T**2** to torque T**1**. Thus, rotor **104** is prevented from rotating back in direction CD**1**, which would cancel the displacement in distance **150**B. Therefore, in the advance mode, for each cycle of torques T**1** and T**2**, rotor **104** rotates distance **150**B in direction CD**2**. For successive cycles of T**1** and T**2** in the advance mode, rotor **104** displaces distance **150**B, with respect to stator **102**, in direction CD**2**. That is, this process is repeatable via successive cycles of torsional forces T**1** and T**2** to attain a desired shift of rotor **104**.

Each distance **150**A is a result of phaser **100**A implementing a full cycle of torsional force forces T**1** and T**2**. To shift rotor **104** in direction CD**1** by distance **152**A, less than distance **150**A, pressurized fluid PF is drained from channel **138**A after rotor **104** has begun rotation in direction CD**1** (by distance **152**A) but before rotor **104** has rotated distance **150**A.

Each distance **150**B is a result of phaser **100**A implementing a full cycle of torsional force forces T**1** and T**2**. To shift rotor **104** in direction CD**2** by distance **152**B, less than distance **150**B, pressurized fluid PF is drained from channel **138**B after rotor **104** has begun rotation in direction CD**2** (by distance **152**B), but before rotor **104** has rotated distance **150**B.

Thus, rotor **104** can be controllably and repeatably rotated virtually any amount with respect to stator **102** in the advance and retard modes.

The following should be viewed in light of FIGS. **2** through **11**. The following describes a method for operating a camshaft phaser including: a stator including a plurality of radially inwardly extending protrusions, each radially inwardly extending protrusion including a radially outermost end; a rotor including a plurality of radially outwardly extending protrusions; a plurality of chambers, each chamber at least partially bounded by a respective radially inwardly extending protrusion and a respective radially outwardly extending protrusion circumferentially adjacent to the radially inwardly extending protrusion; and a plurality of seals, each seal in the plurality of seals disposed in a respective radially innermost end and facing the rotor in a first radial direction. A first step, for each chamber in the plurality of pairs of chambers, flows pressurized fluid, through a respective channel in the rotor, to said each chamber. A second step receives, with the stator, first torque in a first circumferential direction from an engine; and for an advance mode: a third step receives, with the rotor, second torque in the first circumferential direction; a fourth step displaces a first wedge plate, radially disposed between the stator and the rotor, in the first circumferential direction; a fifth step rotates the rotor, with respect to the stator, in the first circumferential direction; for a first chamber included in each pair of chambers, a sixth step opposes the rotation of the rotor in the first circumferential direction with the pressurized fluid; and a seventh step restricts flow, in the second circumferential direction, of the pressurized fluid out of the first chamber radially between a seal included in the plurality of seals and the rotor.

For a retard mode: an eighth step receives, with the rotor, third torque in the second circumferential direction; a ninth step displaces a second wedge plate, radially disposed between the stator and the rotor, in the second circumferential direction; a tenth step rotates the rotor, with respect to the stator, in the second circumferential direction; an eleventh step, for the first chamber, opposes the rotation of the rotor in the second circumferential direction with the pressurized fluid; and a twelfth step restricts flow, in the first circumferential direction, of the pressurized fluid out of the first chamber radially between the seal included in the plurality of seals and the rotor.

In an example embodiment, for the advance mode: a thirteen step frictionally engages a resilient element with the rotor and a cover plate non-rotatably connected to the stator; and a fourteenth step opposes, with the frictional engagement, the rotation of the rotor in the first circumferential direction. In an example embodiment, for the retard mode: a fifteenth step frictionally engages the resilient element with the rotor and the cover plate non-rotatably connected to the stator; and a sixteenth step opposes, with the frictional engagement, the rotation of the rotor in the second circumferential direction.

Advantageously, camshaft phaser **100** and the method described above solve the problem noted above regarding the rotational speed of a rotor for a camshaft phaser during phasing of the rotor with respect to the stator. Specifically, during rotation of rotor **102** with respect to stator **102**, seals **108** and **110** controllably restrict the flow of fluid F between chambers **107**. The controlled leakage enables rotor **104** to rotate, but the speed of the rotation is limited by the leakage past seals **108** and **110**. That is, rotation of rotor **104** is linked to the reduction of fluid volume in chambers **107** due to the leakage. Clearance between seals **108** and **110** and rotor **104** and stator **102**, respectively, can be set to control the amount of leakage out of chambers **107** and hence the speed of rotation of rotor **104**. As noted above, leaked fluid is replaced via channels **114**.

It will be appreciated that various of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations, or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

What is claimed is:

1. A camshaft phaser, comprising:

a stator arranged to receive torque from an engine and including a plurality of radially inwardly extending protrusions, each radially inwardly extending protrusion including a radially outermost end; a rotor arranged to be non-rotatably connected to a camshaft and including a plurality of radially outwardly extending protrusions, each radially outwardly extending protrusion including a radially outermost end;

a plurality of chambers, each chamber at least partially bounded by a respective radially inwardly extending protrusion and a respective radially outwardly extending protrusion circumferentially adjacent to the radially inwardly extending protrusion;

a first plurality of seals, each seal in the first plurality of seals disposed in a respective radially innermost end and facing the rotor in a first radial direction;

a second plurality of seals, each seal in the second plurality of seals disposed in a respective radially outermost end and facing the stator in a second radial direction opposite the first radial direction;

first and second wedge plates radially disposed between the rotor and the stator; and,

a displacement assembly arranged to:

for an advance mode, displace the first wedge plate to enable rotation of the rotor, with respect to the stator, in the first circumferential direction; and,

for a retard mode, displace the second wedge plate to enable rotation of the rotor, with respect to the stator, in a second circumferential direction opposite the first circumferential direction.

2. The camshaft phaser of claim **1**, wherein:

said each seal in the first plurality of seals is separated, in the first radial direction, from the rotor by a first distance;

each radially innermost end is separated, in the first radial direction, from the rotor by a second distance greater than the first distance;

said each seal in the second plurality of seals is separated, in the second radial direction, from the stator by a third distance; and,

each radially outermost end is separated, in the second radial direction, from the stator by a fourth distance greater than the third distance.

3. The camshaft phaser of claim **1**, further comprising:

respective fluid in said each chamber, wherein:

said each seal in the first plurality of seals prevents flow of the respective fluid between the rotor and the respective radially inwardly extending protrusion; and,

said each seal in the second plurality of seals prevents flow of the respective fluid between the stator and a respective radially inwardly extending protrusion.

4. The camshaft phaser of claim **1**, further comprising:

respective fluid in said each chamber, wherein:

said each seal in the first plurality of seals restricts flow of the respective fluid between the rotor and the respective radially inwardly extending protrusion; and,

said each seal in the second plurality of seals restricts flow of the respective fluid between the stator and a respective radially inwardly extending protrusion.

5. The camshaft phaser of claim **1**, further comprising:

a plurality of channels through the rotor, each channel leading to a respective chamber; and,

a respective check valve between said each channel and the respective chamber.

6. The camshaft phaser of claim **5**, wherein:

the plurality of channels are arranged to receive pressurized fluid at a first pressure; and,

each respective check valve is arranged to open to enable flow of the pressurized fluid into the respective chamber for pressure of the respective fluid less than the first pressure.

7. The camshaft phaser of claim **1**, further comprising:

a cover plate fixedly secured to an axial end of the stator; and,

a resilient element axially disposed between the cover and the rotor and in contact with the cover and the rotor.

8. The camshaft phaser of claim **7**, wherein the resilient element reacts against the cover and the rotor to oppose rotation of the rotor with respect to the stator.

9. The camshaft phaser of claim **1**, wherein:

for the advance mode, the displacement assembly is arranged to displace the first wedge plate in the first circumferential direction to enable rotation of the rotor, with respect to the stator, in the first circumferential direction; and,

for the retard mode, the displacement assembly is arranged to displace the second wedge plate in the second circumferential direction to enable rotation of the rotor, with respect to the stator, in the second circumferential direction.

10. The camshaft phaser of claim **9**, wherein:

to block rotation of the rotor, with respect to the stator, in the second circumferential direction, the displacement assembly is arranged to non-rotatably connect the rotor, the second wedge plate, and the stator; and,

to block rotation of the rotor, with respect to the stator, in the first circumferential direction, the displacement assembly is arranged to non-rotatably connect the rotor, the first wedge plate, and the stator.

11. The camshaft phaser of claim **1**, wherein:

the rotor includes first and second pluralities of ramps, respectively;

the first and second wedge plates include third and fourth pluralities of ramps engaged with the third and fourth pluralities of ramps, respectively;

for the advance mode:

the first plurality of ramps are arranged to slide along the third plurality of ramps in the first circumferential direction; and,

the displacement assembly is arranged to slide the fourth plurality of ramps along the second plurality of ramps in the first circumferential direction; and,

for the retard mode:

the second plurality of ramps are arranged to slide along the fourth plurality of ramps in the second circumferential direction; and,

the displacement assembly is arranged to slide the third plurality of ramps along the first plurality of ramps in the second circumferential direction.

12. A camshaft phaser, comprising:

a stator arranged to receive torque from an engine and including a plurality of radially inwardly extending protrusions;

a rotor arranged to be non-rotatably connected to a camshaft and including a plurality of radially outwardly extending protrusions;

a plurality of chambers, each chamber at least partially bounded by a respective radially inwardly extending protrusion and a respective radially outwardly extending protrusion circumferentially adjacent to the radially inwardly extending protrusion;

a plurality of channels through the rotor, each channel leading to a respective chamber;

a respective check valve between said each channel and the respective chamber;

a first plurality of seals, each seal in the first plurality of seals radially disposed between the rotor and a respective radially inwardly extending protrusion;

a second plurality of seals, each seal in the second plurality of seals radially disposed between the stator and a respective radially outwardly extending protrusion;

first and second wedge plates radially disposed between the rotor and the stator; and,

a displacement assembly arranged to:

for an advance mode, displace the first wedge plate to enable rotation of the rotor, with respect to the stator, in a first circumferential direction; and,

for a retard mode, displace the second wedge plate to enable rotation of the rotor, with respect to the stator, in a second circumferential direction opposite the first circumferential direction.

13. The camshaft phaser of claim **12**, further comprising:

respective fluid in said each chamber, wherein:

said each seal in the first plurality of seals restricts flow, in a circumferential direction, of the respective fluid between the rotor and the respective radially inwardly extending protrusion; and,

said each seal in the second plurality of seals restricts flow, in the circumferential direction, of the respective fluid between the stator and a respective radially outwardly extending protrusion.

14. The camshaft phaser of claim **12**, wherein:

the plurality of channels are arranged to receive pressurized fluid at a first pressure; and,

each respective check valve is arranged to open to enable flow of the pressurized fluid into the respective chamber for pressure of the respective fluid less than the first pressure.

15. The camshaft phaser of claim **12**, further comprising:

a cover plate fixedly secured to an axial end of the stator; and,

a resilient element axially disposed between the cover and the rotor and in contact with the cover and the rotor, wherein the resilient element reacts against the cover and the rotor to oppose rotation of the rotor with respect to the stator.

16. The camshaft phaser of claim **12**, wherein:

for the advance mode, the displacement assembly is arranged to displace the first wedge plate in the first circumferential direction to enable rotation of the rotor, with respect to the stator, in the first circumferential direction; and,

for the retard mode, the displacement assembly is arranged to displace the second wedge plate in the second circumferential direction to enable rotation of the rotor, with respect to the stator, in the second circumferential direction.

17. The camshaft phaser of claim **12**, wherein:

the rotor includes first and second pluralities of ramps, respectively;

the first and second wedge plates include third and fourth pluralities of ramps engaged with the third and fourth pluralities of ramps, respectively;

for the advance mode:

the first plurality of ramps are arranged to slide along the third plurality of ramps in a first circumferential direction; and,

the displacement assembly is arranged to slide the fourth plurality of ramps along the second plurality of ramps in the first circumferential direction; and, for the retard mode:

the second plurality of ramps are arranged to slide along the fourth plurality of ramps in a second circumferential direction, opposite the first circumferential direction; and,

the displacement assembly is arranged to slide the third plurality of ramps along the first plurality of ramps in the second circumferential direction.

18. A method of operating a camshaft phaser including: a stator including a plurality of radially inwardly extending protrusions, each radially inwardly extending protrusion including a radially outermost end; a rotor including a plurality of radially outwardly extending protrusions; a plurality of chambers, each chamber at least partially bounded by a respective radially inwardly extending protrusion and a respective radially outwardly extending protrusion circumferentially adjacent to the radially inwardly extending protrusion; and a plurality of seals, each seal in the plurality of seals disposed in a respective radially innermost end and facing the rotor in a first radial direction, the method comprising:

for each chamber in the plurality of pairs of chambers, flowing pressurized fluid, through a respective channel in the rotor, to said each chamber;

receiving, with the stator, first torque in a first circumferential direction from an engine; and,

for an advance mode:

receiving, with the rotor, second torque in the first circumferential direction;

displacing a first wedge plate, radially disposed between the stator and the rotor, in the first circumferential direction;

rotating the rotor, with respect to the stator, in the first circumferential direction;

for a first chamber included in each pair of chambers, opposing the rotation of the rotor in the first circumferential direction with the pressurized fluid; and,

restricting flow, in the second circumferential direction, of the pressurized fluid out of the first chamber radially between a seal included in the plurality of seals and the rotor.

19. The method of claim **18**, further comprising:

for a retard mode:

receiving, with the rotor, third torque in the second circumferential direction;

displace a second wedge plate, radially disposed between the stator and the rotor, in the second circumferential direction;

rotating the rotor, with respect to the stator, in the second circumferential direction;

for the first chamber, opposing the rotation of the rotor in the second circumferential direction with the pressurized fluid; and,

restricting flow, in the first circumferential direction, of the pressurized fluid out of the first chamber radially between the seal included in the plurality of seals and the rotor.

20. The method of claim **18**, further comprising:

for the advance mode:

frictionally engaging a resilient element with the rotor and a cover plate non-rotatably connected to the stator; and,

opposing, with the frictional engagement, the rotation of the rotor in the first circumferential direction; and,

for the retard mode:

frictionally engaging the resilient element with the rotor and the cover plate non-rotatably connected to the stator; and,

opposing, with the frictional engagement, the rotation of the rotor in the second circumferential direction.

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