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HERBEIN et al.(10) **Pub. No.: US 2019/0301313 A1**(43) **Pub. Date: Oct. 3, 2019**(54) **ELECTRIC CAMSHAFT PHASE-SHIFTER
WITH SINGLE SHAFT****Publication Classification**(71) Applicant: **SONCEBOZ AUTOMOTIVE SA,**
Sonceboz (CH)(51) **Int. Cl.**
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(FR)(52) **U.S. Cl.**
CPC **F01L 1/352** (2013.01); **F01L 2001/3521**
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Sonceboz (CH)(57) **ABSTRACT**(21) Appl. No.: **16/302,945**(22) PCT Filed: **May 24, 2017**(86) PCT No.: **PCT/EP2017/062636**

§ 371 (c)(1),

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A regulating device for the continuous phase-shifting of the angle of rotation of a camshaft controlling the gas exchange valves of an internal combustion engine with respect to a driving element, notably a chain or belt, includes an electric regulating motor coupled to a reduction gearbox with three inputs/outputs comprising an external ring gear, an input element and an outer disc, the external ring gear being carried by the drive element, the outfit disc being secured to the camshaft. This device includes a single shaft inside the stator of the electric motor, the single shaft supporting the input element of the reduction gearbox and the rotor of the electric motor.

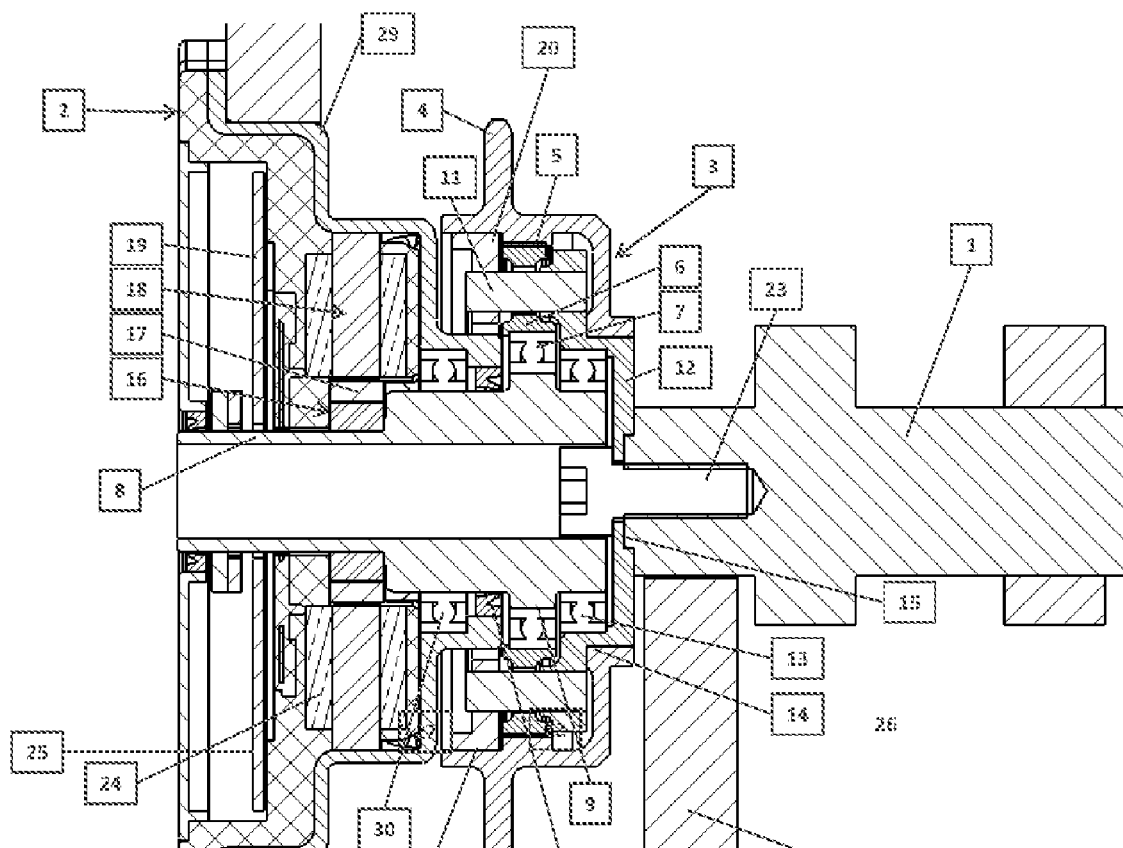


Figure 1a

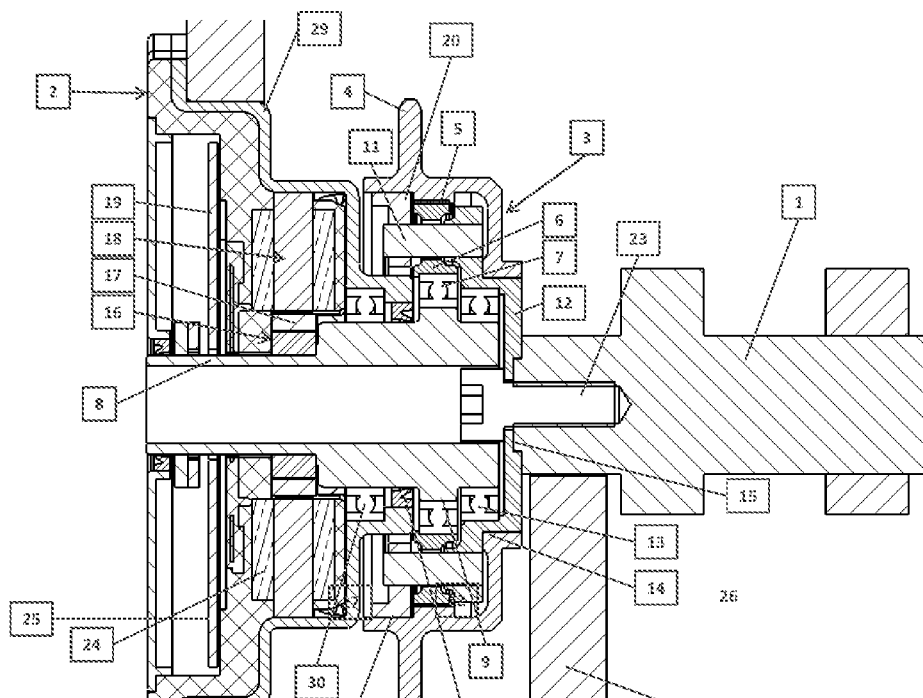


Figure 1b

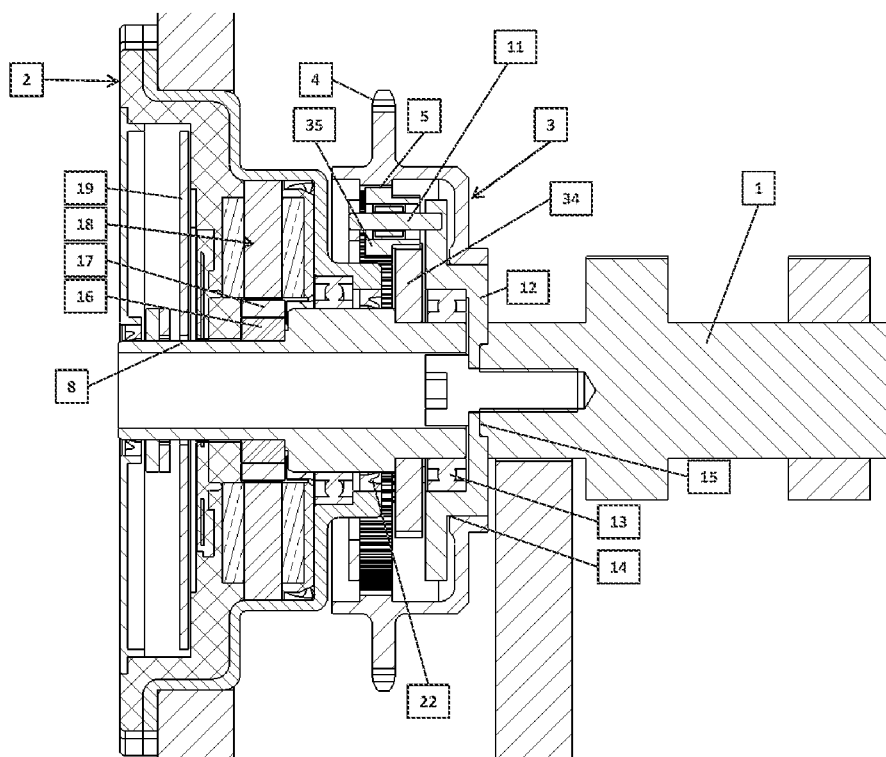


Figure 2

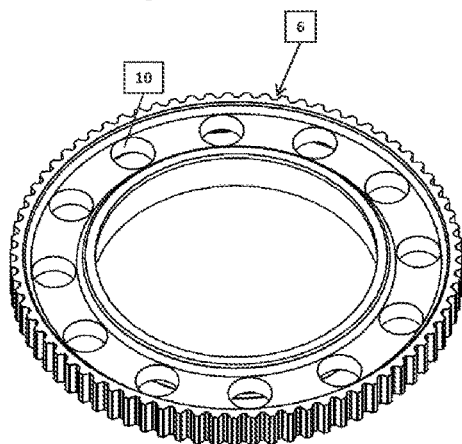


Figure 3

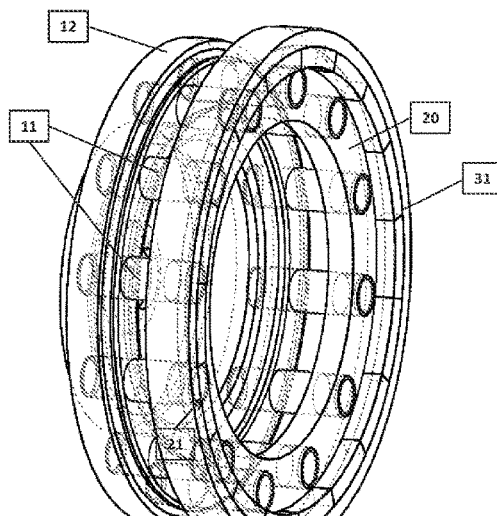


Figure 4

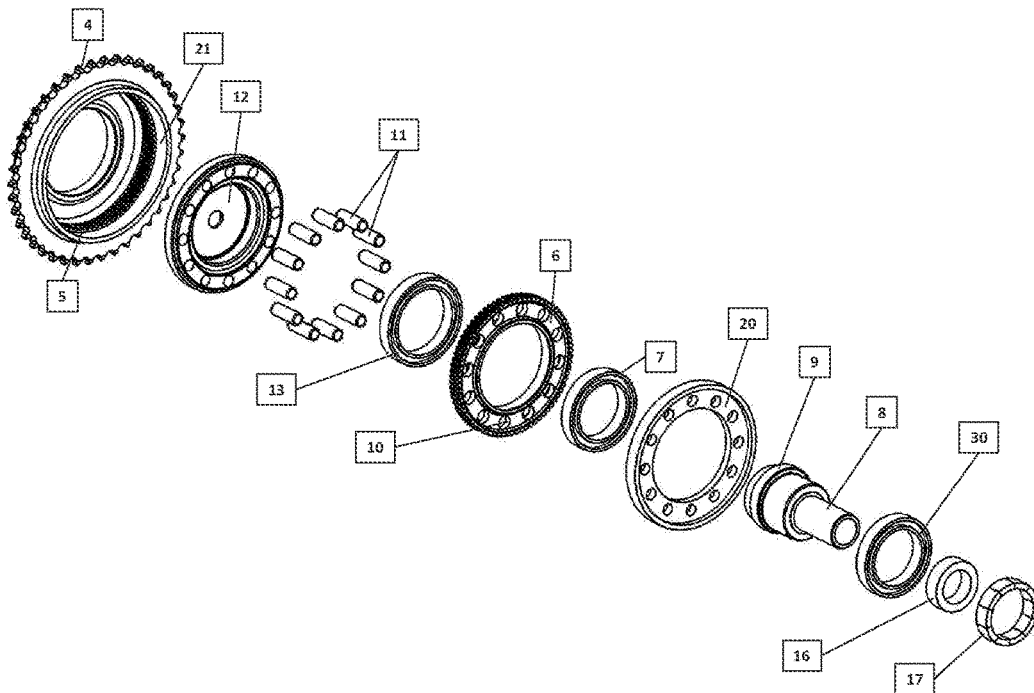


Figure 5

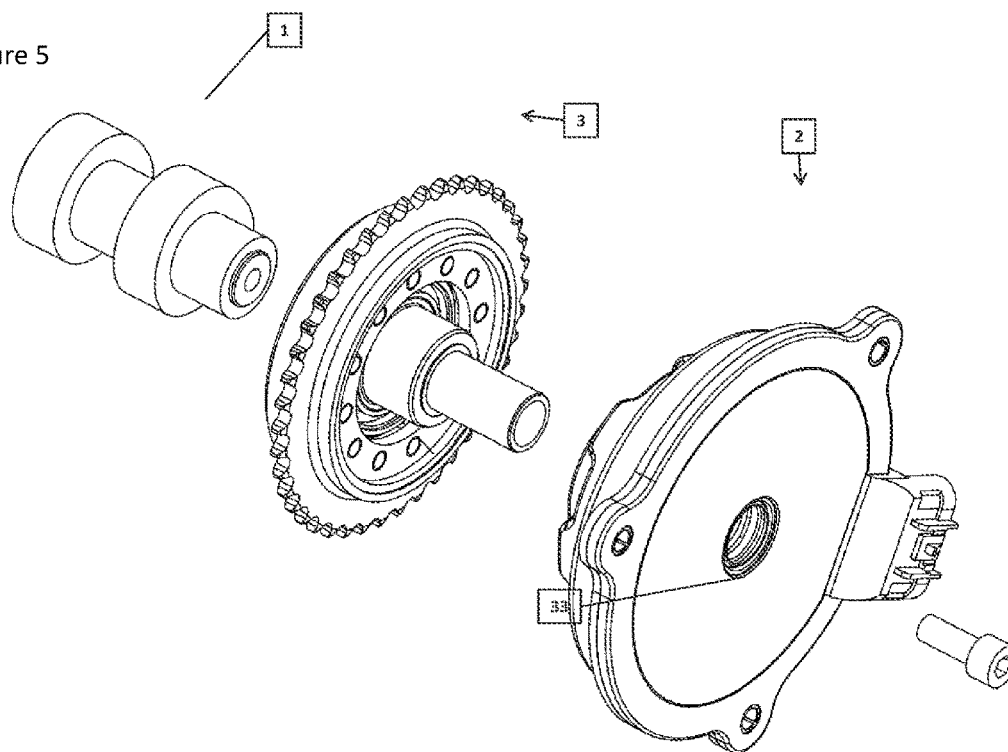


Figure 6

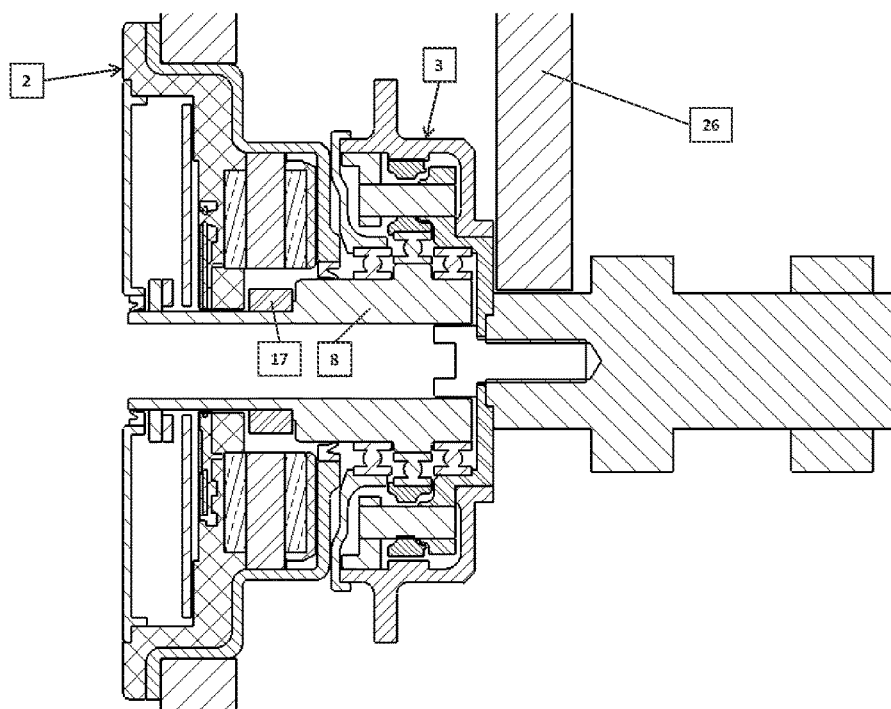


Figure 7

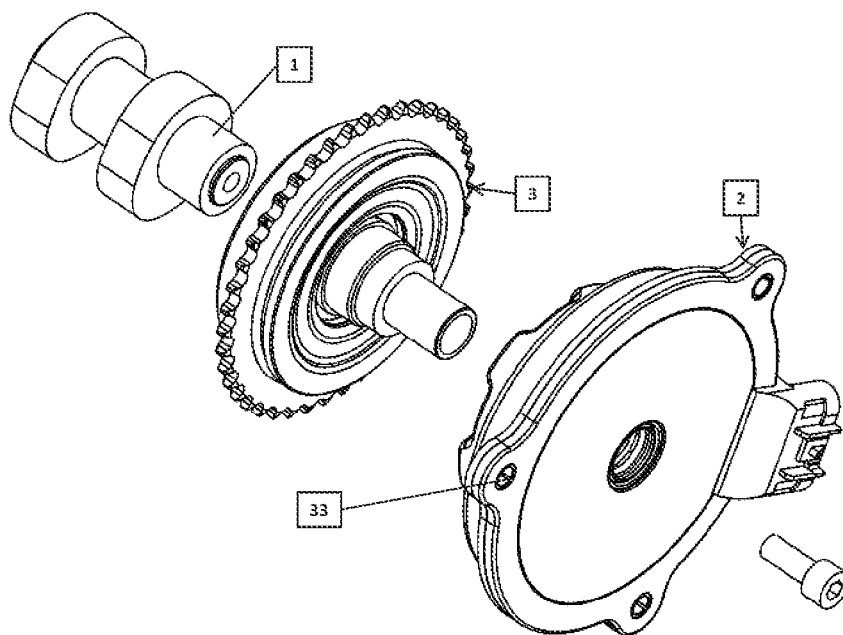


Figure 8

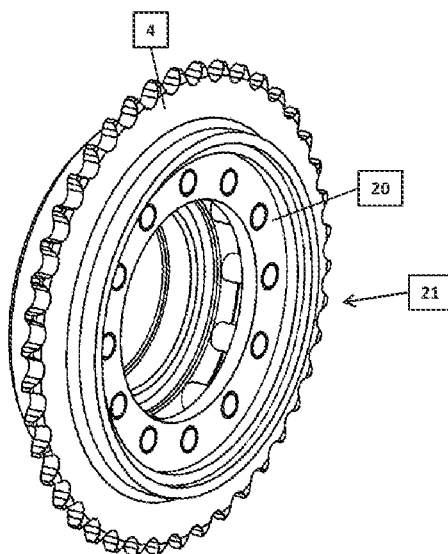


Figure 9

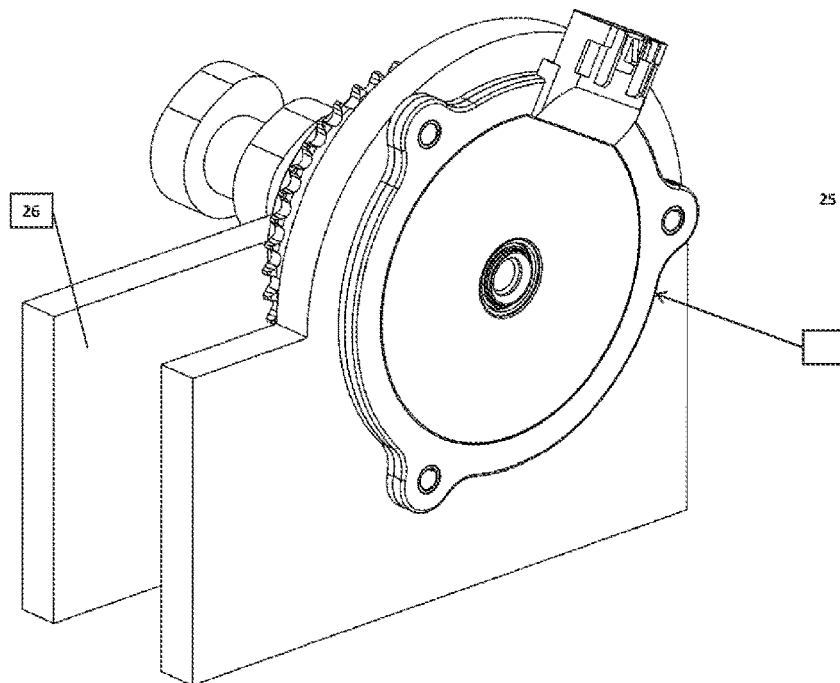


Figure 10

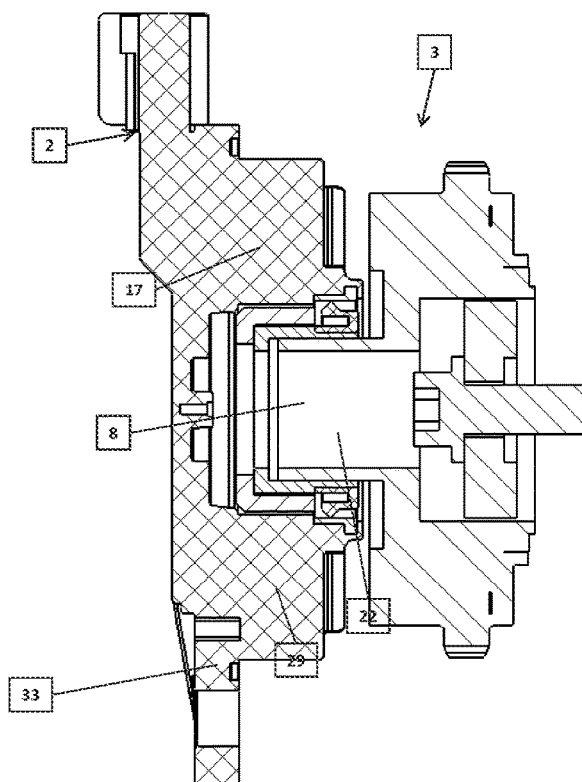
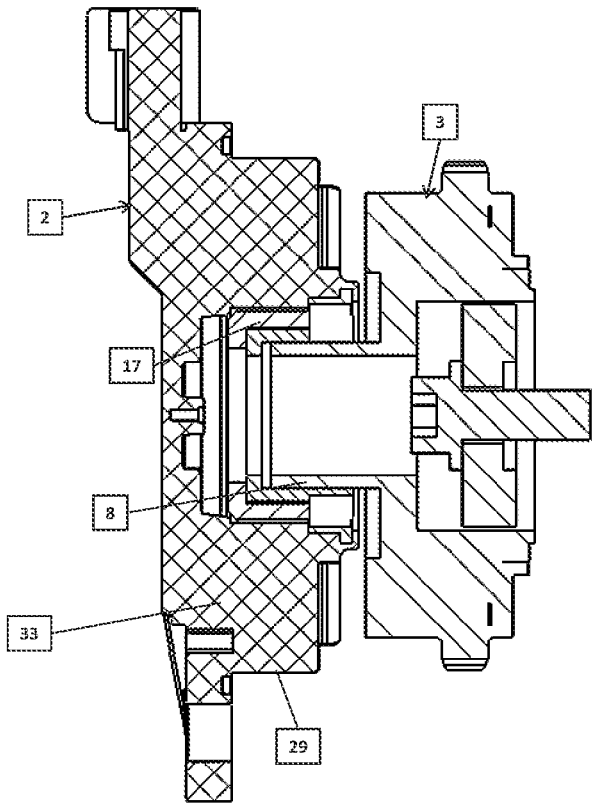


Figure 11



ELECTRIC CAMSHAFT PHASE-SHIFTER WITH SINGLE SHAFT

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a National Stage of International Application No. PCT/EP2017/062636, filed May 24, 2017, which claims priority to French Patent Application Serial. No. 16/54778 filed May 27, 2016. The entire disclosure of both of the above applications are incorporated by reference herein.

TECHNICAL FIELD

[0002] The present invention relates to the field of setting valve lift laws specific to the internal combustion engine. It more particularly relates to a camshaft incorporating a phase-shifting device, intended for a variable distribution engine.

[0003] The setting of the intake and exhaust valve lift laws is generally a compromise between different goals. For example, a search for maximum performance will involve a compromise between a low-end torque and a maximum power at high speed. On the other hand, a compromise between idle stability, the emission of pollutants at low load and a maximum power at high speed, can be considered.

[0004] The principle of a proper setting depending on speed or the load appears therefore interesting. Furthermore, various systems making it possible to achieve such goal mostly only apply to motors with two, respectively one intake and one exhaust, camshafts. The invention more particularly relates to the field of electrical devices for adjusting the rotation angle of a camshaft.

BACKGROUND

[0005] The European patent application EP2194241, which describes a cam variable setting device for a camshaft of an internal combustion engine is known in the state of the art. This device consists of a drive element and a harmonic drive reduction gearbox in operative connection with the drive element, and an output element for driving a camshaft. The reduction gearbox is adjustable by means of a rotary drive shaft. In the embodiments described, this document always refers to an electric machine, the rotor of which is outside the stator. The latter must also be guided, via a bearing, on the output shaft of the reduction gearbox which is screwed onto the camshaft. Assembling the engine is thus relatively complex with a bearing being required between the stator and the output shaft. Besides, using a rotor outside the stator imposes an important mobile inertia such which may be difficult to dynamically drive in the application.

[0006] The international patent application WO/2010/068613 discloses an electric phase-shifting device intended for a camshaft of an internal combustion engine comprising an axial flow electric machine which is incorporated in a differential gear train and which may allow a frictional locking. In this application, the electric machine has no direct coupling link with the shaft, and two bearings are thus required for positioning the stator, on the one hand, and the rotor, on the other hand. The ease of assembly of the engine is thus affected.

[0007] The prior art solutions are not satisfactory in that construction and assembly are not facilitated and require a large number of guidings. In addition, the solutions of the

prior art are not completely satisfactory especially as regards the angular accuracy. The harmonic drive gearboxes do not have a high stiffness in torsion. Given the high torque applied by such devices (about 50 Newtons per meter), this results in a risk of unintentional angular shift.

[0008] Eventually, assemblies of the speed reducing gears on the camshaft, on the one hand, and fixing the engine on the speed reducing gears, on the other hand, are regularly found in concurrent solutions, with such assembly being provided by Oldham's joint making it possible to make up for mechanical clearance between the reduction gearbox and the engine. Such Oldham's joint adds an additional part which imposes some cost and a more complex installation.

SUMMARY

[0009] The object of the invention consists in providing an improvement to the camshaft phase-shifting solutions by using a compact motor reducer, the mounting of which is facilitated and the number of parts in which is minimized. In order to remedy the drawbacks of the prior art, the present invention, in its broadest sense, relates to a regulating device for the continuous phase-shifting of the angle of rotation of a camshaft controlling the gas exchange valves of an internal combustion engine with respect to a drive element, in particular a chain or a belt, comprising a brushless electric regulating motor with a stator which is stationary with respect to an external ring gear, with the engine being coupled to a reduction gearbox with three inputs/outputs comprising the external ring gear, an input element and an output disc, with the outer ring gear being driven by said drive element, with said output drive being secured to the camshaft. The device includes a single shaft inside the stator of the electric motor, with said electric motor comprising a rotor secured to the single shaft so that said single shaft supports the rotor of the electric motor and the input element of the reduction gearbox.

[0010] In a first embodiment, said reduction gearbox is a reduction gearbox of the trochoidal type, and the axial single shaft supports the eccentric(s) enabling a reduction gearbox of the trochoidal type. The inner surface of said external ring gear advantageously has a tubular toothed path meshed with one or more toothed wheel(s) mounted on said eccentrics having bores having a circular cross-section distributed over the annular area of said toothed wheel, with the trochoidal reduction gearbox comprising a set of pins having a section smaller than that of said bores, with said pins being secured to said output disc and passing through said bores to ensure the transmission of the motion between said eccentrically moving toothed wheel and said output disc.

[0011] In a second embodiment, said reduction gearbox is a reduction gearbox of the epicyclic type, and the axial single shaft carries the inner sun gear. In this case, the inner surface of said external ring gear advantageously has a tubular toothed path meshed with one or more satellite(s), with the satellites being rotatable about pins secured to said output disc to ensure the transmission of the motion between the satellite(s) and said output disc. In a particular embodiment, said single shaft has a through bore. Then, said output disc is advantageously secured to the camshaft by a screw having a thread matching the internal thread of the camshaft and bearing against a radial shoulder of said output disc.

[0012] In a preferred embodiment, said electric motor is enclosed in an outer casing having a housing receiving a guide element of said single shaft. In this case, preferably,

the stator of said electric motor is overmolded and secured to said outer casing. To control the device, said electric motor advantageously comprises a printed circuit supporting the electronic components for steering and powering the electric coils carried by the stator. Still to enable the control of the device, the latter preferably comprises at least one position sensor delivering a signal according to the angular position of said output disc.

[0013] The device also preferably comprises at least one position sensor delivering a signal according to the angular position of said external ring gear. If pins are used, these may advantageously be engaged, at their free ends, by a pin-holder, provided with a permanent magnet positioned opposite a magneto-sensitive probe forming said position sensor with said magnet. In order to enable the attachment of the device, said electric motor may have an outer casing having an outer surface matching a housing provided on the cylinder head of the internal combustion engine. In this case, said outer casing can also have fastening elements for attachment on the cylinder head of the combustion engine.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The present invention will be best understood upon reading the following detailed description of a non-restrictive exemplary embodiment, while referring to the appended drawings, wherein:

[0015] FIGS. 1a and 1b show a longitudinal cross-sectional view of a device according to the invention according to a first embodiment and respectively using a reduction gearbox of the trochoidal type and a reduction gearbox of the epicyclic type;

[0016] FIG. 2 shows an isolated view of an exemplary toothed wheel belonging to the reduction gearbox of the trochoidal type which may be used for the invention;

[0017] FIG. 3 shows an isolated view of an exemplary output assembly of a reduction gearbox of the trochoidal type which may be used for the invention;

[0018] FIG. 4 shows an exploded view of an exemplary embodiment of a reduction gearbox of the trochoidal type which may be used for the invention;

[0019] FIG. 5 shows an exploded view of an exemplary embodiment of the sub-assemblies of the invention;

[0020] FIG. 6 shows a longitudinal cross-sectional view of a device according to the invention, according to a second embodiment;

[0021] FIG. 7 shows an exploded view of the second exemplary embodiment of the sub-assemblies of the invention;

[0022] FIG. 8 shows an isolated view of one embodiment of an output assembly highlighting the interest of the pin-holder used for measuring the phase-shifting;

[0023] FIG. 9 shows a view of a regulating device according to the invention mounted on the cylinder head of a combustion engine;

[0024] FIG. 10 shows a longitudinal cross-sectional view of a device according to the invention, according to a third embodiment; and

[0025] FIG. 11 shows a longitudinal cross-sectional view of a device according to the invention, according to a fourth embodiment.

DETAILED DESCRIPTION

[0026] FIG. 1a shows a cross-sectional view of a device according to an exemplary embodiment of the invention, coupled to a camshaft 1. The device consists of an electric motor 2 associated with a reduction gearbox 3, here of the trochoidal type. The reduction gearbox 3 comprises an external ring gear 4 driven by the timing chain or belt of the internal combustion engine (not shown). This external ring gear 4 has a typical outside diameter of 100 to 150 millimeters and has outer teeth adapted to driving by said timing chain. The inner surface thereof has a toothed path 5, with a tubular shape. This external ring gear 4 is free to rotate relative to the camshaft 1.

[0027] An eccentric toothed wheel 6 has a section lower than the inner section of the external ring gear 4, with the number of teeth of the toothed wheel 6 being less than the number of teeth of the toothed path 5 on the inner surface of the external ring gear 4, for an identical module. The difference between the number of teeth of the toothed wheel 6 and the number of teeth of the toothed path 5 on the inner surface of the external ring gear 4 is advantageously one tooth in order to maximize the reduction ratio of the trochoidal reduction gearbox 3. This toothed wheel 6 is guided by a bearing 7 mounted on the single shaft 8 at an eccentric 9 the axis of revolution of which is shifted with respect to the median axis of the single shaft 8. The shifting between the two axes generally ranges from 0.1 to 1 mm and depends on the gearing module of the trochoidal meshing. The eccentric toothed wheel 6 has a series of circular bores 10 angularly distributed on an annular track, as can be seen in FIG. 2.

[0028] As shown in FIG. 3, these bores 10 are traversed by pins 11 having a circular cross-section S_g which is smaller than the section S_p of the circular bores 10. The circular section S_g has a diameter reduced by twice the eccentricity between the single shaft 8 and the eccentric relative to the diameter of the section S_p .

[0029] The pins 11 are erected perpendicularly to the transverse surface of an output disc 12. The output disc 12 is coaxial with the single shaft 8 and is free to rotate with respect to this single shaft 8. It is guided, with respect to this single shaft 8, by a bearing 13.

[0030] In a particular embodiment, the ends of the pins 11 are taken by a pin holder 20 which advantageously makes it possible to increase the stiffness in torsion of the outlet assembly 21 of the reduction gearbox 3, formed by the pin holder 20, the pins 11 and the output disc 12. Said pin holder 20 may, in a particular embodiment, advantageously be guided on a cylindrical inner surface 27 of the external ring gear which thus improves the guiding of the output assembly 21 of the reduction gearbox 3. The output disc 12 has a shoulder 14 for guiding the external ring gear 4. Besides, the output disc 12 is secured to the camshaft 1 by a screw 23 with which it is coupled by means of a radial enlargement 15, closest to the axis of rotation of the assembly formed.

[0031] The invention is not limited to the reduction gearbox of the trochoidal type. As a matter of fact, other reduction gearboxes can be used, for example a reduction gearbox of the epicyclic type. FIG. 1b shows, like FIG. 1a a cross-section using such a reduction gearbox. Selecting one reduction gearbox or another may be dictated by the desired reduction ratio and by the final cost of the solution.

[0032] In the case of the epicyclic reduction gear of FIG. 1b, the single shaft 8 carries a sun gear 34 which meshes with typically two or three satellites 35, which in turn also

mesh with the toothed path 5 of the external ring gear 4. The satellites 35 are rotatable about pins 11 secured to the output disc 12, with the latter forming the planet carrier. The controlled relative motion between the sun gear 34 and the external ring gear 4 makes it possible to thereby regulate the phase-shifting.

[0033] In all cases, and regardless of the reduction gearbox used, the engine 2 comprises a rotor 16 secured to the single shaft 8. It is provided with permanent magnets 17 which are alternately magnetized, typically radially or in a scalloped way. In all cases, the single shaft 8 carries the input element of the reduction gearbox: for instance, the eccentric toothed wheel 6 in the case of the trochoidal gearbox, or the internal sun gear 34 in the case of the epicyclic gearbox.

[0034] The stator 18 of the electric motor 2 consists of a set of electric coils 24 forming a polyphase assembly, and a generally laminated ferromagnetic part. The engine 2 further comprises an electronic control circuit 19 for controlling the operation of the engine, with a rotation synchronized with the distribution chain, except during the phase-shifting control. The assembly formed by the stator 18, the rotor 16 and the electronic circuit 19 is positioned in an outer casing 29 which can be a housing or an overmolding skin. The single shaft 8 can thus be guided relative to the outer casing 29 using a bearing 30 between the reduction gearbox and the rotor 16.

[0035] In order to ensure the sealing of the engine and in particular to prevent oil from rising towards the stator 18 and the electronic control circuit 19, a seal 22, typically a lip seal, is positioned on the single shaft 8 in contact with the outer casing 29 of the engine. The mounting of the motor reducer formed is thus greatly simplified in this embodiment. As a matter of fact, the rotor 16 and the output disc 21, and all the reduction gearbox elements 3 can be mounted on the single shaft 8 and then the electric motor 2 can be mounted on said single shaft 8, after positioning the seal 22 to enable the mounting of the assembly on the camshaft 1 via the radial enlargement 15 which has a smaller diameter than the hollow inner diameter of the single shaft 8. The single shaft 8 can then be attached coaxially with the camshaft 1 by screwing this radial enlargement 15 on the camshaft 1.

[0036] An important advantage of the solution is therefore to provide a totally hollow single shaft 8, which enables the easy screwing of the reduction gearbox 3 after positioning the assembly. FIG. 5 shows the described sub-assemblies and the assembling sequence thereof.

[0037] In the alternative solution of FIG. 6, showing a particular embodiment, the single input shaft 8 of the reduction gearbox, which carries the magnet of the electric motor 2, is fully guided and carried by the reduction gearbox 3. This embodiment makes it possible to position, at first, the reduction gearbox 3 with the single shaft 8 carrying the rotor 16 directly on the camshaft 1, then secondly to directly insert the stator 18 of the electric motor 2 on said input shaft 8. Thus, assembling is facilitated and can be significantly simplified. For this particular embodiment, the mechanical clearance between the magnet 17 of the electric motor 2 and the stator 18 should advantageously be increased in order to tolerate the probable misalignments between the single input shaft 8 of the reduction gearbox 3 and the axis of the cylindrical housing of the magnet of the electric motor 2 in the stator 18. Here, using a brushless motor, i.e. without any mechanical contact between the stator and the rotor, is particularly advantageous in this respect. It should also be

noted that the single shaft 8 can be used as a ferromagnetic yoke for the magnets 17 as shown in FIG. 6.

[0038] FIG. 7 makes it possible to see the easy mounting by first placing the reduction gearbox 3 with the single shaft 8 on the camshaft 1 and then the stator 18 of the electric motor 2 which is further screwed on the engine cylinder head 26, at a housing 25, using fastening elements 33, here in the form of eyelets, so as to form an assembly as shown in FIG. 9. It should also be noted that, in this embodiment, the presence of a totally hollow single shaft 8 is not absolutely necessary since it shall be mounted prior to positioning the stator 18. Thus, as shown in FIG. 10, positioning a rotor 16 attached to the single shaft 8 is possible, after mounting the reduction gearbox 3 on the camshaft 1, with sealing being provided by a reversed lip seal 22, as well as closing the assembly with the stator in its casing 29. The electric motor 2 is then attached by its casing 29 on the cylinder head, using the fastening elements 33. Still in this embodiment, a lip seal may be omitted if sealing is provided by the casing totally overmolding the engine and the electric elements thereof. This alternative solution is shown in FIG. 11.

[0039] Using the reduction gearbox 3, as presented in the various embodiments and defined by the invention, advantageously makes it possible to integrate a position sensor. As illustrated in FIG. 3, the pin holder 20 sliding on the cylindrical inner surface 27 of the external ring gear 4 is connected to the output disc 12 to form the outlet assembly 21. Positioning a sensor magnet secured to this output assembly, for instance in the form of a disc or a magnet ring 31 can also be considered. Positioning a probe for measuring the magnetic field beside the stator 18, opposite the magnet ring or disc 31, thus makes it possible to build a phase-shifting absolute position sensor, i.e. makes it possible to know the position of the camshaft 1. When associating a position sensor 4 connected to the external ring gear 4 or at the shaft of the internal combustion motor, it is possible to know the phase-shifting.

[0040] From the description of the invention that has been made, it obviously is not limited to the type of electric motor used. As a matter of fact, a variable reluctance motor can also be considered instead of the motor with a magnetized rotor.

1. A regulating device for continuous phase-shifting of an, angle of rotation of a camshaft ROM controlling the gas exchange valves of an internal combustion engine with respect to a chain or a belt drive element, the device comprising a brushless electric regulating motor including a stationary stator with respect to an external ring gear, with the engine being coupled to a reduction gearbox with three inputs/outputs comprising an external ring gear, an input element and an output disc), with the external ring gear being driven by the drive element, with the output disc being secured to the camshaft, a single shaft inside the stator of the electric motor, with the electric motor comprising a rotor secured to the single shaft so that the single shaft supports the rotor of the electric motor and the input element of the reduction gearbox.

2. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 1, wherein:

the reduction gearbox is a trochoidal reduction gearbox; and

the axial single shaft supports the eccentric(s) enabling a reduction of the trochoidal type.

3. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 2, wherein the inner surface of the external ring gear has a tubular toothed path meshed with one or more toothed wheel(s) mounted on the eccentrics having bores with a circular cross-section distributed over the annular area of the toothed wheel, and the trochoidal reduction gearbox comprising a set of pins having a section smaller than that of the bores, with the pins being secured to the output disc and passing through the bores to ensure the transmission of the motion between the eccentrically moving toothed wheel and the output disc.

4. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 1, wherein:

the reduction gearbox is an epicyclic reduction gearbox; and

the axial single shaft carries the inner sun gear.

5. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 4, wherein the inner surface of the external ring gear has a tubular toothed path meshed with one or more satellite(s), with the satellites being rotatable about pins secured to the output disc to ensure the transmission of the motion between the satellites and the output disc.

6. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 1, wherein the single shaft has a through bore.

7. A regulating device for the continuous phase-shifting of the angle of rotation of camshaft according to claim 6, wherein the output disc is secured to the camshaft by a screw having a thread matching the internal thread of the camshaft, and bearing against a radial shoulder of the output disc.

8. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 1,

wherein the electric motor is enclosed in an outer casing having a housing receiving a guide element of the single shaft.

9. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 8, wherein the stator of the electric motor is overmolded and secured to the outer casing.

10. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 1, wherein the electric motor comprises a printed circuit supporting the electronic components for steering and powering the electric coils carried by the stator.

11. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 1, further comprising at least one position sensor delivering a signal according to the angular position of the output disc.

12. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 1, further comprising at least one position sensor delivering a signal according to the angular position of the external ring gear.

13. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 12, wherein the pins are engaged, at their free ends, by a pin-holder provided with a permanent magnet positioned opposite a magneto-sensitive probe forming the position sensor with the magnet.

14. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 1, wherein the electric motor has an outer casing having an outer surface matching a housing provided on the cylinder head of the internal combustion engine.

15. A regulating device for the continuous phase-shifting of the angle of rotation of the camshaft according to claim 14, wherein the outer casing has fastening elements for attaching on the cylinder head of the combustion engine.

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