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*[Continued on next page]*

(54) Title: CAM SHAFT PHASER WITH MID-POSITION AND RETARD LOCK POSITION

(57) Abstract: A cam shaft phaser, including: a stator including stops; a rotor rotatable with respect to the stator and including a plurality vanes extending radially outward from a body; a plurality of channels, each channel passing through a respective vane included in the plurality of vanes; and a plurality of pairs of advance and retard chambers at least partially formed by the plurality of radially inwardly extending stops and the plurality of vanes. Advance and retard chambers for each pair of advance and retard chambers are separated in a first circumferential direction by a respective vane from the plurality of vanes. Each channel connects the advance and retard chambers for said each pair of advance and retard chambers. The first plurality of channels are arranged to enable fluid flow through the first plurality of channels to displace the rotor from at least one circumferential position to a mid-lock or retard-lock position.

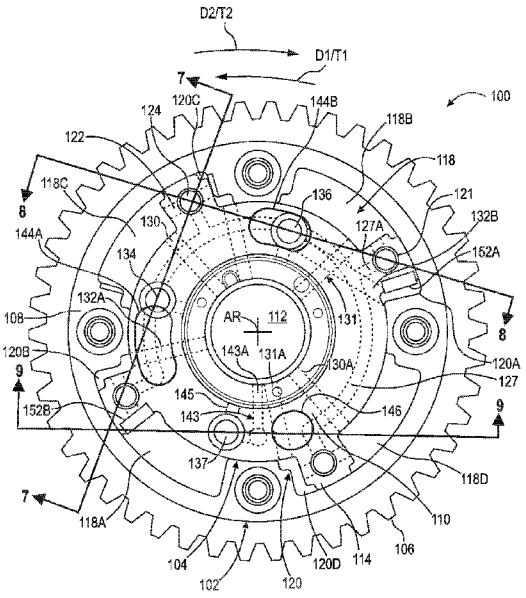



Fig. 4

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LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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# CAM SHAFT PHASER WITH MID-POSITION AND RETARD LOCK POSITION

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims the benefit under 35 U.S.C. §119(e) of U.S. Provisional Patent Application No. 62/120,555, filed February 25, 2015, which application is incorporated herein by reference in its entirety.

## TECHNICAL FIELD

**[0002]** The invention relates generally to a cam shaft phaser configured to adjust and lock a circumferential position of a rotor. In particular, the cam shaft phaser controls pressurized fluid flow between chambers in the rotor and uses cam shaft torsionals to displace the rotor to a mid-lock position or a retard-lock position and locks the rotor in the mid-lock position or retard-lock position.

## BACKGROUND

**[0003]** Pressurized fluid is supplied to advance and return chambers in a cam shaft phaser for an engine in a vehicle to control a circumferential position of a rotor for the phaser with respect to a stator for the phaser. As is known in the art, the position of the rotor is varied according to the requirements of the engine. In some instances, it is desirable for the rotor to be in a mid- position when an engine including the cam shaft phaser is started up. In some instances, it is desirable for the rotor to be in a fully retarded position when an engine including the cam shaft phaser is started up. However, the rotor can come to rest such that at start-up of the engine, the rotor is at neither the mid-position nor the fully retarded position.

## SUMMARY

**[0004]** According to aspects illustrated herein, there is provided a cam shaft phaser, including: a stator including a plurality of radially inwardly extending stops; a rotor rotatable with respect to the stator and including a body with an opening through which an axis of rotation for the cam shaft phaser passes and a plurality vanes extending radially outward from the body; a first plurality of channels, each channel in the first plurality of channels passing through a respective vane included in the plurality of vanes; and a plurality of pairs of advance and retard chambers at least partially formed by the plurality of radially inwardly extending stops and the

plurality of vanes. Advance and retard chambers for each pair of advance and retard chambers are separated in a first circumferential direction by a respective vane from the plurality of vanes. Each channel connects the advance and retard chambers for said each pair of advance and retard chambers. The first plurality of channels are arranged to enable fluid flow through the first plurality of channels to displace the rotor from at least one circumferential position to a mid-lock or retard-lock position.

**[0005]** According to aspects illustrated herein, there is provided a cam shaft phaser, including: a stator including a plurality of radially inwardly extending stops; a rotor rotatable with respect to the stator and including a body with an opening through which an axis of rotation for the cam shaft phaser passes and a plurality vanes extending radially outward from the body; a first plurality of channels, each channel in the first plurality of channels passing through a respective vane included in the plurality of vanes; a first plurality of pins; and a plurality of pairs of advance and retard chambers at least partially formed by the plurality of radially inwardly extending stops and the plurality of vanes. Each vane includes a respective pin from the first plurality of pins partially disposed in the respective channel from the first plurality of channels. The first plurality of pins is displaceable to open the first plurality of channels to displace the rotor from the at least one first circumferential position to a retard-lock position; advance and retard chambers for each pair of advance and retard chambers are separated in a first circumferential direction by a respective vane from the plurality of vanes; Each channel connects the advance and retard chambers for said each pair of advance and retard chambers. The first plurality of channels are arranged to be opened to enable fluid flow through the first plurality of channels to displace the rotor from at least one circumferential position to a retard-lock position. In the retard-lock position, the rotor is rotated to a full extent possible in a direction from respective advance chambers to the respective retard chambers in the plurality of pairs of advance and retard chambers.

**[0006]** According to aspects illustrated herein, there is provided a method of operating a cam shaft phaser including a stator with a plurality of radially inwardly extending stops, a rotor rotatable with respect to the stator and with a body with an opening through which an axis of rotation for the cam shaft phaser passes and a plurality vanes extending radially outward from the body, a first plurality of channels with each channel in the first plurality of channels passing

through a respective vane included in the plurality of vanes, a plurality of pairs of advance and retard chambers at least partially formed by the plurality of radially inwardly extending stops and the plurality of vanes, a first pin, and a front cover with a first slot, the method including: displacing a first plurality of pins, at least partially disposed in the first plurality of channels to connect, with the first plurality of channels, the advance chamber in each pair of advance and retard chambers with the retard chamber in said each pair of advance and retard chambers; flowing pressurized fluid through the first plurality of channels and between the advance chamber in each pair of advance and retard chambers and the retard chamber in said each pair of advance and retard chambers; rotating, with the pressurized fluid, the rotor in a first circumferential direction to a retard-lock position in which the rotor is rotated to a full extent possible in the first circumferential direction; and displacing the first pin into the first slot to rotationally fix the rotor in the retard-lock position.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** The nature and position of operation of the present invention will now be more fully described in the following detailed description of the invention taken with the accompanying figures, in which:

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

Figure 2 is a rear view of a cam shaft assembly including a cam shaft phaser with mid-lock and retard-lock adjustment;

Figure 3 is a cross-sectional view generally along line 3-3 in Figure 2;

Figure 4 is a front view of the cam shaft phaser in Figure 2 with the rear cover removed and the rotor in an advanced position;

Figure 5 is a front view of the cam shaft phaser in Figure 2 with the rear cover removed and the rotor in a mid-lock position;

Figure 6 is a front view of the cam shaft phaser in Figure 4 with the rear cover removed and the rotor in a retard-lock position;

Figure 7 is a cross-sectional views generally along line 7-7 in Figure 4;

Figure 8 is a cross-sectional views generally along line 8-8 in Figure 4;

Figure 9 is a cross-sectional views generally along line 9-9 in Figure 4;

Figure 10 is a block diagram of an engine including the cam shaft phaser in Figure 2;

Figure 11 is a cross-sectional views generally along line 11-11 in Figure 5;

Figure 12 is a cross-sectional views generally along line 12-12 in Figure 5;

Figure 13 is a cross-sectional views generally along line 13-13 in Figure 5;

Figure 14 is a cross-sectional views generally along line 14-14 in Figure 5;

Figure 15 is a cross-sectional views generally along line 15-15 in Figure 6;

Figure 16 is a cross-sectional views generally along line 16-16 in Figure 6; and,

Figure 17 is a cross-sectional views generally along line 17-17 in Figure 6.

## DETAILED DESCRIPTION

**[0008]** At the outset, it should be appreciated that like drawing numbers on different drawing views identify identical, or functionally similar, structural elements of the invention. While the present invention is described with respect to what is presently considered to be the preferred aspects, it is to be understood that the invention as claimed is not limited to the disclosed aspect. The present invention is intended to include various modifications and equivalent arrangements within the spirit and scope of the appended claims.

**[0009]** Furthermore, it is understood that this invention 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 invention, which is limited only by the appended claims.

**[0010]** 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 invention belongs. Although any methods, devices or materials similar or equivalent to those described herein can be used in the practice or testing of the invention, the preferred methods, devices, and materials are now described.

**[0011]** Figure **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**.

**[0012]** 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**.

**[0013]** Figure 2 is a rear view of a cam shaft assembly including cam shaft phaser **100** with mid-lock and retard-lock adjustment.

**[0014]** Figure 3 is a cross-sectional view generally along line 3-3 in Figure 2.

**[0015]** Figure 4 is a front view of cam shaft phaser **100** in Figure 2 with the rear cover removed and the rotor in an advanced position.

**[0016]** Figure 5 is a front view of cam shaft phaser **100** in Figure 2 with the rear cover removed and the rotor in a mid-lock position.

**[0017]** Figure 6 is a front view of cam shaft phaser **100** in Figure 4 with the rear cover removed and the rotor in a retard-lock position. The following should be viewed in light of Figures 2 through 6. Cam shaft phaser **100** includes stator **102** and rotor **104** rotatable with respect to stator **102**. Phaser **100** also includes front cover **105,** rear cover **106**, and bolts **107** fixing stator **102**, cover **105** and cover **106** together. Stator **102** includes radially inwardly extending stops **108**. Rotor **104** includes body **110** with opening **112** through which axis of rotation **AR** for cam shaft phaser **100** passes, and vanes **114** extending radially outward from the

body. Cam shaft phaser **100** includes pairs **116** of advance chambers **118** and retard chambers **120**. Chambers **118** and **120** are at least partially formed by stator **102** and rotor **104**, in particular by stops **108** and vanes **114**.

**[0018]** In an example embodiment, rotor **104** includes slots **126** and channels **122** in vanes **114**. Each channel **122** connects the advance and retard chambers separated by the vane **114** in which the channel **122** is located. Each channel **122** is wholly surrounded by the vane **114** in which the channel is located and is open only to a slot **126** and the advance and retard chambers separated by the vane **114** in which the channel **122** is located. In an example embodiment, each vane **114** includes a pin **124** partially disposed in a respective channel **122** and a respective slot **126**. Each slot **126** is connected to a source of pressurized fluid by a respective portion **127A** of channel **127**.

**[0019]** Rotor **104** can come to rest or be actively operating in an advanced position (as shown in Figure 4), a mid, or mid-lock position (as shown in Figure 5) or a retarded, or retard-lock position (as shown in Figure 6). In Figure 5, the respective volumes of chambers **118** and **120** are equal or are different by a relatively nominal degree. Stated otherwise, vanes **114** are approximately half-way between circumferentially adjacent stops. In some circumstances, it is desirable to adjust the rotor to and lock the rotor in the mid-lock or retard-lock position. To displace rotor **104** to the desired locked positions of Figures 5 or 6, pins **124** are arranged to be displaced to open channels **122** as described below to enable flow between chambers **118** and **120**.

**[0020]** In an example embodiment, rotor **104** includes channels **130**, **131**, **132A**, and **132B**. Chambers **118B-D** are connected to opening **112** with a respective channel **130**. Retard chambers **120B-D** are connected to opening **112** with a respective channel **131**. Channels **130** and **131** are used to supply pressurized fluid to and drain fluid from chambers **118** and **120**, respectively. Chambers **118A** and **120A** are not directly supplied with pressurized fluid by channels **130** and **131**, respectively. Instead: channel **132A** connects chamber **118C** to chamber **118A** and is to supply pressurized fluid to and drain fluid from chamber **118C** to chamber **118A**; and channel **132B** connects chamber **120C** to chamber **120A** and is used to supply pressurized fluid to and drain fluid from chamber **120C** to chamber **120A**.

**[0021]** Cam shaft phaser **100** incudes pins **134**, **136** and **137**. Pins **134** and **136** are partially disposed in channels **132A** and **132B**, respectively. Pins **134** and **136** are disposed in slots **138A** and **138B**, respectively in body **110**. Pin **137** is disposed in slot **139** and is connected to a system for supplying pressurized fluid for the phaser (hereinafter referred to as "the fluid system") by channels **141**, **143** and **145**. The fluid system supplies fluid to and drains fluid from rotor **104** via openings 130A and 131A at opening 112 for channels 130 and 131, respectively. The fluid system supplies fluid to and drains fluid from slot 139 by opening 143A at opening 112.

**[0022]** Figure 7 is a cross-sectional views generally along line 7-7 in Figure 4.

**[0023]** Figure 8 is a cross-sectional views generally along line 8-8 in Figure 4.

**[0024]** Figure 9 is a cross-sectional views generally along line 9-9 in Figure 4. The following should be viewed in light of Figures 2 through 9. In Figure 4, phaser **100** is in an advanced position and it is desired to lock the rotor in the mid-lock or retard-lock position. Figures 7 through 9 illustrates the adjustment of the rotor in direction D2 from the position in Figure 4 to the mid-lock position in Figure 5 or the retard-lock position of Figure 6.

**[0025]** To initiate the adjustment to the mid-lock position or retard-lock position, channels **127** and portions **127A** are connected to the fluid system so that there is little or nominal fluid pressure in channels **127** and portions **127A**. As a result, springs **128** displace pins **124** in direction **AD1** so that slots **124A** are aligned with channels **122** to enable flow through channels **122** and between chambers **118** and **120** as shown in Figure 7. The function of channels **122** is further described below. In addition, pin **134** is in contact with cover **106**, which aligns slot **134A** of pin **134** with channel **132A** to enable flow between chambers **118C** and **118A**.

**[0026]** As shown in Figure 8, springs **128** displace pins **124** in direction **AD1** so that slots **124A** are aligned with channels **122** to enable flow through channels **122** and between chambers **118** and **120**. Spring **142** pushes pin **136** in direction **AD1** so that slots **136A** is misaligned with channel **132B** blocking flow through channel **132A**. As shown in Figure 9, pin **137** is in contact with the front cover so pin **137** does not block rotation of the rotor. The locations of slots **144A** and **144B** in the rear cover plate are shown as they would be positioned in Figures 4 through 6. The location of slot **146** in the front cover is shown as a solid line in Figures 4 through 6 to clarify the presentation, given the number of dashed lines in the figures.

**[0027]** Phaser 100 includes check valve, or one-way valves 152A and 152B. Valve 152A is located at the opening of channel 122 at chamber 120A and valve 152B is located at the opening of channel 122 at chamber 118A. Valve 152A enables fluid flow from chamber 118B to chamber 120A, but blocks flow from chamber 120A to chamber 118B. Valve 152B enables fluid flow from chamber 120B to chamber 118A, but blocks flow from chamber 118A to chamber 120B.

**[0028]** Figure **10** is a block diagram of engine **E** including cam shaft phaser **100** in Figure 2 connected to camshaft **C** as is known in the art. The following provides further example detail regarding operation of cam shaft phaser **100**. In particular, the following describes the process of displacing the rotor from the position in Figure 4 to the mid-lock position shown in Figure 5 or the retard-lock position shown in Figure 6. The following sequence can occur as engine **E** is being turned off, as engine **E** is turned on, or as engine **E** is running.

**[0029]** Pressurized fluid is applied to channels **130**. As camshaft **C** rotates, the camshaft alternately transmits rotational torque **T1** and **T2** to rotor **104** in opposite directions **D1** and **D2**, respectively. That is, the camshaft transmits alternating "pulses" of torque **T1** and **T2** that urge the rotor in directions **D1** and **D2**, respectively. As further described below, each time torque **T1** rotates the rotor in direction D1, fluid flows through each chamber **118** to the respective chamber **120** through the respective channel **122** to enable the rotor to rotate in direction D1 and to fill the spaces in the chambers **120** created by the rotation. Thus, in particular, chamber **120A** expands in size and is filled with fluid. As torque T2 rotates in direction D2, the rotor is urged in direction D2. However, pin **136** is blocking channel **132B** and one-way valve **152A** prevents fluid from passing through the respective channel **122** from chamber **120A** to chamber **118B**. Thus, the rotor cannot rotate in direction D2 and the rotor remains in the position caused by the rotation due to torque T1.

**[0030]** The above process is repeated until the rotor has rotated to the position shown in Figure 5 or 6. For example: in response to the next iteration of torque T1, the rotor rotates further in direction D1, chamber **120A** expands in size, and chamber **120** is filled with fluid from chamber **118B**; and in response to the next iteration of torque T2, pin **136** and valve **152A** prevent fluid from draining from chamber **120A**, and the fluid in chamber **120A** prevents the rotor from rotating in direction D2.

**[0025]** The above procedure is used to rotate the rotor in direction D1 to the mid-lock position with the following changes. Pin **136** is in contact with the rear cover to open channel **132B** and pin **134** is in slot **144A** to block channel **132**. For each iteration of torque T2, the rotor is displaced in direction D2 and chamber **118A** increases in size and is filled with fluid from chamber **120B**. For each iteration of torque T1, chamber **118A** blocks rotation of the rotor in direction D1 since pin **134** and check valve **152B** prevent fluid from draining from chamber **120B**.

**[0025]** In Figure 5, the sequence described above for Figures 4 through 9 has rotated the rotor to the mid-lock position shown in Figure 5. Channel **127** remains unpressurized. Therefore, pin **132** remains in slot **144A** in the rear cover and pins **134** is pushed into slot **144B** in the rear cover by springs **142**. Pin **134** blocks rotation of the rotor in direction D1 and pin **136** blocks rotation of the rotor in direction D2.

**[0031]** Figure **11** is a cross-sectional views generally along line **11-11** in Figure 5.

**[0032]** Figure **12** is a cross-sectional views generally along line **12-12** in Figure 5.

**[0033]** Figure **13** is a cross-sectional views generally along line **13-13** in Figure 5.

**[0034]** Figure **14** is a cross-sectional views generally along line **14-14** in Figure 5. The following should be viewed in light of Figures 2 through **14** and describes the transition from the mid-lock position to an operating position which enables controlled positioning of the rotor as needed for operation of a vehicle including phaser **100**. Pressurized fluid is supplied to channel **127** and portions **127A**. As shown in Figures **11** and **12**, the pressurized fluid overcomes the force applied by springs **128** and displaces pins **124** in direction AD2 so that slots **124A** and channels **122** are misaligned and pin 124 block fluid flow through the respective channels **122**. As shown in Figure **11**, the pressurized fluid in channel **127** has displace pin **134** in direction AD2 so that pin **134** does not interfere with rotation of the rotor. Slot **134A** and channel **132A** are aligned to enable flow from chamber **118C** to chamber **118A**.

**[0035]** As shown in Figure **12**, the pressurized fluid in channel **127** has displaced pin **136** in direction AD2 so that pin **136** does not interfere with rotation of the rotor. Slot **136A** and channel **132B** are aligned to enable flow from chamber **120C** to chamber **120A**. As seen in Figure **13**, pin **137** is in contact with the front cover. Pressurized fluid is supplied to slot **139** through channels **141**, **143**, and **145** to urge pin **137** in direction AD1 against the force applied by

spring **150**. Therefore, as the rotor rotates and pin **137** rotates into alignment with slot **146**, the pressurized fluid prevents pin **137** from displacing into slot **146**. As seen in Figure **14**, pressurized fluid in portion **127A** has displaced pins **124** in direction AD2 to misalign slots **124A** and channels **122** to prevent fluid flow through channels **122**.

**[0036]** Figure **15** is a cross-sectional views generally along line **15-15** in Figure 6.

**[0037]** Figure **16** is a cross-sectional views generally along line **16-16** in Figure 6.

**[0038]** Figure **17** is a cross-sectional views generally along line **17-17** in Figure 6. The following should be viewed in light of Figures 2 through **17**. Figures **15** through **17** show the configuration in the retard-lock position. In figures **15** through **17**, channel **127** and portions **127A** are not pressurized. As seen in Figures **15** and **16**, pins **124** are in contact with the rear cover. As seen in Figure **15**, pin **134** is displaced into slot **144A** by pin **142**. As seen in Figure **16**, pin **136** is in contact with the rear cover. As seen in Figure **17**, pin **137** is displaced into slot **146** by spring **150**. Pin **132** blocks rotation in direction D2 and pin **137** blocks rotation in at least direction D1.

**[0039]** The following describes a method of operating a cam shaft phaser such as cam shaft phaser **100**, including a stator 106 with radially inwardly extending stops 108, rotor 104 rotatable with respect to stator 106 and with body 110 with opening 112 through which axis of rotation AR for the cam shaft phaser passes and vanes 114 extending radially outward from the body, channels 122 with each channel 122 passing through a respective vane 114, pairs 116 of advance chambers 118 and retard chambers 120 at least partially formed by stops 108 and vanes 114, pin 137, and front cover 105 with slot 146, the method comprising: displacing pins 124, at least partially disposed channels 122 to connect, with channels 122, the advance chamber in each pair 116 with the retard chamber in each pair 116; flowing pressurized fluid: through channels 122 and between the advance chamber in each pair 116 and the retard chamber in each pair 116; rotating, with the pressurized fluid, the rotor in a first circumferential direction to a retard-lock position in which the rotor is rotated to a full extent possible in the first circumferential direction; and displacing pin 137 into slot 139 to rotationally fix the rotor in the retard-lock position.

**[0040]** Advantageously, cam shaft phaser **100** and a method using cam shaft phaser **100** addresses the problem noted above in which a rotor, such as rotor **104**, comes to rest, or is in a position too far advanced or too far retarded. As noted above, controlling the various pins,

channels and flow paths described above creates a ratcheting action that displaces the rotor into the mid-lock position. Further, it should be noted that the configuration and operation of cam shaft phaser **100** described above has no deleterious effect on normal operation of the phaser, for example, during normal operation of engine **E**, when the circumferential position of rotor **104** is modified according to the requirements of engine **E**, pins **124** block channels **122** and pins **134** and **136** are positioned so that channels **132A** and **132B**, respectively, are open.

**[0041]** 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 cam shaft phaser, comprising:

a stator including a plurality of radially inwardly extending stops;

a rotor rotatable with respect to the stator and including:

a body with an opening through which an axis of rotation for the cam shaft phaser passes; and,

a plurality vanes extending radially outward from the body;

a first plurality of channels, each channel in the first plurality of channels passing through a respective vane included in the plurality of vanes; and,

a plurality of pairs of advance and retard chambers at least partially formed by the plurality of radially inwardly extending stops and the plurality of vanes, wherein:

advance and retard chambers for each pair of advance and retard chambers are separated in a first circumferential direction by a respective vane from the plurality of vanes;

said each channel connects the advance and retard chambers for said each pair of advance and retard chambers; and,

the first plurality of channels are arranged to enable fluid flow through the first plurality of channels to circumferentially displace the rotor.

2. The cam shaft phaser of claim 1, wherein:

the stator is arranged to be rotated in the first circumferential direction;

the advance chamber for said each pair of advance and retard chambers is located past the retard chamber for said each pair of advance and retard chambers in the first circumferential direction; and,

the retard chamber for said each pair of advance and retard chambers is located past the advance chamber for said each pair of advance and retard chambers in a second circumferential direction, opposite the first circumferential direction.

3. The cam shaft phaser of claim 1, further comprising:

a rear cover including first and second slots;

a front cover including a third slot; and,

first, second, and third pins, wherein:

in a mid-lock position, the first and second pins are arranged to displace into the first and second slots, respectively, to block rotation of the rotor;

in a retard-lock position, the third pin is arranged to displace into the third slot to block rotation of the rotor in at least one circumferential direction;

in the mid-lock position, said each respective vane is approximately mid-way between circumferentially adjacent stops included in the plurality of stops; and,

in the retard-lock position, said each respective vane is proximate a respective stop, included in the plurality of stops, forming a portion of a retard chamber for said each pair of advance and retard chambers.

4. The cam shaft phaser of claim 1, further comprising:

a first plurality of pins, wherein:

each respective vane includes a respective pin from the first plurality of pins:

the respective pin is partially disposed in said each channel in the first plurality of channels; and,

the first plurality of pins is displaceable to:

enable the fluid flow through the first plurality of channels; and,

block the fluid flow through the first plurality of channels.

5. The camshaft assembly of claim 1, further comprising:

second and third pluralities of channels in the body of the rotor; and,

first and second channels in the body of the rotor, wherein:

with the exception of a first advance chamber, every advance chamber included in the plurality of pairs of advance and retard chambers is connected to the opening with a respective channel from the second plurality of channels;

with the exception of a first retard chamber, every retard chamber included in the plurality of pairs of advance and retard chambers is connected to the opening with a respective channel from the third plurality of channels;

the first channel connects the first advance chamber to a second advance chamber included in the plurality of pairs of advance and retard chambers; and,

the second channel connects the first retard chamber to a second retard chamber included in the plurality of pairs of advance and retard chambers.

6. The cam shaft phaser of claim 5, wherein the rotor includes first and second slots, the cam shaft phaser further comprising:

a cover plate with third and fourth slots:

a first pin at least partially disposed in the first channel and the first slot; and,

a second pin at least partially disposed in the second channel and the second slot, wherein to rotate the rotor from the at least one circumferential position to the mid-lock position the first pin is arranged contact the rear cover plate such that the first channel is open between the first and second advance channels, and the second pin is arranged to displace into the fourth slot to block the second channel.

7. The cam shaft phaser of claim 5, wherein the rotor includes first and second slots, the cam shaft phaser further comprising:

a cover plate with third and fourth slots:

a first pin at least partially disposed in the first channel and the first slot; and,

a second pin at least partially disposed in the second channel and the second slot, wherein to rotate the rotor from the at least one circumferential position to the mid-lock position the second pin is arranged contact the rear cover plate such that the through the second channel is open between the first and second retard chambers, and the first pin is arranged to displace into the third slot to block the second channel.

8. The cam shaft phaser of claim 5, wherein the body of the rotor includes first, second, and third slots, the cam shaft phaser further comprising:

a rear cover plate with third and fourth slots;

a front cover with a fifth slot;

a first pin at least partially disposed in the first channel and the first slot;

a second pin at least partially disposed in the second channel and the second slot; and,

a third pin, wherein:

to rotate the rotor from the at least one circumferential position to the retard-lock position:

the first pin is arranged to displace into the third slot to block fluid flow through the first channel; and,

the second pin is arranged to contact the rear cover plate such that fluid flow through the second channel is enabled; and,

in the retard-lock position, the third pin is arranged to displace into the fifth slot to block rotation of the rotor in at least one circumferential direction.

9. A cam shaft phaser, comprising:

a stator including a plurality of radially inwardly extending stops;

a rotor rotatable with respect to the stator and including:

a body with an opening through which an axis of rotation for the cam shaft phaser passes; and,

a plurality vanes extending radially outward from the body;

a first plurality of channels, each channel in the first plurality of channels passing through a respective vane included in the plurality of vanes;

a first plurality of pins; and,

a plurality of pairs of advance and retard chambers at least partially formed by the plurality of radially inwardly extending stops and the plurality of vanes, wherein:

said each vane includes a respective pin from the first plurality of pins partially disposed in the respective channel from the first plurality of channels;

the first plurality of pins is displaceable to open the first plurality of channels to displace the rotor from the at least one first circumferential position to a retard-lock position;

advance and retard chambers for each pair of advance and retard chambers are separated in a first circumferential direction by a respective vane from the plurality of vanes;

said each channel connects the advance and retard chambers for said each pair of advance and retard chambers;

the first plurality of channels are arranged to be opened to enable fluid flow through the first plurality of channels to displace the rotor from at least one circumferential position to the retard-lock position; and,

in the retard-lock position, the rotor is rotated to a full extent possible in a direction from respective advance chambers to the respective retard chambers in the plurality of pairs of advance and retard chambers.

10. A method of operating a cam shaft phaser including a stator with a plurality of radially inwardly extending stops, a rotor rotatable with respect to the stator and with a body with an opening through which an axis of rotation for the cam shaft phaser passes and a plurality vanes extending radially outward from the body, a first plurality of channels with each channel in the first plurality of channels passing through a respective vane included in the plurality of vanes, a plurality of pairs of advance and retard chambers at least partially formed by the plurality of radially inwardly extending stops and the plurality of vanes, a first pin, and a front cover with a first slot, the method comprising:

displacing a first plurality of pins, at least partially disposed in the first plurality of channels to connect, with the first plurality of channels, the advance chamber in each pair of advance and retard chambers with the retard chamber in said each pair of advance and retard chambers;

flowing pressurized fluid:

through the first plurality of channels; and,

between the advance chamber in each pair of advance and retard chambers and the retard chamber in said each pair of advance and retard chambers;

rotating, with the pressurized fluid, the rotor in a first circumferential direction to a retard-lock position in which the rotor is rotated to a full extent possible in the first circumferential direction; and,

displacing the first pin into the first slot to rotationally fix the rotor in the retard-lock position.

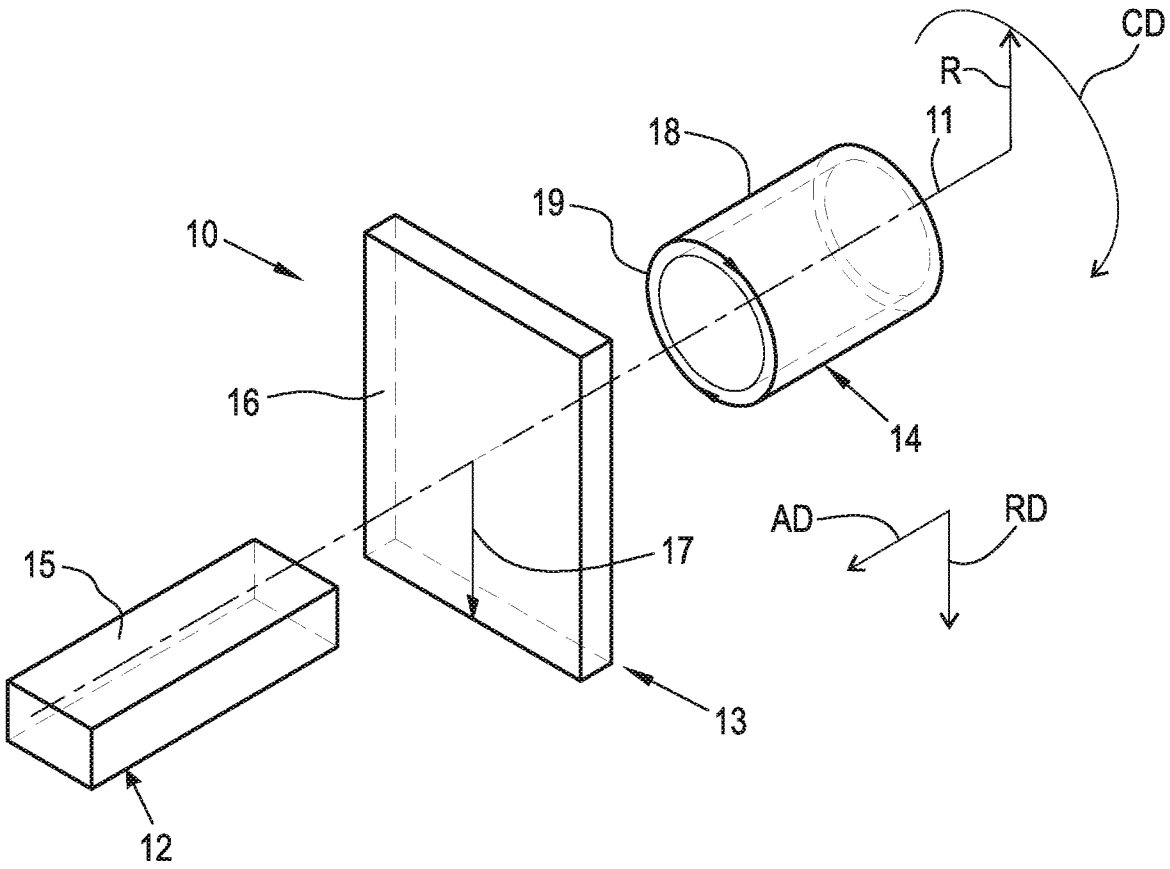



Fig.1

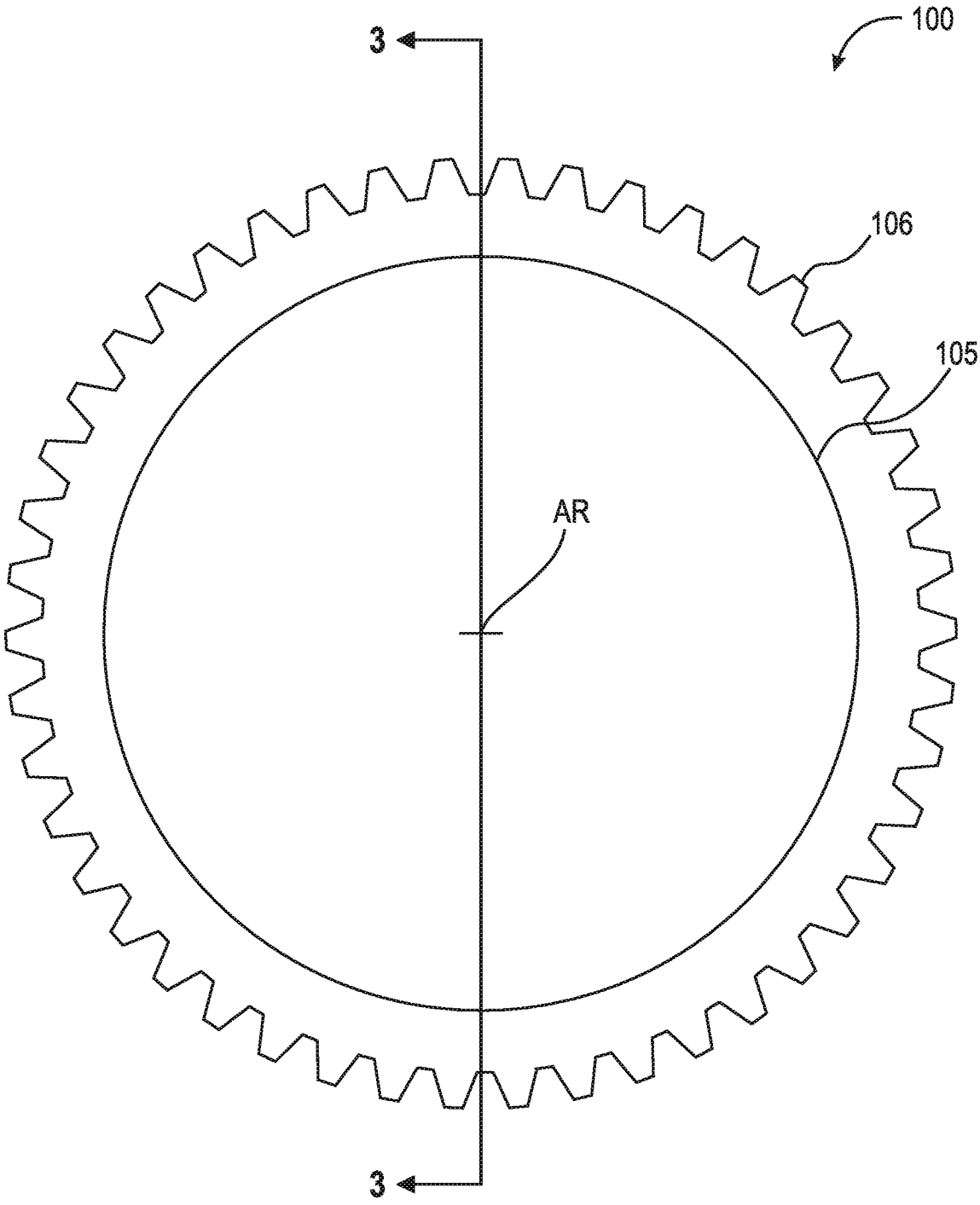



Fig. 2

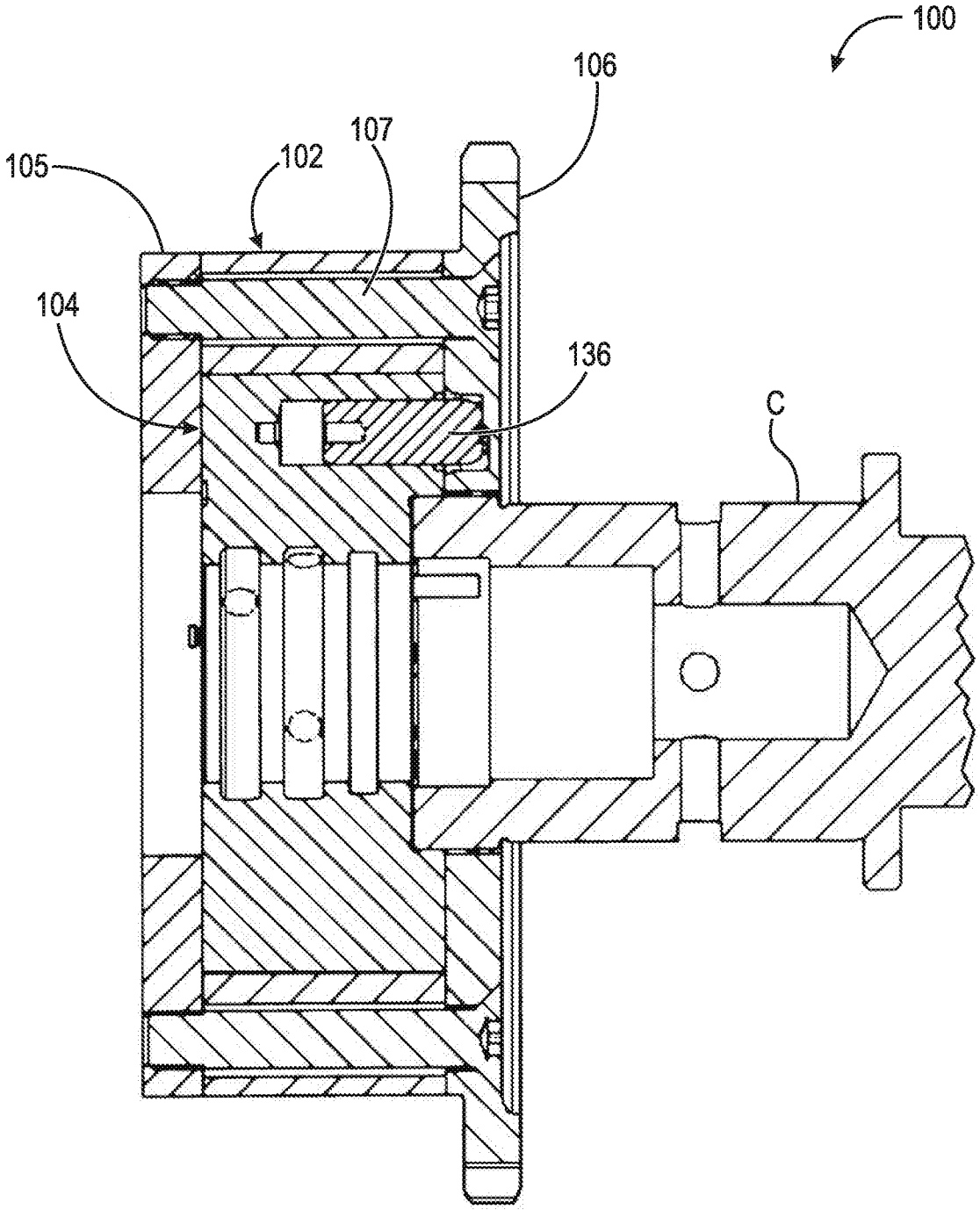



Fig. 3

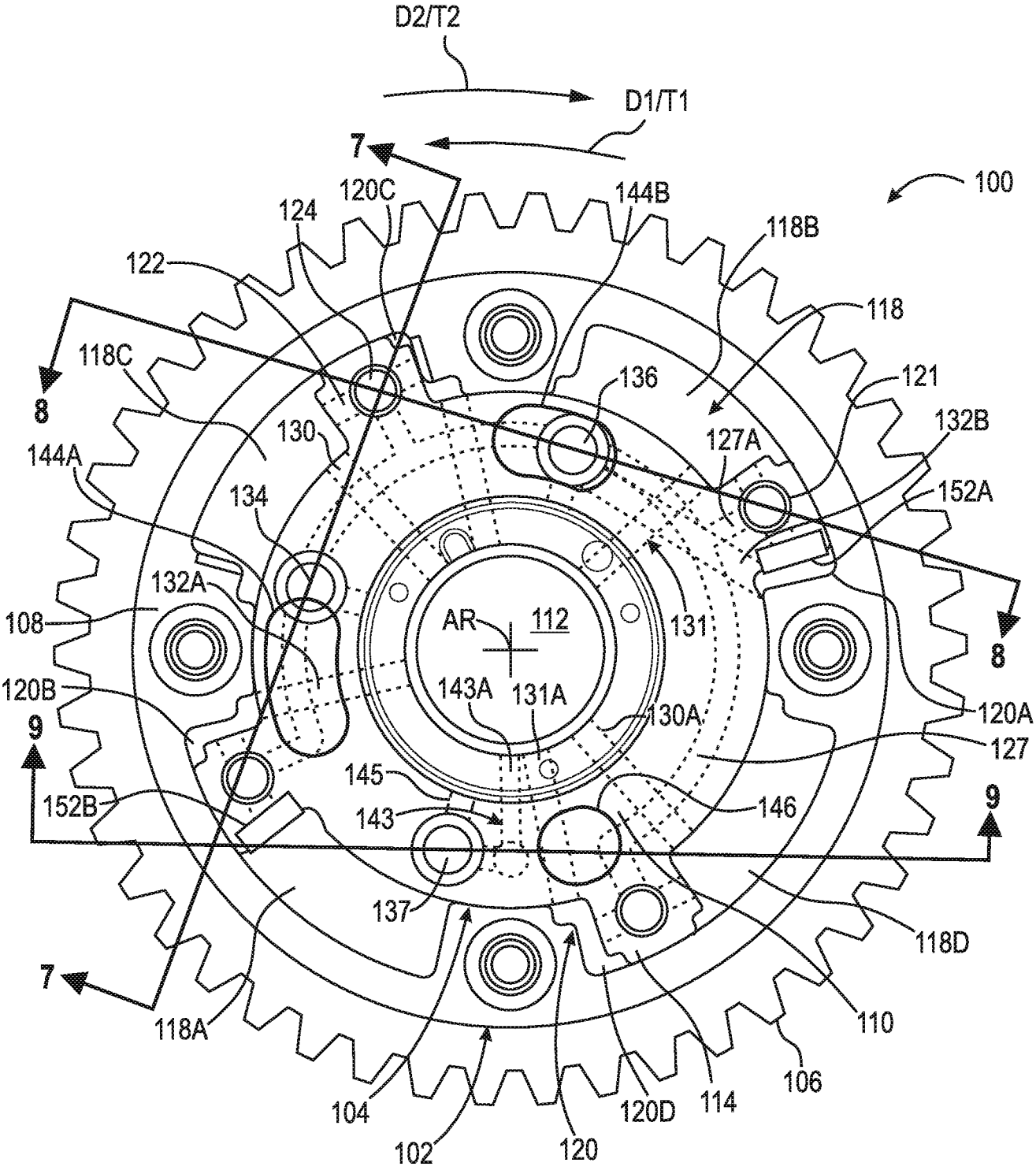

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Fig. 4

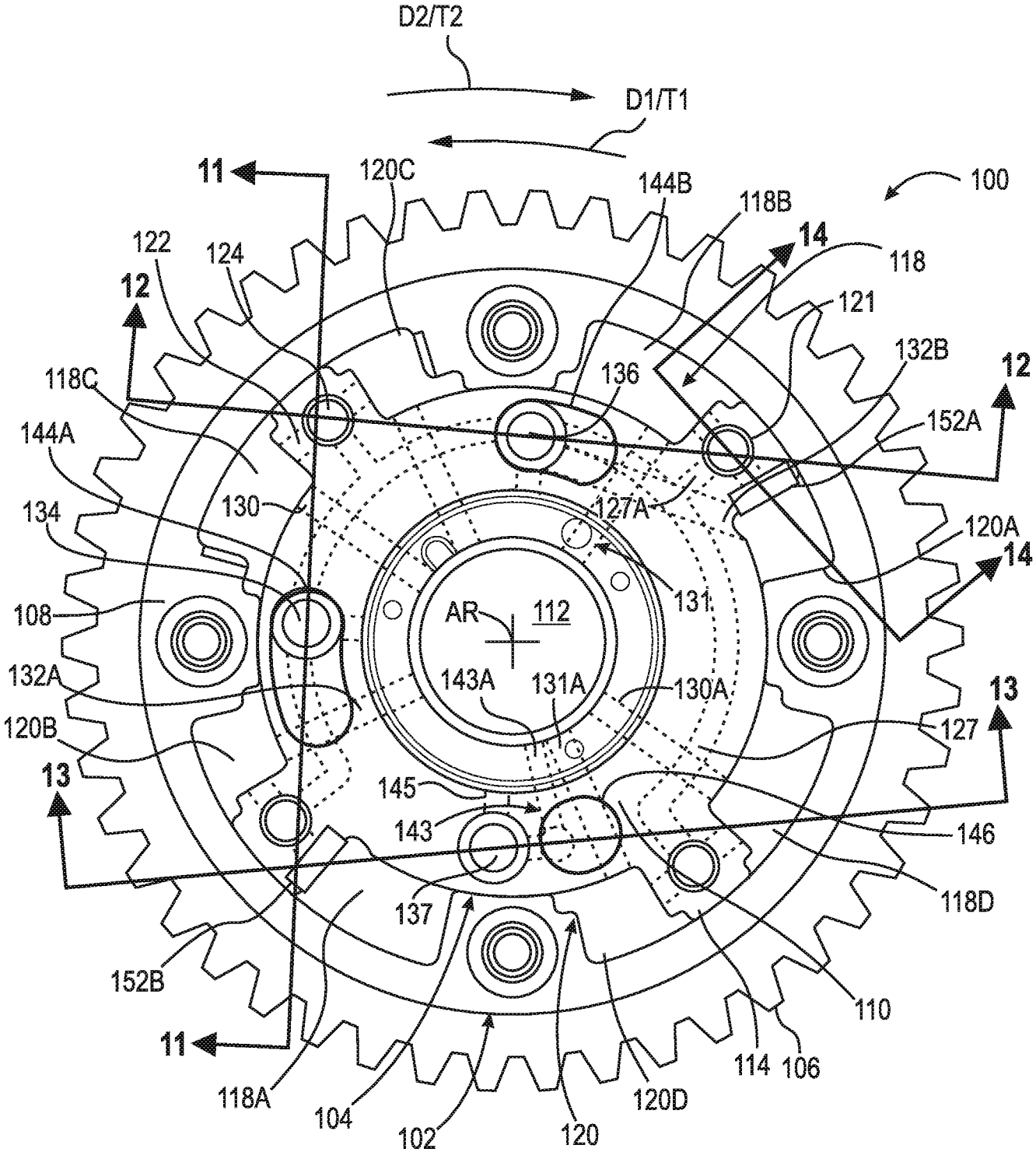

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Fig. 5

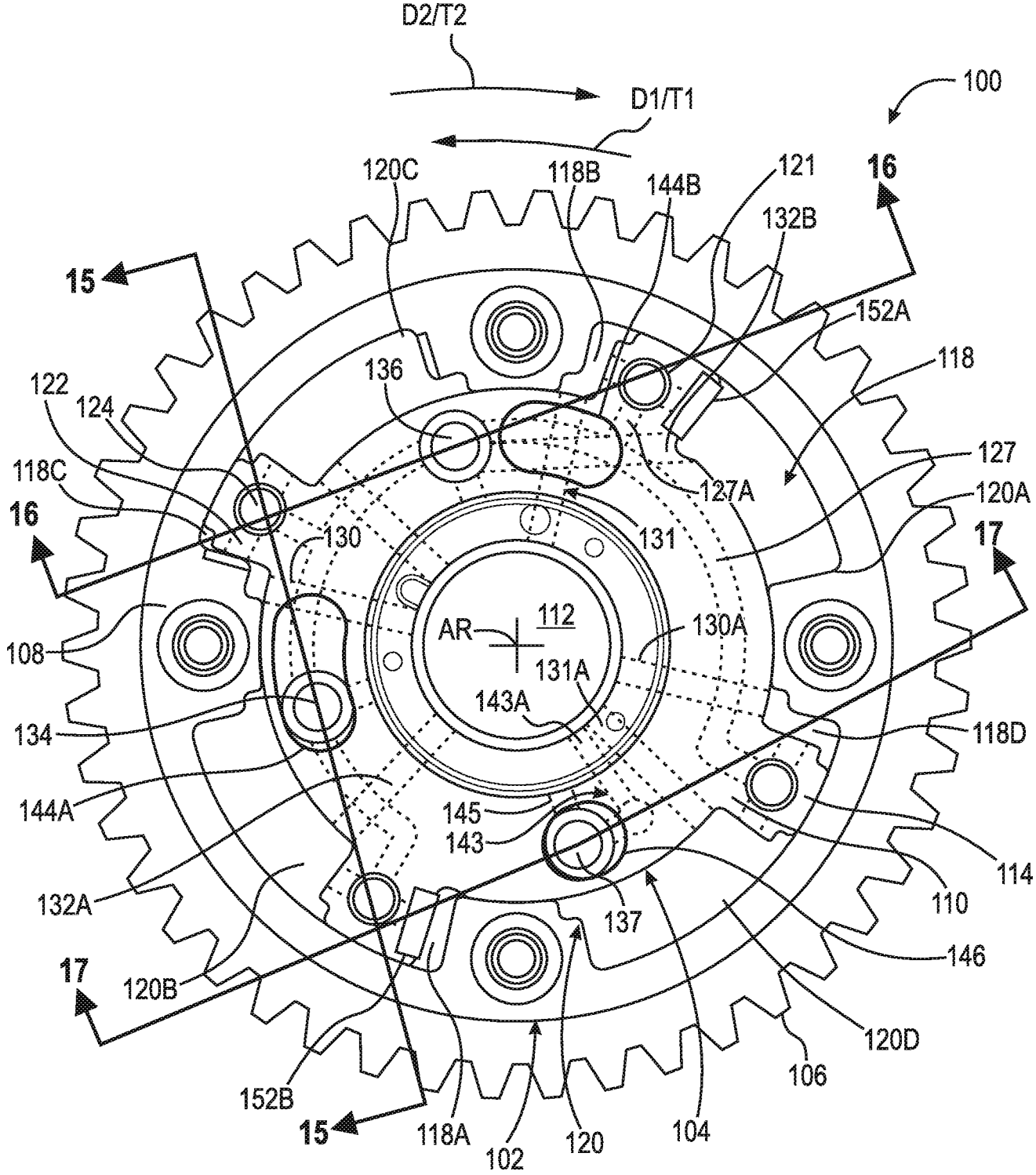

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Fig. 6

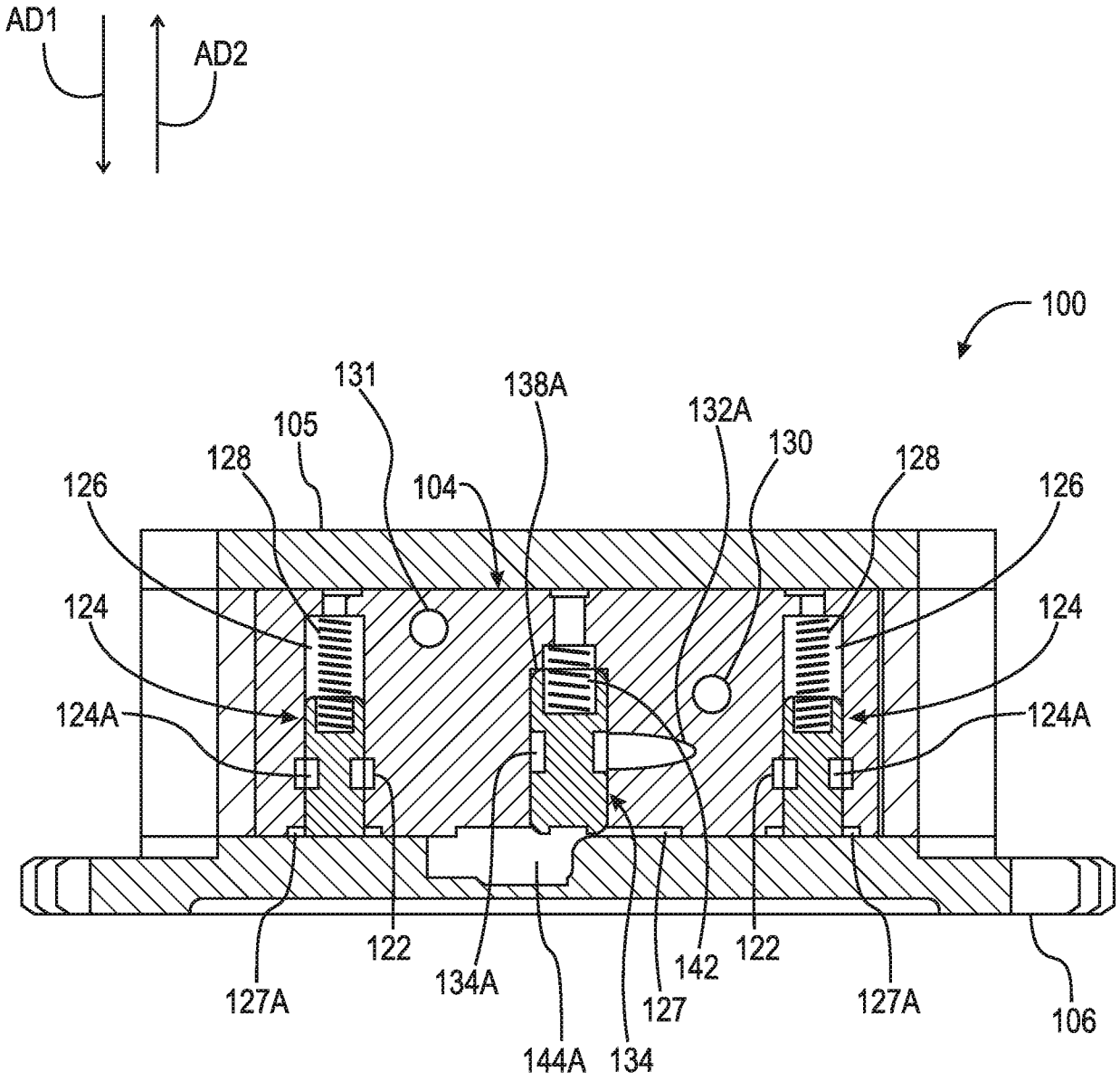

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Fig. 7

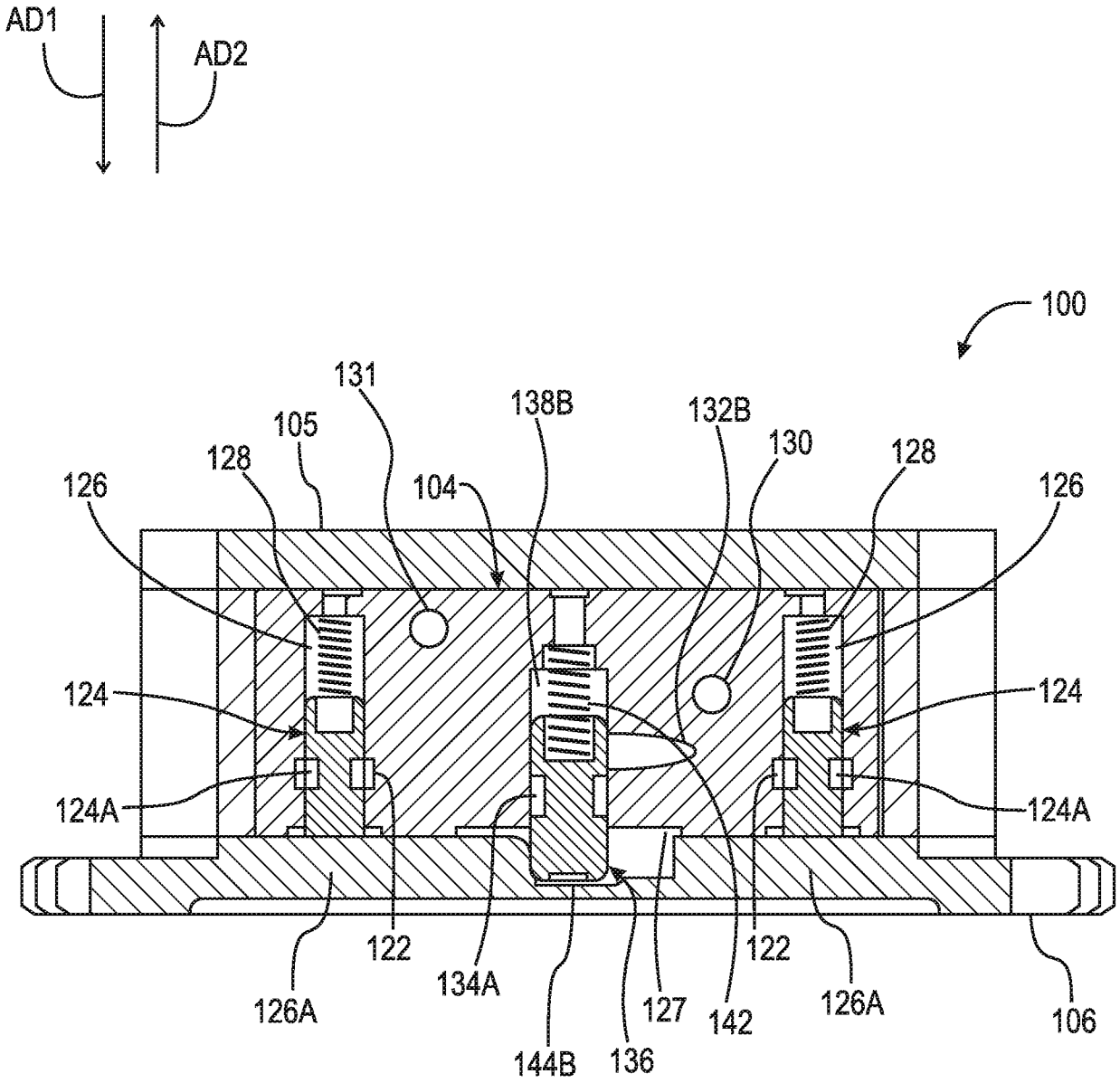

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Fig. 8

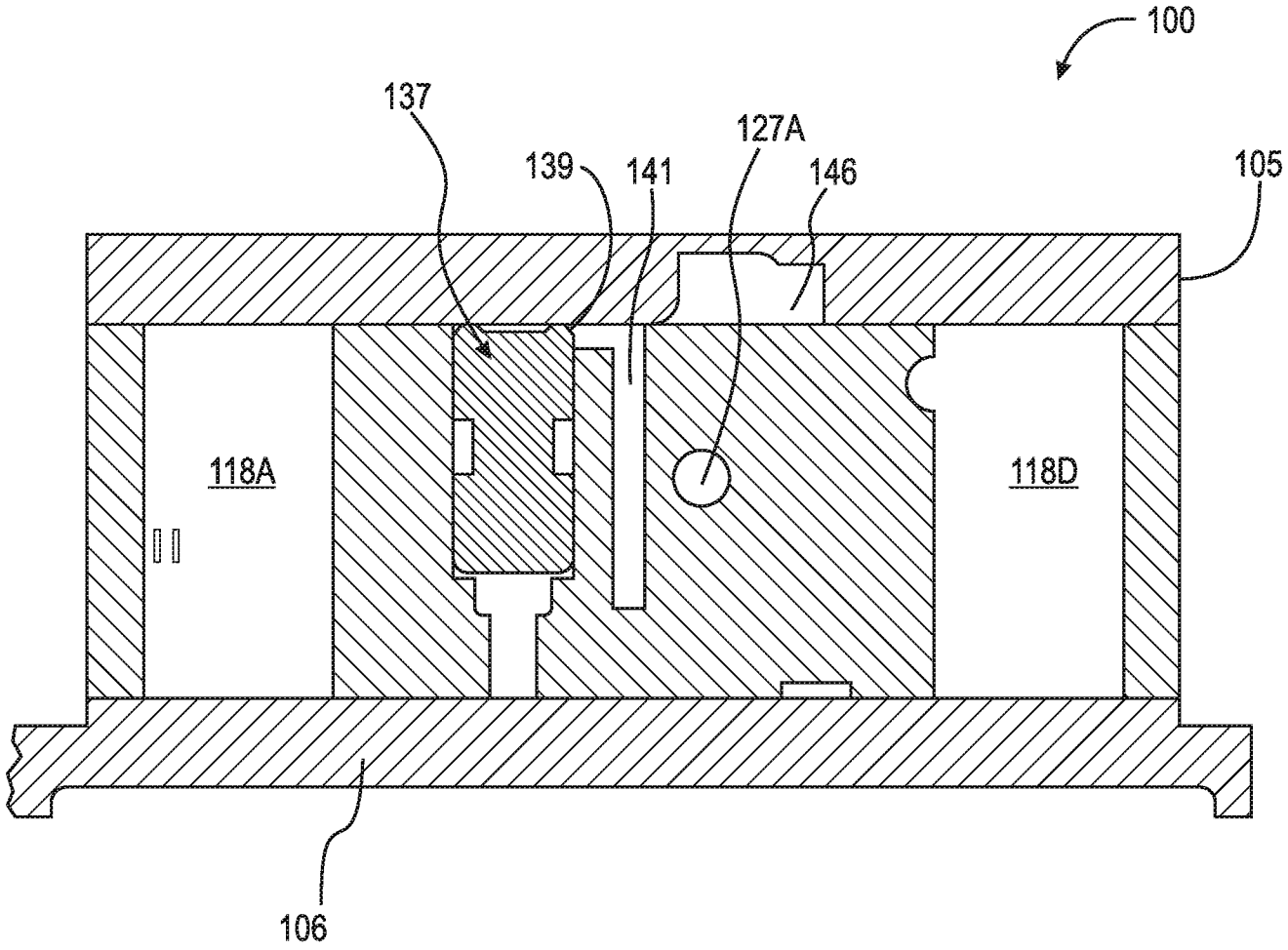



Fig. 9

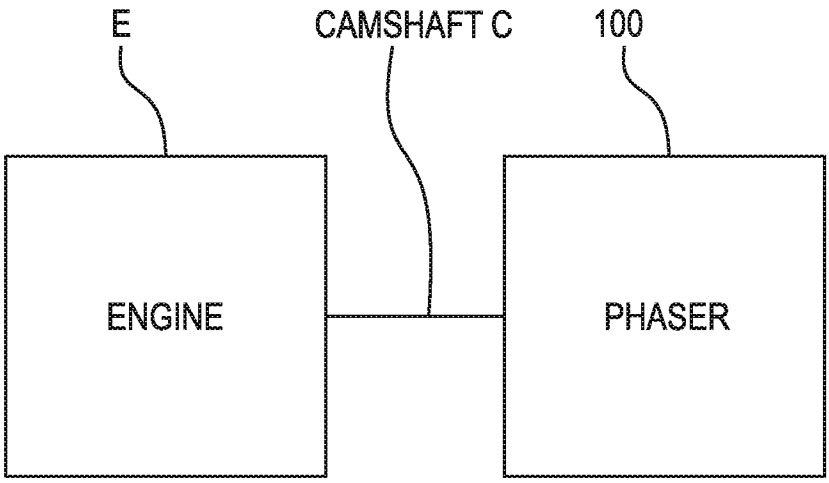



Fig. 10

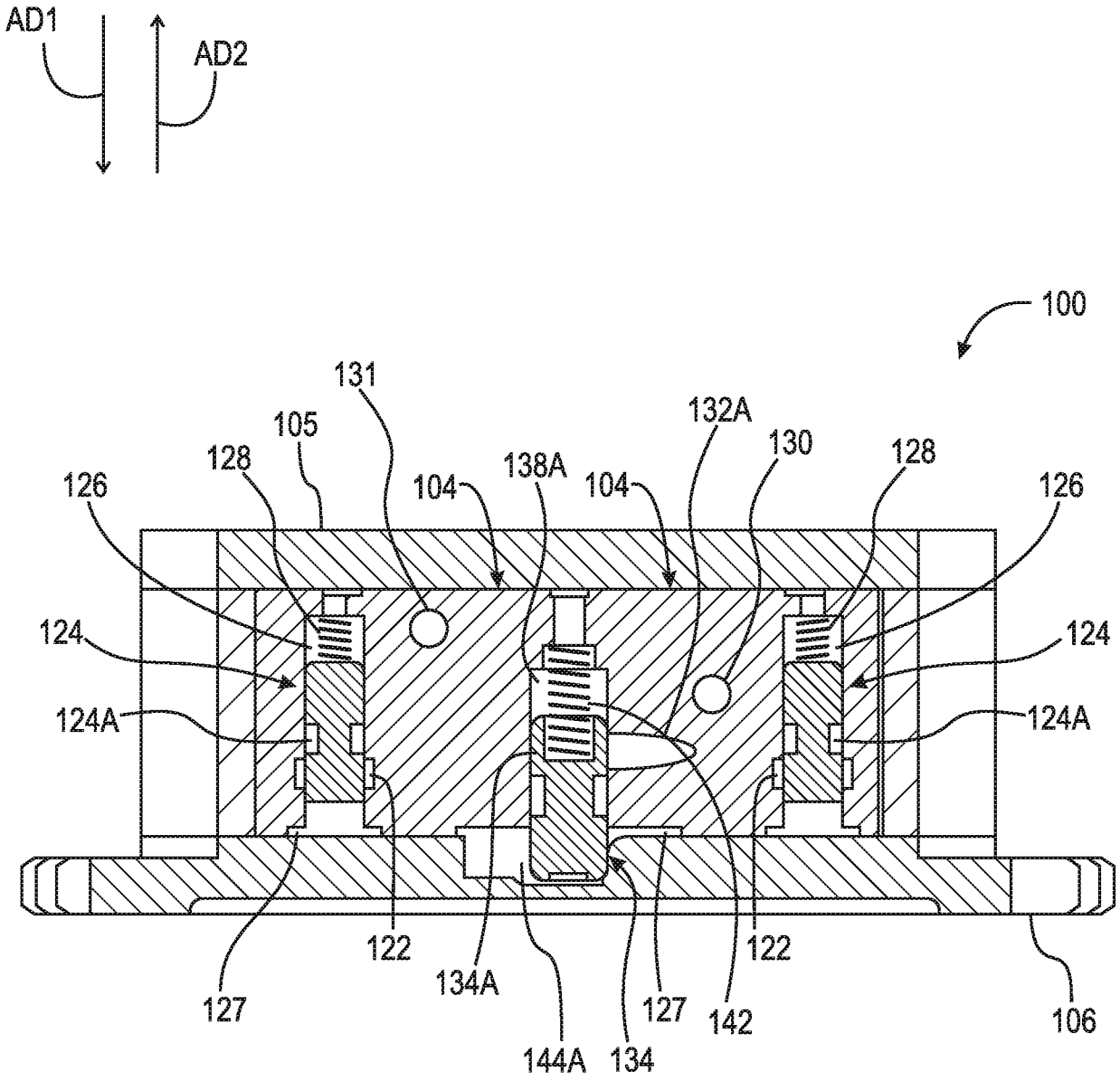

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Fig. 11

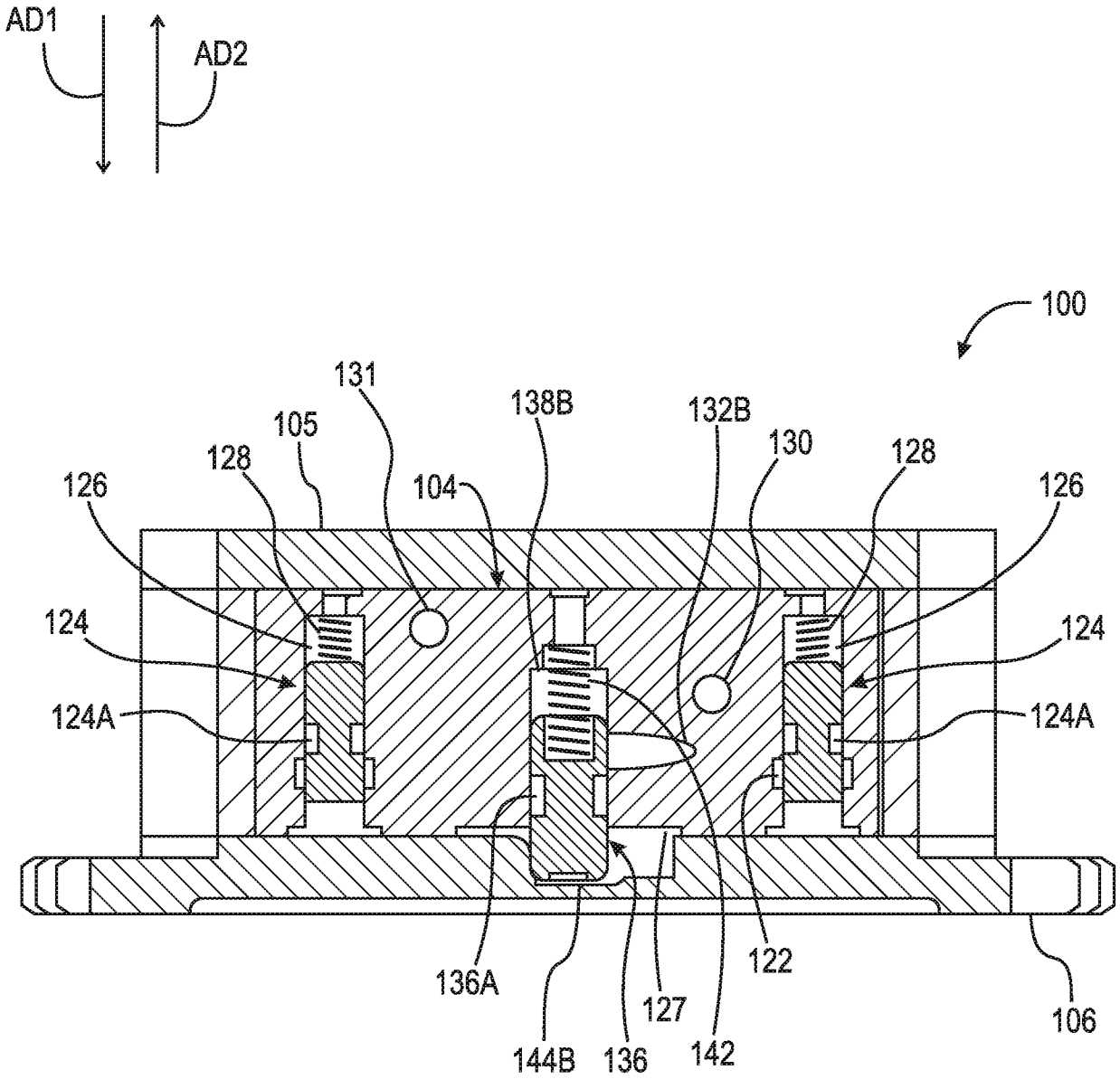

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Fig. 12

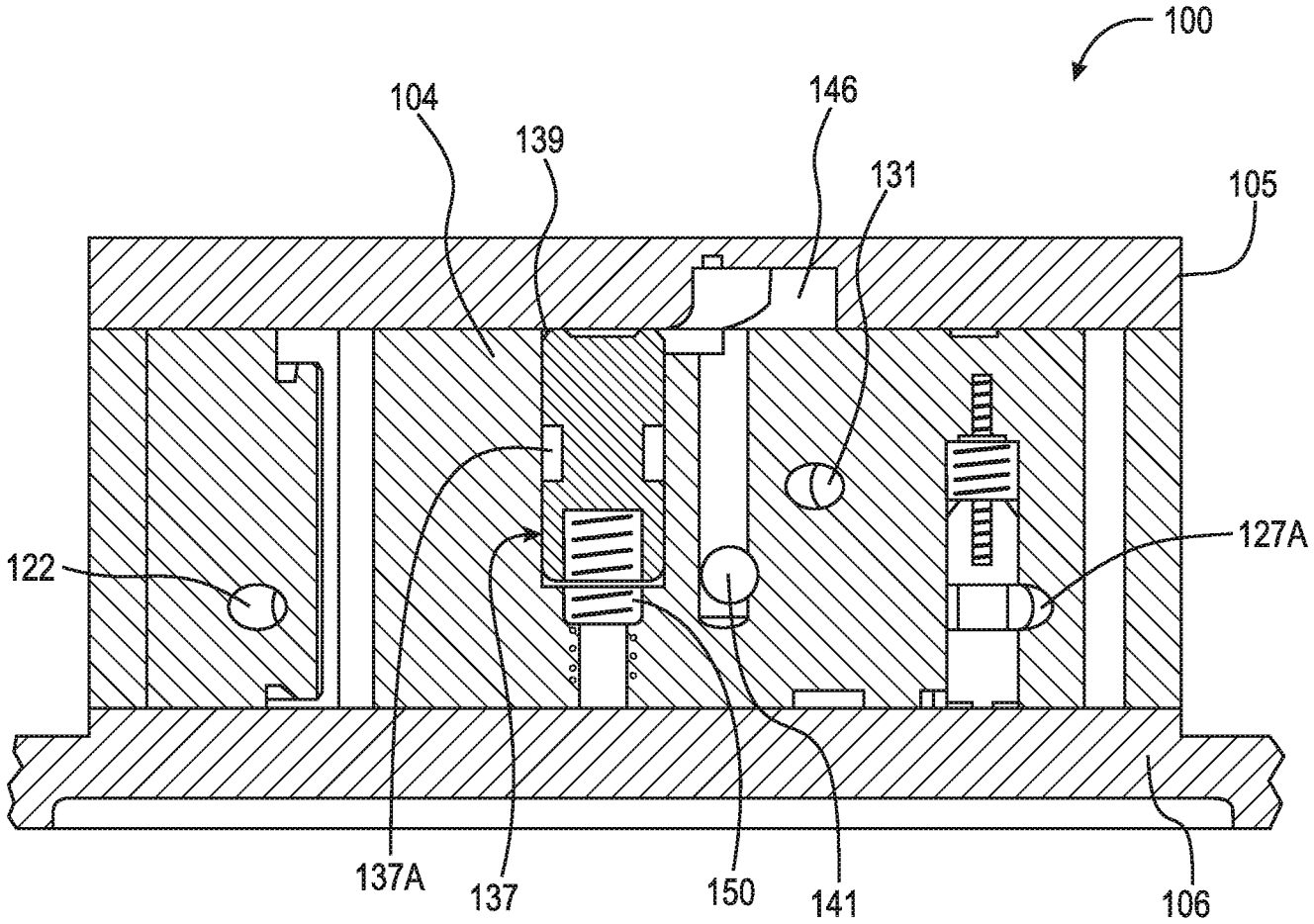



Fig. 13

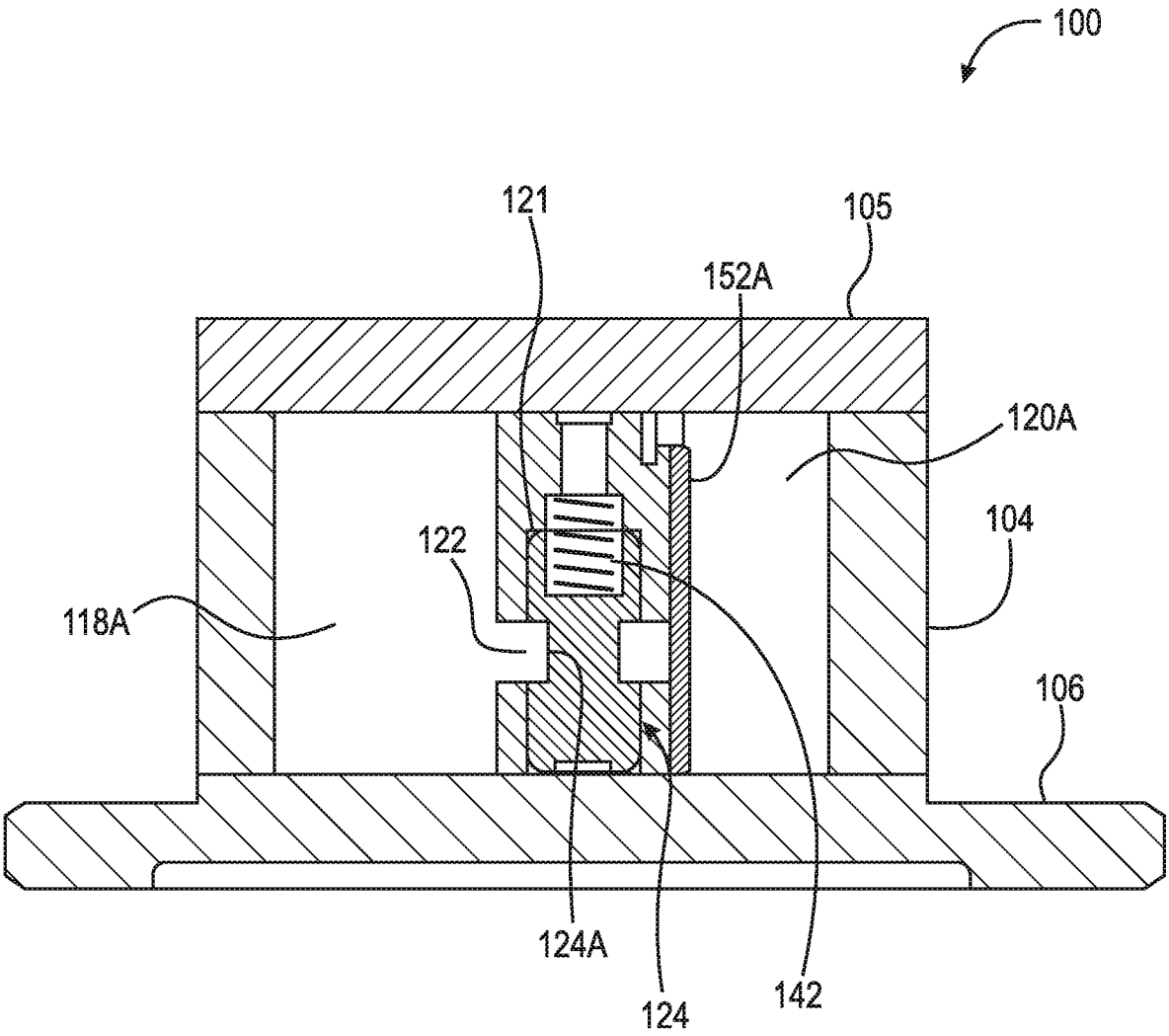



Fig. 14

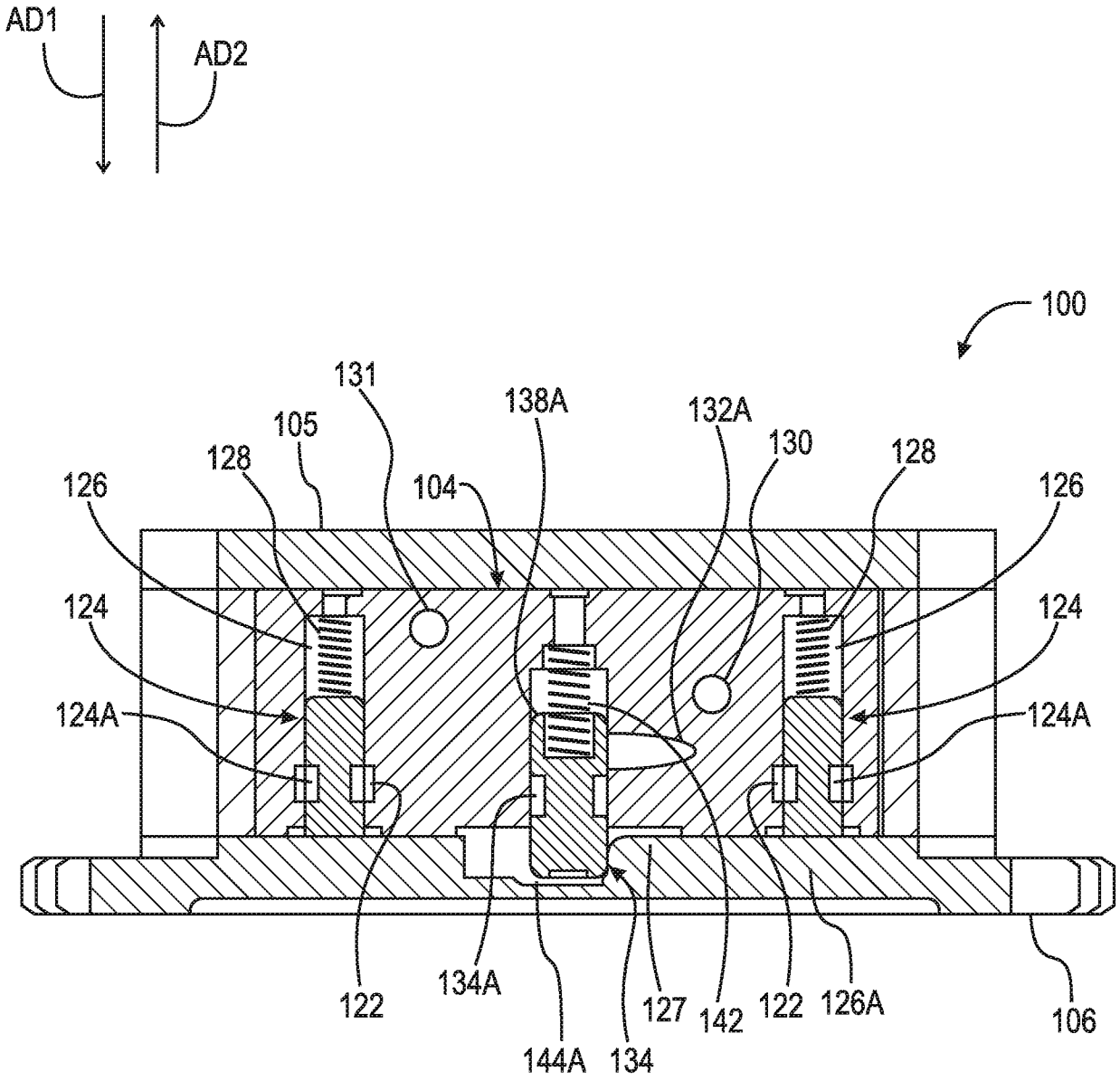

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Fig. 15

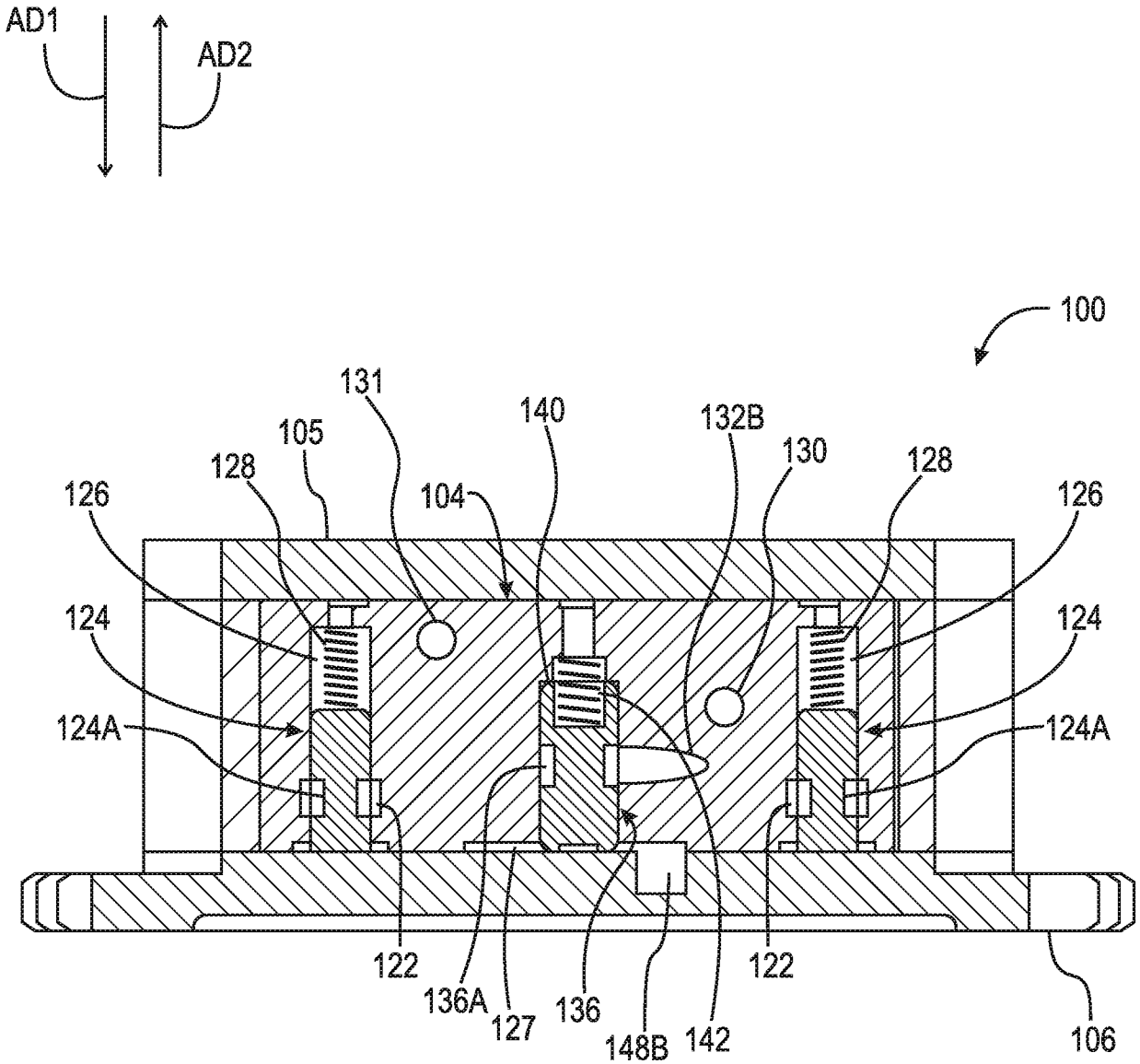

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Fig. 16

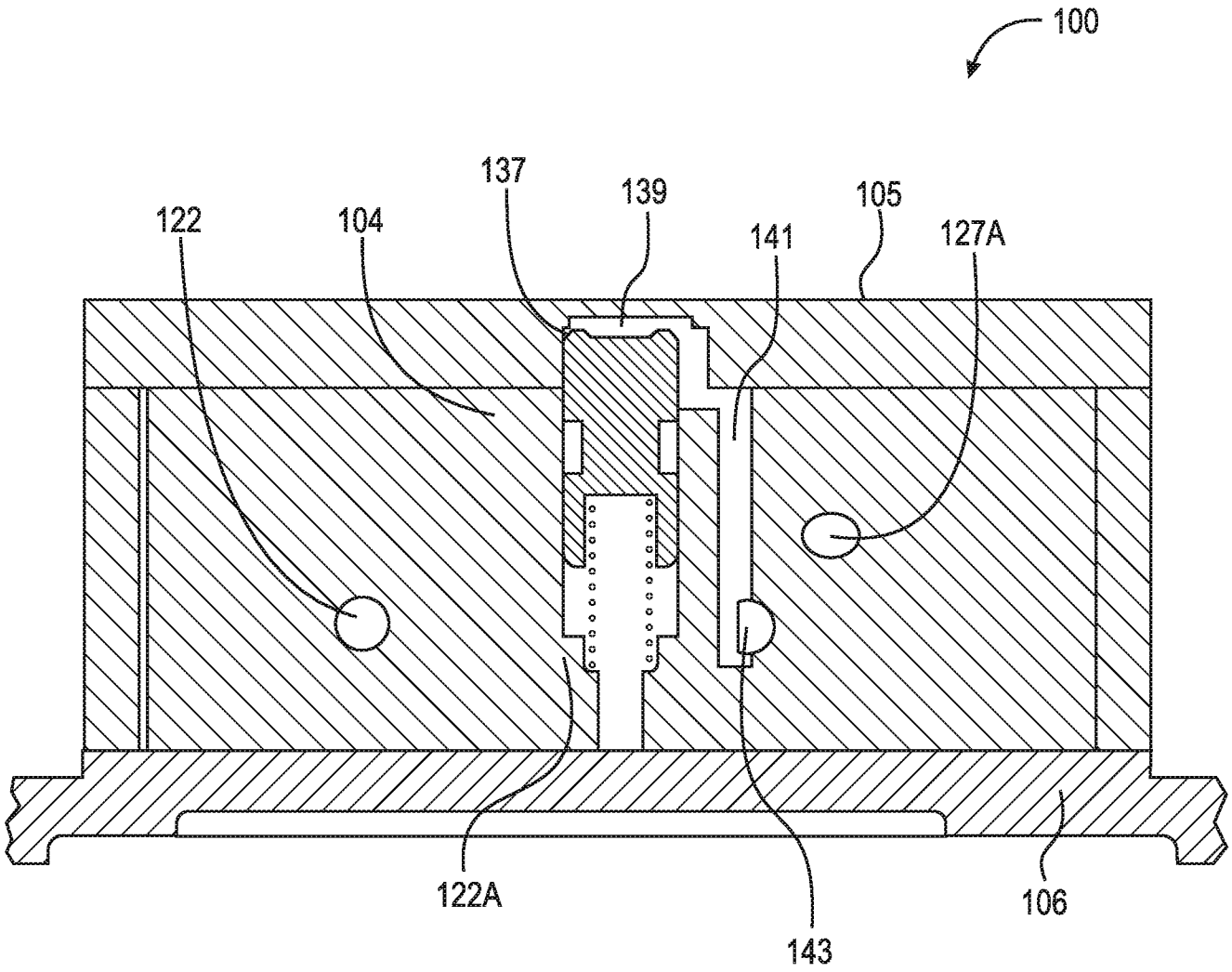



Fig. 17

**INTERNATIONAL SEARCH REPORT**

International application No.
**PCT/US2016/018694**

**A. CLASSIFICATION OF SUBJECT MATTER**

**F01L 1/344(2006.01)i, F01L 1/34(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
F01L 1/344; F02D 13/02; F01L 1/356; F01L 1/34

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: camshaft, phaser, stator, rotor, vane, channel, pin, advance chamber, retard chamber, and lock

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 2007-0107684 A1 (TAKAHASHI et al.) 17 May 2007<br>See paragraphs [0033]-[0070] and figures 1-6. | 1-2 |
| A | | 3-10 |
| Y | US 2013-0000576 A1 (TANAKA et al.) 03 January 2013<br>See paragraphs [0060]-[0061] and figures 1-5. | 1-2 |
| A | US 2014-0290606 A1 (KANAI, HIROSHI) 02 October 2014<br>See paragraphs [0011]-[0016] and figures 1-2. | 1-10 |
| A | JP 2014-240639 A (DENSO CORP.) 25 December 2014<br>See abstract, paragraphs [0027]-[0035], [0041]-[0044], and figures 3-5. | 1-10 |
| A | JP 2013-189910 A (NIPPON SOKEN INC. et al.) 26 September 2013<br>See abstract, paragraphs [0015]-[0020], and figures 2, 4-5. | 1-10 |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 19 May 2016 (19.05.2016) | **20 May 2016 (20.05.2016)** |


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Telephone No. +82-42-481-8440

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.
**PCT/US2016/018694**

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
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| | | JP 2007-138739 A | 07/06/2007 |
| | | JP 4459892 B2 | 28/04/2010 |
| | | US 7290510 B2 | 06/11/2007 |
| US 2013-0000576 A1 | 03/01/2013 | JP 2013-015057 A | 24/01/2013 |
| US 2014-0290606 A1 | 02/10/2014 | CN 103764958 A | 30/04/2014 |
| | | CN 103764958 B | 02/12/2015 |
| | | DE 112011105910 T5 | 18/09/2014 |
| | | JP 5725203 B2 | 27/05/2015 |
| | | US 9022000 B2 | 05/05/2015 |
| | | WO 2013-080359 A1 | 27/04/2015 |
| | | WO 2013-080359 A1 | 06/06/2013 |
| JP 2014-240639 A | 25/12/2014 | None | |
| JP 2013-189910 A | 26/09/2013 | None | |