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# (54) CAM PHASERS FOR INTERNAL COMBUSTION ENGINES

(57) An internal combustion engine (12) includes a plurality of pistons (16) housed in respective ones of a plurality of cylinders (14), an air intake system to provide air to the plurality of cylinders through respective ones of a plurality of intake valves (22), and an exhaust system to release exhaust gas from the plurality of cylinders through respective one of a plurality of exhaust valves (24). A cam phaser (90) is provided that is controllable to advance or retard the exhaust valve opening/closing timing by up to 90 crank angle degrees.

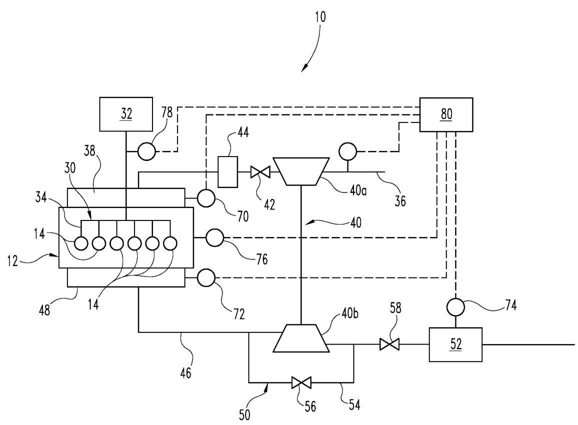

Fig. 1

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## Description

### Field of the Invention:

**[0001]** The present invention relates to internal combustion engines, and more particularly, but not exclusively, relates to cam phasers for internal combustion engines.

### BACKGROUND

**[0002]** Internal combustion engines can be controlled to attempt to achieve certain performance outputs during operation that are desirable for engine braking and/or in order to maintain desired operating temperatures for aftertreatment subsystems. For example, thermal management of the aftertreatment system and/or engine temperatures can provide operational benefits such as more efficient combustion processes, more effective aftertreatment device operations, and fuel economy. As a result, various engine braking and thermal management systems have been developed to better achieve these performance outputs.

**[0003]** Turbochargers with variable geometry (VG) inlets have been used to increase exhaust temperatures. However, VG turbochargers are costlier than wastegated turbochargers. Exhaust heaters can also be used, but require additional costs and a generator to create energy to run the heater. Exhaust throttles for engine braking and thermal management also require additional costs and have reliability concerns over time. Other strategies such as hydrocarbon (HC) dosing and cylinder deactivation have been used for thermal management of aftertreatment systems but could be more effective. These thermal management and engine braking strategies can this require multiple additional components to implement and therefore increase the cost and complexity of the system. Therefore, there is a continuing demand for further contributions in this area of technology.

### SUMMARY

**[0004]** Certain embodiments of the present application includes unique systems, methods and apparatus relating to internal combustion engines that include one or more cam phasers. The one or more cam phasers can be modulated or controlled to increase and/or decrease engine thermal output to provide thermal management of one or more aftertreatment components. The one or more cam phasers can also or alternatively be modulated or controlled to increase and/or decrease engine braking power. Other embodiments include unique apparatus, devices, systems, and methods involving cam phasers and internal combustion engines that employ the same.

**[0005]** In an embodiment, a cam phaser is disclosed for advancing and retarding exhaust valves of an internal combustion engine. The cam phaser includes a rotor including a hub and a plurality of vanes. The plurality of vanes extend radially outwardly from the hub. The cam phaser also includes a stator including a rim and a plurality of lugs. The plurality of lugs extend radially inwardly from the rim. The rotor is positioned in the stator so that each vane of the plurality of vanes is positioned between a corresponding pair of lugs of the plurality of lugs. Each vane of the rotor is positioned adjacent a first lug of the corresponding pair of lugs to fully retard the exhaust valves. Each vane of the rotor is positioned adjacent a second lug of the corresponding pair of lugs to fully advance the exhaust valves. The vanes of the rotor rotate 45 degrees from the fully retarded position to the fully advanced position.

**[0006]** In an embodiment, a method for braking an internal combustion engine includes receiving a charge flow into a plurality of cylinders of the internal combustion engine to produce an exhaust gas by combustion of a fuel provided to at least a portion of the plurality of cylinders. In response to an engine braking request, changing phase angles for camshafts that control an exhaust valve opening/closing timing and an intake valve opening/closing timing of one or more of the plurality of cylinders to increase a braking power of the engine.

**[0007]** In an embodiment, a method for thermally managing an aftertreatment device or an internal combustion engine includes producing an exhaust gas by combustion of fuel received in an air flow into at least a portion of a plurality of cylinders of the internal combustion engine. In response to a thermal management condition for the engine or aftertreatment device, the method includes changing a phase angle of an exhaust camshaft that controls an exhaust valve opening/closing timing by more than 80 crank angle degrees.

**[0008]** This summary is provided to introduce a selection of concepts that are further described below in the illustrative embodiments. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter. Further embodiments, forms, objects, features, advantages, aspects, and benefits shall become apparent from the following description and drawings.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0009]**

FIG. 1 is a schematic view of one embodiment of an internal combustion engine including a cam phaser.

FIG. 2 is a diagrammatic and schematic view of one embodiment of a cylinder of the internal combustion engine of FIG. 1 and a cam phaser.

FIG. 3 is a perspective view of an embodiment of a cam phaser connected to a camshaft for opening and closing the intake valves or the exhaust valves of the cylinder in FIG. 2.

FIG. 4 is an exploded perspective view of an embodiment of an exhaust cam phaser.

FIG. 5 is a perspective view of the exhaust cam phaser of FIG. 4.

FIG. 6 is a back elevation view of a rotor and stator assembly of the cam phaser of FIG. 4.

FIG. 7 is a front elevation view of the rotor and stator assembly of FIG. 6 mounted to a drive gear.

FIG. 8 is an elevation view of an embodiment of a vane or rotor seal.

FIG. 9 is a perspective view of an embodiment of a rotor and stator assembly for an intake cam phaser.

FIG. 10 is a schematic diagram of a portion of a fluid flow path for providing a control fluid to control a cam phaser.

FIG. 11 is a schematic diagram showing the control fluid flow paths to the rotor and stator assemblies of the intake camshaft and the exhaust camshaft.

FIG. 12 is a flow diagram of a procedure according to an embodiment of the present disclosure.

FIG. 13 is a flow diagram of another embodiment procedure according to the present disclosure.

## DETAILED DESCRIPTION OF REPRESENTATIVE EMBODIMENTS

**[0010]** While the present invention can take many different forms, for the purpose of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended. Any alterations and further modifications of the described embodiments, and any further applications of the principles of the invention as described herein are contemplated as would normally occur to one skilled in the art to which the invention relates.

**[0011]** Referring to FIGs. 1-11, a cam phaser 90 is disclosed for advancing and retarding exhaust valves 24 of an internal combustion engine 12. The cam phaser 90 includes a rotor 140 including a hub 142 and a plurality of vanes 144. The plurality of vanes 144 extend radially outwardly from the hub 142. The cam phaser 90 also includes a stator 170 including a rim 176 and a plurality of lugs 174. The plurality of lugs 174 extend radially inwardly from the rim 177. The rotor 140 is positioned in the stator 170 so that each vane 144 of the plurality of vanes 144 is positioned between a corresponding pair of lugs 174 of the plurality of lugs 174. Each vane 144 of the rotor 140 has a fully retarded position 192 adjacent a first lug 174 of the corresponding pair of lugs 174 to fully retard the exhaust valves 24. Each vane 144 of the rotor 140 has a fully advanced position 194 adjacent a second lug 174 of the corresponding pair of lugs 174 to fully advance the exhaust valves 24. The vanes 144 of the rotor 140 rotate 45 degrees from the fully retarded position 192 to the fully advanced position 194.

**[0012]** Referring further to FIG. 12, a method for braking internal combustion engine 12 includes receiving a charge flow into cylinders 14 of the internal combustion engine 12 to produce an exhaust gas by combustion of a fuel provided to at least a portion of the plurality of cylinders 14. In response to an engine-braking request, the method includes changing phase angles for camshafts 92, 192 that control an exhaust valve 24 opening/closing timing and an intake valve 22 opening/closing timing of one or more of the plurality of cylinders 14to increase a braking power of the engine 12.

**[0013]** Referring further to FIG. 13, a method for thermally managing an internal combustion engine 12 or aftertreatment device 52 includes producing an exhaust gas by combustion of fuel in at least a portion of a plurality of cylinders of the internal combustion engine 12. In response to a thermal management condition for the engine 12 or aftertreatment device 52, the method includes changing a phase angle of the exhaust camshaft 92 that controls the exhaust valve 24 opening/closing timing by more than 80 crank angle degrees.

**[0014]** With reference to FIGs. 1 and 2, a system 10 is disclosed that includes a four-stroke internal combustion engine 12. FIG. 1 illustrates an embodiment where the engine 12 is a diesel engine, but any engine type is contemplated, including compression ignition, spark-ignition, hydrogen, gasoline, natural gas, and combinations of these. The engine 12 can include a plurality of cylinders 14 that, as discussed further below, are operably connected with a cam phaser 90, 190 (FIG. 2) that adjusts the intake and/or exhaust valve opening and closing timing in response to a cam phaser position command.

**[0015]** FIG. 1 illustrates the plurality of cylinders 14 in an arrangement that includes six cylinders 14 in an in-line arrangement for illustration purposes only. Any number of cylinders and any arrangement of the cylinders suitable for use in an internal combustion engine can be utilized. The number of cylinders 14 that can be used can range from one cylinder to eighteen or more. Furthermore, the following description at times will be in reference to one of the cylinders 14. It is to be realized that corresponding features in reference to the cylinder 14 described in FIG. 2 and at other locations herein can be present for all or a subset of the other cylinders 14 of engine 12.

**[0016]** As shown in FIG. 2, the cylinder 14 houses a piston 16 that is operably attached to a crankshaft 18 that is rotated by reciprocal movement of piston 16 in a combustion chamber 28 of the cylinder 14. Within a cylinder head 20 of the cylinder 14, there is at least one intake valve 22, at least one exhaust valve 24, and a fuel injector 26 that provides fuel to the combustion chamber 28 formed by cylinder 14 between the piston 16 and the cylinder head 20. In other embodiments, fuel can be provided to combustion chamber 28 by port injection, or by injection in the intake system, upstream of combustion chamber 28.

**[0017]** The term "four-stroke" herein means the following four strokes - intake, compression, power, and exhaust - that the piston 16 completes during two separate revolutions of the engine's crankshaft 18. A stroke begins either at a top dead center (TDC) position when the piston 16 is at the top of cylinder head 20 of the cylinder 14, or at a bottom dead center (BDC) position, when the piston 16 has reached its lowest point in the cylinder 14.

**[0018]** During the intake stroke, the piston 16 descends away from cylinder head 20 of the cylinder 14 to a bottom (not shown) of the cylinder, thereby reducing the pressure in the combustion chamber 28 of the cylinder 14. A combustion charge is created in the combustion chamber 28 by an intake of air through the intake valve 22 when the intake valve 22 is opened.

**[0019]** In an embodiment, the fuel from the fuel injector 26 is supplied by a high pressure common-rail system 30 (FIG. 1) that is connected to the fuel tank 32. Fuel from the fuel tank 32 is suctioned by a fuel pump (not shown) and fed to the common-rail fuel system 30. The fuel fed from the fuel pump is accumulated in the common-rail fuel system 30, and the accumulated fuel is supplied to the fuel injector 26 of each cylinder 14 through a fuel line 34. The accumulated fuel in common rail system can be pressurized to boost and control the fuel pressure of the fuel delivered to combustion chamber 28 of each cylinder 14. Other embodiments contemplate any other type of fuel system for liquid and/or gaseous fuel.

**[0020]** During the compression stroke, in certain modes of operation, both the intake valve 22 and the exhaust valve 24 are closed. The piston 16 returns toward TDC and fuel is injected near TDC in the compressed air in a main injection event, and the compressed fuel-air mixture ignites in the combustion chamber 28 after a short delay. In the instance where the engine 12 is a diesel engine, this results in the combustion charge being ignited. The ignition of the air and fuel causes a rapid increase in pressure in the combustion chamber 28, which is applied to the piston 16 during its power stroke toward the BDC. Combustion phasing in combustion chamber 28 is calibrated so that the increase in pressure in combustion chamber 28 pushes piston 16, providing a net positive in the force/work/power of piston 16.

**[0021]** During the exhaust stroke, the piston 16 is returned toward TDC while the exhaust valve 24 is open. This action discharges the burnt products of the combustion of the fuel in the combustion chamber 28 and expels the spent fuel-air mixture (exhaust gas) out through the exhaust valve 24. As discussed further below, the cam phaser 90 can be adjusted to change the crank angle at which the exhaust valve 24 is opened and closed to vary the thermal output from engine 12 into the exhaust system. In addition, the cam phasers 90, 190 can be adjusted to change the crank angle at which both the intake valve 22 and the exhaust valve 24 is opened and closed to increase the braking power of engine 12, at least during certain operating conditions.

**[0022]** The intake air flows through an intake passage 36 and intake manifold 38 before reaching the intake valve 22. The intake passage 36 may be connected to a compressor 40a of a turbocharger 40 and an optional intake air throttle 42. The intake air can be purified by an air cleaner (not shown), compressed by the compressor 40a and then aspirated into the combustion chamber 28 through the intake air throttle 42. The intake air throttle 42 can be controlled to influence the air flow into the cylinders 14.

**[0023]** The intake passage 36 can be further provided with a cooler 44 that is provided downstream of the compressor 40a. In one example, the cooler 44 can be a charge air cooler (CAC). In this example, the compressor 40a can increase the temperature and pressure of the intake air, while the CAC 44 can increase a charge density and provide more air to the cylinders. In another example, the cooler 44 can be a low temperature aftercooler (LTA). The CAC 44 uses air as the cooling media, while the LTA uses coolant as the cooling media.

**[0024]** The exhaust gas flows out from the combustion chamber 28 into an exhaust passage 46 from an exhaust manifold 48 that connects the cylinders 14 to the exhaust passage 46. The exhaust passage 46 is connected to a turbine 40b and a wastegate 50 of the turbocharger 40 and then into an aftertreatment system 52. The exhaust gas that is discharged from the combustion chamber 28 drives the turbine 40b to rotate. The wastegate 50 is a device that enables part of the exhaust gas to by-pass the turbine 40b through a passageway 54. Less exhaust gas energy is thereby available to the turbine 40b, leading to less power transfer to the compressor 40a. Typically, this leads to reduced intake air pressure rise across the compressor 40a and lower intake air density/flow.

**[0025]** The wastegate 50 can include an electronically controllable valve 56 that can be an open/closed (two position) type of valve, or a full authority valve allowing control over the amount of by-pass flow, or anything between. In some embodiments, the exhaust passage 46 can further or alternatively include an exhaust throttle 58 for adjusting the flow of the exhaust gas through the exhaust passage 46. The exhaust gas, which can be a combination of by-passed and turbine flow, then enters the aftertreatment system 52.

**[0026]** The aftertreatment system 52 may include one or more devices useful for handling and/or removing material from exhaust gas that may be harmful constituents, including carbon monoxide, nitric oxide, nitrogen dioxide, hydrocarbons, and/or soot in the exhaust gas. In some examples, the aftertreatment system 52 can include at least one of a catalytic device and a particulate matter filter. The catalytic device can be a diesel oxidation catalyst (DOC) device, ammonia oxidation (AMOX) catalyst device, a selective catalytic reduction (SCR) device, three-way catalyst (TWC), lean NOX trap (LNT) etc. The reduction catalyst can include any suitable reduction catalysts, for example, a urea selective reduction catalyst. The particulate matter filter can be a diesel particulate filter (DPF), a partial flow particulate filter (PFF), etc. A PFF functions to capture the particulate matter in a portion of the flow; in contrast the entire exhaust gas volume passes through the particulate filter.

**[0027]** The arrangement of the components in the aftertreatment system 52 can be any arrangement that is suitable for use with the engine 12. For example, in one embodiment, a DOC and a DPF are provided upstream of a SCR device. In one example, a reductant delivery device is provided between the DPF and the SCR device for injecting a reductant into the exhaust gas upstream of SCR device. The reductant can be urea, diesel exhaust fluid, or any suitable reductant injected in liquid and/or gaseous form.

**[0028]** A controller 80 is provided to receive data as input from various sensors, and send command signals as output to various actuators. Some of the various sensors and actuators that may be employed are described in detail below. The controller 80 can include, for example, a processor, a memory, a clock, and an input/output (I/O) interface.

**[0029]** The system 10 may include various sensors such as an intake manifold pressure/temperature sensor 70, an exhaust manifold pressure/temperature sensor 72, one or more aftertreatment sensors 74 (such as a differential pressure sensor, temperature sensor(s), pressure sensor(s), constituent sensor(s)), engine sensors 76 (which can detect the air/fuel ratio of the air/fuel mixture supplied to the combustion chamber, a crank angle, the rotation speed of the crankshaft, an engine load, etc.), and a fuel sensor 78 to detect the fuel pressure and/or other properties of the fuel, common rail 38 and/or fuel injector 26. Any other sensors known in the art for an engine system are also contemplated, and one or more of the sensors can be a physical sensor or a virtual sensor.

**[0030]** System 10 can also include various actuators for opening and closing the intake valves 22, for opening and closing the exhaust valves 24, for injecting fuel from the fuel injector 26, for opening and closing the wastegate valve 56, for the intake air throttle 42, and/or for the exhaust throttle 58. The actuators are not illustrated in FIG. 1, but one skilled in the art would know how to implement the mechanism needed for each of the components to perform the intended function. Furthermore, in one embodiment, the actuators for opening and closing the intake and exhaust valves 22, 24 is operably connected to respective ones of an intake cam phaser 190 or an exhaust cam phaser 90, such as shown in FIG. 3.

**[0031]** Referring further to FIG. 3, further details regarding one embodiment of an exhaust or intake cam phaser 90, 190 is shown. Exhaust cam phaser 90 can adjust a relative positioning and timing of the exhaust valve opening and closing during a thermal management mode of operation to, for example, increase an exhaust gas temperature for thermal management of one or more components of the aftertreatment system 52. Exhaust cam phaser 90 can also adjust a relative positioning and timing of the exhaust valve opening and closing, in conjunction with intake cam phaser 190 adjusting the intake valve opening and closing, during an engine braking mode of operation to, for example, increase an engine braking power of engine 12.

**[0032]** As depicted in FIG. 3, cam phaser 90, 190 is shown with a camshaft 92, 192 that includes exhaust/intake camshaft lobe(s) 94, 194 and camshaft bearings 96, 196. The exhaust camshaft lobe(s) 94 and intake camshaft lobes 194 are followed by rocker levers or other motion transmitting structure (not shown) that actuate the exhaust valves 24 and intake valves 22 accordingly. In one embodiment, the intake camshaft lobe(s) are not phased and remain in sync with the engine's traditional camshaft drive mechanism. The exhaust cam phaser 90 can be used to control the phase angle of the exhaust camshaft lobes(s) 94 independently of the intake camshaft lobe(s) 194. Likewise, the intake cam phaser 190 can be used to control the phase angle of the intake camshaft lobes(s) 194 independently of the exhaust camshaft lobe(s) 194.

**[0033]** Cam phasers 90, 190 may each include a front camshaft bearing 98 and an actuator 102 that is configured to adjust a phase angle of the exhaust camshaft lobe(s) 94 or intake camshaft lobe(s) 194 A concentric camshaft drive gear 100 is connected to the engine crankshaft 18 (FIG. 2) and is driven at a specified and constant drive ratio. The concentric camshaft drive gear 100 also serves as the housing or mount for the rotor and stator assembly 110 of the exhaust camshaft phaser 90 or the rotor and stator assembly 210 for the intake camshaft phaser 190.

**[0034]** During a thermal management mode of operation, the actuator 102 is configured to control exhaust cam phaser 90 to selectively advance the phase angle of the exhaust camshaft lobe(s) 94 to vary the timing at which the exhaust camshaft lobe(s) 94 provide an earlier opening and closing of the exhaust valve(s) 24 on demand during the exhaust stroke of the piston 16. In another embodiment, during an engine braking mode of operation, the actuator for the intake cam phaser 190, in conjunction with an exhaust cam phaser 90, is configured to selectively vary the phase angle of the intake camshaft lobe(s) 194 and exhaust camshaft lobe(s) 94 to vary the timing at which the intake camshaft lobe(s) 194 and exhaust camshaft lobe(s) 94 open and close the intake valve(s) 22 and exhaust valve(s) 24 on demand during the intake stroke and the exhaust stroke of the piston 16 to increase engine braking power.

**[0035]** Referring to FIGs. 4-5, an embodiment of exhaust cam phaser 90 is shown without camshaft 92. Exhaust cam phaser 90 includes drive gear 100 and a rotor and stator assembly 110 mounted to drive gear 100. Drive gear 100 includes a disc-shaped body 112 with a plurality of gear teeth 114 around the outer circumference of body 112. Body 112 includes a central hole 116 to receive the camshaft 92, and a number of fastener bores 118 to receive fasteners 120 that mount rotor and stator assembly 110 to drive gear 100. Body 112 further includes a locking pin receptacle 122 to movably receive a locking pin that controllably locks and unlocks rotor and stator assembly 110 to drive gear 100.

**[0036]** Rotor and stator assembly 110 includes a retainer plate 124, a bias spring 126, a cover plate 128, a coupling member 130, and mounting rods 132. Rotor and stator assembly 110 also includes a rotor 140 and a stator 170. When assembled, and as discussed further below, rotor 140 is positioned in, and rotatable relative to, stator 170 with vanes 144 of rotor 140 between corresponding pairs of lugs 174 of stator 170.

**[0037]** Cover plate 128 is engaged to drive gear 100 with fasteners 120 extending through corresponding ones of the stator bores 172 and into fastener bores 118 of drive gear 100. Rotor 140 is coupled to the camshaft 92 with coupling member 130 and with mounting rods 132 that extend through hole 136 of cover plate 128 and into slots 138 of retainer plate 124. The ends of biasing member 126 are linked to stator 170 through pins 133 that extend from cover plate 128. Biasing member 126 transfers a rotational force that biases stator 170 and drive gear 100 to a desired position, such as a fully retarded position. In the illustrated embodiment, biasing member 126 is a spirally wound torsion spring, but other types of biasing members are also contemplated and not precluded.

**[0038]** FIG. 6 is an elevation view of an embodiment of a rotor and stator assembly 110 that is looking toward the side of rotor stator assembly 110 that is mounted to drive gear 100. FIG. 7 is an elevation view of the rotor and stator assembly 110 looking in the opposite direction of FIG. 6 toward drive gear 100. Rotor 140 includes a center hub 142, and a plurality of vanes 144 that extend radially outwardly from center hub 142. Vanes 144 are spaced equi-angularly from one another around center hub 142. However, one of the vane 144 is greater in width to accommodate lock pin 145 and to take a majority of the load during phasing.

**[0039]** Center hub 142 includes a central passage 146 extending axially therethrough. Passage 146 is centered and extends along a rotation axis of rotor and stator assembly 110. The side of center hub 142 facing drive gear 100 forms a pocket 147 for receipt of the camshaft 92. Center hub 144 also includes holes 148 for receiving mounting rods 132 that couple retainer plate 124 to rotor 140.

**[0040]** Each of the vanes 144 includes a width between opposite sidewalls 152 that is tapered such that the outer ends 150 of each vane 144 is wider than at hub 142. The opposite sidewalls 152 extend from hub 142 to the outer end 150 of the corresponding vane 142. Each outer end 150 includes a receptacle 154 that receives a respective one of the vane seals 160 therein.

**[0041]** Rotor 140 is positioned in stator 170 with vanes 144 positioned between lugs 174 so that a control volume 178 is defined between each vane 144 and a pair of adjacent lugs 174 located on opposite sides of the corresponding vane 144. Stator 170 includes a rim 176, and each lug 174 includes opposite sidewalls 184 extending from rim 176 to its corresponding inner end 180. Lugs 174 extend radially inwardly from rim 176 toward hub 142 of rotor 140. Each of the lugs 174 includes a width between opposite sidewalls 184 that is tapered such that the inner ends 180 of each lug 144 is narrower than at rim 176. The inner end 180 of each lug 174 includes a receptacle 182 that receives a respective one of the stator seals 190 therein.

**[0042]** The vanes 144 and lugs 174 are configured so that a range of motion R is provided for the camshaft 92 its associated exhaust camshaft lobes 94. In an embodiment, the range of motion R is 45 degrees, allowing the exhaust camshaft lobes 94 to be advanced or retarded by up to 90 crank angle degrees of crankshaft 18. In the illustrated embodiment, the width of each vane 144 between opposite sidewalls 152 and the width 184 of each lug 174 between sidewalls 184 are configured to provide a control volume 178 sized to allow rotational displacement of up to 45 degrees of rotor 140 relative to stator 170.

**[0043]** In the illustrated embodiment, there are four vanes 144 on rotor 140 and four lugs 174 on stator 170. Other embodiments contemplate three or fewer vanes and lugs, or more than four vanes and lugs, so long as cam phasing is possible up to 90 crank angle degrees.

**[0044]** In an embodiment, the rotor 140 is locked in a starting position that is the fully retarded position 192, as shown in FIG. 7, in which rotor 140 is rotated clockwise so that a sidewall 152 of each vane 144 is positioned adjacent to or against a sidewall 184 of a corresponding lug 174. Rotor 140 can be rotated counterclockwise toward a fully advanced position, as indicated at 194, with control fluid supplied to and removed from the control volume 178 on opposites sides of each vane 144. Rotation of rotor 140 can also be stopped at any rotational position between the fully advanced and fully retarded position to provide the desired cam phasing.

**[0045]** The capability to rotate rotor 140 relative to stator 170 to provide up to 90 crank angle degrees of phasing of the exhaust camshaft lobes 194 provides a cost-effective thermal management device, such as maintaining desired operating efficiencies of the aftertreatment system 52 during cold start, idle, keep warm, and/or motoring conditions of engine 12. For example, the turbine outlet temperature of turbine 40b can be maintained at or near a desired threshold temperature during cold start, idle, and/or motoring conditions by advancing the exhaust valve opening time up to 90 crank angle degrees using cam phaser 90 with rotor and stator assembly 110.

**[0046]** In a specific embodiment, a desired threshold temperature of about 300 degrees Celsius at the turbine outlet can be maintained by utilizing the 90 degree range of authority provided by rotor and stator assembly 110 of cam phaser 90 to make engine 12 work harder and increase the pumping work of engine 12. In certain embodiments, using rotor and stator assembly 110 of cam phaser 90 allows exhaust gas recirculation and/or variable geometry turbine (VGT) control to increase aftertreatment temperatures during cold start and other conditions may be eliminated, or reduced. In certain embodiments, EGR systems and/or VGT's can be eliminated in systems employing the cam phaser 90 with rotor and stator assembly 110.

**[0047]** In a specific embodiment, exhaust flow during motoring or idle conditions of engine 12 is reduced to keep aftertreatment system 52 warm by utilizing the 90 degree range of authority provided by rotor and stator assembly 110 of cam phaser 90. For example, the exhaust flow at idle can be reduced to make engine 12 work harder at idle and increase exhaust temperature, or air flow through cylinders 14 can be reduced during motoring to reduce cooling of aftertreatment system 52. As a result, the cam phaser 90 with rotor and stator assembly 110 can eliminate the use of intake air throttle/exhaust throttle valve control during idle and motoring conditions, although the use of the same is not precluded in all embodiments.

**[0048]** In an embodiment, wastegate 50 is used in conjunction with rotor and stator assembly 110 of cam phaser 90 during certain operating conditions. For example, wastegate 50 and rotor and stator assembly 110 of cam phaser 90 can be controlled to maintain engine out NOx within prescribed limits. Utilizing the wastegate 50 in conjunction with the cam phaser 90 with rotor and stator assembly 110 can reduce drawbacks associated with using cam phasers in general, such as higher intake manifold temperature, noise, valve load, and reduced fuel economy, such as may occur during engine loading greater than 20% of rated or maximum load.

**[0049]** An embodiment of rotor seal 160 and/or stator seal 190 is shown in FIG. 8. Seals 160, 190 can include the same configuration as shown, but other configurations are possible, so long as the seals 160, 190 are configured to be received in the corresponding receptacles 154, 182 and provide sealing engagement between the ends of the vanes 144 with rim 176, and/or the ends of lugs 174 with hub 142.

**[0050]** Each seal 160, 190 includes an elongated body 192 having an outer side 194 facing outwardly from seal receptacle 154, 182. The elongated body 192 also has an inner side 196 facing inwardly into the seal receptacle 154, 182. The inner side 196 has a cavity 198 located between opposite end flanges 200, 202 of the elongated body 192. A spring 204 is located in the cavity 198. Spring 204 contacts the corresponding vane 144 or lug 174 in the receptacle 154, 182. The spring 204 outwardly biases the outer side 194 of the elongated body 192 into sealing contact with the adjacent rim 176 or hub 142.

**[0051]** In an embodiment spring 204 is a coil spring. In an embodiment, spring 204 is a leaf spring. Other embodiments contemplate other types, configurations, and/or shapes for spring 204.

**[0052]** In an embodiment, one or more of seals 160, 190 is comprised of plastic material. In an embodiment, one or more of seals 160, 190 is comprised of powdered metal material. Other embodiments contemplate other materials for one or more of seals 160, 190, including metal materials, elastomers, composite materials, and combinations of these.

**[0053]** FIG. 9 is a perspective of another embodiment rotor and stator assembly 210. In an embodiment, rotor and stator assembly 210 is provided on cam phaser 190 connected to the intake camshaft 192 having cam lobes 194 that control the opening and closing timing of the intake valves 22. In the illustrated embodiment, rotor and stator assembly 210 includes a rotor 212 having a plurality of vanes 214 extending from central hub 216. Rotor and stator assembly 210 also includes a stator 220 including a plurality of lugs 222 extending radially inwardly from rim 224. Rotor 212 is positioned within stator 220 so that each vane 214 is located in a control volume between an adjacent pair of lugs 222.

**[0054]** Control fluid, such as oil, is provided to and drained from control volume 218 to rotate rotor 212 relative to stator 220 along a range of motion 226 to retard or advance the opening and closing timing of the intake valves 22. In an embodiment, the range of motion 226 is 25 degrees, allowing the opening and closing timing of the intake valves 22 to be advanced or retarded over a range of 50 crank angle degrees.

**[0055]** In an embodiment, rotor and stator assembly 210 is employed on an intake cam phaser 190 that is used to adjust the intake valve opening and closing timing over a range of 50 crank angle degrees, in conjunction with rotor and stator assembly 110 being employed on an exhaust cam phaser 90 that is used to adjust the exhaust valve opening and closing timing over a range of 90 crank angle degrees. The intake valve opening/closing timing may be retarded in conjunction with advancing the exhaust valve opening/closing timing in order to increase a braking power of engine 12 during certain engine operating conditions.

**[0056]** In an embodiment, the certain engine operating conditions in which the intake valve opening and closing timing is retarded and the exhaust valve opening and closing timing is advanced to increase engine braking power output is an engine speed that is between 1000 RPMs and 2500 RPMs. In an embodiment, while between 1000 RPMs and 2500 RPMs, the exhaust cam phaser 90 is rotated to advance and/or retard the exhaust valve opening/closing timing up to 20 degrees, and/or the intake cam phaser 190 is rotated to advance and/or retard the intake valve opening/closing timing up to 25 degrees.

**[0057]** FIG. 10 provides an example of part of a flow circuit 300 for providing control fluid to control volumes 178, 218. A perimeter flow path 302 is formed around camshaft 92, 192, and radially inwardly extending passages 304. The radially inwardly passages 304 provide the control fluid to the annular space 306 between camshaft 92, 192 and the hub 142, 216 of the respective rotor 140, 210. A second set of similarly arranged radially inwardly extending passages in camshaft 92, 192 may also provide control fluid to a set of axially extending passages 308 along the camshaft 92, 192.

**[0058]** Referring further to FIG. 11, the rotors 140, 210 include retard passages 320 and advance passages 322 in hubs 142, 216. The retard passages 320 provide control fluid to the corresponding control volume 178, 218 in order to retard the corresponding exhaust valves 24 or intake valves 22, while the corresponding advance passages 322 simultaneously drain control fluid from the control volume 178, 218. Conversely, the advance passages 322 provide control fluid to the corresponding control volume 178, 218 in order to advance the corresponding exhaust valves 24 or intake valves 22, while the corresponding retard passages 320 simultaneously drain control fluid from the control volume 178, 218.

**[0059]** It should be understood that cam phasers 90, 190 can be operated simultaneously to advance the exhaust valve opening/closing timing while retarding the intake valve opening/closing timing. For example, as shown in FIG. 11, the exhaust cam phaser 90 is parked with the rotor 140 in a full retard position, and the intake cam phaser 210 is parked with the rotor 210 in the full advance position. During an engine braking event, the exhaust cam phaser 90 can be operated to advance rotor 140 to a mid-stop position, such as up to 20 crank angle degrees, while rotor 210 is retarded to a mid-stop position, such as up to 25 crank angle degrees.

**[0060]** Referring to FIG. 12, a flow diagram of one embodiment of a procedure 1200 for engine braking of engine 12 is provided. The procedure 1200 includes an operation 1202 that includes operating the internal combustion engine 12. In an embodiment, engine 12 includes a plurality of cylinders 14 that receive a charge flow from intake passage 36. Furthermore, at least a portion of the plurality of cylinders 14 receives fuel from fuel system 30 in response to a vehicle or engine speed request.

**[0061]** Procedure 1200 continues at conditional 1204 to determine the presence or absence of an engine braking request. The determination of the engine braking request being present can result from, for example, an input from a vehicle operator such as a brake pedal position, accelerator pedal position, or engine brake request input switch. If conditional 1204 is negative, procedure 1200 returns to operation 1202.

**[0062]** In response to conditional 1204 determining an engine braking request being present, procedure 1200 can continue at operation 1206 to change phase angles for camshafts 92, 192 that control an exhaust valve 24 opening/closing timing and an intake valve 22 opening/closing timing of one or more of the plurality of cylinders 14 to increase a braking power of the engine 12.

**[0063]** In one embodiment of the procedure 1200, changing the phase angles includes operating the exhaust cam phaser 90 connected to exhaust camshaft 92 having one or more exhaust cam lobes 94 to advance and/or retard the exhaust valve opening/closing timing; and operating intake cam phaser 100 connected to an intake camshaft 192 having one or more intake cam lobes 194 to advance and/or retard the intake valve 22 opening/closing timing. In an embodiment, the exhaust cam phaser 90 is parked in one of a fully advanced or fully retarded condition, and the intake cam phaser 190 is parked in one of a fully advanced or fully retarded condition.

**[0064]** In an embodiment, changing the phase angle includes changing the phase angle in response to the engine braking request while an engine speed is between 1000 RPMs and 2500 RPMs. In an embodiment, changing the phase angle includes changing the phase angle in response to the engine braking request only when the engine speed is between 1000 RPMs and 2500 RPMs.

**[0065]** In an embodiment, changing phase angles includes rotating exhaust cam phaser 90 connected to exhaust camshaft 92 having one or more exhaust cam lobes 94 to advance and/or retard the exhaust valve opening/closing timing up to 20 degrees. In an embodiment, changing phase angles includes rotating intake cam phaser 190 connected to intake camshaft 192 having one or more intake cam lobes 194 to advance and/or retard the intake valve 22 opening/closing timing up to 25 degrees.

**[0066]** Referring to FIG. 13, a flow diagram of one embodiment of a procedure 1300 for controlling cam phaser 90 to provide thermal management of one or more of engine 12, aftertreatment device 52, or other component of system 10 is provided. The procedure 1300 includes an operation 1302 that includes operating the internal combustion engine 12. In an embodiment, engine 12 includes a plurality of cylinders 14 that receive a charge flow from intake passage 36. Furthermore, at least a portion of the plurality of cylinders 14 receives fuel from fuel system 30 in response to a vehicle or engine speed request.

**[0067]** Procedure 1300 continues at conditional 1304 to determine the presence or absence of a thermal management condition. The determination of the thermal management condition being present can result from, for example, a deviation of a temperature of an aftertreatment component or turbine outlet from a target temperature, a cold start condition, an idle condition, and/or a motoring condition. If conditional 1304 is negative procedure 1300 returns to operation 1302.

**[0068]** In response to conditional 1304 determining a thermal management condition being present, procedure 1300 continues at operation 1306 to change a phase angle of the exhaust camshaft 92 that controls exhaust valve 24 opening/closing timing by more than 80 crank angle degrees. In an embodiment, the exhaust valve opening/closing timing is changed during an exhaust stroke of one or more cylinders of the internal combustion engine.

**[0069]** In an embodiment, the exhaust valve opening/closing timing is changed by 90 crank angle degrees. In an embodiment, in response to an engine braking request, the phase angle for the exhaust camshaft 92 and the phase angle for the intake camshaft 192 that controls intake valve 22 opening/closing timing of one or more of the plurality of cylinders 14 is changed to increase a braking power of the engine 12.

**[0070]** In an embodiment, the control procedures 1200, 1300 are implemented by the controller 80, such as by a processor of controller 80 executing program instructions (algorithms) stored in the memory of the controller 80. In certain embodiments, the system 10 further includes a controller 80 structured or configured to perform certain operations to control system 10 in achieving one or more target conditions such as a cam phaser position. In certain embodiments, the controller 80 forms a portion of a processing subsystem including one or more computing devices having memory, processing, and communication hardware. The controller 80 may be a single device or a distributed device, and the functions of the controller 80 may be performed by hardware and/or by instructions encoded on a computer readable medium.

**[0071]** In certain embodiments, the controller 80 includes one or more modules structured to functionally execute the operations of the controller. The description herein including modules emphasizes the structural independence of the aspects of the controller, and illustrates one grouping of operations and responsibilities of the controller. Other groupings that execute similar overall operations are understood within the scope of the present application. Modules may be implemented in hardware and/or software on a non-transient computer readable storage medium, and modules may be distributed across various hardware or other computer components.

**[0072]** Certain operations described herein include operations to interpret or determine one or more parameters. Interpreting or determining, as utilized herein, includes receiving values by any method known in the art, including at least receiving values from a datalink or network communication, receiving an electronic signal (e.g. a voltage, frequency, current, or PWM signal) indicative of the value, receiving a software parameter indicative of the value, reading the value from a memory location on a non-transient computer readable storage medium, receiving the value as a run-time parameter by any means known in the art, and/or by receiving a value by which the interpreted or determined parameter can be calculated, and/or by referencing a default value that is interpreted or determined to be the parameter value.

**[0073]** Various aspects of the present disclosure are contemplated. For example, in one aspect a cam phaser for advancing and retarding exhaust valves of an internal combustion engine is provided. The cam phaser includes a rotor including a hub and a plurality of vanes and a stator including a rim and a plurality of lugs. The plurality of vanes extending radially outwardly from the hub, and the plurality of lugs extending radially inwardly from the rim. The rotor is positioned in the stator so that each vane of the plurality of vanes is positioned between a corresponding pair of lugs of the plurality of lugs. Each vane of the rotor is positioned adjacent a first lug of the corresponding pair of lugs to fully retard the exhaust valves, and each vane of the rotor is positioned adjacent a second lug of the corresponding pair of lugs to fully advance the exhaust valves. The vanes of the rotor rotate 45 degrees from the fully retarded position to the fully advanced position.

**[0074]** In an embodiment, the cam phaser includes a plurality of vane seals between the plurality of vanes of the rotor and the rim of the stator, and a plurality of lug seals between the plurality of lugs of the stator and the hub of the rotor.

**[0075]** In a further embodiment, at least one of the plurality of vane seals and the plurality of lug seals are comprised of plastic material.

**[0076]** In a further embodiment, at least one of the plurality of vane seals and the plurality of lug seals are comprised of powdered metal material.

**[0077]** In a further embodiment, each of the plurality of vanes includes an outer end facing the rim of the stator, and each of the plurality of vane seals is positioned within a seal receptacle of a corresponding one of the outer ends. Each of the plurality of lugs includes an inner end facing the hub of the rotor, and each of the plurality of lug seals is positioned within a seal receptacle of a corresponding one of the inner ends.

**[0078]** In yet a further embodiment, at least one of the plurality of vane seals and the plurality of lug seals includes an elongated body having an outer side facing outwardly from seal receptacle. The elongated body has an inner side facing inwardly into the seal receptacle, the inner side having a cavity located between opposite end flanges of the elongated body. A spring is located in the cavity that contacts the corresponding lug or vane in the receptacle. The spring outwardly biasing the outer side of the elongated body into sealing contact with the adjacent rim or hub.

**[0079]** In an embodiment, the rotor is locked in a starting position adjacent the first lug to fully retard the exhaust valves.

**[0080]** In an embodiment, the cam phaser includes a drive gear positioned on a first side of the stator, a cover plate positioned on a second side of the stator opposite the first side, and a plurality of fasteners extending through the stator and engaging the cover plate to the drive gear.

**[0081]** In a further embodiment, the cam phaser includes a biasing member engaged to the cover plate. The biasing member biases the plurality of lugs of the stator toward respective ones of the plurality of vanes of the rotor.

**[0082]** In yet a further embodiment, the cam phaser includes a camshaft in the hub of the rotor, and a retainer plate connected to the camshaft, the cover plate, and the biasing member.

**[0083]** Another aspect of the present disclosure includes a method for braking an internal combustion engine. The method includes receiving a charge flow into a plurality of cylinders of the internal combustion engine to produce an exhaust gas by combustion of a fuel provided to at least a portion of the plurality of cylinders; and in response to an engine braking request, changing phase angles for camshafts that control an exhaust valve opening/closing timing and an intake valve opening/closing timing of one or more of the plurality of cylinders to increase a braking power of the engine.

**[0084]** In an embodiment, wherein changing phase angles includes: operating an exhaust cam phaser connected to an exhaust camshaft having one or more exhaust cam lobes to advance and/or retard the exhaust valve opening/closing timing; and operating an intake cam phaser connected to an intake camshaft having one or more intake cam lobes to advance and/or retard the intake valve opening/closing timing.

**[0085]** In a further embodiment, the method includes parking the exhaust cam phaser in one of a fully advanced or fully retarded condition; and parking the intake cam phaser in one of a fully advanced or fully retarded condition.

**[0086]** In an embodiment, changing the phase angles includes changing the phase angles in response to the engine braking request while an engine speed is between 1000 RPMs and 2500 RPMs.

**[0087]** In a further embodiment, changing phase angles includes rotating an exhaust cam phaser connected to an exhaust camshaft having one or more exhaust cam lobes to advance and/or retard the exhaust valve opening/closing timing up to 20 degrees.

**[0088]** In a further embodiment, changing phase angles includes rotating an intake cam phaser connected to an intake camshaft having one or more intake cam lobes to advance and/or retard the intake valve opening/closing timing up to 25 degrees.

**[0089]** Another aspect is directed to a method for thermally managing an aftertreatment device or an internal combustion engine. The method includes producing an exhaust gas by combusting a fuel received in at least a portion of a plurality of cylinders of the internal combustion engine; and in response to a thermal management condition for the engine or aftertreatment device, changing a phase angle of an exhaust camshaft that controls an exhaust valve opening/closing timing by more than 80 crank angle degrees.

**[0090]** In an embodiment, the exhaust valve opening/-closing timing is changed during an exhaust stroke of one or more cylinders of the internal combustion engine.

**[0091]** In an embodiment, the exhaust valve opening/-closing timing is changed by 90 crank angle degrees.

**[0092]** In an embodiment, the method includes, in response to an engine braking condition, changing the phase angle for the exhaust camshaft and changing a phase angle for an intake camshaft that controls an intake valve opening/closing timing of one or more of the plurality of cylinders to increase a braking power of the engine.

**[0093]** While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only certain exemplary embodiments have been shown and described. Those skilled in the art will appreciate that many modifications are possible in the example embodiments without materially departing from this invention. Accordingly, all such modifications are intended to be included within the scope of this disclosure as defined in the following claims.

**[0094]** In reading the claims, it is intended that when words such as "a," "an," "at least one," or "at least one portion" are used there is no intention to limit the claim to only one item unless specifically stated to the contrary in the claim. When the language "at least a portion" and/or "a portion" is used the item can include a portion and/or the entire item unless specifically stated to the contrary.

## Claims

**1.** A cam phaser for advancing and retarding exhaust valves of an internal combustion engine, the cam phaser comprising:

> a rotor including a hub and a plurality of vanes, the plurality of vanes extending radially outwardly from the hub;
> a stator including a rim and a plurality of lugs, the plurality of lugs extending radially inwardly from the rim, wherein:
>
> > the rotor is positioned in the stator so that each vane of the plurality of vanes is positioned between a corresponding pair of lugs of the plurality of lugs;
> > each vane of the rotor is positioned adjacent a first lug of the corresponding pair of lugs to fully retard the exhaust valves;
> > each vane of the rotor is positioned adjacent a second lug of the corresponding pair of lugs to fully advance the exhaust valves; and
> > the vanes of the rotor rotate 45 degrees from the fully retarded position to the fully advanced position.

**2.** The cam phaser of claim 1, further comprising:

> a plurality of vane seals between the plurality of vanes of the rotor and the rim of the stator;
> a plurality of lug seals between the plurality of lugs of the stator and the hub of the rotor.

**3.** The cam phaser of claim 2,

> wherein at least one of the plurality of vane seals and the plurality of lug seals are comprised of plastic material, or

wherein at least one of the plurality of vane seals and the plurality of lug seals are comprised of powdered metal material, or
wherein:

each of the plurality of vanes includes an outer end facing the rim of the stator, and each of the plurality of vane seals is positioned within a seal receptacle of a corresponding one of the outer ends; and
each of the plurality of lugs includes an inner end facing the hub of the rotor, and each of the plurality of lug seals is positioned within a seal receptacle of a corresponding one of the inner ends.

**4.** The cam phaser of claim 3, wherein at least one of the plurality of vane seals and the plurality of lug seals includes:

an elongated body having an outer side facing outwardly from seal receptacle, the elongated body having an inner side facing inwardly into the seal receptacle, the inner side having a cavity located between opposite end flanges of the elongated body; and
a spring located in the cavity that contacts the corresponding lug or vane in the receptacle, the spring outwardly biasing the outer side of the elongated body into sealing contact with the adjacent rim or hub.

**5.** The cam phaser of claim 1, wherein the rotor is locked in a starting position adjacent the first lug to fully retard the exhaust valves.

**6.** The cam phaser of claim 1, further comprising:

a drive gear positioned on a first side of the stator;
a cover plate positioned on a second side of the stator opposite the first side; and
a plurality of fasteners extending through the stator and engaging the cover plate to the drive gear, and optionally, the cam phaser further comprising;
a biasing member engaged to the cover plate, wherein the biasing member biases the plurality of lugs of the stator toward respective ones of the plurality of vanes of the rotor.

**7.** The cam phaser of claim 6, further comprising:

a camshaft in the hub of the rotor; and
a retainer plate connected to the camshaft, the cover plate, and the biasing member.

**8.** A method for braking an internal combustion engine, the method comprising:

receiving a charge flow into a plurality of cylinders of the internal combustion engine to produce an exhaust gas by combustion of a fuel provided to at least a portion of the plurality of cylinders; and
in response to an engine braking request, changing phase angles for camshafts that control an exhaust valve opening/closing timing and an intake valve opening/closing timing of one or more of the plurality of cylinders to increase a braking power of the engine.

**9.** The method of claim 8, wherein changing phase angles includes:

operating an exhaust cam phaser connected to an exhaust camshaft having one or more exhaust cam lobes to advance and/or retard the exhaust valve opening/closing timing; and
operating an intake cam phaser connected to an intake camshaft having one or more intake cam lobes to advance and/or retard the intake valve opening/closing timing, or.
wherein changing the phase angles includes changing the phase angles in response to the engine braking request while an engine speed is between 1000 RPMs and 2500 RPMs.

**10.** The method of claim 9, further comprising:

parking the exhaust cam phaser in one of a fully advanced or fully retarded condition; and
parking the intake cam phaser in one of a fully advanced or fully retarded condition.

**11.** The method of claim 10, wherein changing phase angles includes rotating an exhaust cam phaser connected to an exhaust camshaft having one or more exhaust cam lobes to advance and/or retard the exhaust valve opening/closing timing up to 20 degrees.

**12.** The method of claim 10 or claim 11, wherein changing phase angles includes rotating an intake cam phaser connected to an intake camshaft having one or more intake cam lobes to advance and/or retard the intake valve opening/closing timing up to 25 degrees.

**13.** A method for thermally managing an aftertreatment device or an internal combustion engine, the method comprising:

producing an exhaust gas by combusting a fuel received in at least a portion of a plurality of cylinders of the internal combustion engine; and in response to a thermal management condition for the engine or aftertreatment device, changing a phase angle of an exhaust camshaft that controls an exhaust valve opening/closing timing by more than 80 crank angle degrees.

**14.** The method of claim 13,

wherein the exhaust valve opening/closing timing is changed during an exhaust stroke of one or more cylinders of the internal combustion engine, or
wherein the exhaust valve opening/closing timing is changed by 90 crank angle degrees.

**15.** The method of claim 13, further comprising, in response to an engine braking condition, changing the phase angle for the exhaust camshaft and changing a phase angle for an intake camshaft that controls an intake valve opening/closing timing of one or more of the plurality of cylinders to increase a braking power of the engine.

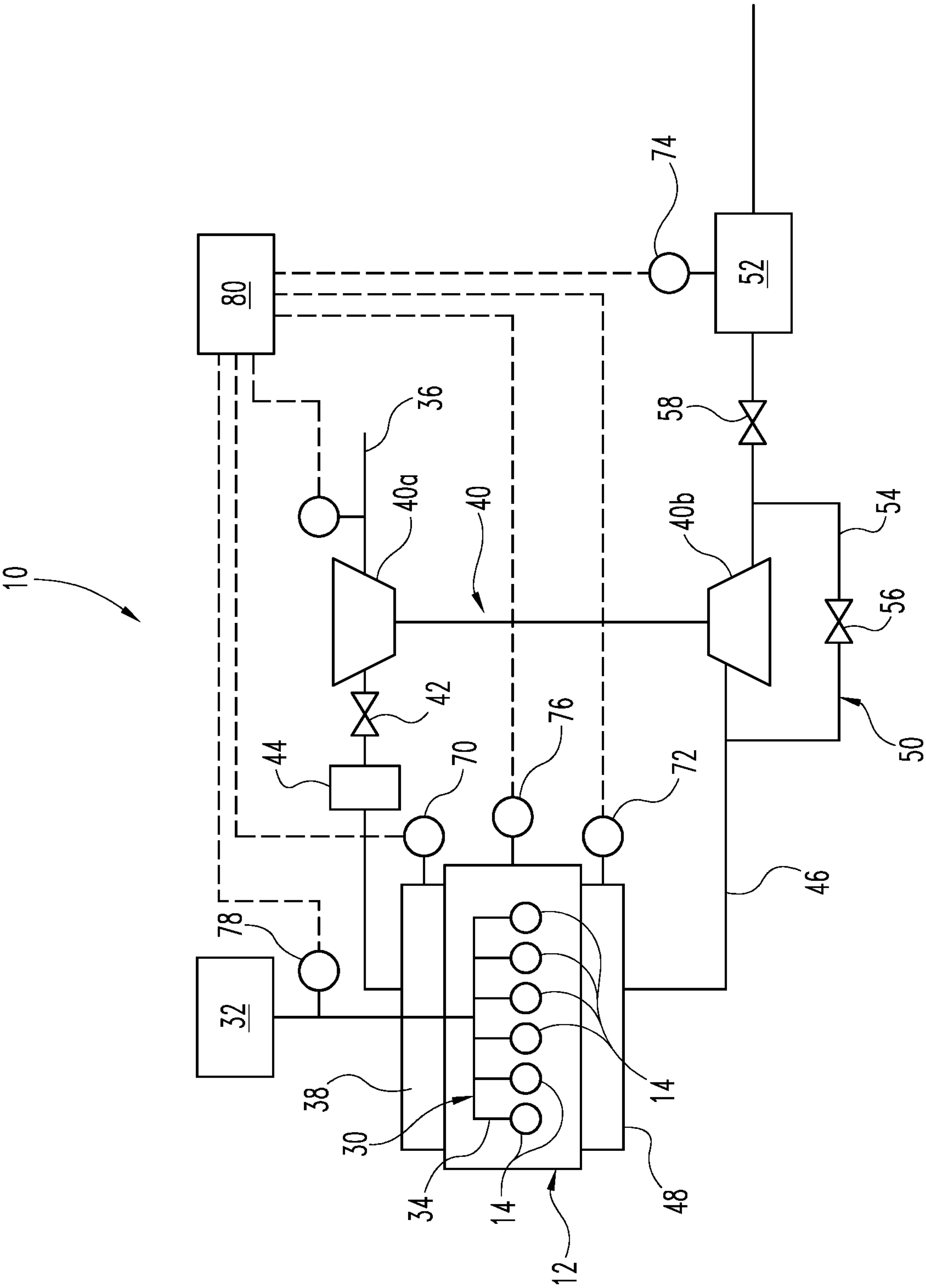
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*Fig. 1*

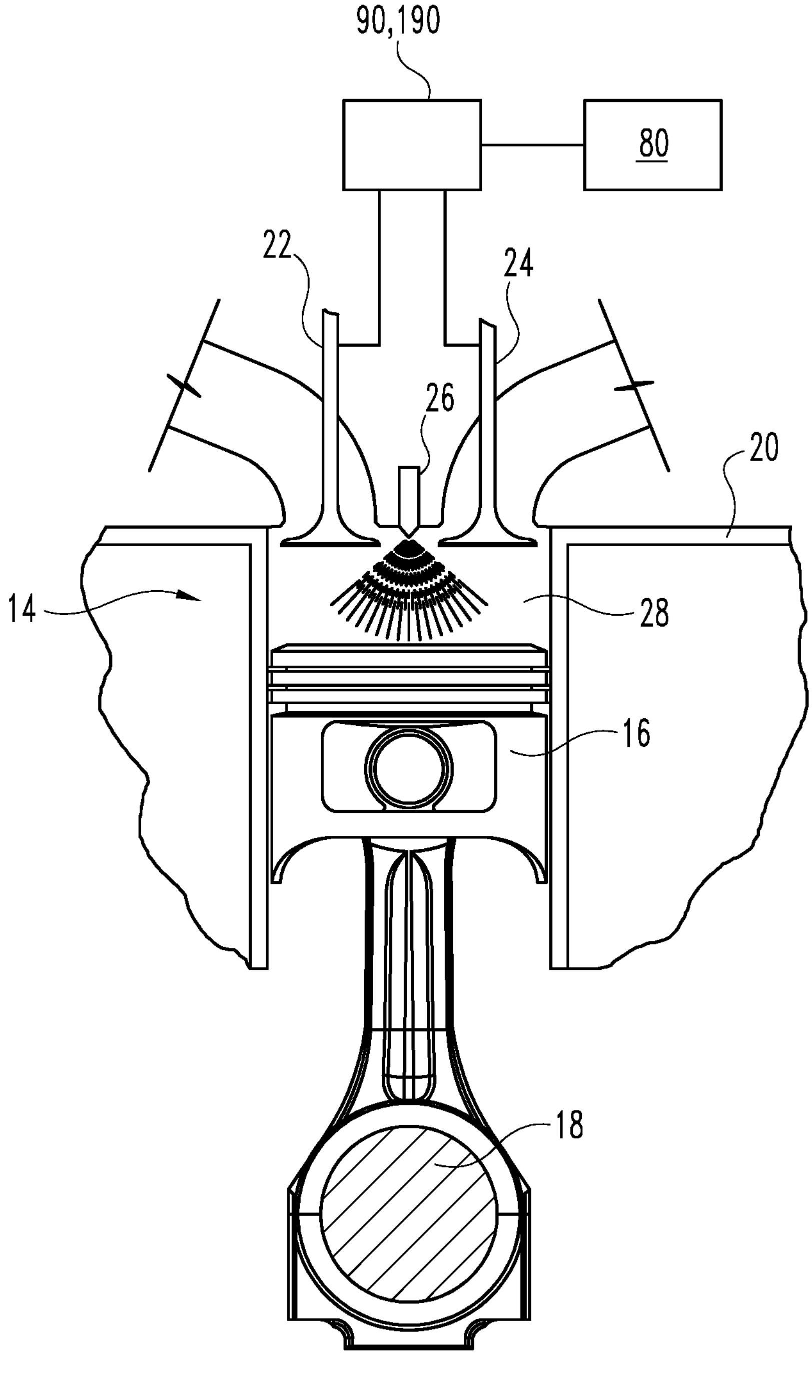
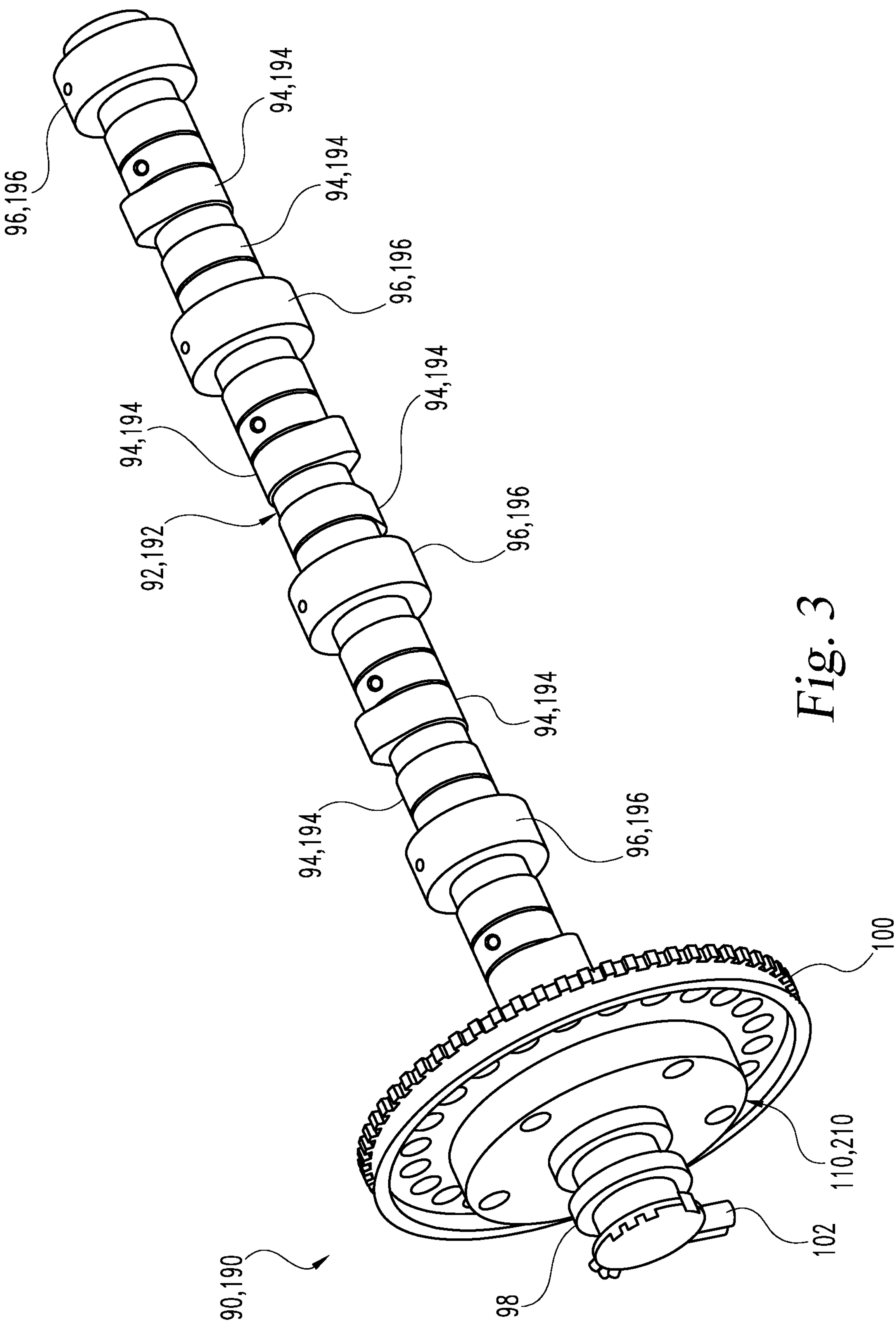



*Fig. 2*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90,190

*Fig. 3*

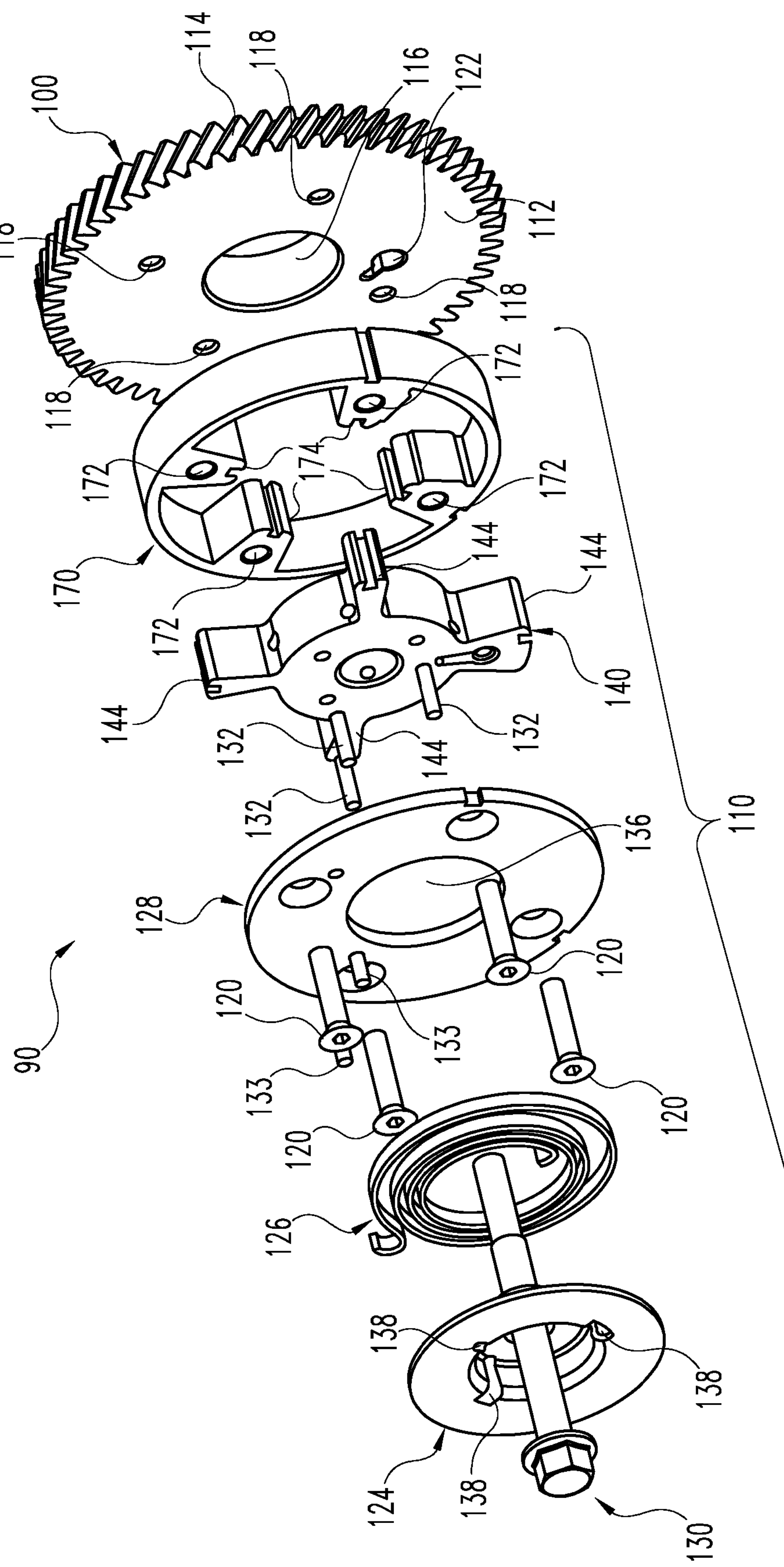
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*Fig. 4*

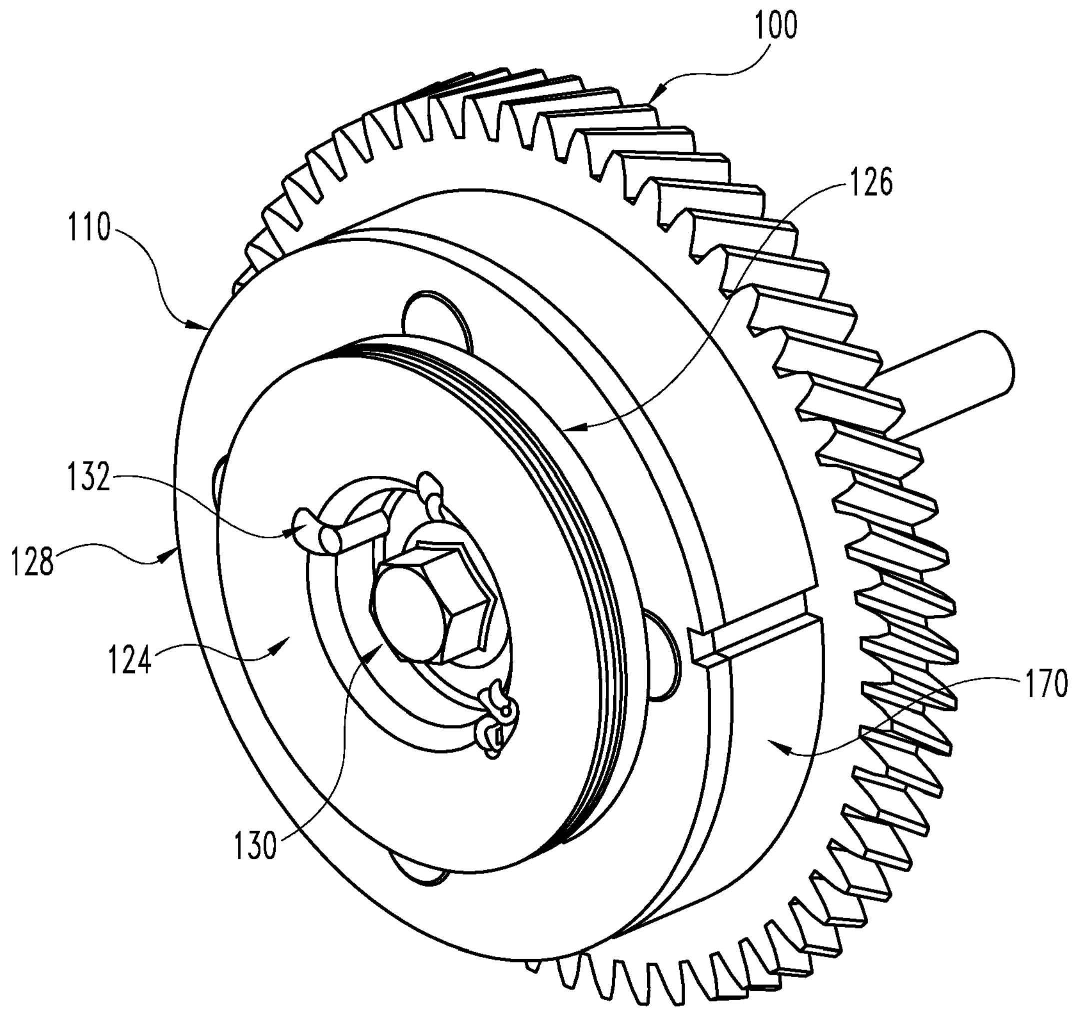


*Fig. 5*

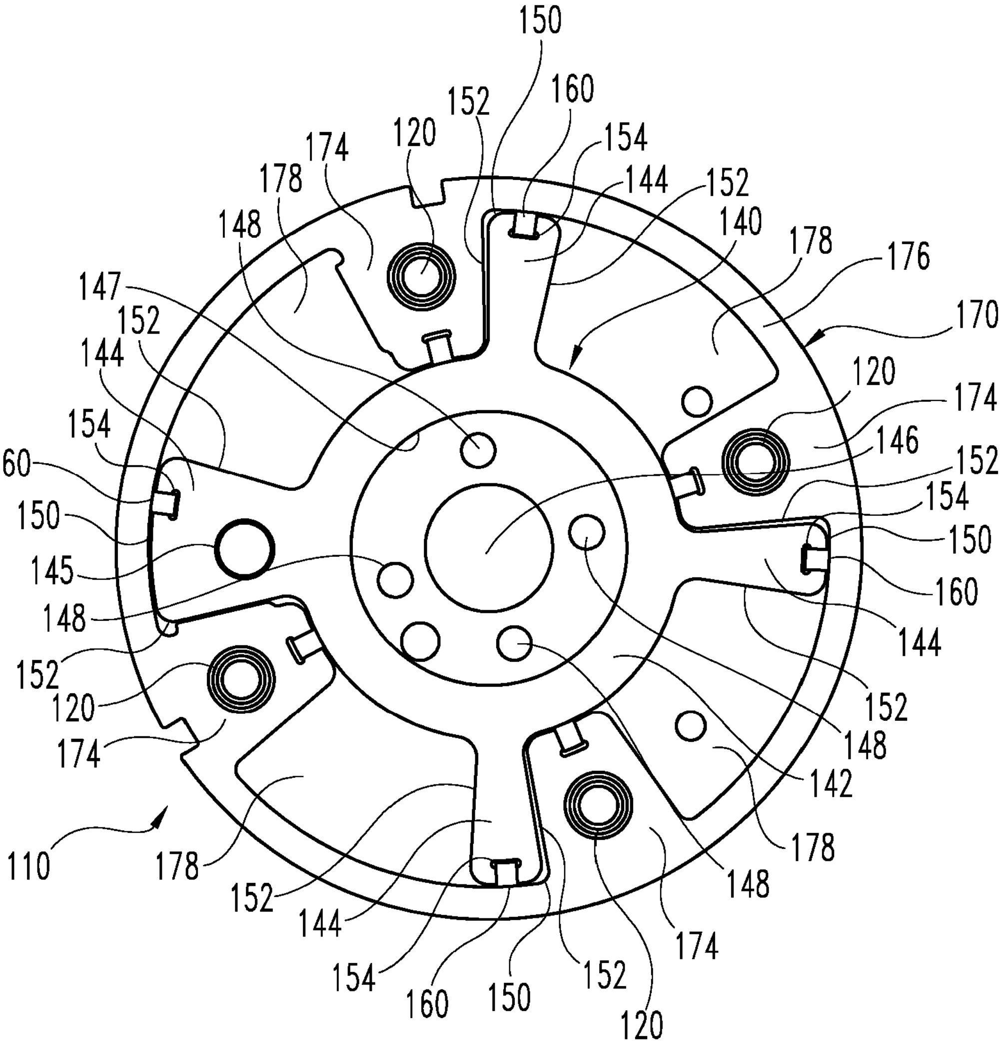
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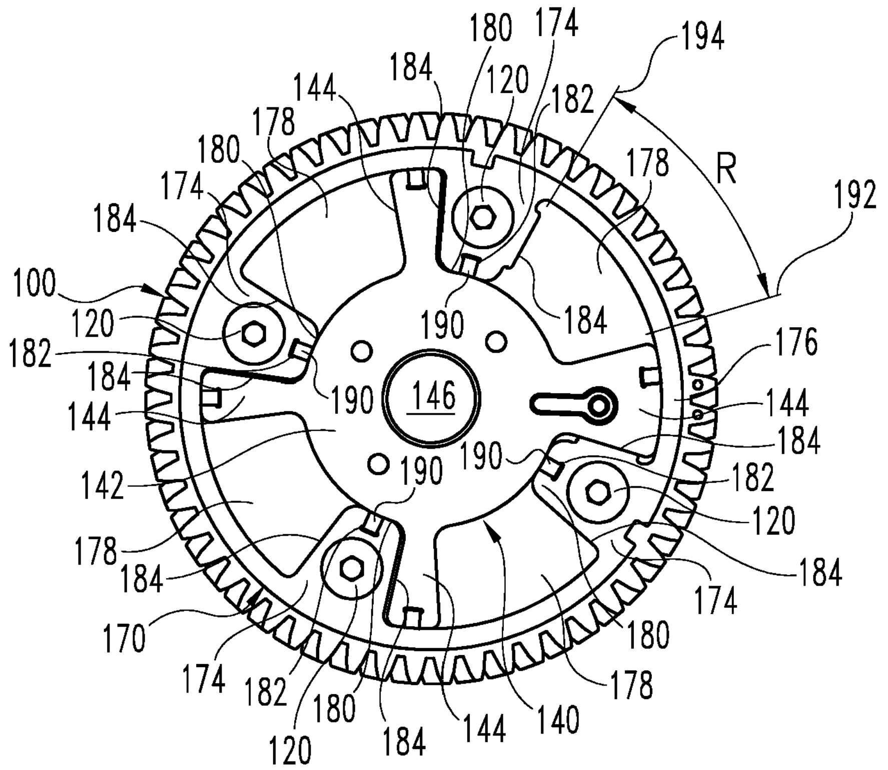
*Fig. 6*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146
176
144
144
184
190
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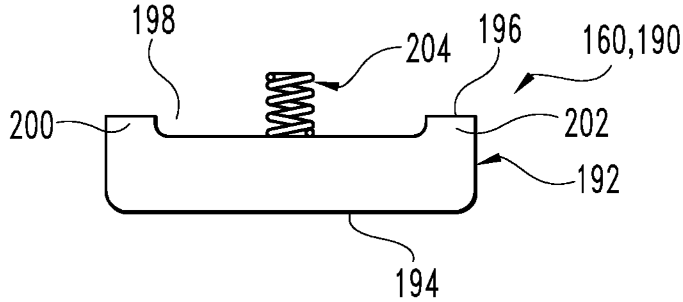
144
140

*Fig. 7*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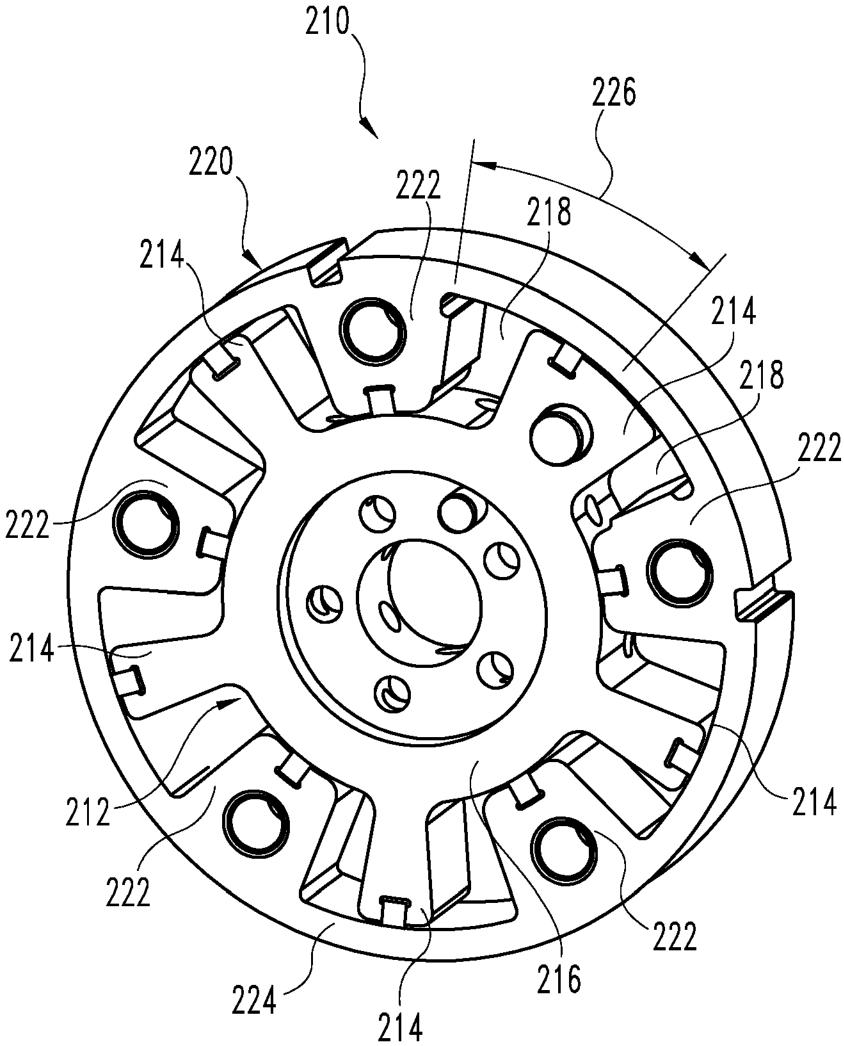
192
194

*Fig. 8*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214

*Fig. 9*

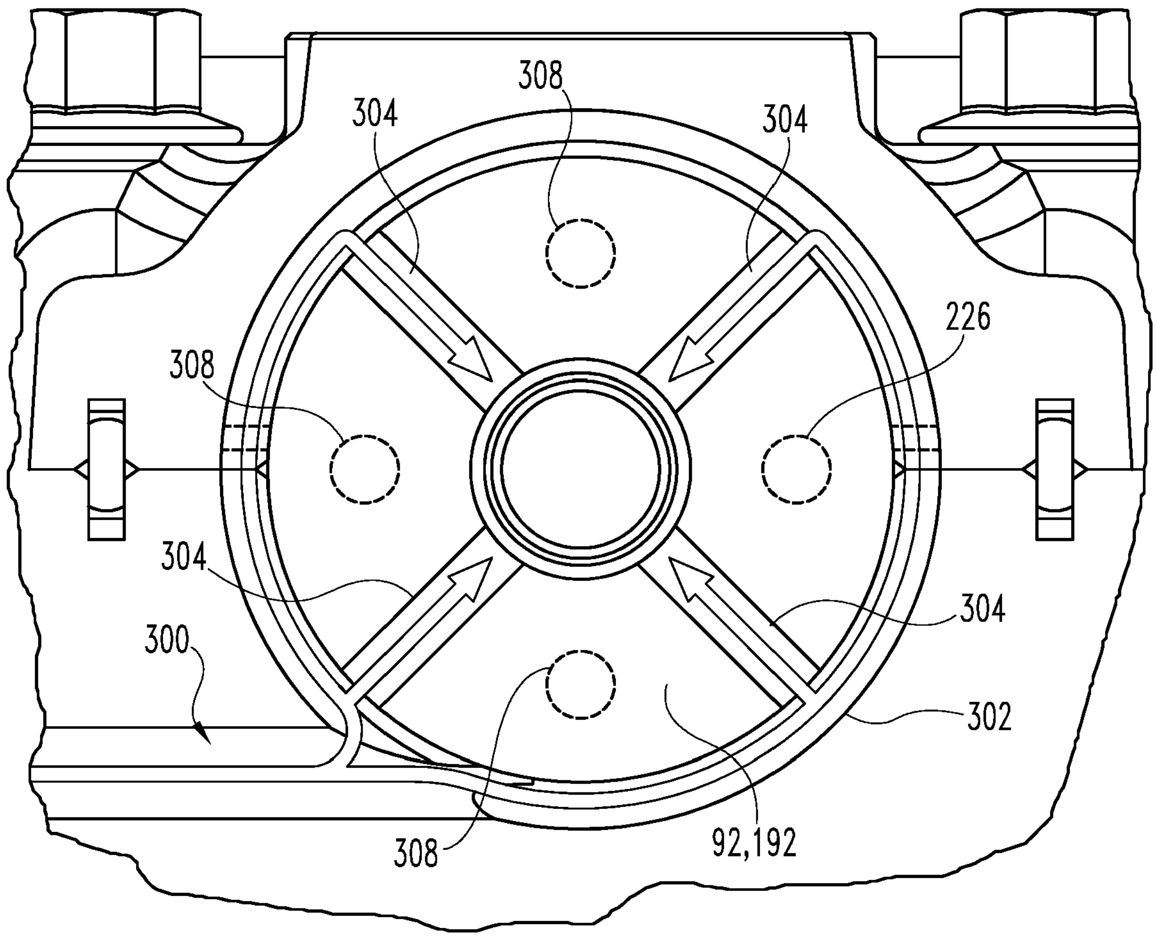
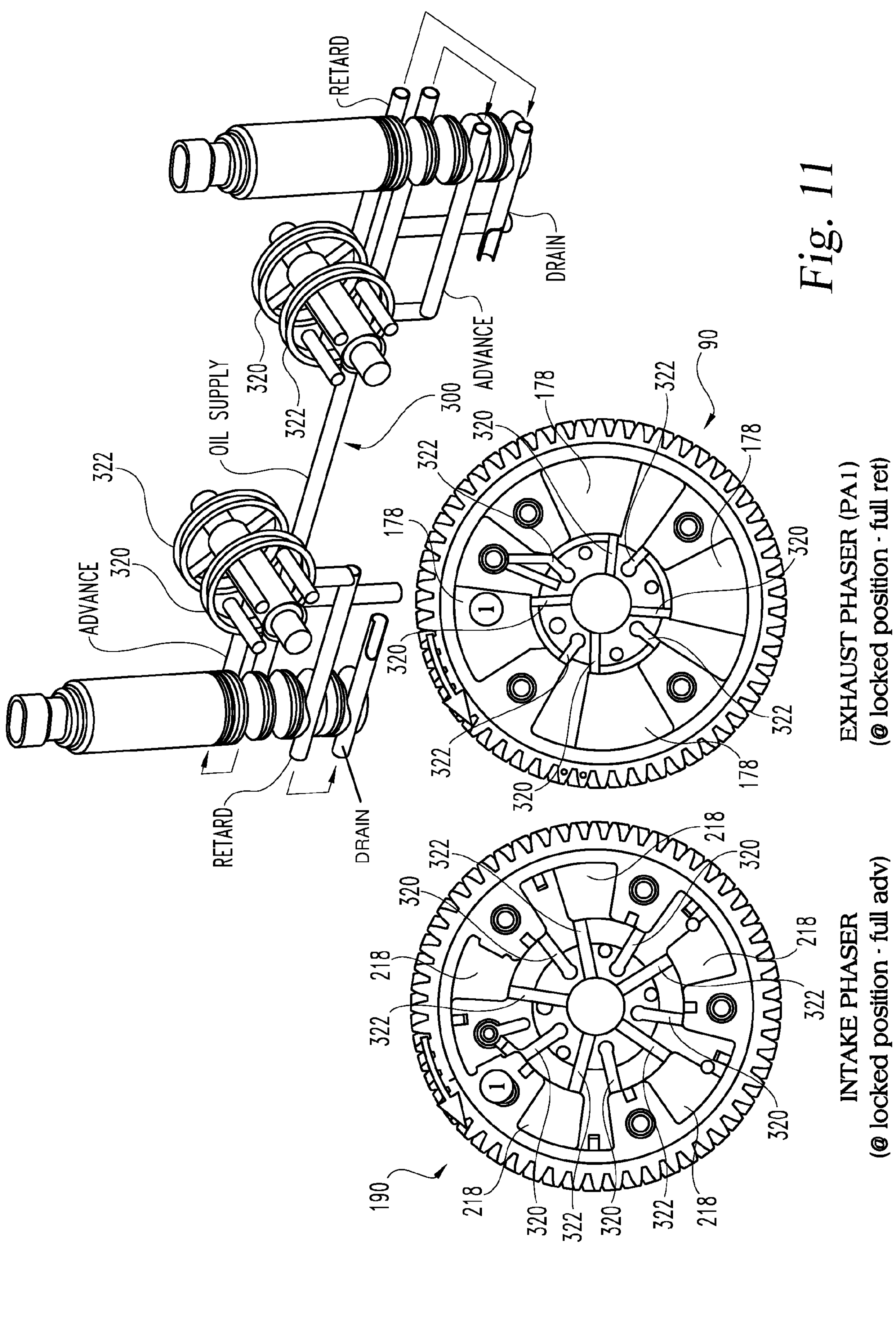



*Fig. 10*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322
OIL SUPPLY
300
ADVANCE
322
320
RETARD
DRAIN
178
320
322
90
EXHAUST PHASER (PA1)
(@ locked position - full ret)
190
218
322
320
INTAKE PHASER
(@ locked position - full adv)
1

Fig. 11

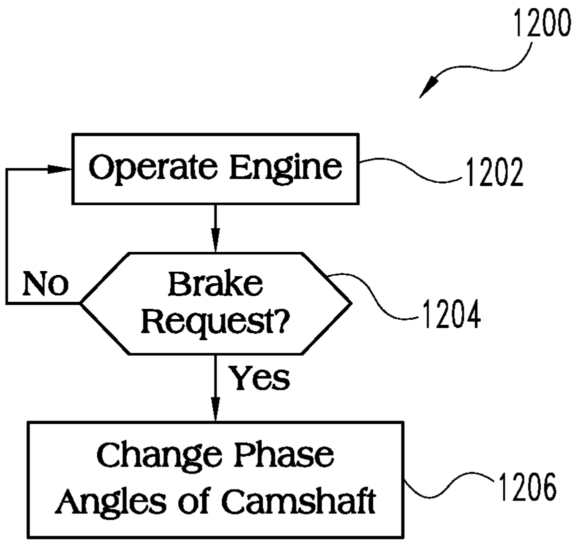
1200
Operate Engine
1202
No
Brake Request?
1204
Yes
Change Phase Angles of Camshaft
1206

*Fig. 12*

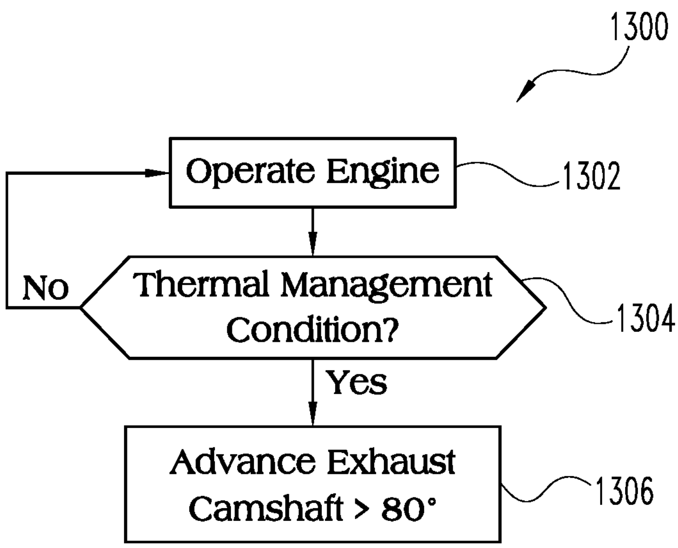
1300
Operate Engine
1302
No
Thermal Management Condition?
1304
Yes
Advance Exhaust Camshaft > 80°
1306

*Fig. 13*