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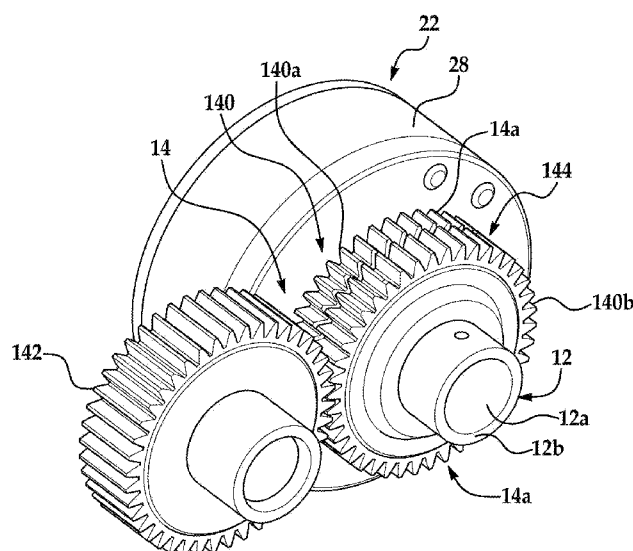
(54) **Title:** CONCENTRIC CAMSHAFT PHASER TORSIONAL DRIVE MECHANISM

FIG. 1

(57) **Abstract:** A variable cam timing assembly (10) and method for an internal combustion engine of a motor vehicle includes a cam phaser (22) connected between an inner camshaft (12a) and an outer camshaft (12b) of a concentric camshaft (12). A torsional drive mechanism (14) connects between the cam phaser (22) and the inner camshaft (12a) for transmitting rotational torque. The torsional drive mechanism (14) permits adjustment for perpendicularity and axial misalignment of the inner and outer camshafts (12a, 12b), while maintaining a torsionally stiff coupling between the cam phaser (22) and one of the inner and outer camshafts (12a, 12b) of the concentric camshaft (12). The torsional drive mechanism (14) can be formed from one of a flexible shaft coupling (40), a transversely split driven gear (140), a transversely split sprocket ring gear (240), a transverse face spline gear (340), and a pin and slot combination drive (440).

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CONCENTRIC CAMSHAFT PHASER TORSIONAL DRIVE MECHANISMFIELD OF THE INVENTION

[0001] The invention relates to rotational torque transmitted via a torsional
5 drive mechanism for rotary camshafts, wherein the torsional drive mechanism can
include a plurality of teeth or splines formed on a driving rotary member and a driven
rotary member, or a flexible coupling having a flexible link body connect to a driving
rotary member and a driven rotary member, and more particularly, to rotational
torque transmitted via a cam phaser and concentric rotary camshafts for operating at
10 least one poppet-type intake or exhaust valve of an internal combustion engine of a
motor vehicle.

BACKGROUND

[0002] Variable valve-timing mechanisms for internal combustion engines are
generally known in the art. For example, see U.S. Patent No. 4,494,495; U.S. Patent
15 No. 4,770,060; U.S. Patent No. 4,771,772; U.S. Patent No. 5,417,186; and U.S.
Patent No. 6,257,186. Internal combustion engines are generally known to include
single overhead camshaft (SOHC) arrangements, dual overhead camshaft (DOHC)
arrangements, and other multiple camshaft arrangements, each of which can be a two-
valve or a multi-valve configuration. Camshaft arrangements are typically used to
20 control intake valve and/or exhaust valve operation associated with combustion
cylinder chambers of the internal combustion engine. In some configurations, a
concentric camshaft is driven by a crankshaft through a timing belt, chain, or gear to
provide synchronization between a piston connected to the crankshaft within a
particular combustion cylinder chamber and the desired intake valve and/or exhaust
25 valve operating characteristic with respect to that particular combustion cylinder
chamber. To obtain optimum values for fuel consumption and exhaust emissions
under different operating conditions of an internal combustion engine, the valve timing
can be varied in dependence on different operating parameters.

[0003] A concentric camshaft includes an inner camshaft and an outer
30 camshaft. The two camshafts can be phased relative to each other using a mechanical
device, such as a cam phaser, to vary the valve timing. Cam phasers require precise

tolerances and alignment to function properly. Misalignment between the inner camshaft and the outer camshaft of the concentric camshaft can create problems preventing proper function of the cam phaser. It would be desirable to provide an assembly capable of adapting to misalignment between inner and outer camshafts of a concentric camshaft and a cam phaser. It would be desirable to provide an assembly capable of accommodating tolerance stack up and thereby resolving binding issues that adversely affect concentric camshaft and phaser system assemblies.

[0004] Flexible cable drive systems are generally known, see U.S. Pat. No. 7,717,795; U.S. Pat. No. 7,562,763; U.S. Pat. No. 7,168,123; U.S. Pat. No. 6,978,884; U.S. Pat. No. 5,554,073; U.S. Pat. No. 5,022,876; U.S. Pat. No. 4,911,258; U.S. Pat. No. 4,779,471; U.S. Pat. No. 4,257,192; and U.S. Pat. No. 3,481,156. In a typical rotatable flexible shaft, a wire mandrel has a plurality of layers of closely coiled wire wound there over, each of the layers being successively wound over another in alternately opposing directions, i.e., right or left-hand lay. This shaft is usually covered by a flexible casing, metallic or covered, and a clearance between the shaft and casing is provided in order that the shaft may rotate freely within the casing. These flexible cable drive systems are typically used for light duty power transmission, such as speedometer cables, power seat adjustment, and marine propulsion applications. It would be desirable to provide an assembly capable of adapting to misalignment between inner and outer camshafts of a concentric camshaft and a cam phaser.

SUMMARY

[0005] A concentric camshaft includes two shafts; an inner shaft and an outer shaft. The two shafts are phased relative to each other using a mechanical device such as a cam phaser. Cam phasers require precise tolerances and alignment to function properly. A problem can exist with respect to the alignment of the inner shaft to the outer shaft of the concentric camshaft. A torsional drive mechanism can correct this problem when mounted between the phaser rotor and the inner shaft. The torsional drive mechanism allows for the phaser to adjust for perpendicularity, and axial misalignment, while maintaining a torsionally stiff coupling.

[0006] The torsional drive mechanism is intended to solve a tolerance stack-up binding problem that can exist when a cam phaser is attached to both parts of a concentric camshaft. To account for misalignment of the shafts and perpendicularity tolerances of the phaser parts as the parts are mounted to the inner and outer shafts of the concentric cam, a torsionally rigid/axially compliant coupling is required. The idea presented includes torsion drive mechanisms having at least one of a combination pin/slot drive mechanism located between the outer shaft and the phaser assembly, a single driving gear/dual driven gear drive mechanism (sometimes referred to herein as a transversely split gear drive mechanism), a single endless loop flexible driving member/dual driven sprocket ring gear drive (sometimes referred to herein as a transversely split sprocket ring gear drive mechanism), and a transverse face spline drive located between a sprocket ring gear and an end plate of the phaser assembly.

[0007] The torsional drive mechanism can include a plurality of teeth or splines formed between a driving member and a driven member for a concentric camshaft. The torsional drive mechanism allows for misalignment of the inner shaft to rotor joint. If the misalignment of the inner shaft to rotor joint was not corrected, the rotor could bind within the housing portion of the cam phaser assembly.

[0008] The pin drive connection can use a simple pin as a torsional drive member between a cam phaser and one of the shafts of a concentric camshaft system. The pin can be press fit into a mating part on one side and can have an outer end of the pin with a slip fit with respect to a slot formed in another complementary part. This allows torque to be transmitted through the pin while also allowing some tipping or axial run out between the parts as the system rotates.

[0009] The transversely split spur gear or transversely split sprocket ring gear design can also transmit torque between the cam phaser and the concentric camshaft system while allowing some axial motion between the two. This is done by separating the phaser and cam, which are usually rigidly fastened together, and instead driving a separate, individual spur or pinion gear or separate, individual sprocket ring gear for each of the phaser and cam with a single common driving gear or endless loop flexible power transmission member.

[0010] The transverse face spline connection between the drive sprocket ring gear and the end plate of the phaser assembly can allow for misalignment between the two components while still allowing torque transfer between the components. This "compliant" joint is needed to provide a flexible joint to allow for misalignment
5 between the inner and outer shaft of a concentric camshaft. The transverse face spline allows typically longer meshing surfaces than a spline on a longitudinal or axial surface. This in turn decreases the amount of backlash required to take up the same amount of parallelism error. Transverse face splines can typically be found in the application of torque limiting devices. In those devices the two components would
10 need to be displaced axially one from another. For this device, the axial positions will be maintained throughout operation, therefore only allowing take-up of parallelism errors due to tolerances.

[0011] The torsion drive mechanism permits assembly of a concentric cam based camshaft phaser while allowing misalignment of components as caused by
15 manufacturing tolerances. In the transverse face spline connection case, the misalignment is meant to be taken up between the end plate of the phaser and the cam drive sprocket ring gear. By decoupling the end plate from the sprocket ring gear, the end plate is allowed to conform to the angular inclination of the rotor (as defined by the inner shaft). As the outer and inner end plates are bolted together through the
20 phaser housing portion, the end plates can align to the rotor. The sprocket ring gear is affixed rigidly to the outer shaft of the camshaft assembly. The orientation of the inner to outer shaft, and subsequently the rotor, along with housing portion and end plates assembly, to the cam drive sprocket ring gear is provided by the cam lobes. Since the end plate of the assembly is held in close proximity to the cam drive
25 sprocket ring gear, a face spline can be used between the two components to provide torque transmittal, while also allowing for slight differences in parallelism between the two. Backlash between the two components needs to be minimized to avoid poor noise, vibration, harshness (NVH) performance of the assembly.

[0012] The torsion drive mechanism can include a flex shaft coupling to
30 correct the alignment problem between the inner shaft and the outer shaft of the concentric camshaft when mounted between the phaser rotor and the inner shaft. The

flex shaft coupling allows for the phaser to adjust for perpendicularity, and axial misalignment, while maintaining a torsionally stiff coupling. The flexible shaft coupling can use a flexible cable shaft as a torsional drive member between the rotor and inner shaft of a concentric camshaft. The flexible shaft allows for misalignment of the inner shaft to rotor joint. If the misalignment of the inner shaft to rotor joint was not corrected, the rotor could bind within the housing of the cam phaser.

[0013] Other applications of the present invention will become apparent to those skilled in the art when the following description of the best mode contemplated for practicing the invention is read in conjunction with the accompanying drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The description herein makes reference to the accompanying drawings wherein like reference numerals refer to like parts throughout the several views, and wherein:

[0015] Figure 1 is a perspective view of a cam phaser and concentric camshaft assembly including a housing portion, a rotor, a torsional drive mechanism, where the concentric camshaft has an inner camshaft and an outer camshaft;

15

[0016] Figure 2 is a plan view of the cam phaser and concentric camshaft assembly of Figure 1;

[0017] Figure 3 is a cross sectional view of the cam phaser and concentric camshaft assembly of Figure 1;

20

[0018] Figure 4 is a cross sectional view of a cam phaser and concentric camshaft assembly including a housing portion, a rotor, a torsional drive mechanism, where the concentric camshaft has an inner camshaft and an outer camshaft and the torsional drive mechanism includes a split sprocket ring gear having one portion connected to the outer camshaft and another portion connected to the housing portion of the cam phaser;

25

[0019] Figure 5 is a cross sectional view of a cam phaser and concentric camshaft assembly including a housing portion, a rotor, a torsional drive mechanism, where the concentric camshaft has an inner camshaft and an outer camshaft and the torsional drive mechanism includes at least one drive pin captured within an aperture;

30

[0020] Figure 6 is a perspective view of a cam phaser and concentric camshaft assembly including a housing portion, a rotor, a torsional drive mechanism, where the concentric camshaft has an inner camshaft and an outer camshaft;

[0021] Figure 7 is a cross sectional perspective view of the cam phaser and concentric camshaft of Figure 6;

[0022] Figure 8 is an exploded view the cam phaser and concentric camshaft assembly of Figure 6;

[0023] Figure 9 is a side view of a cam phaser and concentric camshaft assembly including a housing, a rotor, a flexible shaft coupling, where the concentric camshaft has an inner camshaft and an outer camshaft;

[0024] Figure 10 is a cross section view taken as shown in Figure 12 of the cam phaser and concentric camshaft assembly of Figure 9;

[0025] Figure 11 is a detailed view of the flexible shaft coupling taken as shown in Figure 10;

[0026] Figure 12 is an end view of the cam phaser and concentric camshaft assembly of Figure 9; and

[0027] Figure 13 is a cross section view taken as shown in Figure 9 of the cam phaser and concentric camshaft assembly.

DETAILED DESCRIPTION

[0028] Referring now to Figures 1-8, a portion of a variable cam timing (VCT) assembly 10 is illustrated including a concentric camshaft 12 having an inner camshaft 12a and an outer camshaft 12b. Primary rotary motion can be transferred to the concentric camshaft 12, while secondary rotary motion, or phased relative rotary motion between inner camshaft 12a and outer camshaft 12b, can be provided by a cam phaser or other mechanical actuator 22. The mechanical actuator or cam phaser 22 can be operably associated with an inner camshaft 12a. A rotor 36 can be pressed onto the inner camshaft 12a and secured with a pin. The rotor 36 can be enclosed within a housing portion 28 of the cam phaser 22. Cam phasers 22 require precise tolerances and alignment to function properly. Misalignment between the inner camshaft 12a and the outer camshaft 12b of the concentric camshaft 12 can create problems preventing proper function of the cam phaser 22.

[0029] A torsional drive mechanism 14 can be provided to compensate for misalignment between inner camshaft 12a and outer camshaft 12b of the concentric camshaft 12 and cam phaser 22. A torsional drive mechanism can be connected between the inner camshaft 12a and the outer camshaft 12b of the concentric camshaft 12 for transmitting rotational torque therebetween. The torsional drive mechanism 14 permits adjustment for perpendicularity and axial misalignment of the inner and outer camshafts 12a, 12b, while maintaining a torsionally stiff coupling between a cam phaser 22 and one of the inner and outer camshafts 12a, 12b of the concentric camshaft 12. The torsional drive mechanism 14 can include a plurality of driven teeth 14a.

[0030] Referring now to Figures 1-3, the torsional drive mechanism 14 can include a driven gear 140 having an axis of rotation and transversely split into independent, separate, axially adjacent, first and second driven teeth portions 140a, 140b. The first driven teeth portion 140a can be connected to a housing portion 28 of the phaser 22 and the second driven teeth portion 140b can be connected to the outer camshaft 12b. A single common drive gear 142 can be assembled in driving engagement with both first and second driven teeth portions 140a, 140b of the driven gear 140. Alternatively, two separate drive gears, each of which is attached to the same common shaft, can be used to drive both driven gears. In operation, relative movement between the first and second driven teeth portions 140a, 140b of the driven gear 140 allows for adjustment for perpendicularity and axial misalignment of the inner and outer camshafts 12a, 12b, while maintaining a torsionally stiff coupling between a cam phaser 22 and one of the inner and outer camshafts 12a, 12b of the concentric camshaft 12. The assembly of the phaser 22 and inner camshaft 12a can adjust relative to the outer camshaft 12b due to a gap 144 between the first and second driven teeth portions 140a, 140b of the driven gear 140. In other words, the gap 144 between the first and second driven teeth portions 140a, 140b allows tipping or axial motion, such as axial run-out, of the first driven teeth portion 140a relative to the second driven teeth portion 140b to compensate for any perpendicularity and/or axial misalignments of the inner and outer camshafts 12a, 12b.

[0031] Referring now to Figure 4, the torsional drive mechanism 14 can include a driven sprocket ring gear 240 having an axis of rotation and transversely split into independent, separate, axially adjacent, first and second driven teeth portions 240a, 240b. The first driven teeth portion 240a can be connected to a housing portion 28 of the phaser 22 and the second driven teeth portion 240b can be connected to the outer camshaft 12b. A single common endless loop flexible drive member 242 can be assembled in driving engagement with both driven teeth portions 240a, 240b of the driven sprocket ring gear 240. In operation, relative movement between the first and second driven teeth portions 240a, 240b of the driven sprocket ring gear 240 allows for adjustment for perpendicularity and axial misalignment of the inner and outer camshafts 12a, 12b, while maintaining a torsionally stiff coupling between a cam phaser 22 and one of the inner and outer camshafts 12a, 12b of the concentric camshaft 12. The assembly of the phaser 22 and inner camshaft 12a can adjust relative to the outer camshaft 12b due to a gap 244 between the first and second driven teeth portions 240a, 240b of the driven sprocket ring gear 240. In other words, the gap 244 between the first and second driven teeth portions 240a, 240b allows tipping or axial motion, such as axial run-out, of the first driven teeth portion 240a relative to the second driven teeth portion 240b to compensate for any perpendicularity and/or axial misalignments of the inner and outer camshafts 12a, 12b. The split spur gear or split sprocket ring gear design also transmits torque between the cam phaser and the concentric camshaft system while allowing some axial motion between the two. This is done by separating the phaser and cam, which are usually rigidly fastened together, and instead driving each with its own spur gear or sprocket ring gear.

[0032] Referring now to Figures 6-8, the torsional drive mechanism 14 can include a pair of opposing transversely extending faces 344a, 344b between a housing portion 28 of the phaser 22 and a flange 316 of a sprocket ring gear 340. The transversely extending faces 344a, 344b can include a plurality of intermeshing teeth or face splines 340a, 340b assembled in driving engagement with one another. In operation, relative movement between the first and second teeth or face spline portions 340a, 340b of the phaser housing portion 28 and driving sprocket ring gear

340 allows for adjustment for perpendicularity and axial misalignments of the inner and outer camshafts 12a, 12b, while maintaining a torsionally stiff coupling between the cam phaser 22 and one of the inner and outer camshafts 12a, 12b of the concentric camshaft 12. The assembly of the phaser 22 and inner camshaft 12a can adjust
5 relative to the outer camshaft 12b due to axially intermeshing teeth or face spline interface 344 between the first and second teeth or face spline portions 340a, 340b of the phaser 22 and driving sprocket ring gear 340. In other words, the interface 344 between the first and second teeth or face spline portions 340a, 340b allows tipping or axial motion, such as axial run-out, of the first driving teeth or spline portion 340a
10 relative to the second driven teeth or spline portion 340b to compensate for any perpendicularity and/or axial misalignments of the inner and outer camshafts 12a, 12b.

[0033] The configuration illustrated in Figures 6-8 uses a face spline between the driving sprocket ring gear and the end plate of the phaser assembly. The face
15 spline allows misalignment between the two components while still allowing torque transfer between the two components. The two components used in conjunction with one another will allow the transfer of torque while still providing the ability to take up errors in parallelism. This "compliant" joint provides a flexible joint to allow for misalignment between the inner and outer shafts of a concentric camshaft. The two
20 parts are allowed to mesh through the face spline to allow torque transmittal. The fact that each component is affixed and positioned axially along the two different shafts allows the components to stay in constant mesh. The face spline allows typically longer meshing surfaces than a spline on a perpendicular surface. This in turn decreases the amount of backlash required to take up the same amount of
25 parallelism error. For this device the axial positions will be maintained throughout operation therefore only allowing take-up of parallelism errors due to tolerances.

[0034] The described device is meant as a means of allowing assembly of a concentric cam based camshaft phaser while allowing misalignment of components as caused by manufacturing tolerances. In this case, the misalignment is meant to be
30 taken up between the end plate of the phaser and the cam drive sprocket ring gear. By decoupling the end plate from the sprocket ring gear, the end plate is allowed to

conform to the angular inclination of the rotor, as defined by the inner shaft. As the outer and inner end plates are bolted together through the phaser housing portion, the end plates can align with respect to the rotor. The sprocket ring gear is affixed rigidly to the outer shaft of the camshaft assembly. The orientation of the inner to outer
5 shaft, and subsequently the rotor, along with housing portion and end plates assembly, to the cam driving sprocket ring gear is provided by the cam lobes. Since the end plate of the assembly is held in close proximity to the cam driving sprocket ring gear, a face spline can be used between the two components to provide a means of torque transmittal while also allowing for slight differences in parallelism between the two.
10 Backlash between the two components should be minimized so that the assembly does not have poor noise, vibration, and harshness (NVH) performance.

[0035] It should be recognized from a comparison of Figures 1-3 and 6-8 that the first and second teeth or face spline portions 140a, 140b; 240a, 240b; 340a, 340b can be in any desired orientation. By way of example and not limitation, the first and
15 second teeth or face spline portions 140a, 140b; 240a, 240b; 340a, 340b can be formed in an orientation with a face width direction 140c, 240c, 340c of the tooth profile extending in a radial direction along a face disposed angularly with respect to a longitudinal rotational axis of the concentric camshafts (Figures 6-8), or extending in a radial direction along a transverse face disposed normal or perpendicular to a
20 longitudinal rotational axis of the concentric camshafts (Figures 6-8), or extending in a transverse direction with respect to a longitudinal rotational axis of the concentric camshafts and having a plurality of intersecting teeth (Figures 6-8), or extending in a transverse direction with respect to the longitudinal rotational axis of the concentric camshafts and having at least two groups of parallel teeth intersecting one another
25 (not shown), or extending in an axial direction or longitudinal direction with respect to a longitudinal rotational axis of the concentric camshafts along a circumferential face (Figures 1-4). By way of example and not limitation, the face width of the tooth profile can extend in an axial direction as shown in Figures 1-4 for teeth 140a, 140b; 240a, 240b or in a radial direction as shown in Figures 6-8 for teeth or splines 340a,
30 340b; or any angular orientation therebetween (not shown). When extending in a radial direction as shown in Figures 6-8, the tooth profile can taper from a wider tooth

profile at a radially outward position to a narrower tooth profile at a radially inward position.

[0036] Referring now to Figure 5, the torsional drive mechanism 14 can include a combination pin and slot drive mechanism 440 located between a housing wall portion 22a of the cam phaser 22 and a flange 442 of the sprocket ring gear 456. The pin drive connection uses a simple pin 440a as a torsional drive member between an inner housing wall portion 22a of the cam phaser 22 and one of the shafts of a concentric camshaft system. More particularly, the pin drive connection uses an interface between the flange 442 of the sprocket ring gear 456 and the inner housing wall portion 22a of the cam phaser 22. A pin 440a can be press fit into a mating part on one side, either on the flange 442 or the inner housing wall portion 22a, and engaged with a slip fit within an aperture or slot 440b on the other mating part, either the inner housing wall portion 22a or flange 442 respectively. This allows torque to be transmitted through the pin and slot combination while also allowing some tipping or axial run-out between the parts as the system rotates.

[0037] A variable cam timing assembly 10 for an internal combustion engine of a motor vehicle can have a cam phaser 22 connected between an inner camshaft 12a and an outer camshaft 12b of a concentric camshaft 12 for providing phased relative rotary motion between inner camshaft 12a and outer camshaft 12b. A torsional drive mechanism 14 can be connected between the cam phaser 22 and one of the inner and outer camshafts 12a, 12b of the concentric camshaft 12 for transmitting rotational torque. The torsional drive mechanism 14 can permit adjustment for perpendicularity and axial misalignment of the inner and outer camshafts 12a, 12b with respect to one another and/or with respect to the phaser 22, while maintaining a torsionally stiff coupling between the cam phaser 22 and one of the inner and outer camshafts 12a, 12b of the concentric camshaft 12. The torsional drive mechanism 14 can include complementary, operably engaged, shaped interface surfaces located between a driving member 142, 242, 342, 442 and at least one driven member 140, 240, 340, 440, or more particularly, by way of example and not limitation, such as driving gear 142 and driven gear 140 with driven teeth 140a, 140b (Figures 1-3), or endless loop power transmitting driving member 242 and driven sprocket ring gear

240 with sprocket teeth 240a, 240b (Figure 4), or driving sprocket ring gear 456 with pin 440a and driven wall portion 28a with aperture 440b of cam phaser 22 (Figure 5), or driving sprocket ring gear 342 with splines or teeth 340a and driven wall portion 28a with splines or teeth 340b of cam phaser 322 (Figures 6-8).

5 **[0038]** A variable cam timing assembly 10 for operating at least one poppet-type valve of an internal combustion engine of a motor vehicle can include a cam phaser 22 having a housing portion 28 enclosing a rotor 36 with an axis of rotation connected to a concentric camshaft 12 including an inner rotary camshaft 12a and an outer rotary camshaft 12b. A torsional drive mechanism 14 can be connectible
10 between the cam phaser 22 and one of the inner and outer camshafts 12a, 12b of the concentric camshaft 12 for transmitting rotational torque therebetween. The torsional drive mechanism 14 can permit adjustment for perpendicularity and axial misalignment of the inner and outer camshafts 12a, 12b with respect to one another and/or with respect to the cam phaser 22, while maintaining a torsionally stiff coupling between
15 the cam phaser 22 and the concentric camshaft 12. The torsional drive mechanism 14 can be formed from one of a transversely split driven gear 140, a transversely split sprocket ring gear 240, a transverse face spline gear 340, and a pin and slot combination drive 440.

[0039] A method of assembling a variable cam timing assembly 10 for an
20 internal combustion engine of a motor vehicle having a cam phaser 22 to be connected between an inner camshaft 12a and an outer camshaft 12b of a concentric camshaft 12 can include connecting a torsional drive mechanism 14 between the cam phaser 22 and one of the inner and outer camshafts 12a, 12b of the concentric camshaft 12 for transmitting rotational torque. The torsional drive mechanism 14 can permit
25 adjustment for perpendicularity and axial misalignment of the inner and outer camshafts 12a, 12b with respect to one another and/or with respect to the cam phaser 22, while maintaining a torsionally stiff coupling between the cam phaser 22 and one of the inner and outer camshafts 12a, 12b of the concentric camshaft 12. The method can also include assembling one of a transversely split driven gear 140, a transversely
30 split sprocket ring gear 240, a transverse face spline gear 340, and a pin and slot

combination drive 440 between the driving member and the driven portion of the inner and outer camshafts 12a, 12b.

[0040] In operation, the torsional drive mechanism 14 is located between one of the inner and outer camshafts 12a, 12b and the phaser 22. The torsional drive
5 mechanism 14 accommodates misalignment of the inner and outer camshafts 12a, 12b with respect to one another and/or with respect to a joint with the rotor 36 or housing portion 28 of the cam phaser 22, which if uncorrected could cause the rotor 36 to bind within the housing portion 28 of the cam phaser 22. The torsional drive mechanism 14 adjust for perpendicularity and axial misalignment between the inner
10 and outer camshafts 12a, 12b and the phaser 22 assembly, while maintaining a torsionally stiff coupling between one of the inner and outer camshafts 12a, 12b and the rotor 36 or housing portion 28 of the phaser 22. The torsional drive mechanism 14 permits limited perpendicularity and axial realignment of the rotor 36 or housing portion 28 of the phaser 22 with respect to one of the inner and outer camshafts 12a,
15 12b while transmitting torque and rotation movement between the rotor 36 and inner camshaft 12a, or housing portion 28 and outer camshaft 12b, in either rotational direction. The inner camshaft 12a remains free to rotate relative to the outer camshaft 12b in response to actuation of phaser 22, as both inner and outer camshafts 12a, 12b of the concentric camshaft 12 are driven in rotation.

[0041] Referring now to Figures 9-13, a portion of a variable cam timing
20 (VCT) assembly 10 is illustrated including a concentric camshaft 12 having an inner camshaft 12a and an outer camshaft 12b. Primary rotary motion can be transferred to the concentric camshaft 12 through the assembly of sprocket ring 52 to annular flange 16 operably associated with outer camshaft 12b. Secondary rotary motion, or phased
25 relative rotary motion between inner camshaft 12a and outer camshaft 12b, can be provided by a cam phaser or other mechanical actuator 22. Cam phasers 22 require precise tolerances and alignment to function properly. Misalignment between the inner camshaft 12a and the outer camshaft 12b of the concentric camshaft 12 can create problems preventing proper function of the cam phaser 22. The torsional drive
30 mechanism 14 can include a flexible shaft coupling 40 to compensate for misalignment between inner camshaft 12a and outer camshaft 12b of the concentric camshaft 12 and

cam phaser 22. An annular flange 16 can be operably associated with the outer camshaft 12b. A flexible shaft coupling 40 can be connected to the inner camshaft 12a by a non-circular complementary male-female shaped coupling 18 having one end portion 18a connected to a body 40a of the flexible shaft coupling 40. A mechanical actuator or cam phaser 22 can be operably associated with an inner camshaft 12a. From an opposite side of the flexible shaft coupling 40, the flexible shaft coupling 40 can be connected to the rotor 36 of the cam phaser 22 by a non-circular complementary male-female shaped coupling 24 having one end portion 24a connected to the body 40a of the flexible shaft coupling 40. Rotor 36 can be pressed onto the inner camshaft 12a and secured with a pin 38. The rotor 36 can be housed between the inner plate 32, the housing 28, and the outer plate 30.

[0042] A variable cam timing assembly 10 for an internal combustion engine of a motor vehicle can have a cam phaser 22 connected between an inner camshaft 12a and an outer camshaft 12b of a concentric camshaft 12 for providing phased relative rotary motion between inner camshaft 12a and outer camshaft 12b. The torsional drive mechanism 14 can include a flexible shaft coupling 40 connected between the cam phaser 22 and the inner camshaft 12a of the concentric camshaft 12 for transmitting rotational torque. The flexible shaft coupling 40 can have a flexible body 40a permitting adjustment for perpendicularity and axial misalignment, while maintaining a torsionally stiff coupling between the cam phaser 22 and at least one of the inner and outer camshafts 12a, 12b of the concentric camshaft 12.

[0043] The flexible shaft coupling 40 can be a torque transmitting cable assembly. The flexible shaft coupling 40 can include a plurality of spiral wound strands 40b joined together to preclude unraveling thereof and connected at one end to the inner camshaft 12a and to the cam phaser 22 at another end. The spiral wound strands can include metallic strands 40b welded together and connected at one end to the inner camshaft 12a and to the cam phaser 22 at an opposite end. At least one male-female shaped coupling 18, 24 having an end portion 18a, 24a of non-circular cross-section can be provided on the flexible shaft coupling 40 for attachment to a complementary corresponding male-female shaped fitting 18b, 24b located on one of the inner camshaft 12a and the cam phaser 22. It should be recognized that the

flexible shaft coupling 40 can be formed with either a male or female mating end portion 18a, 24a for engagement with a complementary female or male mating end of the corresponding complementary male-female shaped fittings 18b, 24b formed on the inner camshaft 12a and/or cam phaser 22. The flexible shaft coupling 40 can be
5 constructed of at least one of wound cable, wound steel, and wound plastic, and any combination thereof. At least one male-female shaped coupling 18, 24 can be non-rotatably joined with the flexible shaft coupling 40. The flexible shaft coupling 40 can be at least partially sheathed within the outer camshaft 12b.

[0044] A variable cam timing assembly 10 for operating at least one poppet-
10 type valve of an internal combustion engine of a motor vehicle can include a cam phaser 22 having a housing 28, 30, 32 at least partially enclosing a rotor 36 with an axis of rotation connected to a concentric camshaft 12 including an inner rotary camshaft 12a and an outer rotary camshaft 12b. The torsional drive mechanism 14 can include an elongate flexible shaft coupling 40 can have one end connectible
15 between the rotor 36 of the cam phaser 22 and another end connectible to the inner camshaft 12a of the concentric camshaft 12 for transmitting rotational torque therebetween. The elongate flexible shaft coupling 40 can have a flexible body 40a permitting adjustment for perpendicularity and axial misalignment, while maintaining a torsionally stiff coupling between the cam phaser 22 and the concentric camshaft 12.
20 The flexible shaft coupling 40 can be formed of a torque transmitting cable assembly. At least one end of the elongate flexible shaft coupling 40 can have a non-circular periphery for making a driving connection with at least one of the rotor 36 and the inner camshaft 12a.

[0045] A method of assembling a variable cam timing assembly 10 for an
25 internal combustion engine of a motor vehicle having a cam phaser 22 to be connected between an inner camshaft 12a and an outer camshaft 12b of a concentric camshaft 12 can include connecting the torsional drive mechanism 14, where the torsional drive mechanism 14 includes a flexible shaft coupling 40 between the cam phaser 22 and the inner camshaft 12a of the concentric camshaft 12 for transmitting rotational torque.
30 The flexible shaft coupling 40 can have a flexible body 40a permitting adjustment for perpendicularity and axial misalignment, while maintaining a torsionally stiff coupling

between the cam phaser 22 and at least one of the inner and outer camshafts 12a, 12b of the concentric camshaft 12. The method can also include forming at least one complementary male-female shaped coupling 18, 24 having an end portion 18a, 24a of non-circular cross-section for attachment of at least one end of the flexible shaft coupling 40 to the inner camshaft 12a and to the cam phaser 22. The male-female shaped coupling 18, 24 can be assembled by coupling at least one end portion 18a, 24a of non-circular cross-section complementary male-female shaped couplings 18, 24 with respect to a complementary corresponding male-female shaped fittings 18b, 24b for attachment of one end of the flexible shaft coupling 40 to at least one of the inner camshaft 12a at one end and the cam phaser 22 at an opposite end. The flexible shaft coupling 40 can be formed by joining spiral wound strands 40b together to define the flexible shaft coupling 40 and to preclude unraveling thereof. At least one end of the flexible shaft coupling 40 can be connected to at least one of the inner camshaft 12a and the cam phaser 22.

[0046] In operation, the flexible shaft coupling 40 is located between the inner camshaft 12a and the rotor 36 of the phaser 22. The flexible shaft coupling 40 accommodates misalignment of the inner camshaft 12a with respect to the joint with the rotor 36, which if uncorrected could cause the rotor 36 to bind within the housing 28, 30, 32 of the cam phaser 22. The flexible shaft coupling 40 for the rotor 36 of the phaser 22 to adjust for perpendicularity, and axial misalignment, while maintaining a torsionally stiff coupling between the inner camshaft 12a and the rotor 36. The flexible shaft coupling 40 permits limited perpendicularity and axial realignment of the rotor 36 with respect to the inner camshaft 12a while transmitting torque and rotation movement between the rotor 36 and inner camshaft 12a in either rotational direction. The inner camshaft 12a remains free to rotate relative to the outer camshaft 12b in response to phaser 22 actuation, as both inner and outer camshafts 12a, 12b of the concentric camshaft 12 are driven in rotation by the sprocket ring 52 and annular flange 16 assembly.

[0047] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiments but,

on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims, which scope is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures as is permitted under the law.

What is claimed is:

1. In a variable cam timing assembly (10) for an internal combustion engine of a motor vehicle having a cam phaser (22) connected between an inner camshaft (12a) and an outer camshaft (12b) of a concentric camshaft (12), the
5 improvement comprising:
a torsional drive mechanism (14) connected between the inner camshaft (12a) and the outer camshaft (12b) of the concentric camshaft (12) for transmitting rotational torque therebetween, the torsional drive mechanism (14) permitting adjustment for perpendicularity and axial misalignment, while maintaining a
10 torsionally stiff coupling between the cam phaser (22) and at least one of the inner and outer camshafts (12a, 12b) of the concentric camshaft (12).
2. The improvement of claim 1, wherein the torsional drive mechanism (14) includes a plurality of driven teeth (14a).
15
3. The improvement of claim 2, wherein the plurality of driven teeth (14a) of the torsional drive mechanism (14) further comprises:
a driven gear (140) having an axis of rotation and transversely split into a first driven teeth portion (140a) connected to a housing portion (28) of the
20 phaser (22) and a second driven teeth portion (140b) connected to the outer camshaft (12b).
4. The improvement of claim 3 further comprising:
a single common drive gear (142) in driving engagement with both first
25 and second driven teeth portions (140a, 140b) of the driven gear (140).
5. The improvement of claim 2, wherein the plurality of driven teeth (14a) of the torsional drive mechanism (14) further comprises:
a driven sprocket ring gear (240) having an axis of rotation and
30 transversely split into a first driven teeth portion (240a) connected to a housing

portion (28) of the phaser (22) and a second driven teeth portion (240b) connected to the outer camshaft (12b).

6. The improvement of claim 5 further comprising:

5 a common endless loop flexible drive member (242) in driving engagement with both driven teeth portions (240a, 240b) of the driven sprocket ring gear (240).

7. The improvement of claim 2, wherein the plurality of driven teeth
10 (14a) of the torsional drive mechanism (14) further comprises:

a pair of opposing transversely extending faces (344a, 344b) located between a housing portion (28) of the phaser (22) and a flange (316) of a sprocket ring gear (340) having a plurality of intermeshing teeth (340a, 340b).

8. The improvement of claim 2, wherein the plurality of driven teeth
15 (14a) of the torsional drive mechanism (14) extend in at least one face width direction (140c, 240c, 340c) with respect to a rotational axis of the concentric cam (12) selected from an axial direction (140c, 240c), a radial direction (340c), and any combination thereof.

20

9. The improvement of claim 1, wherein the torsional drive mechanism (14) further comprises:

a combination pin and slot drive mechanism (440) located between a housing portion (28) of the phaser (22) and a flange (442) of a sprocket ring gear
25 (456).

10. The improvement of claim 1, wherein the torsional drive mechanism (14) further comprises:

a flexible shaft coupling (40) defined by a torque transmitting cable
30 assembly.

11. The improvement of claim 10, wherein the flexible shaft coupling (40) further comprises:

spiral wound strands (40b) joined together to preclude unraveling thereof and connected at one end to the inner camshaft (12a) and to the cam phaser (22) at an opposite end.

12. The improvement of claim 10, wherein the flexible shaft coupling (40) further comprises:

at least one complementary male-female shaped coupling (18, 24) having an end portion (18a, 24a) of non-circular cross-section for attachment to a complementary male-female shaped fitting (18b, 24b) located on one of the inner camshaft (12a) and the cam phaser (22).

13. A method of assembling a variable cam timing assembly (10) for an internal combustion engine of a motor vehicle having a cam phaser (22) connected between an inner camshaft (12a) and an outer camshaft (12b) of a concentric camshaft (12) comprising:

connecting a torsional drive mechanism (14) between the inner camshaft (12a) and the outer camshaft (12b) of the concentric camshaft (12) for transmitting rotational torque, the torsional drive mechanism (14) permitting adjustment for perpendicularity and axial misalignment, while maintaining a torsionally stiff coupling between the cam phaser (22) and at least one of the inner and outer camshafts (12a, 12b) of the concentric camshaft (12).

14. The method of claim 13 further comprising:

forming a plurality of driven teeth (14a) on the torsional drive mechanism (14).

15. The method of claim 14, wherein forming the plurality of driven teeth (14a) of the torsional drive mechanism (14) further comprises:

forming a driven gear (140) having an axis of rotation and transversely split into a first driven teeth portion (140a) connected to a housing portion (28) of the phaser (22) and a second driven teeth portion (140b) connected to the outer camshaft (12b); and

5 assembling a single common drive gear (142) in driving engagement with both first and second driven teeth portions (140a, 140b) of the driven gear (140).

16. The method of claim 14, wherein forming the plurality of driven teeth (14a) of the torsional drive mechanism (14) further comprises:

10 forming a driven sprocket ring gear (240) having an axis of rotation and transversely split into a first driven teeth portion (240a) connected to a housing portion (28) portion of the phaser (22) and a second driven teeth portion (240b) connected to the outer camshaft (12b); and

assembling a common drive chain (242) in driving engagement with
15 both driven teeth portions (240a, 240b) of the driven sprocket ring gear (240).

17. The method of claim 14, wherein forming the plurality of driven teeth (14a) of the torsional drive mechanism (14) further comprises:

forming a plurality of intermeshing teeth (340a, 340b) on a pair of
20 opposing transversely extending faces (344a, 344b) located between a housing portion (28) of the phaser (22) and a flange (316) of a sprocket ring gear (356).

18. The method of claim 13, wherein connecting the torsional drive mechanism (14) further comprises:

25 interconnecting a combination pin and slot drive mechanism (440a, 440b) located between a housing portion (28) of the phaser (22) and a flange (442) of a sprocket ring gear (456).

19. The method of claim 13, wherein connecting the torsional drive
30 mechanism (14) further comprises:

connecting a flexible shaft coupling (40) between the cam phaser (22) and the inner camshaft (12a) of the concentric camshaft (12) for transmitting rotational torque, the flexible shaft coupling (40) having a flexible body (40a) permitting adjustment for perpendicularity and axial misalignment, while maintaining a torsionally stiff coupling between the cam phaser (22) and at least one of the inner and outer camshafts (12a, 12b) of the concentric camshaft (12).

20. The method of claim 19 further comprising:
joining spiral wound strands (40b) together to define the flexible shaft coupling (40) and to preclude unraveling thereof;
forming at least one complementary male-female shaped coupling (18, 24) having an end portion (18a, 24a) of non-circular cross-section for attachment of at least one end of the flexible shaft coupling (40) to one of the inner camshaft (12a) and the cam phaser (22); and
connecting the at least one end of the flexible shaft coupling (40) to at least one of the inner camshaft (12a) and the cam phaser (22).

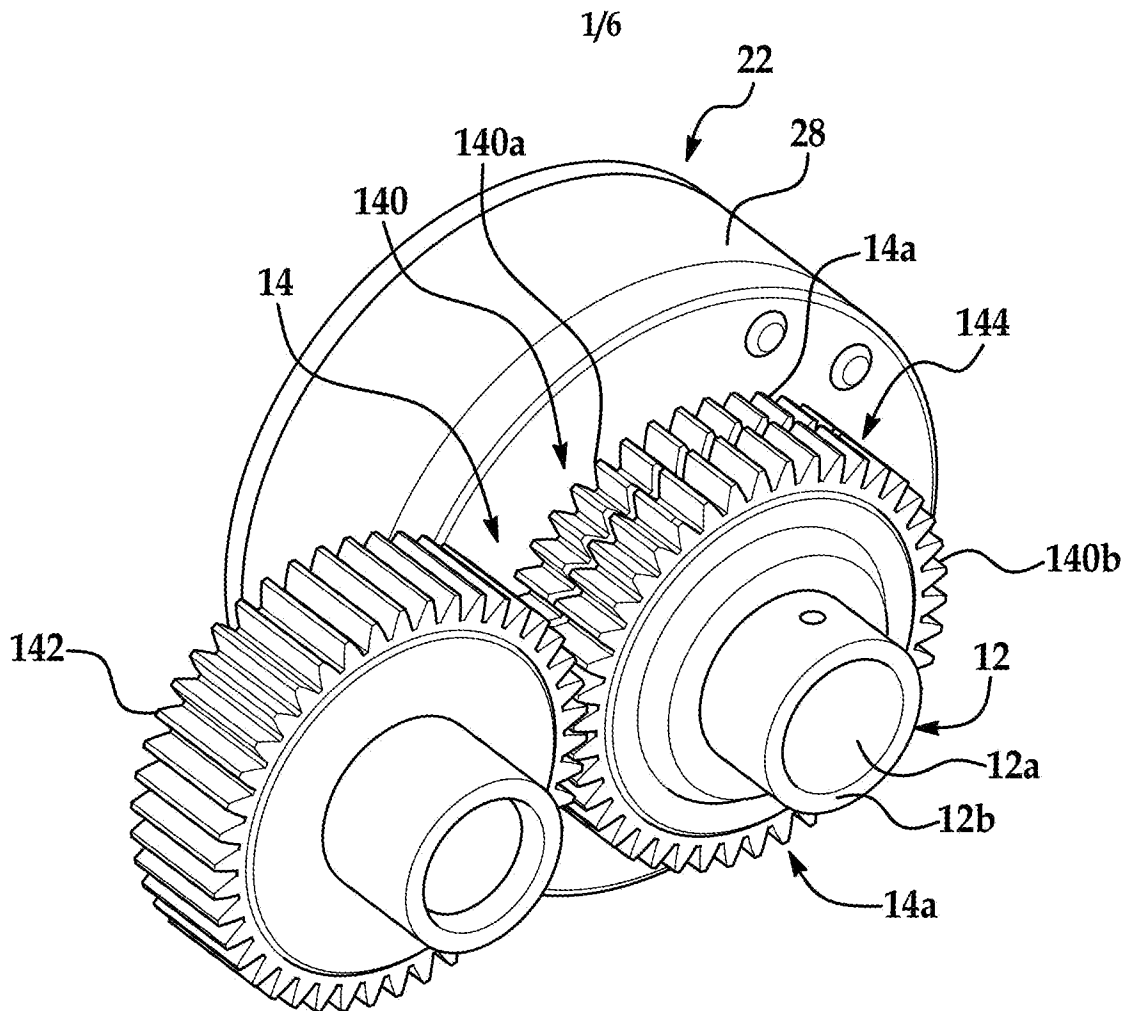


FIG. 1

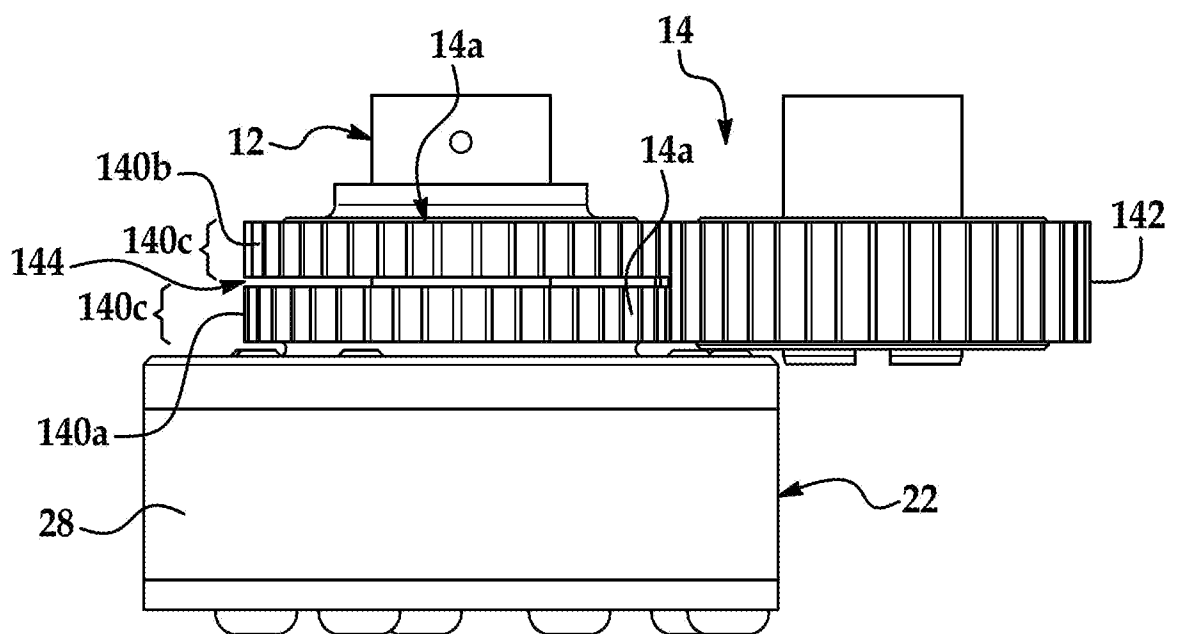


FIG. 2

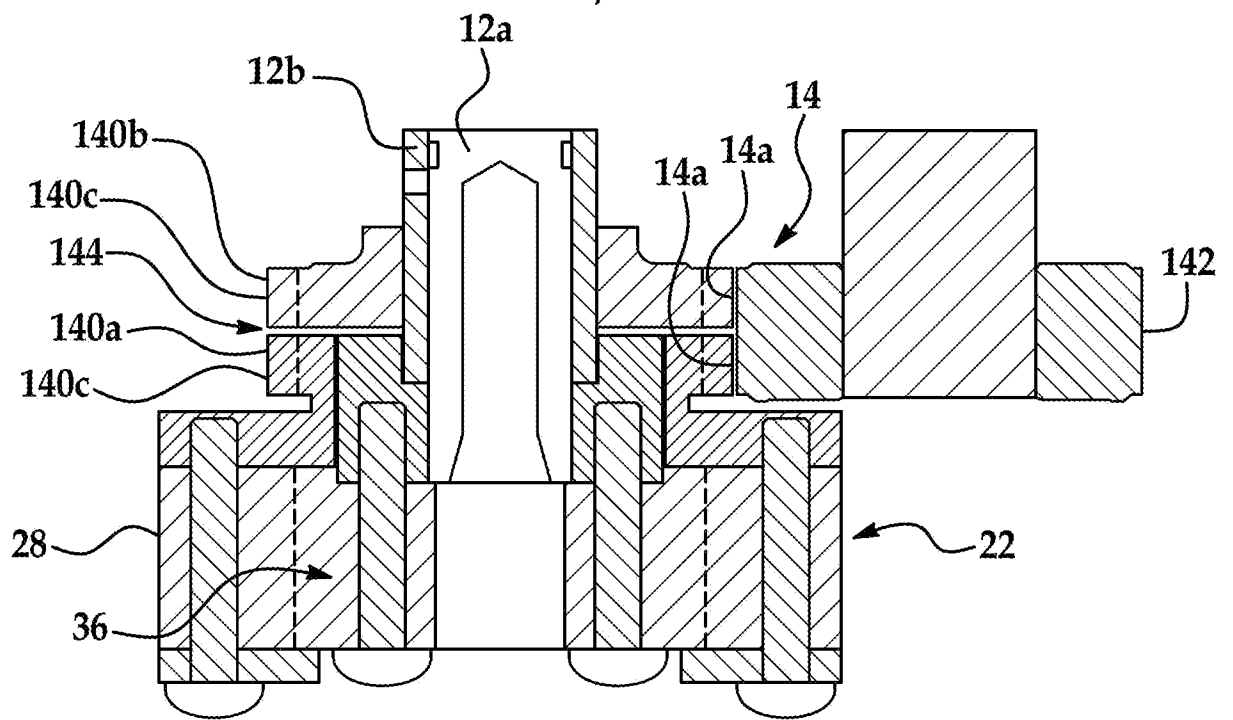


FIG. 3

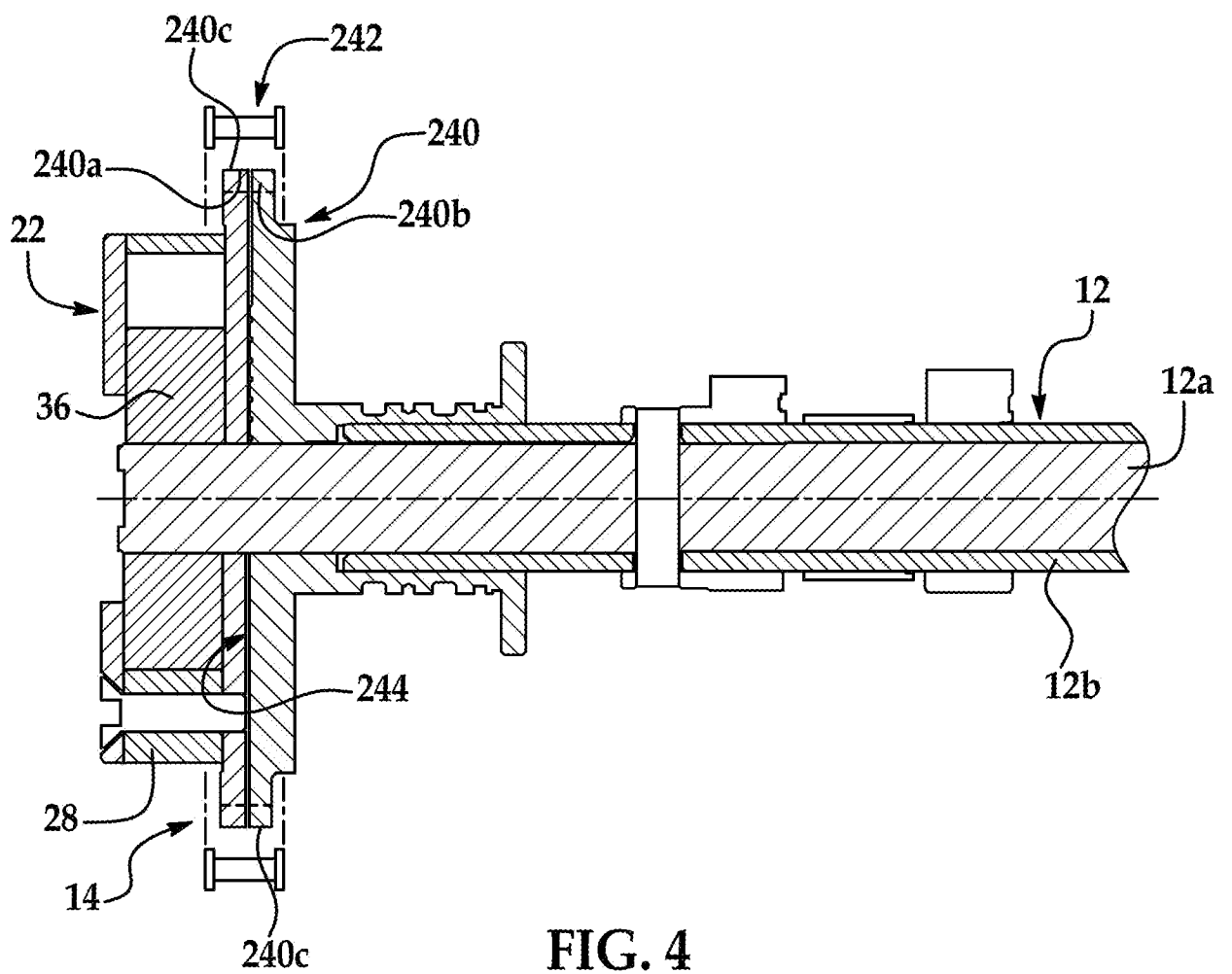


FIG. 4

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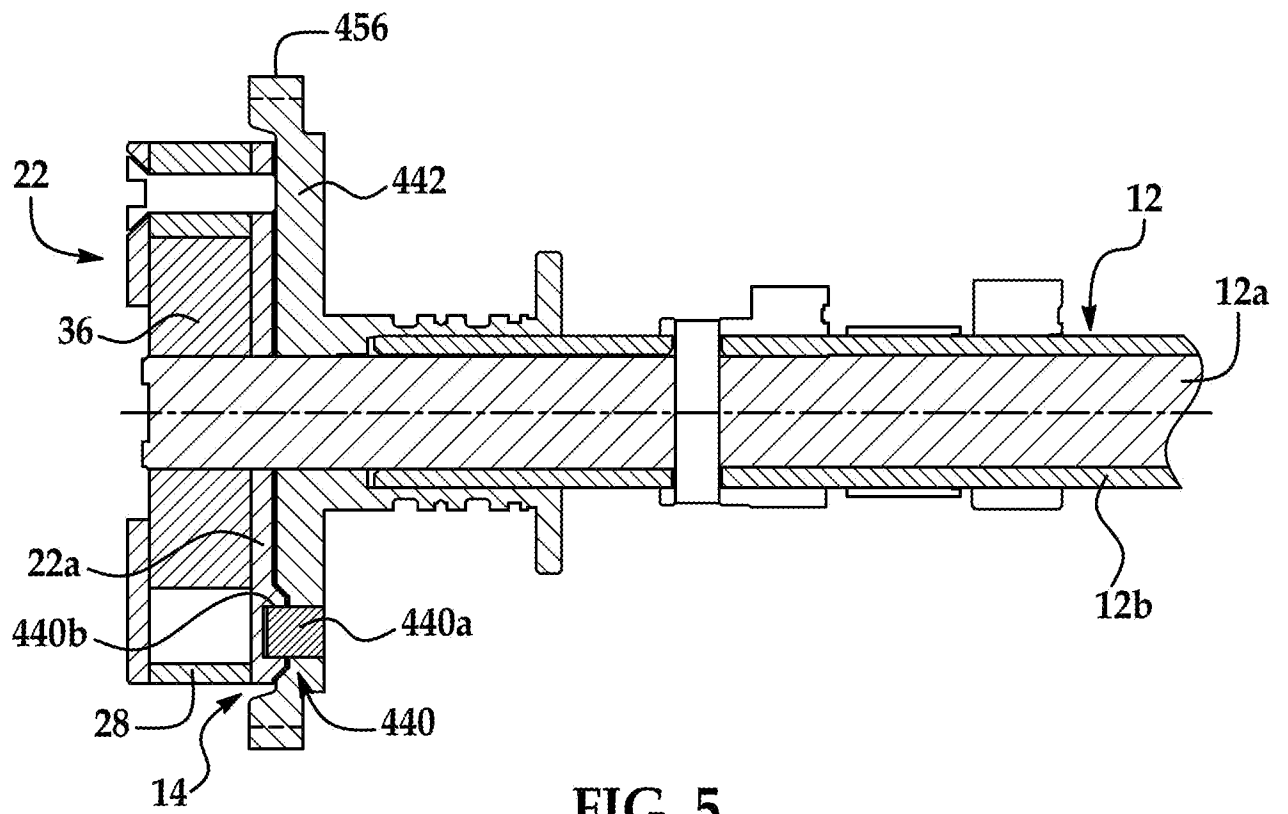


FIG. 5

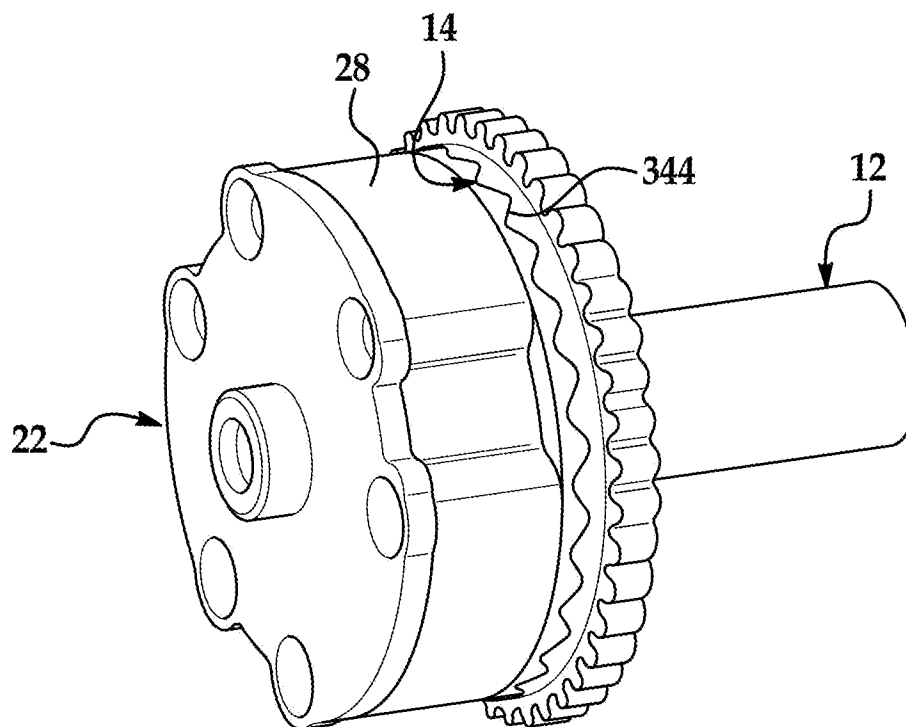


FIG. 6

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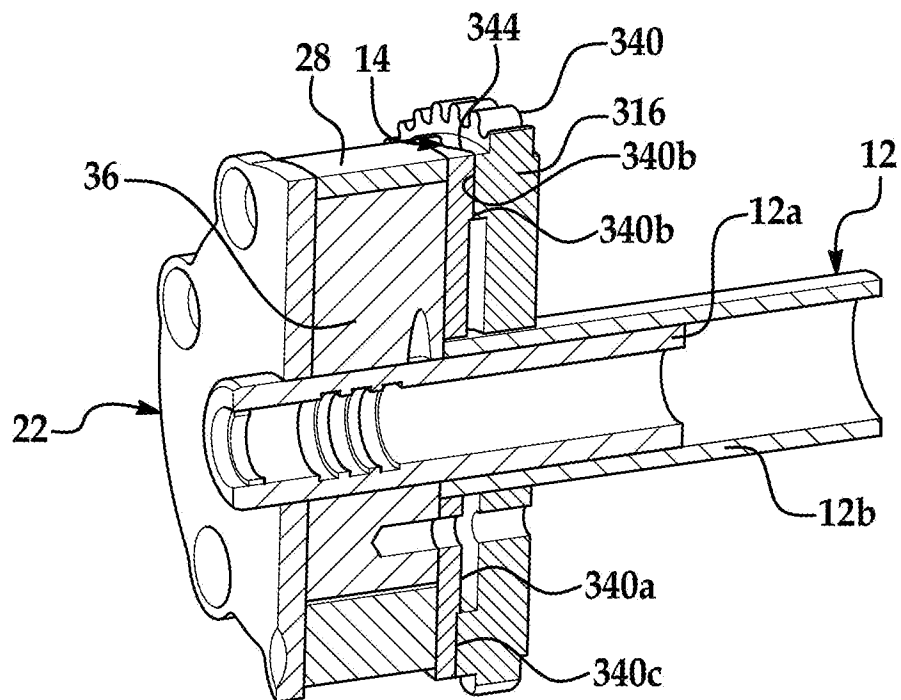


FIG. 7

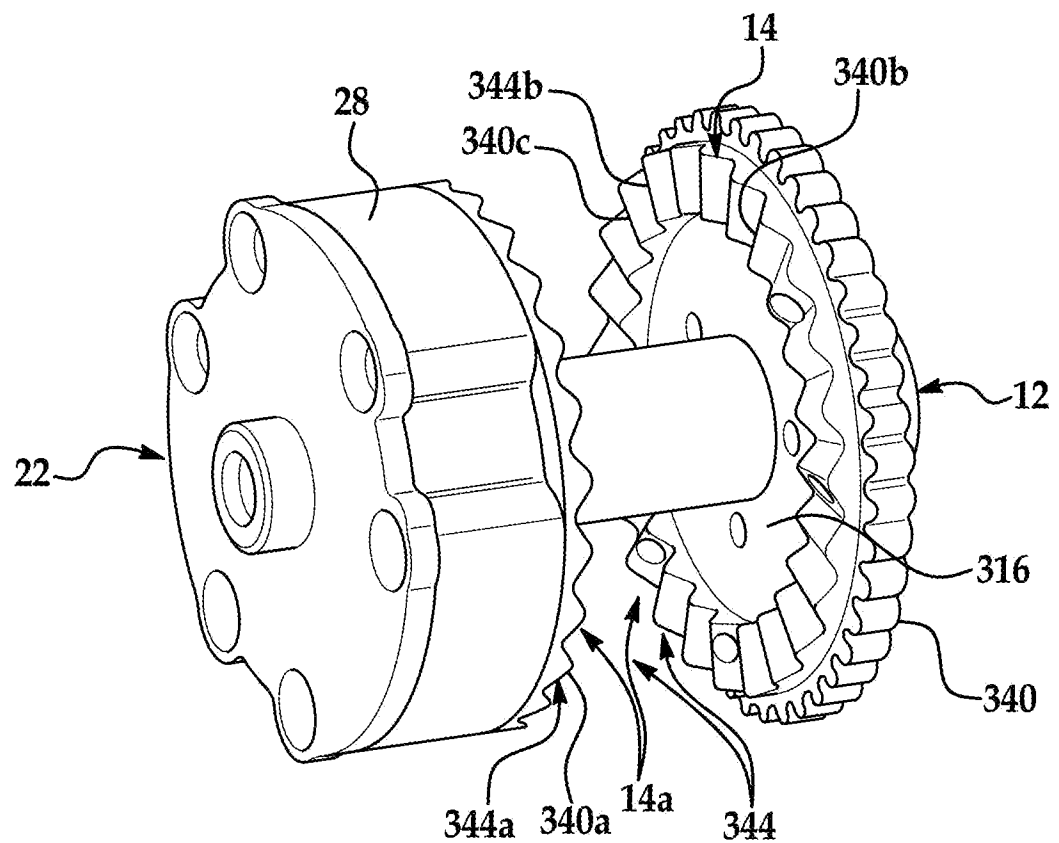


FIG. 8

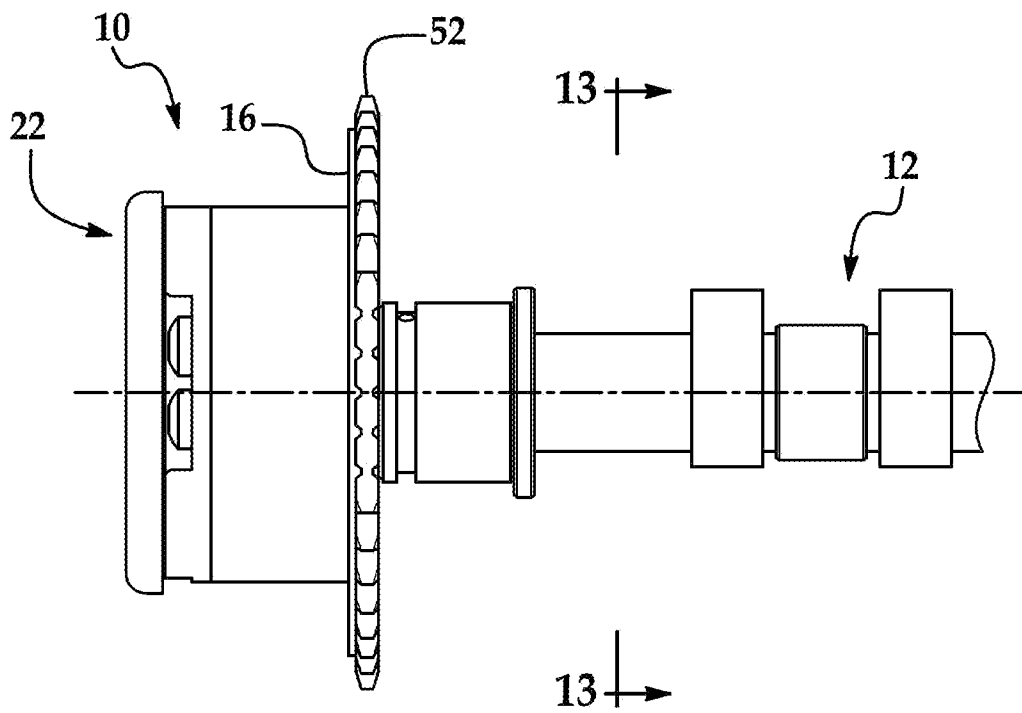


FIG. 9

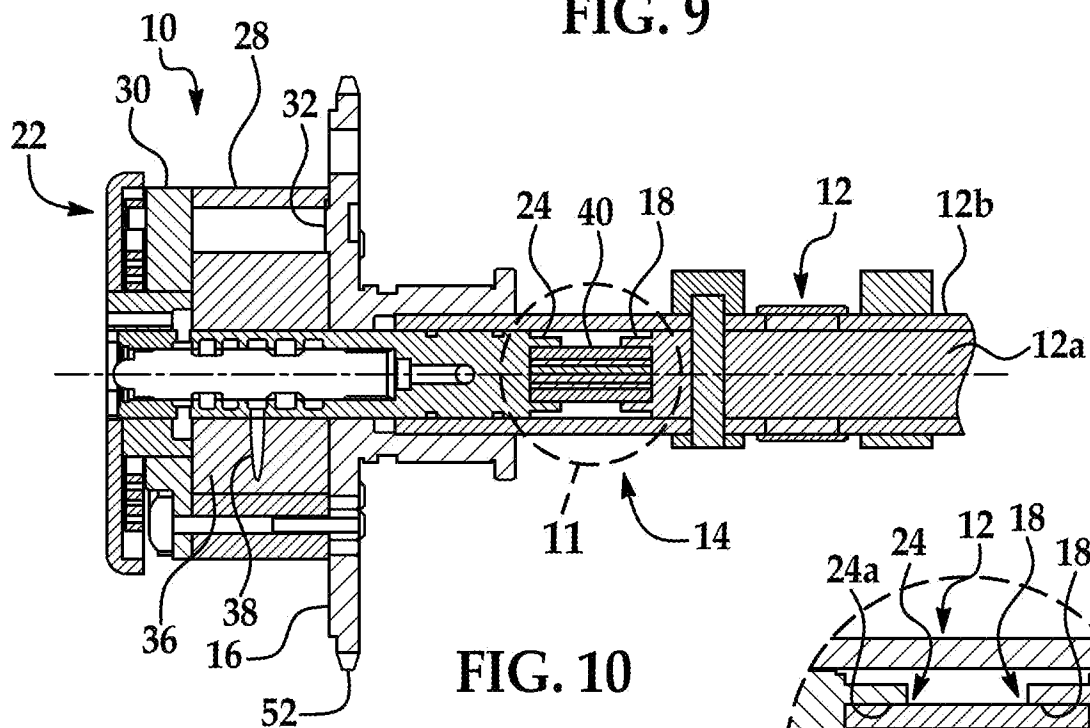


FIG. 10

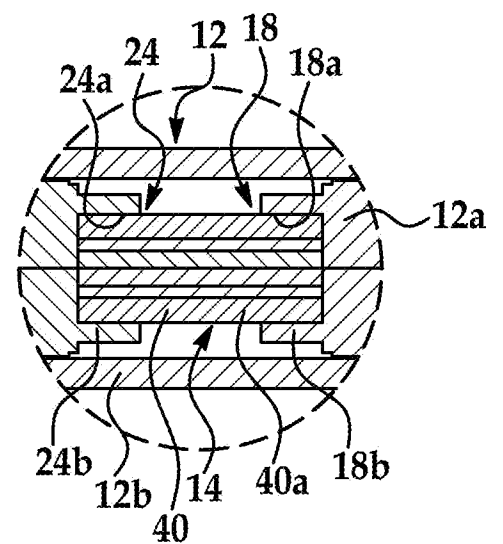


FIG. 11

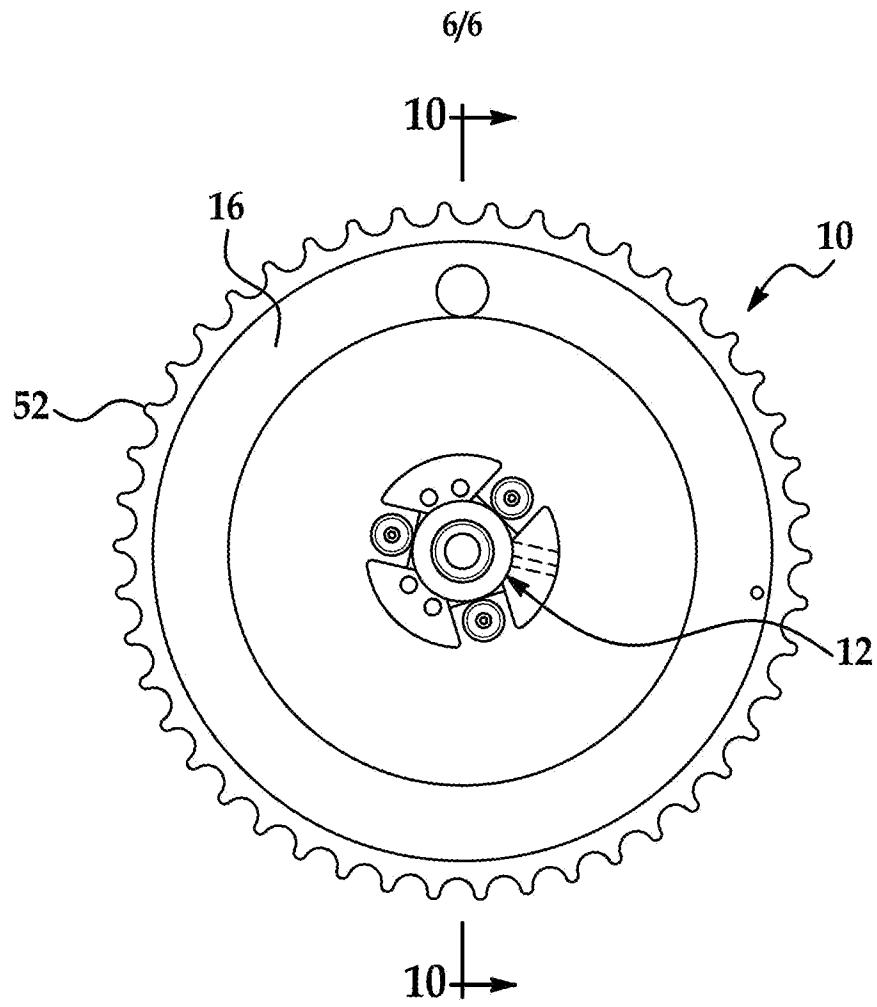


FIG. 12

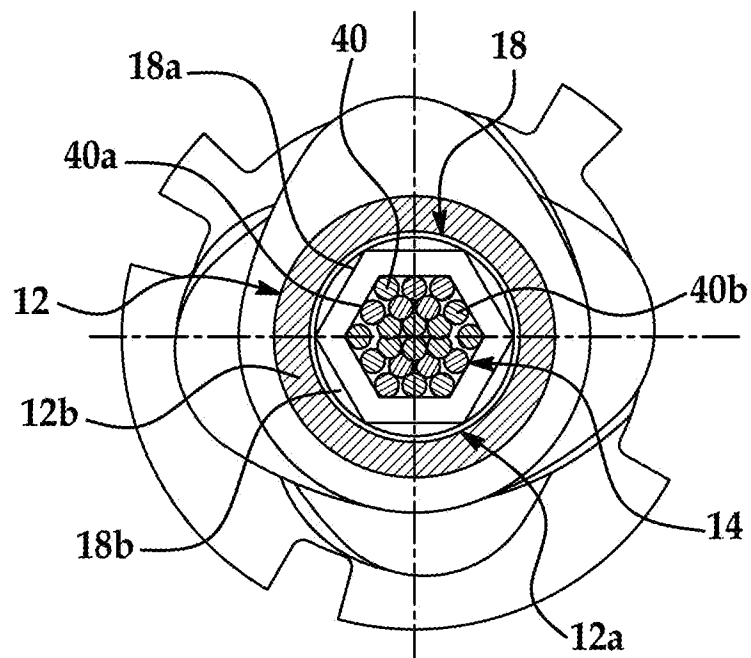


FIG. 13