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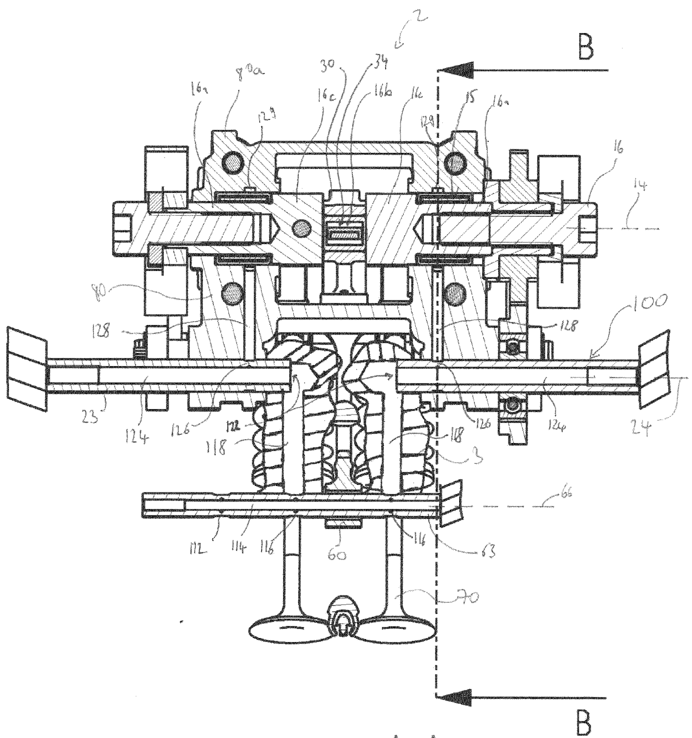
(54) VARIABLE VALVETRAIN HAVING LUBRICANT SUPPLY SYSTEM

(57) A variable valvetrain 2 for actuating a valve 70 of an internal combustion engine is provided. The valvetrain 2 comprises a rotatable valve crank 16 rotatably mounted by a valve crank bearing 15 to a rigid support body 80. The support body 80 is pivotably mounted on a pivot shaft 23. The valvetrain further comprises and a lubricant supply system 100 with a support-body lubricant supply channel 128 passing from the pivot shaft 23 through the support body 80 to the valve crank bearing 15.



A-A

Fig. 2

EP 3 623 592 A1

Description

[0001] The present invention relates to an internal combustion engine, in particular an internal combustion engine with a valvetrain. Furthermore, the invention relates to a variable valvetrain for actuating a valve of an internal combustion engine, especially of an intake valve.

Technical background:

[0002] Variable valvetrains are known in the art. Such variable valvetrains allow to adjust (change) a valve lift, i.e. a quantity characterizing the valve lift behavior such as the lift height (maximum height of the valve opening during an engine cycle), duration and / or phase of the valve opening relative to the engine cycle. A variable valvetrain allows adjusting the lift height as a function of, for example, a number of driving parameters (e.g., rotational speed) and of a gas command (e.g., position of a gas lever or pedal).

[0003] A particularly advantageous variable valvetrain is known from DE 10 2005 057 127 A1 (hereinafter DE'127), in which also other valvetrains are cited. DE'127 in particular discloses a valvetrain having elements corresponding to those shown in Figs. 1a, 1b and in Fig. 6 of the present application. Some additional elements shown in Figs. 1a, 1b and 6 are not disclosed in DE'127. In the valvetrain of DE'127 a position of the valve crank axis 14 can be adjusted by pivoting a pivoting frame 80, in order to adjust the valve lift.

Summary of the invention:

[0004] An object of the present invention is to provide a valvetrain of an internal combustion engine with at least some of the advantages of the solution shown in DE'127, which moreover is running with low friction and/or which is relatively easy and efficient to lubricate.

[0005] The object is achieved by the valvetrain according to claim 1 and by the internal combustion engine according to claim 13.

[0006] According to one aspect of the invention, a variable valvetrain is provided for actuating a (i.e. at least one) valve of an internal combustion engine.

[0007] An actuation system of the valvetrain for periodically opening and closing the valve comprises a rotatable valve crank (16); a transmission unit for transmitting the rotational movement of the valve crank (16) into a periodical lifting movement for actuating the valve (70); and a lubricant supply system. The valve crank (16) is rotatably mounted about a valve crank axis (14) by a valve crank bearing (15), the valve crank bearing (15) connecting the valve crank (16) to a rigid support body. The support body (80) is mounted on a pivot shaft (23) to be pivotable about a pivot axis. The pivoting of the support body (80) about the pivot axis (24) causes a change in the position of the first rotational axis (14) along a circle segment about the pivot axis (24) for adjusting a valve lift, e.g., the lift height of the valve. The lubricant supply system comprises a support-body lubricant supply channel passing from the pivot shaft through the support body to the valve crank bearing.

[0008] Thereby, a reliable supply of lubricant to the valve crank bearing is obtained without need of any further elements of the valvetrain. Thereby, embodiments of the invention enable a mechanically simple, inexpensive, reliable and / or durable design of the valvetrain. Further, the other benefits mentioned in DE'127 can be at least partially achieved.

[0009] The valvetrain according to an aspect of the invention can be used in a particularly advantageous manner in internal combustion engines of devices or vehicles with high engine speeds, such as in motorcycles. Further, it can also be used in, e.g., automobiles, trucks, aircraft or watercraft.

[0010] Further advantages, features, aspects, details of the invention, preferred embodiments and specific aspects of the invention can be seen from the dependent claims, the description and the drawings.

Brief description of drawings:

[0011] Embodiments of the invention are illustrated in the drawings and are described in more detail below. In the drawings,

Fig. 1a shows a perspective view of a valvetrain in accordance with a first embodiment of the invention;

Fig. 1b shows a side view of the valvetrain of the first embodiment;

Fig. 2 shows a cross-sectional view of the valvetrain of the first embodiment along the line A-A shown in Fig. 1b;

Fig. 3a shows a cross-sectional side view of the valvetrain of the first embodiment along the line B-B shown in Fig. 2;

Fig. 3b shows a further cross-sectional side view of the valvetrain of the first embodiment;

Fig. 4 shows a cross-sectional view of the valvetrain of the first embodiment along the line C-C shown in Fig. 3a;

Fig. 5 shows a cross-sectional view of the valvetrain of the first embodiment along the line D-D shown in Fig. 3a;

Fig. 6 shows a side view of a valvetrain in accordance with a second embodiment of the invention;

Fig. 7 shows a cross-sectional view of the valvetrain of the second embodiment along the line A-A shown in Fig. 6;

Fig. 8 shows a cross-sectional side view of the valvetrain of the second embodiment along the line B-B shown in Fig. 7;

Fig. 9a shows a cross-sectional view of the valvetrain of the second embodiment along the line C-C shown in Fig. 8;

Fig. 9b shows an enlarged portion of Fig. 9a;

Fig. 10a shows a cross-sectional view of the valvetrain of the second embodiment along the line D-D shown in Fig. 8;

Fig. 10b shows an enlarged portion of Fig. 10a;

Fig. 11 shows a further cross-sectional side view of the valvetrain of the second embodiment; and

Fig. 12 shows a schematic top view of a valve crank for use in the valvetrain of the first and second embodiments.

Description of first embodiment (Figs. 1a-5):

[0012] Hereinafter, a valvetrain 2 according to an aspect of the invention will be described with reference to Figs. 1a-5. The valvetrain may have any element(s) described in DE'127, for example the elements shown in Figs. 1a-5 , in WO 2014/135321 A1, and/or in WO 2017/129820 A1. The contents of these three documents - in particular, paragraphs [0144] - [0159] of DE'127 - are herewith included by reference. In addition, the valvetrain 2 is equipped with a lubricant supply system described herein.

[0013] The valvetrain 2 shown in Figs. 1a-5 comprises a valve crank 16 and a transmission unit or gear unit. The valve crank 16 provides a rotational movement. The rotational movement is preferably synchronous to the motor cycle of the combustion engine, so that one full rotation corresponds to one full motor cycle, and it is particularly preferred that the rotational movement is driven by the crank shaft of the combustion engine 1.

[0014] For driving the valve crank 16 (also referred to as first driving member), the valvetrain 2 comprises a driving gearwheel 22 and a valve crank gearwheel 12. The driving gearwheel 22 is mounted stationarily in the cylinder head 3 and rotatably about a driving axis 24. The valve crank gearwheel 12 is fixedly connected to the valve crank 16. The valve crank 16 and the valve crank gearwheel 12 are rotatably mounted about a valve crank axis 14 (also referred to as first rotational axis) by a valve crank bearing 15 (Figs. 3a and 4). Here and in the following, the term "axis" means a geometrical axis and/or a rotational axis.

[0015] The driving gearwheel 22 is driven by a crank shaft of the combustion engine 1. The driving is synchronous to the motor cycle, i.e. a full rotation of the driving gearwheel 22 corresponds to a motor cycle. In a four stroke engine, this is the case if the transmission between crank shaft and driving gearwheel is 2:1.

[0016] The driving gearwheel 22 is in meshing connection with the valve crank gearwheel 12. The transmission ratio between driving gearwheel 22 and valve crank gearwheel 12 is 1:1. Thereby, also the valve crank gearwheel is driven synchronously to the motor cycle.

[0017] Fig. 12 is a schematic top view of the valve crank 16 shown in Figs. 1a-5. As shown there, the valve crank 16 comprises a bearing pin 16a, which is arranged along and is rotatable about the valve crank axis 14, a lifting pin 16b, which is arranged parallel and eccentric to the valve crank axis 14, and a crank arm (radial element) 16c, which connects the bearing pin 16a and the lifting pin 16b to each other. The crank arm 16c has a crank arm side surface 16d. Further, the valve crank gearwheel 12 is mounted fixedly on the bearing pin 16a of the valve crank 16. The valve crank 16 is mounted, at the bearing pin 16a, in a rotational bearing 15 (here a roller bearing), such as to be rotatable about the valve crank axis 14.

[0018] The transmission unit transmits the rotational movement of the valve crank 16 into a periodical lifting movement for actuating the valve 70. An actuation of the valve is herein understood to be a lifting movement of the valve 70, which opens and/or closes the valve 70, preferably synchronously to the motor cycle.

[0019] For this purpose, the transmission unit of Figs. 1a - 5 comprises a connecting rod 30 with a first connecting rod joint 34 and a second connecting rod joint 36; and a guiding member 60 for guiding the connecting rod. The guiding member is mounted on a guiding member shaft 63 such as to be pivotable around a guiding member axis 66. The connecting rod 30 is joined with its first connecting rod joint 34 to the first driving member 16 and with its second connecting rod joint 36 to the guiding member 60. The transmission unit further comprises a pushing member (roller) 40 fastened to the guiding member 60, and a transmission member 50 (a lever pivotable around a lever axis 52). The transmission member 50 is in releasable mechanical contact with the pushing member 40 along a contact surface 54 of the transmission member 50, for transmitting a force exerted by the pushing member 40 towards the valve 70.

[0020] According to an aspect of the invention, in the valvetrain shown in Fig. 1 the position of the valve crank axis 14 can be adjusted. To this purpose, the valve crank 16 is mounted, by the valve crank bearing 15, in a pivoting frame 80 (also referred to as support body). In other words, the valve crank bearing 15 connects the valve crank 16 to the pivoting frame 80. The pivoting frame 80 is rigid, consists in this example of several parts that are rigidly connected with one another. It is mounted on the cylinder head 3 pivotally about the pivoting axis, wherein the pivoting axis is identical to the driving axis 24 shown in Fig. 1. Because the valve crank 16 is mounted in the pivoting frame 80, the pivoting of a pivoting frame 80 causes a pivoting of the valve crank axis 14, i.e. a change of the position of the valve crank axis 14 along a circular path about the pivoting axis 24.

[0021] Because the pivoting axis 24 and the driving axis are identical, it is guaranteed that the position of the valve crank axis 14 remains, in every pivoting position of the pivoting frame 80, on a circular segment about the driving axis 24. As a result, it is ensured that the valve crank gearwheel 12 mounted rotatably about the valve crank axis 14 and the driving gearwheel 22 remain in meshing connection, regardless of the pivoting position of the pivoting frame 80.

[0022] By means of a pivoting drive 90, the pivoting frame 80 can be held in a fixed position or be pivoted. The pivoting drive 90 comprises a coupling rod 94b attached to the pivoting frame 80. Further details and possible variations of the pivoting drive are described, for example, in DE'127, WO 2014/135321 A1, and WO 2017/129820 A1.

[0023] Next, still with reference to Figs. 1a-5, details of the lubricant supply for the valvetrain according to an embodiment are described. As is described in more detail in the following, the lubricant supply 100 is a manifold receiving lubricant from an entry 112 and supplying the lubricant to (at least) the pivot shaft 23, the guiding member shaft 63, and the valve crank bearing 15. The lubricant supply 100 further supplies lubricant to the interface between the pushing member 40 and the contact surface 54. The lubricant pressure at the entry 112 of the lubricant supply system is about 0.2 bar to 1 bar.

[0024] The lubricant supply system 100 has, in a direction from upstream to downstream, the following elements: a guiding-member-shaft channel 114 being provided in the guiding-member 63 and having a channel entry 112 connected to a lubricant supply line (extending through the cylinder head, not shown) and two channel exits 116; a pair of cylinder-head lubricant supply channels 118 provided in the cylinder head (solid cylinder head body) 3 and extending parallel to each other. Each of the cylinder-head lubricant supply channels 118 is connected at their inlet to a respective one of the channel exits 116. The lubricant supply system 100 further has a pair of pivot-shaft channels 124 provided in the pivot shaft 23 (which is divided into two pivot shaft portions with a gap in the middle), and each having a pivot-shaft entry 122 (connected to an outlet of the the cylinder-head lubricant supply channels 118) and a pivot-shaft exit 126. The lubricant supply system 100 further has a support-body lubricant supply channel 128 connected at their inlet to a respective one of the pivot-shaft exits 126, and at their outlet, via a valve crank bearing lubricant supply volume 129, to the valve crank bearing 15.

[0025] The channel entry 112 and the channel exits 116 of the guiding-member-shaft channel 114 are provided as radial bores in the guiding member 63 connecting the guiding-member-shaft channel 114 to a volume surrounding the guiding member 63 and contacting to the cylinder-head lubricant supply channel 118. The pivot-shaft entries 122 are provided as open ends of the respective pivot shaft portions connecting the cylinder-head lubricant supply channels 118 to the pivot-shaft channels 124. The pivot-shaft exits 126 are provided as radial bores in the pivot shaft 23 connecting the pivot-shaft channel 124 to a volume surrounding the pivot shaft 23 and contacting to an entry side of the support-body lubricant supply channel 128. At the exit side of the support-body lubricant supply channel 128, the valve crank bearing lubricant supply volume 129 surrounds and supplies lubricant to the valve crank bearing 15 through passages connecting the valve crank bearing lubricant supply volume 129 to the valve crank 15.

[0026] Here the valve crank bearing 15 is a roller bearing, but in an alternative embodiment also a different bearing such as a friction bearing can be used.

[0027] Further, with reference to Figs. 3b and 4, the lubricant supply system 100 has a lubricant outlet 140 connected to the valve crank bearing lubricant supply volume 129. The lubricant outlet is directed towards the contact surface 54 and/or to the pushing member 40 for supplying the lubricant to the contact surface 54, the pushing member 40, and/or the interface therebetween. The lubricant outlet 140 supplies the lubricant by ejecting, from the outlet 140, lubricant through an unpressurized volume in the cylinder head portion of the engine (typically a free space within a cylinder head housing of the engine) towards the contact surface 54 and/or to the pushing member 40. To this purpose, the lubricant outlet 140 comprises a lubricant outlet channel 146 being provided in the support body 80 and being connected at its inlet side to the valve crank bearing lubricant supply volume 129, and having an exit side being connected to the unpressurized volume.

[0028] In order to maintain an oil pressure in the lubricant supply system 100, it is advantageous that the lubricant outlet 140 is an intermittent lubricant outlet, i.e., that it lets out the lubricant intermittently. For this purpose, the lubricant outlet 140, more precisely its exit side, is located at a surface of the support body 80 that is periodically obstructed by an obstruction member 135 such as to block the lubricant outlet 140 (but that is unobstructed in intermediate periods).

[0029] As can be seen in Figs. 3b and 4, the periodical obstructions are achieved by the lubricant outlet 140 being arranged at a position that is obstructed, in some angular positions of the valve crank 16, by the crank arm side surface 16d acting as the obstruction member 135, while being unobstructed in other angular positions of the valve crank 16.

[0030] Furthermore, the lubricant outlet 140 is positioned and oriented in such a manner that at least a portion of the ejected lubricant is directed towards the contact surface 54 and/or to the pushing member 40 of the actuation system. The motion of the valve crank 16 contributes to this transport, due to the momentum imparted by the moving valve crank 16, especially by the crank arm 16c, onto the lubricant ejected from the lubricant outlet 140.

[0031] The lubricant supply system 100 further has a second lubricant outlet 130 that is generally analogous to the above description of the (first) lubricant outlet 140. However, contrary to the lubricant outlet 140, the second lubricant outlet 130 is directed towards a portion (actuation system) of the valvetrain for the outlet valve 78, in particular towards the cam and/or a portion contacted by a cam of the outlet valve, here towards cam and the forcing member 58.

[0032] To this purpose, the second lubricant outlet 130 comprises a lubricant outlet channel 136 being provided in the support body 80 and being connected at its inlet side to the valve crank bearing lubricant supply volume 129, and having an exit side being connected to the unpressurized volume. The second lubricant outlet 130 is arranged at a position that is obstructed, in some angular positions of the valve crank 16, by the same obstruction member 135 as the first lubricant outlet 140, i.e., by the crank arm side surface 16d. In all other respects, the above description of the first lubricant outlet 140 also applies to the second lubricant outlet 130.

General aspects of the valvetrain

[0033] Next, some general (i.e., optional) aspects of a valvetrain are described that are illustrated in Figs. 1a-5 and are explained by the reference numerals of these figures. These aspects can also be realized independently of the embodiment of Figs. 1a-5, in conjunction with any other aspects of the invention. Generally, any aspects described herein can be combined, independently of other details, with any other embodiment or aspect described herein.

[0034] According to an aspect, the valvetrain is arranged in the cylinder head portion of the combustion engine. According to a further aspect, the valvetrain (in particular, the actuation system) further comprises a connecting rod 30 with a first connecting rod joint 34 and a second connecting rod joint 36; and a guiding member 60 for guiding the connecting rod, the guiding member being pivotable around a guiding member axis 66. According to a further aspect, the connecting rod 30 is joined with its first connecting rod joint 34 to the first driving member 16. According to a further aspect, the connecting rod 30 is joined with its second connecting rod joint 36 to the guiding member 60.

[0035] According to a further aspect, a second driving member 22 of the valvetrain is provided for driving the first driving member 16. The second driving member 22 is rotatable about a second rotation axis 24.

[0036] According to a further aspect, the second driving member 22 is a second driving gearwheel. The valvetrain comprises a first driving gearwheel 12 for driving the first driving member 16, wherein the first driving gearwheel 12 is rotatable about the first rotation axis 14.

[0037] According to a further aspect, a pushing member 40 is fastened to the guiding member 60. According to a further aspect, the pushing member 40 is a roller. According to a further aspect, the valvetrain 1 comprises a transmission member 50 in releasable mechanical contact with the pushing member 40. According to a further aspect, the transmission member 50 is biased, by a forcing member 58, towards the valve 70. According to a further aspect, the combustion engine 1 comprises a fixed stop 57 for defining a maximum displacement of the transmission member 50.

[0038] According to a further aspect, the transmission member 50 is a lever, which is pivotable around a lever axis 52. According to a further aspect, the lever 50 is a one-arm lever. According to a further aspect, a movement of the pushing member 40 toward the lever axis 52 causes the valve to open.

[0039] According to a further aspect, the valve 70 is an intake valve. According to a further aspect, the combustion engine further comprises a second intake valve, which is preferably also actuated by the valvetrain. According to a further aspect, the second driving member also actuates an exhaust valve 78.

[0040] According to a further aspect, a valve lift (a quantity characterizing valve lifting behavior) is adjustable by the adjustment of the position of the first rotation axis 14. According to a further aspect, the quantity characterizing the valve lifting behavior 90 is a lift height, a duration of the valve opening, or both. According to a further aspect, a phase relation between a rotational angle of the first driving member 16 and an engine cycle is adjustable by the adjustment of the position of the first rotation axis 14.

[0041] According to a further aspect, the pushing member 40 is guided to follow a guided path, and the guided path of the pushing member 40 is adjustable by the adjustment of the position of the first rotation axis 14. According to a further aspect, the adjustment of the position of the first rotation axis 14 is a pivoting of the first rotation axis 14 around a pivoting axis 24.

[0042] According to a further aspect, the connecting rod 30 and the guiding member 60 are members of a pinned, planar linkage.

[0043] It is a general aspect of the invention that the valvetrain 2 comprises a planar linkage with four links, and/or a pinned linkage of four links. Herein, the joints preferably comprise the pivot shaft 23 (driving axis 24), the guiding shaft 63 (guiding axis 66), the first connecting rod joint 34 and the second connecting rod joint 36. All elements of the linkage described herein are connected to each other in a form-fit manner.

[0044] It is a general aspect of the invention that the valvetrain 2 is provided in a cylinder head portion of the combustion engine, as is exemplified in Fig. 1. An arrangement in the cylinder head portion is to be understood as follows: The valve crank 16 is generally (i.e., in at least one possible position of the rotational axis 14 and/or in at least one pivotal position of a pivoting frame 80), mounted on a cylinder head side relative to a dividing surface between the motor block and the cylinder head. Even if a cylinder head and a motor block are not clearly distinguishable from one another in the combustion engine, such a dividing surface can be defined, for example, by a surface defined by the piston head, wherein the piston is in the top dead center position. According to this characterization, the valvetrain 2 corresponds to an overhead camshaft valvetrain, wherein the valve crank 16 corresponds to the camshaft.

[0045] By this arrangement, an encapsulated setup of the valvetrain is enabled, in which the parts of the valvetrain are arranged within an encapsulation.

[0046] According to an aspect, the valvetrain 2 can be subdivided into an active subsystem and a passive subsystem. The active subsystem can be characterized as follows: The motional state of the active subsystem is substantially determined by the motional state of the valve crank 16 (i.e., by a rotational angle of the valve crank 16 and by the position of the valve crank axis 14), and/or the active subsystem is connected to the valve crank 16 in a form-fit manner. The passive subsystem is connected to the active subsystem in a force-fit manner, in particular by means of the valve spring 72.

General aspects of lubricant supply system 100:

[0047] Next some general aspects of the lubricant supply system 100, illustrated in Fig. 2 but not limited to the embodiment of Fig. 2, are described.

[0048] According to an aspect, the variable valvetrain 2 comprises a rotatable valve crank 16 rotatably mounted by a valve crank bearing 15 to a rigid support body 80. The support body 80 is pivotably mounted on a pivot shaft 23. The valvetrain further comprises and a lubricant supply system 100 with a support-body lubricant supply channel 128 passing from the pivot shaft 23 through the support body 80 to the valve crank bearing 15.

[0049] According to an aspect, the lubricant supply system 100 comprises a pair of support-body lubricant supply channels 128 extending within the support body 80. Preferably each of the support-body lubricant supply channels 128 (and of the valve crank bearings 15) is arranged on opposite sides of a (virtual) dividing plane, the dividing plane being orthogonal to a pivot axis 24 of the pivot shaft 23 and preferably at a central position of the valvetrain / of the pivot axis 24.

[0050] According to an aspect, the pivot shaft 23 comprises a pair of pivot shaft portions, preferably mechanically separate from each other, preferably separated from each other by the dividing plane. The lubricant supply system 100 may comprise a pair of pivot-shaft channels 124 each provided in a respective one of the pivot shaft portions. The pivot-shaft entries 122 may be provided as open ends of the respective pivot shaft portions, preferably facing each other, and preferably being connected to respective lubricant supplies (such as the cylinder-head lubricant supply channels 118) provided in the cylinder head 3. According to an aspect, a pair of cylinder-head lubricant supply channels 118 is provided in the cylinder head (solid cylinder head body) 3.

[0051] According to an aspect, the lubricant supply system 100 has two separate supply path portions at least downstream of the pivot shaft 23 (downstream of the pivot-shaft channel(s) 124) and preferably separate from each other also at the pivot shaft 23, with the dividing plane separating the supply path portions from each other without overlap. Thereby, a central portion (including the dividing plane) of the support body 80 can be made stable and rigid due to the separation of the lubricant supply system 100 from the location of the dividing plane, typically at a central position of the support body 80 where space is limited. According to an aspect, the valvetrain comprises a pair of valve crank bearings 15, each being supplied with lubricant via a respective one of the supply path portions.

[0052] According to an aspect, a pair of pivot-shaft channels 124 is provided in the pivot shaft 23 (in two separate portions of the pivot shaft), each being provided as a longitudinal bore in the respective pivot shaft 23 portion. According to an aspect, the pivot-shaft channels 124 are arranged parallel and/or concentrically with respect to each other and/or with respect to the pivot shaft axis 24.

[0053] According to an aspect, the supply path portions are fed by a single lubricant supply at or downstream of the pivot shaft 23. According to an aspect, the lubricant supply system 100 comprises a guiding-member-shaft channel 114 being provided in the guiding-member 63 and having a channel entry 112 connected to a lubricant supply line and two channel exits 116, each connected to a respective one of the supply path portions / of the cylinder-head lubricant supply channels 118 / (indirectly) of the pivot-shaft channels 124, thereby bifurcating the lubricant supply.

[0054] According to an aspect, the lubricant supply system bifurcates within the support body 80 into a first and a second supply subsystem. According to an aspect, the supply subsystems are analogous to each other, so that for any described element of the lubricant supply system downstream of the bifurcation, there are a first and second such element belonging to the first and a second supply subsystem, respectively. The bifurcation may be at or downstream of the guiding-member-shaft channel 114 and/or upstream of the crank bearings 15. According to an aspect, the first and a second supply subsystems are associated with a first and second subset of the valves 70 (e.g., a first valve and a second valve), respectively.

[0055] According to an aspect, the first and a second supply subsystem are arranged on two different sides of the support body separated by a central plane orthogonal to the axis 66. Thereby a stable construction of the support body is enabled.

[0056] According to an aspect, the lubricant supply system is arranged for lubricating at least some of the bearings of the guiding member shaft 63, the pivot shaft

23, the valve crank bearing 15, and the contact surface 54. According to an aspect, the lubricant supply system is arranged for lubricating the above members, or at least a subset thereof, in the order, from upstream to downstream, indicated in the above list.

[0057] According to an aspect, the lubricant supply system 100 is arranged for supplying the lubricant from the pivot shaft 23 through the support body 80 to the valve crank bearing 15 and optionally (possibly intermittently) to an unpressurized volume.

[0058] According to an aspect, the lubricant supply system 100 further comprises a cylinder-head lubricant supply channel 118 upstream of the pivot shaft 23, and according to an aspect more upstream of the support-body lubricant supply channel 128. The cylinder-head lubricant supply channel 118 may pass from the guiding member shaft 63 through the cylinder head 3 to the pivot shaft 23. The cylinder-head lubricant supply channel 118 may be fluidly connected to the pivot-shaft channel 124 and may be downstream of the pivot-shaft channel 124. The cylinder-head lubricant supply channel 118 may be fluidly connected to the guiding-member-shaft channel 114 and may be upstream of the guiding-member-shaft channel 114.

[0059] According to an aspect, the pivot-shaft channel 124 is fluidly connected to the support-body lubricant supply channel 128, and is located upstream of the support-body lubricant supply channel 128. According to an aspect, the pivot-shaft channel 124 is fluidly connected to the cylinder-head lubricant supply channel 118 and is arranged downstream of the cylinder-head lubricant supply channel 118.

[0060] According to an aspect, the lubricant supply system 100 comprises a guiding-member-shaft channel 114 being a longitudinal bore in the guiding member shaft (63). The guiding-member-shaft channel 114 may extend in parallel and/or concentrically to the guiding member axis 66.

[0061] According to an aspect, the guiding-member-shaft channel 114 is a longitudinal bore in the guiding member shaft 63, i.e., parallel to and / or concentrically to the guiding pivot axis 24 and/or to the guiding member axis 66.

[0062] According to an aspect, the lubricant supply system 100 comprises a support-body lubricant supply channel 128 for pressurized lubricant passing from the pivot shaft 23 through the support body 80 to the valve crank bearing 15.

[0063] In case of a pair of pivot-shaft channels 124 and/or support-body lubricant supply channels 128, the above may apply to both pivot-shaft channels 124 and/or to both respective respective lubricant supply channels 128.

[0064] Further details and general aspects of the intermittent lubrication will be discussed after the following discussion of a further embodiment.

<u>Description of a second embodiment (Figs. 6-11):</u>

[0065] Hereinafter, a valvetrain is described according to a second embodiment of the invention with reference to Figs. 6-11. Therein, corresponding parts are given the same reference numerals as in Figs. 1a-5, although some geometrical details may be changed. The description of Figs. 1a-5, and the description given in DE'127, also apply to this embodiment, insofar as not described differently in the following or shown differently in the figures.

[0066] The lubricant system of the second embodiment is adapted for a pressure at the entry 112 of the lubricant supply system of about 1.5 bar to 5 bar.

[0067] Some differences with respect to the embodiment of Figs. 1a-5 can be seen in Fig. 7: The pivot shaft 23 is provided as a single shaft with a solid shaft portion (no gap) in the middle. Still, similar to the embodiment of Fig. 2, provided in the pivot shaft 23 is a pair of pivot-shaft channels 124, separated from each other by the solid shaft portion. The pivot-shaft channels 124 are provided on opposite sides of a central dividing plane (central plane orthogonal to the pivot axis 24). Alternatively, the pivot shaft 23 can be provided with two separate shaft portions as shown for the first embodiment.

[0068] Each of the pivot-shaft channels 124 has a pivot-shaft entry 122 connected to an outlet of the cylinder-head lubricant supply channels 118. The pivot-shaft entries 122 are provided as radial bores in the pivot shaft 23 connecting the pivot-shaft channels 124 to the cylinder-head lubricant supply channels 118.

[0069] The crank 16 is assembled from two crank pieces, the left piece in Fig. 7 comprising the lifting pin 16b.

[0070] The valve crank bearing 15 is a friction bearing as shown schematically in Figs. 7 and 8, and comprises a crankshaft lubricant volume 134 (being a hollow portion within the crankshaft 16). Alternatively, also a roller bearing can be used instead.

[0071] The support-body lubricant supply channels 128 are connected at their outlet, via a valve crank bearing lubricant supply volume 129 circumferentially surrounding the valve crank bearing 15, to the valve crank bearing 15 and specifically, via a radial bore 133 provided in the crankshaft 16, to the crankshaft lubricant volume 134.

[0072] Next, the lubricant outlets 150, 160 are in the following described with particular reference to Figs. 9a, 9b and 10a, 10b. Here, while a number of details differ from the lubricant outlets 130, 140 of the first embodiment, the general principles are analogous: The lubricant outlet 160 supplies the lubricant by ejecting, from the outlet 160, lubricant through an unpressurized volume in the cylinder head portion of the engine towards the contact surface 54 and/or to the pushing member 40. To this purpose, the lubricant outlet 160 comprises a lubricant outlet channel 166 being provided in the support body 80 and being connected at its inlet side to the crankshaft lubricant volume 134, and having an exit side being connected to the unpressurized volume.

[0073] In order to maintain an oil pressure in the lubricant supply system 100, it is advantageous that the lubricant outlet 160 is an intermittent lubricant outlet, i.e., that it lets out the lubricant intermittently. For this purpose, the lubricant outlet 160 has an obstruction member blocking the lubricant outlet 160 periodically (but being non-blocking in intermediate periods).

[0074] In the second embodiment the obstruction member 155 is provided as a crankshaft portion surrounding the crankshaft lubricant volume 134. As can be seen in Fig. 9b, the crank shaft has a radial bore 153 at the axial position of the lubricant outlet channel 166 for connecting the crankshaft lubricant volume 134 to the lubricant outlet channel 166 at a predetermined rotational position of the crankshaft, whereas otherwise (at rotational positions of the crankshaft 16 for which the bore 153 is not aligned with the lubricant outlet channel 166) this connection is blocked by the crankshaft portion (obstructing member 155).

[0075] The lubricant supply system 100 of the second embodiment further has a second lubricant outlet 150 that is generally analogous to the above description of the (first) lubricant outlet 160, but with the analogous modifications as described above for the first embodiment: The second lubricant outlet 150 is directed towards a portion (actuation system) of the valvetrain for the outlet valve 78, in particular towards the cam and/or a portion contacted by a cam of the outlet valve, here towards cam and the forcing member 58.

[0076] The second lubricant outlet 150 is arranged at a position that is obstructed, in some angular positions of the valve crank 16, by the same obstruction member 155 as the first lubricant outlet 160, i.e., by the crankshaft portion surrounding the crankshaft lubricant volume 134 (see Fig. 10b): At a predetermined rotational position of the crank shaft 16 the radial bore 153 is aligned with the lubricant outlet channel 156 for connecting the crankshaft lubricant volume 134 to the lubricant outlet channel 156, whereas for another rotational positions this connection is blocked by the crankshaft portion (obstructing member 155). In all other respects, the above description of the first lubricant outlet 160 also applies to the second lubricant outlet 150.

General aspects of the intermittent lubrication:

[0077] Next, general aspects of the lubricant outlet 130, 140, 150, 160 and in particular of the intermittent lubrication are discussed. Reference signs relate to the first and second embodiments discussed above but are for illustration only. The aspects may be used independently of these embodiments in combination with any aspect or embodiment described herein.

[0078] According to an aspect, the lubricant outlet 130, 140, 150, 160 is an intermittent lubricant outlet for intermittently letting out lubricant, e.g., towards the contact surface 54 and/or other parts located in the cylinder head portion.

[0079] According to an aspect, the lubricant outlet has an obstruction member 135, 155 configured to move in accordance with a rotation of the valve crank 16. In a first rotational position of the valve crank 16, the obstruction member 135, 155 may be in an unobstructing position allowing passage of the lubricant through the lubricant outlet. In a second rotational position of the valve crank 16, the obstruction member 135, 155 may be in an obstructing position so that the passage of the lubricant is obstructed. Herein, the terms "unobstructed" and "obstructed" may also include partial obstructions, as long as the obstructing position is (relatively) significantly more obstructing than the unobstructing position and in particular allows maintaining a desired level of lubricant pressure in the lubricant supply.

[0080] According to an aspect, the obstruction member 135, 155 may co-rotate with the valve crank 16 or pivot with the connecting rod 30.

[0081] According to an aspect, the lubricant outlet 130, 140, 150, 160 further comprises a stationary outlet portion 136, 146, 156, 166 which remains stationary upon rotation of the valve crank 16, i.e., stationary with respect to the support body 80 and/or to the cylinder head. In the first rotational position of the valve crank 16, the obstructing portion and the stationary outlet portion 136, 146, 156, 166 do not overlap with each other (e.g., openings provided therein are aligned with each other), so that the passage of the lubricant through the lubricant outlet is unobstructed, allowing passage of the lubricant through the lubricant outlet. In the second rotational position of the valve crank 16, the obstruction member 135, 155 and the stationary outlet portion 136, 146, 156, 166 overlap with each other (e.g., openings therein are not aligned with each other), so that the passage of the lubricant is relatively more obstructed. Thereby, the intermittent outlet of the lubricant is obtained in accordance with a rotation of the valve crank 16.

[0082] According to an aspect, the lubricant throughput through the lubricant outlet 130, 140, 150, 160 in the unobstructing position (e.g., first rotational position of the valve crank 16) is larger by a factor of at least 2, preferably at least 5, compared to the obstructing position (e.g., second rotational position of the valve crank 16).

[0083] According to an aspect, the lubricant outlet 130, 140, 150, 160 lets out the lubricant from within the support body 80 to an unpressurized volume. According to an aspect, the lubricant outlet 140, 160 is directed, through the unpressurized volume, towards the contact surface 54 for lubricating the contact surface 54. According to an aspect, the lubricant outlet is fluidly connected to the valve crank bearing 15, is arranged downstream of the support-body lubricant supply channel 128, and preferably also downstream of the valve crank bearing 15.

[0084] According to an aspect, illustrated by the first embodiment, the obstruction member 135 is a crank arm side surface 16d of the valve crank 16. According to an alternative aspect, illustrated by the second embodiment, the obstruction member 155 is a substantially cylindrical shaft portion co-rotating with the valve crank 16 having a hollow interior portion 136 and a substantially radial outlet channel portion 154 being formed as a through-channel at a predetermined circumferential position of the shaft.

[0085] According to an aspect, the lubricant supply 140, 160 supplies lubricant at least to the valve crank bearing 15, and preferably also to other parts of the valvetrain, e.g. to the pivot shaft 23, the guiding member shaft 63, and/or to parts of the transmission unit such as the pushing member 40 and/or the contact surface 54. According to an aspect, the lubricant supply 130, 150 supplies lubricant at least to a portion of the valve train for driving a further valve, e.g., an exhaust valve.

[0086] According to an aspect, the valve crank bearing 15 comprises at least one of a roller bearing and a friction bearing. According to a further aspect, the lubricant supply system 100 comprises a lubricant entry supplying the lubricant at a lubricant pressure (at the inlet of the lubricant supply system) of at least 0.2 bar, at least 1 bar, or even at least 1.5 bar. According to a further aspect, the lubricant supply system 100 comprises a lubricant entry supplying the lubricant at a lubricant pressure of at most 5 bar, at most 2 bar, or at most 1 bar. Especially in the case of a friction bearing the lubricant pressure is preferably at least 1.5 bar and/or at most 5 bar. Especially in the case of a roller bearing the lubricant pressure is preferably at least 0.2 bar and/or at most 1 bar.

[0087] The embodiments described here can be varied and adapted in other ways. In particular, individual aspects of each embodiment can also be used in other embodiments and / or combined with other aspects, thereby obtaining yet further embodiments. For example, the bifurcation of the lubricant supply within the support body 80 shown in the first and second embodiments is optional and may be implemented in another (e.g., bifurcation downstream of the pivot shaft 23). Also the lubrication outlet 130, 140, 150, 160 is optional and can be even fully omitted (replaced by any other lubrication outlet).

Claims

1. A variable valvetrain (2) for actuating a [intake] valve (70) of an internal combustion engine, the variable valvetrain being adapted to be arranged in a cylinder head (3) portion of the internal combustion engine, the variable valvetrain comprising:

an actuation system for periodically opening and closing the valve (70), the actuation system comprising

- a rotatable valve crank (16);
- a transmission unit for transmitting the rotational movement of the valve crank (16) into a periodical lifting movement for actuating the valve (70); and
- a lubricant supply system (100), wherein

the valve crank (16) is rotatably mounted about a valve crank axis (14) by a valve crank bearing (15), the valve crank bearing (15) connecting the valve crank (16) to a rigid support body (80), and wherein
the support body (80) is mounted on a pivot shaft (23) to be pivotable about a pivot axis (24), wherein pivoting of the support body (80) about the pivot axis (24) causes a change in the position of the first rotational axis (14) along a circle segment about the pivot axis (24) for adjusting the valve lift, and wherein
the lubricant supply system (100) comprises a support-body lubricant supply channel (128) passing from the pivot shaft (23) through the support body (80) to the valve crank bearing (15).

2. Variable valvetrain according to any one of the preceding claims, wherein
the transmission unit comprises

- a connecting rod (30) with a first joint (34) and a second joint (36), and
- a guiding member (60) for guiding the connecting rod, the guiding member being mounted on a guiding member shaft (63) to be pivotable about a guiding member axis (66), wherein

the connecting rod (30) is joined with its first joint (34) to the valve crank (16), and the connecting rod (30) is joined with its second joint (36) to the guiding member (60).

3. Variable valvetrain according to the preceding claim, wherein
the transmission unit further comprises

- a pushing member (40) fastened to the guiding member (60), and
- a transmission member (50) in mechanical contact with the pushing member (40) along a contact surface (54) for transmitting a force exerted by the pushing member (40) towards the valve (70).

4. Variable valvetrain according to any one of the preceding two claims, wherein the lubricant supply system (100) further comprises a guiding-member-shaft channel (114) being a longitudinal bore in the guiding member shaft (63).

5. Variable valvetrain according to any one of the preceding claims, wherein
the lubricant supply system (100) further comprises

a pivot-shaft channel (124) being a longitudinal bore in the pivot shaft (23) and being fluidly connected to the support-body lubricant supply channel (128) upstream of the support-body lubricant supply channel (128).

6. Variable valvetrain according to any one of the preceding claims, wherein
the lubricant supply system (100) further comprises a cylinder-head lubricant supply channel (118) upstream of the pivot shaft (23) and passing through the cylinder head (3) to the pivot shaft (23).

7. Variable valvetrain according to any one of the preceding claims, wherein
the lubricant supply system (100) further comprises a lubricant outlet (130, 140, 150, 160) from the support body (80) ..

8. Variable valvetrain according to the preceding claim, wherein
the lubricant outlet (140, 160) is directed towards the contact surface (54) for lubricating the contact surface (54).

9. Variable valvetrain according to the preceding two claims, wherein
the lubricant outlet (130, 140, 150, 160) is an intermittent lubricant outlet for intermittently letting out lubricant.

10. Variable valvetrain according to the preceding claim, wherein
the lubricant outlet (130, 140, 150, 160) is adapted for intermittently letting out lubricant in accordance with a rotation of the valve crank (16).

11. Variable valvetrain according to the preceding claim, wherein
the lubricant outlet (130, 140, 150, 160) has an obstruction member (135, 155) configured to move in accordance with a rotation of the valve crank (16), wherein in a first rotational position of the valve crank (16), the obstruction member is in an unobstructing position allowing passage of the lubricant through the lubricant outlet (130, 140, 150, 160), and
in a second rotational position of the valve crank (16), the obstruction member is in an obstructing position so that the passage of the lubricant is obstructed.

12. Variable valvetrain according to any one of the preceding claims, wherein
the lubricant outlet (140, 160) is a first lubricant outlet, and wherein
the lubricant supply system (100) further comprises a second lubricant outlet (130, 150) directed towards a further actuation system for a further valve (78).

13. Internal combustion engine comprising a variable valvetrain according to any one of the preceding claims, the variable valvetrain being arranged in a cylinder head (3) portion of the internal combustion engine.

14. Use of a variable valvetrain according to any one of the claims 1 to 13 for a combustion engine, the variable valvetrain being arranged in a cylinder head (3) portion of the internal combustion engine.

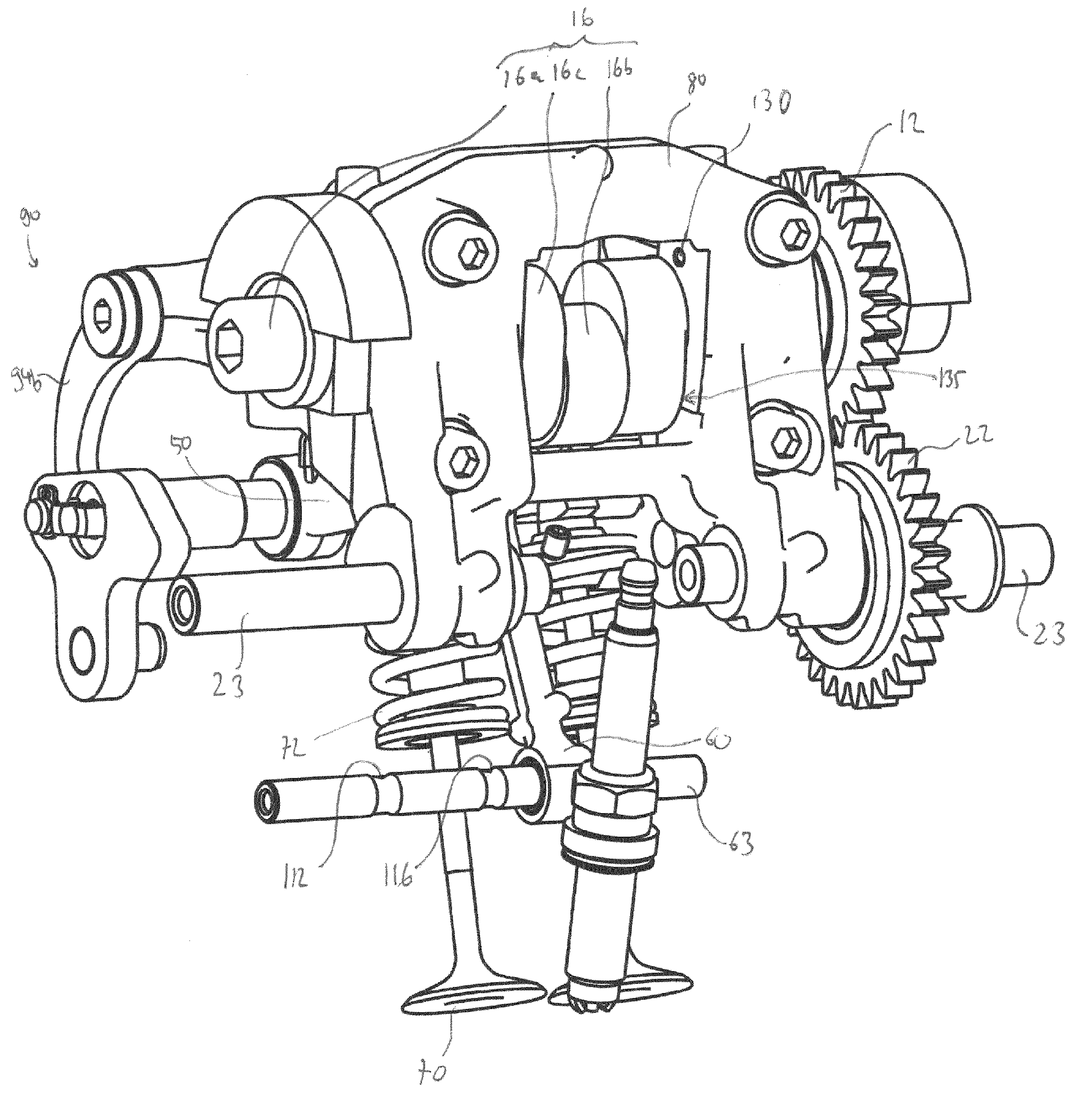


Fig. 1a

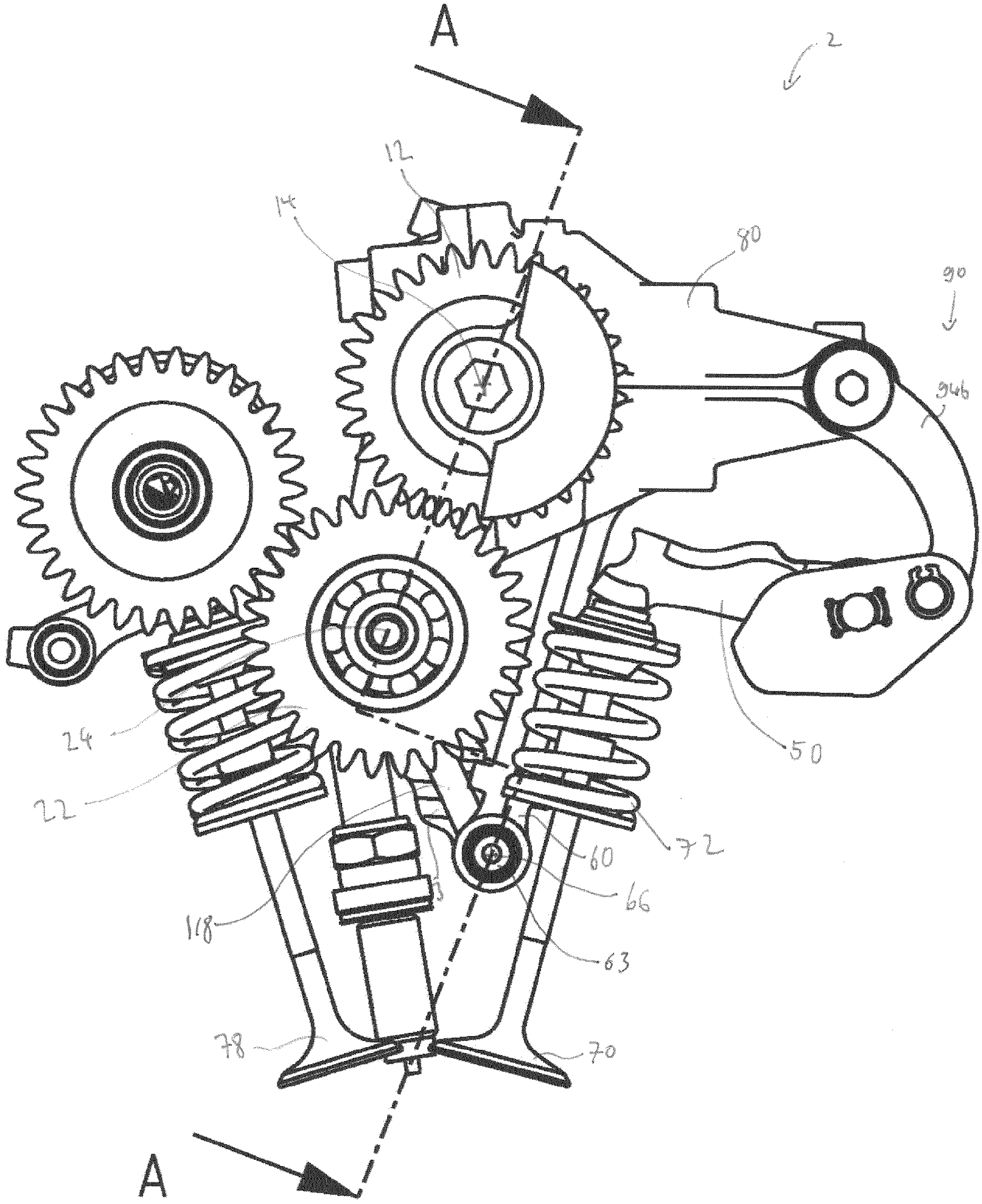
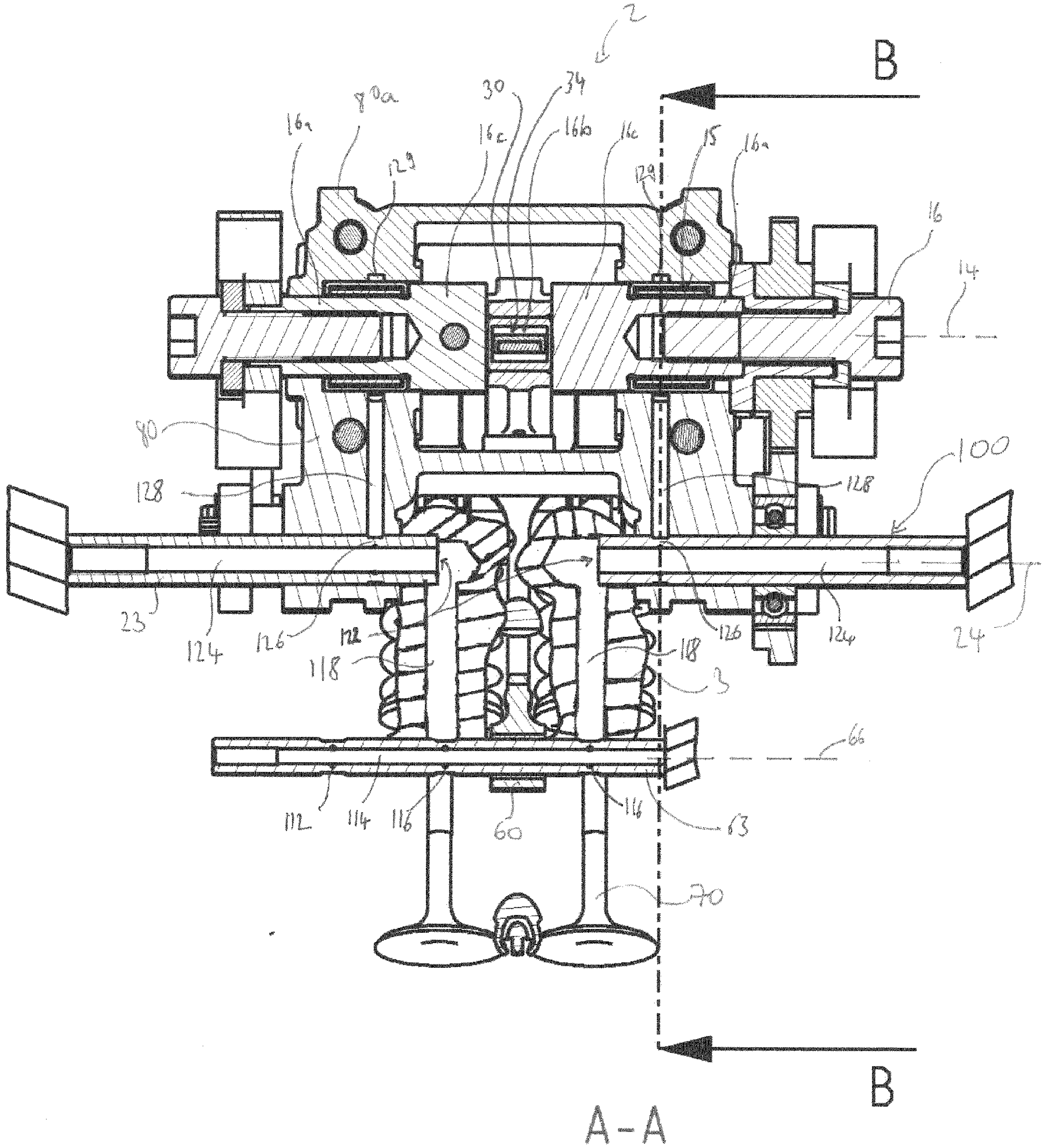


Fig. 1b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16a
16a
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100
23
124
126
122
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18
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66
112
114
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60
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63
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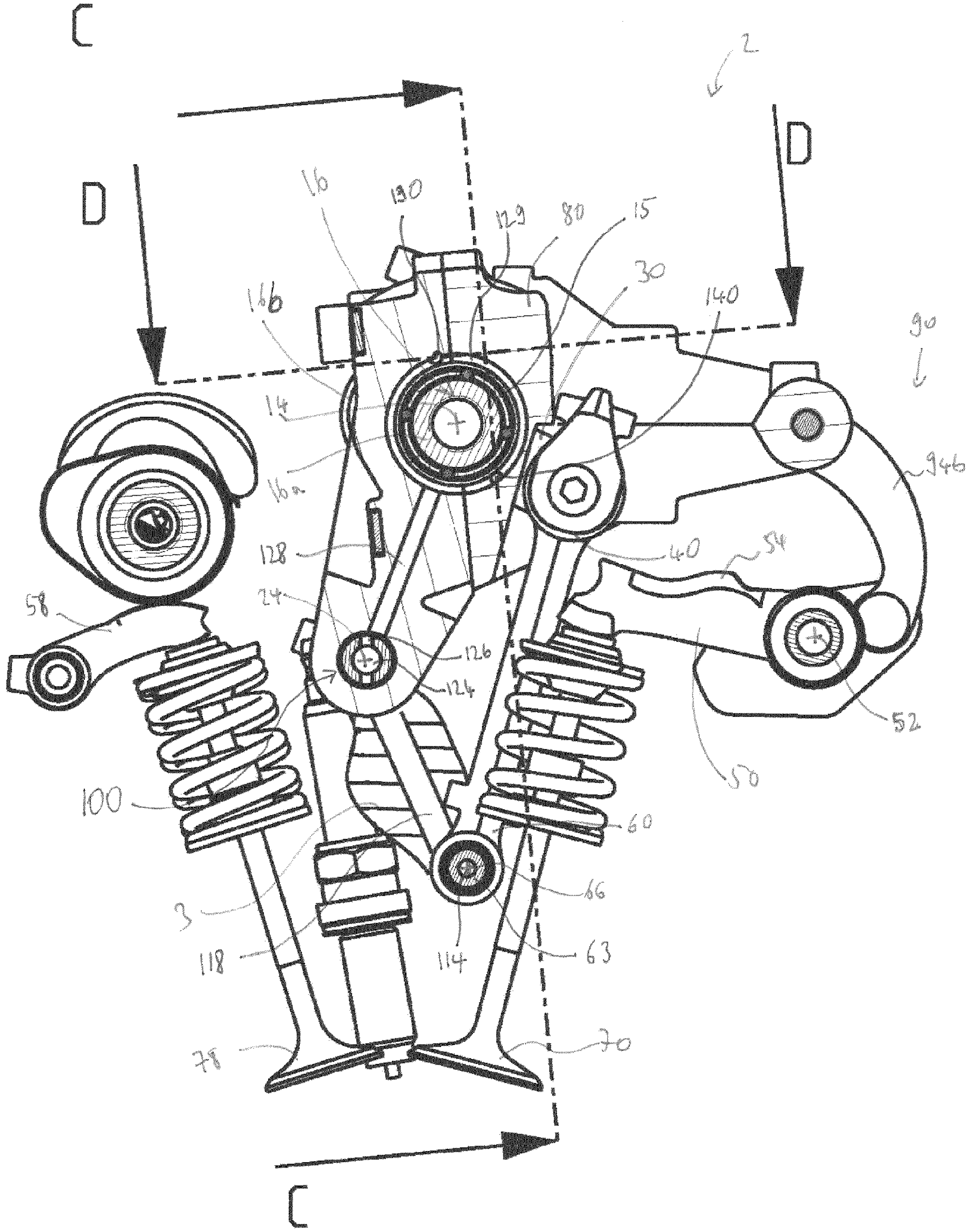
B
A-A

Fig. 2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3
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70
C

Fig. 3a B-B

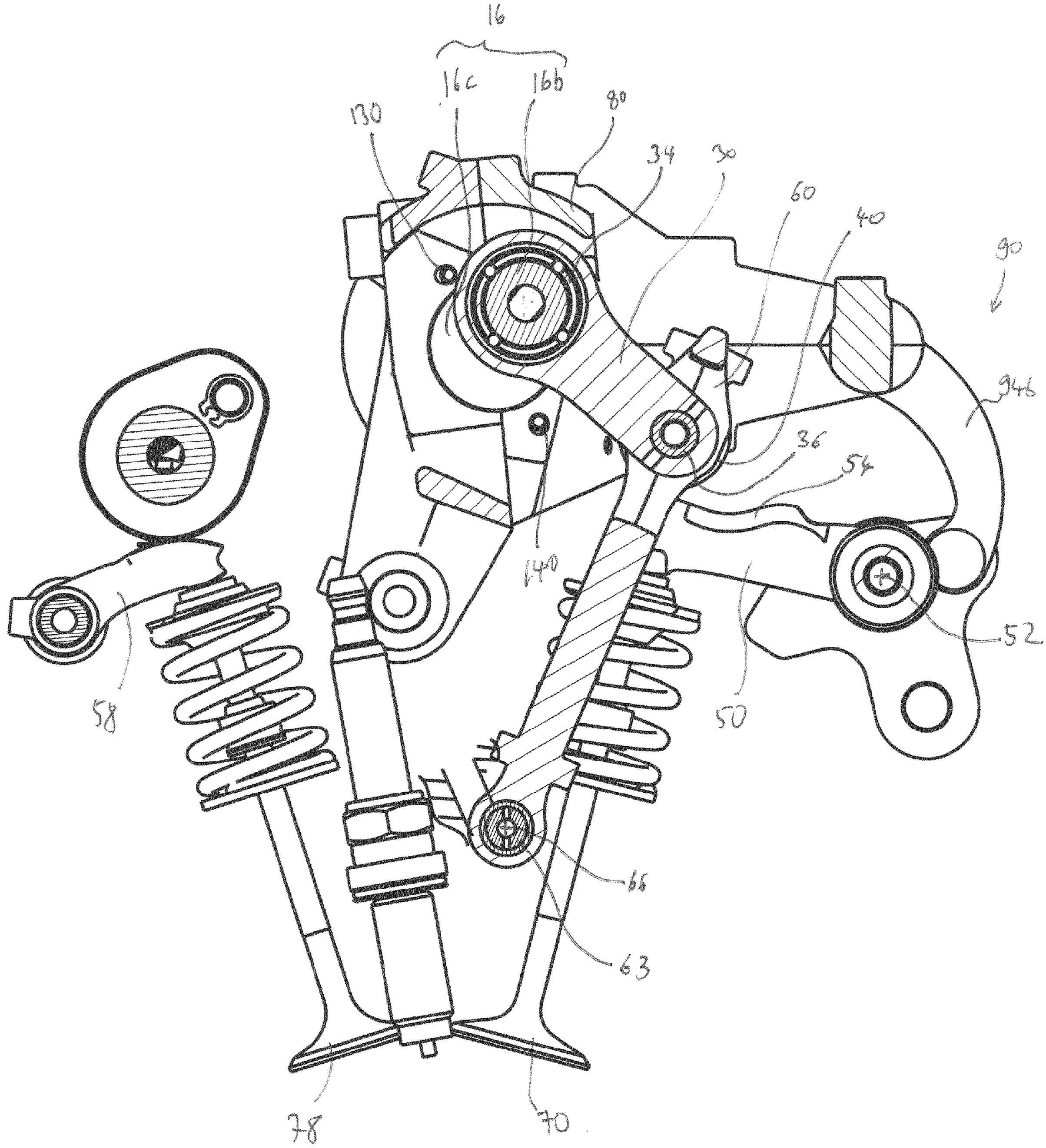
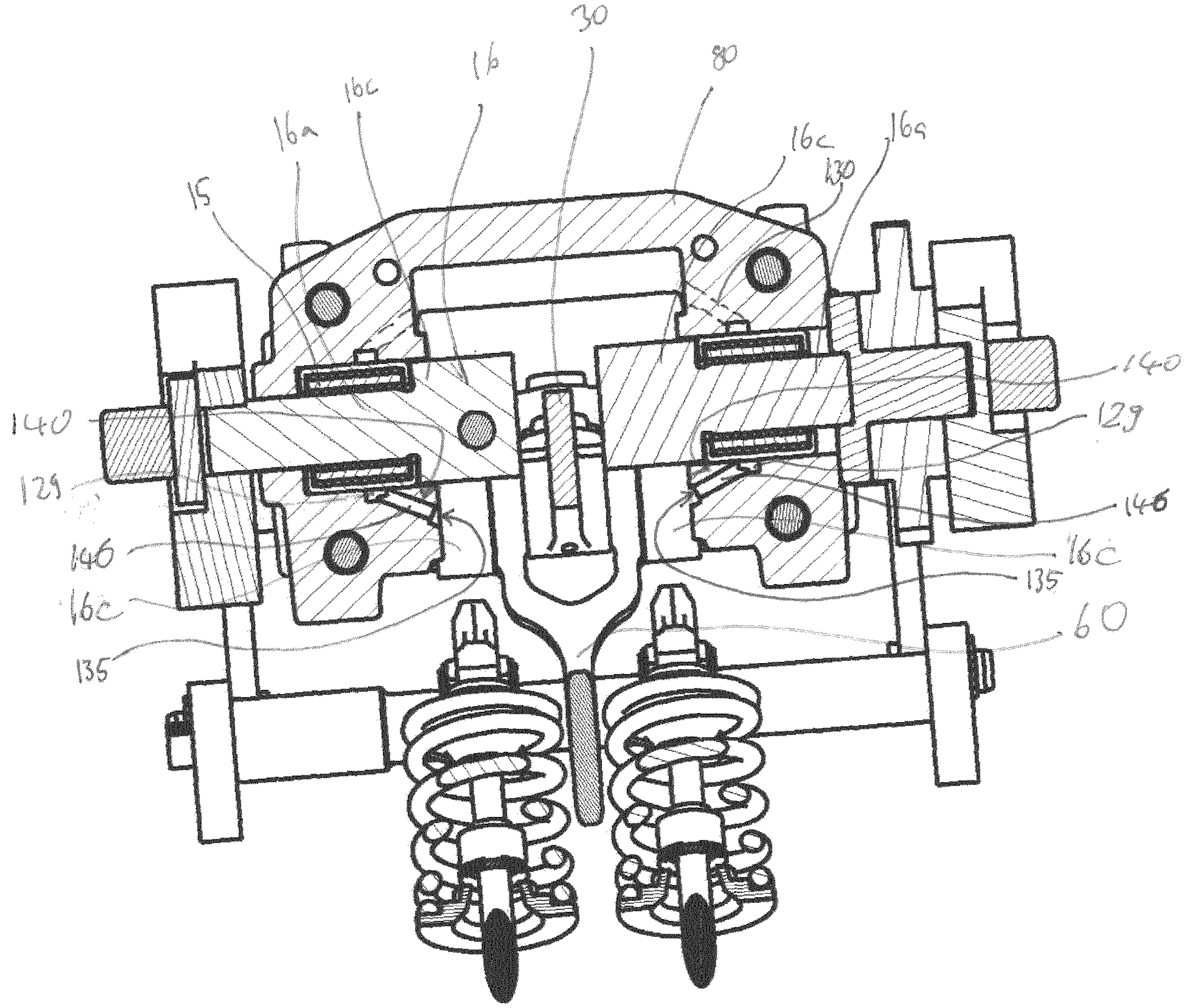


Fig. 3b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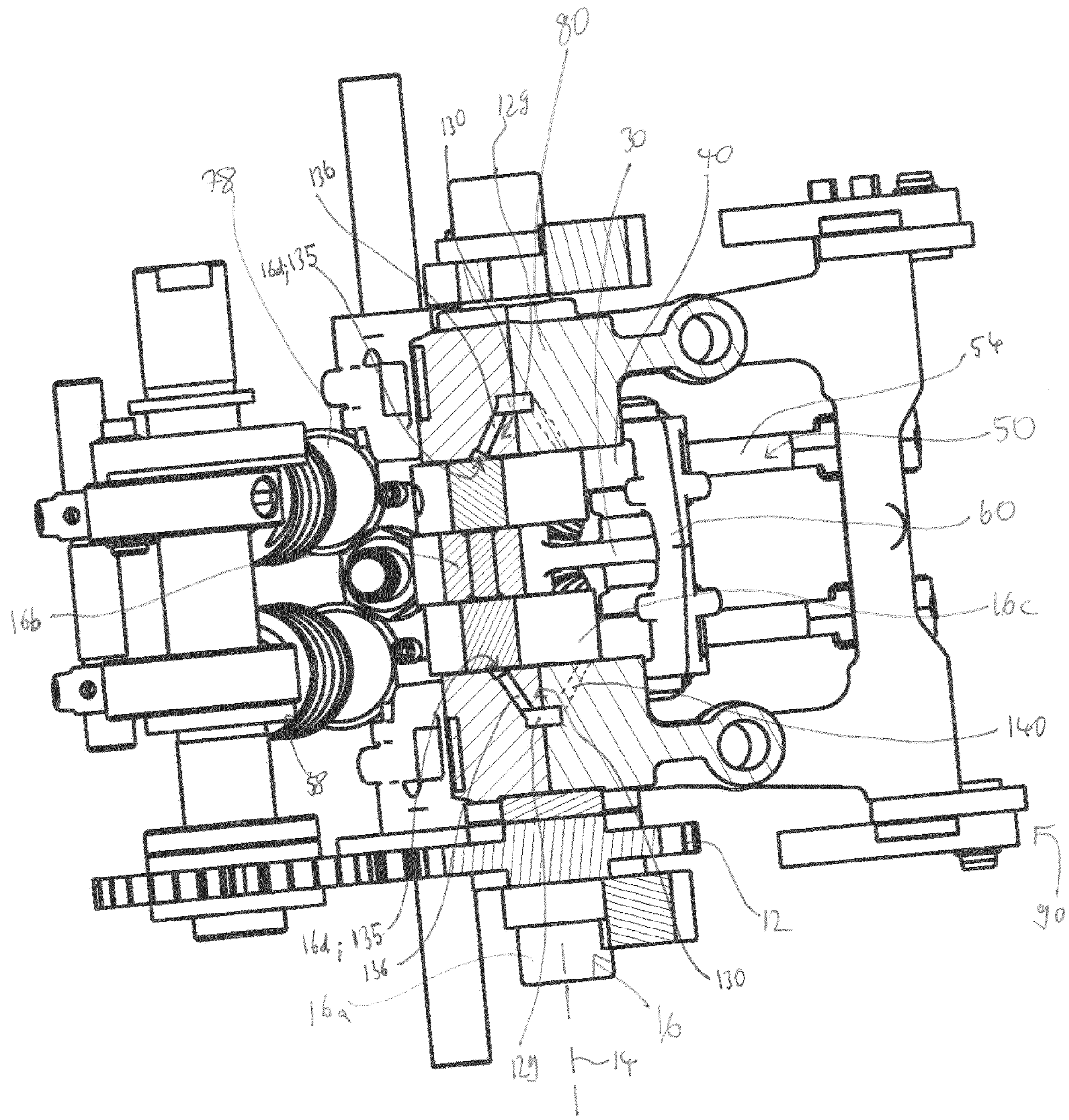
C-C

Fig. 4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16d;135
136
130
16a
16
129
14

D-D

Fig. 5

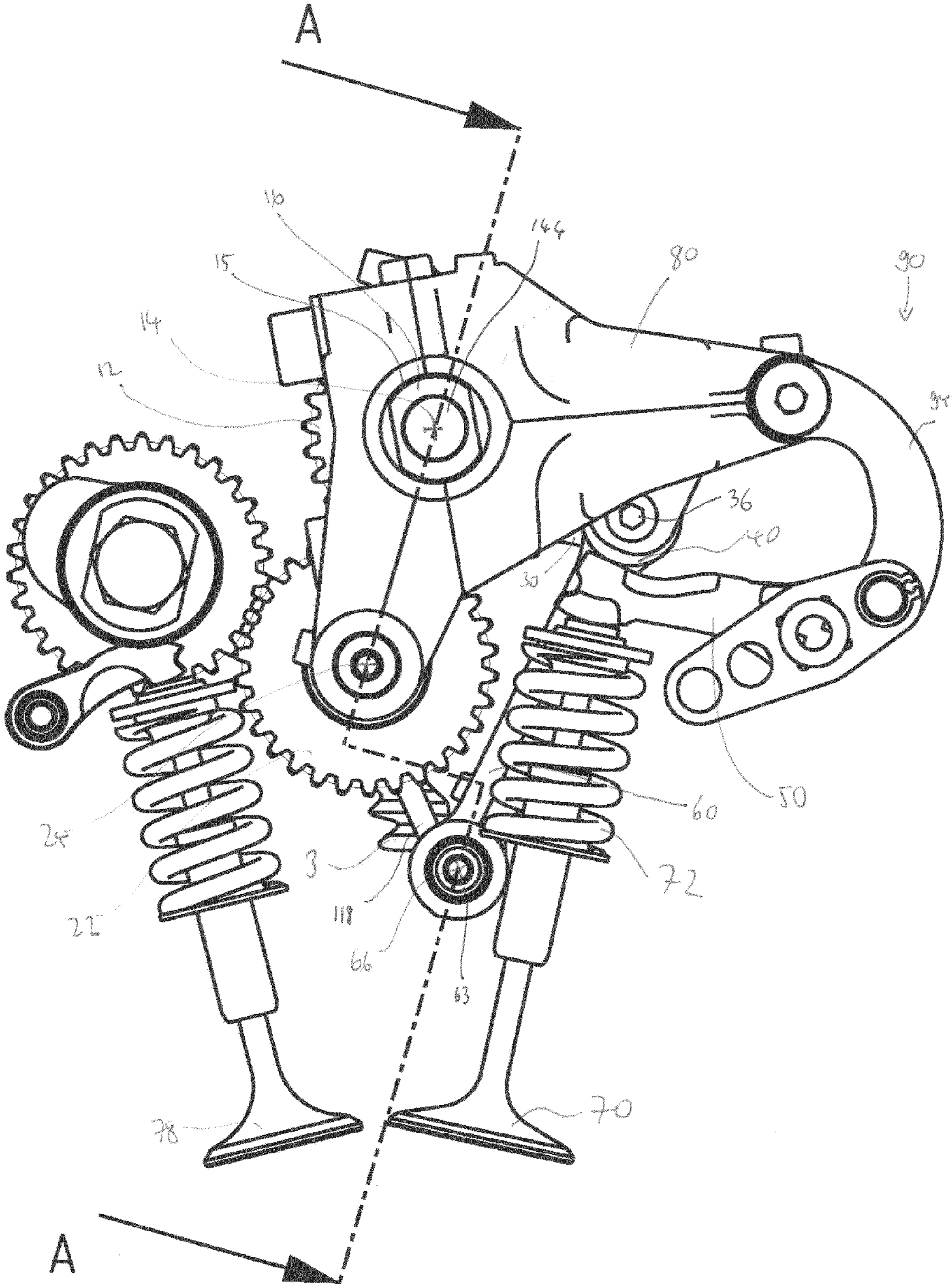
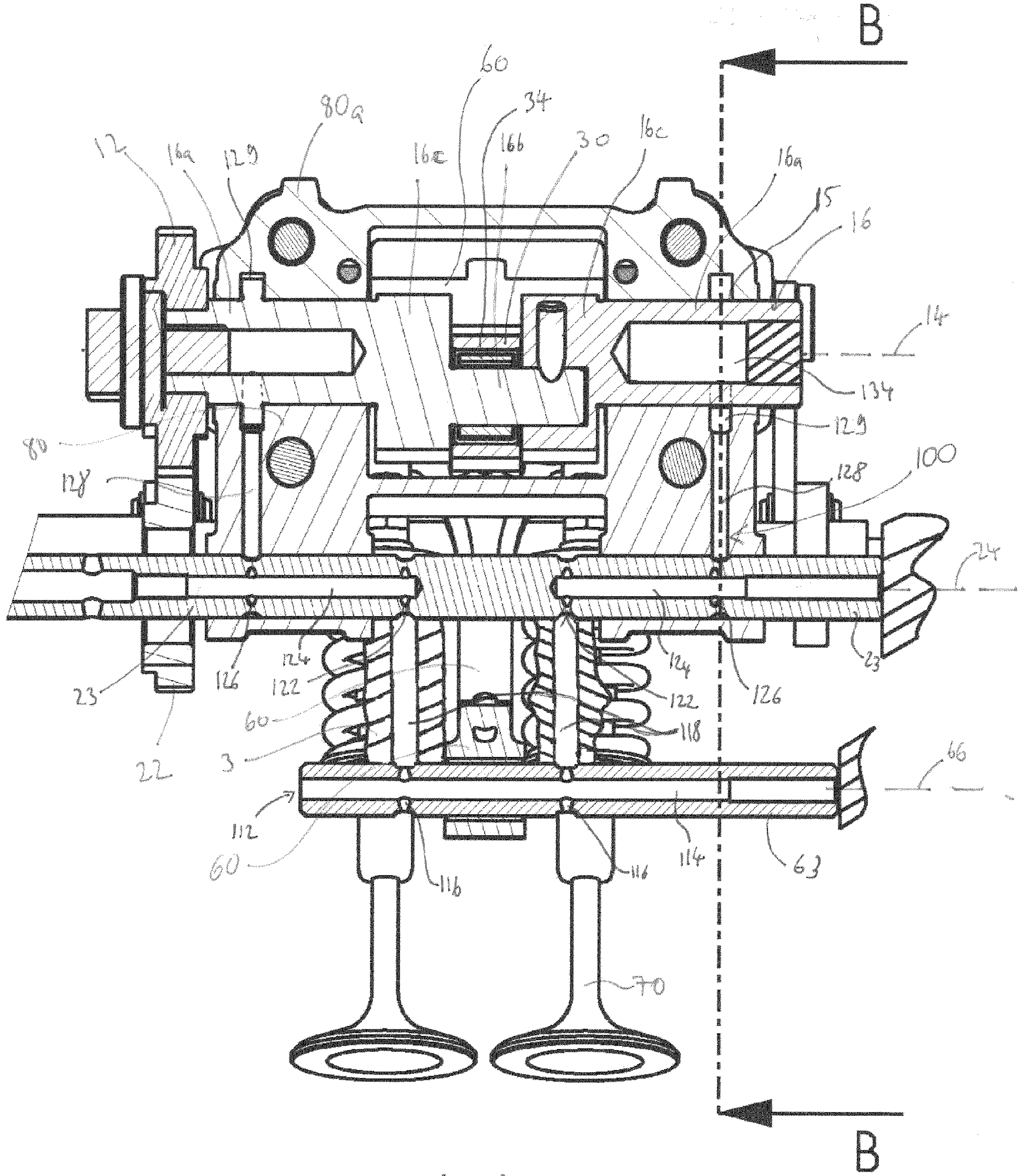


Fig. 6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B

A-A

Fig. 7

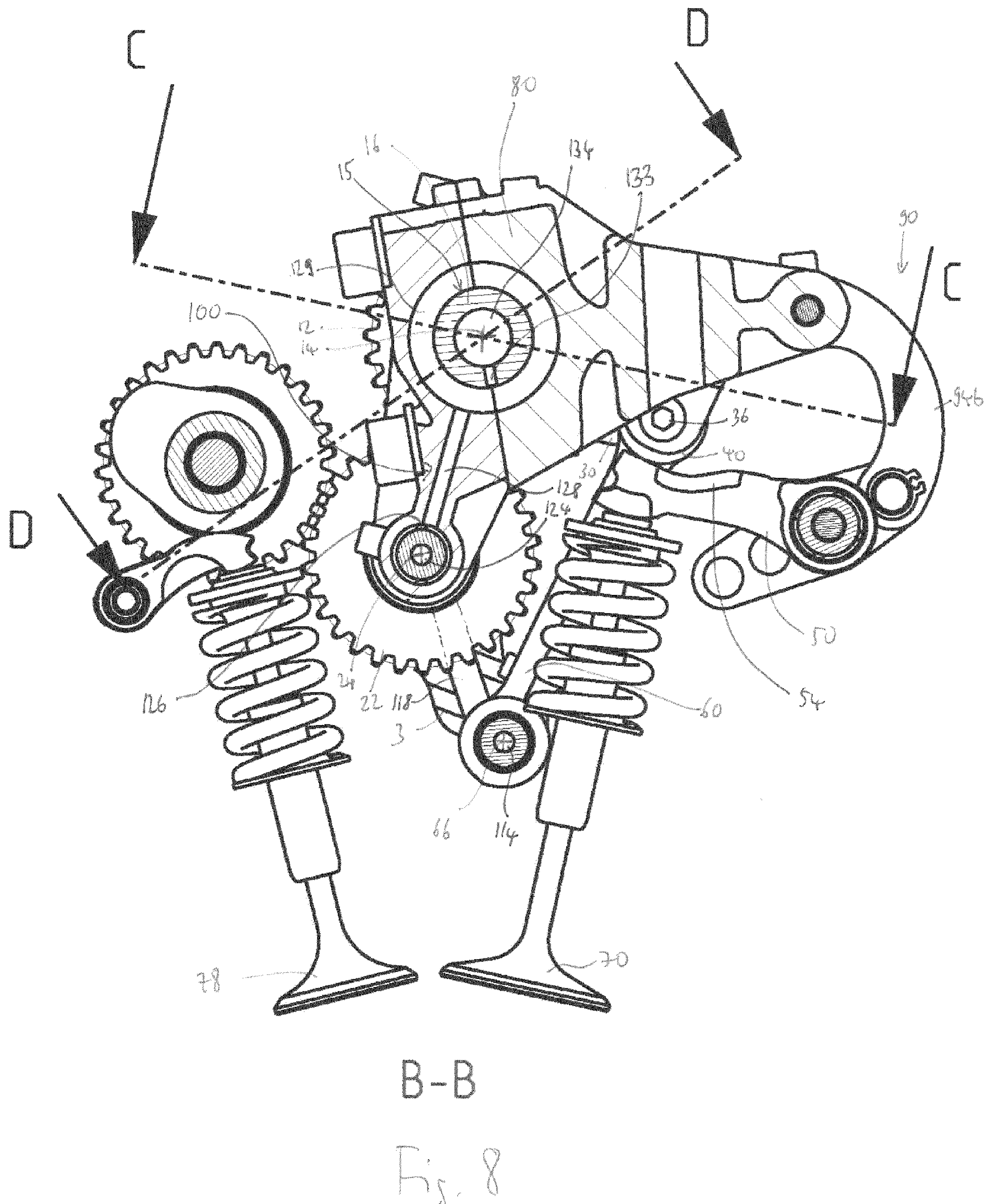
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Fig. 8

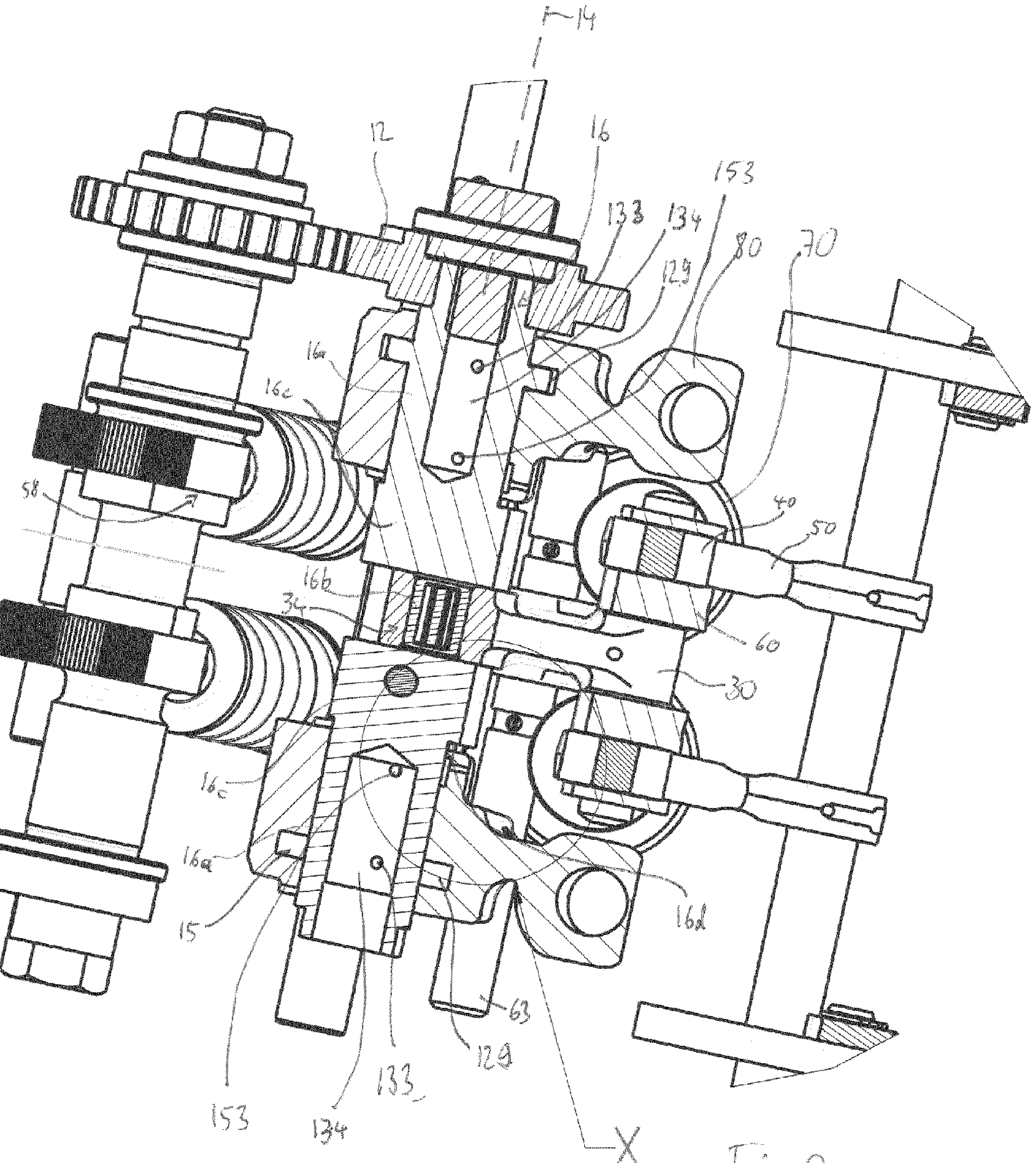
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Fig. 9a

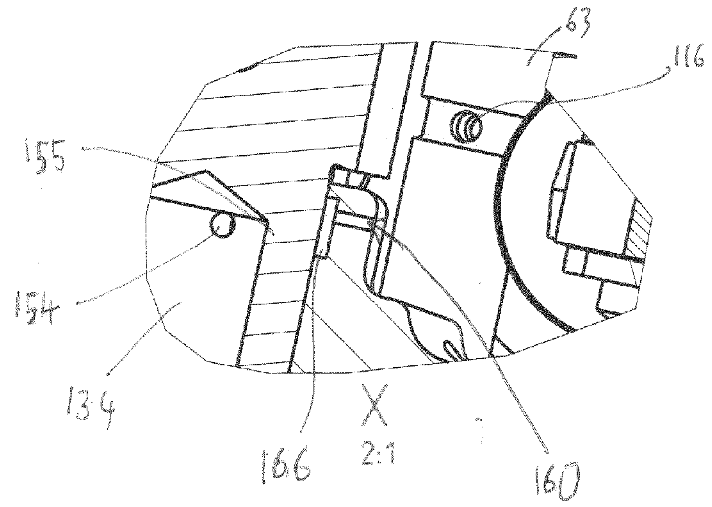
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Fig. 9b

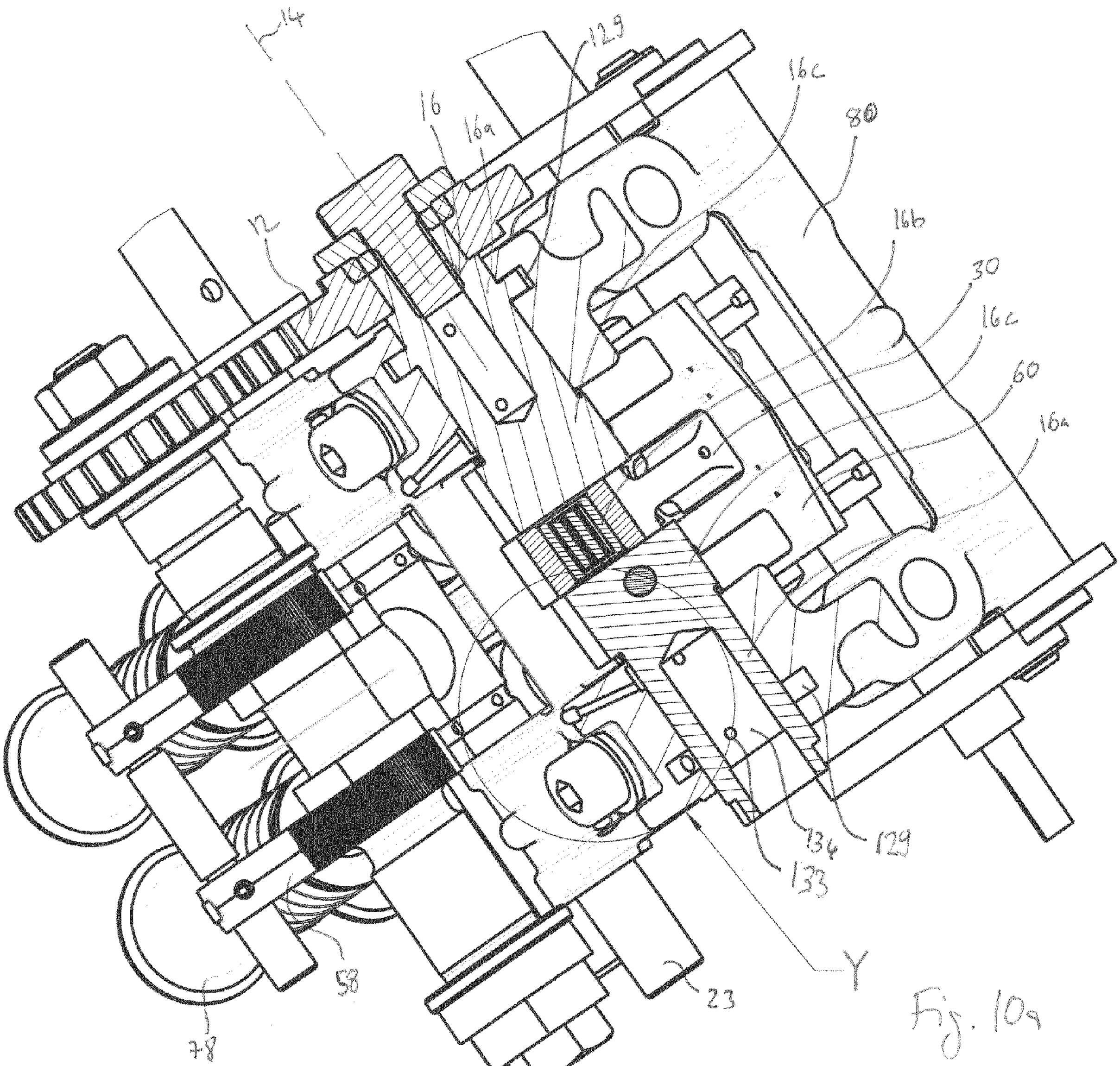


Fig. 10a

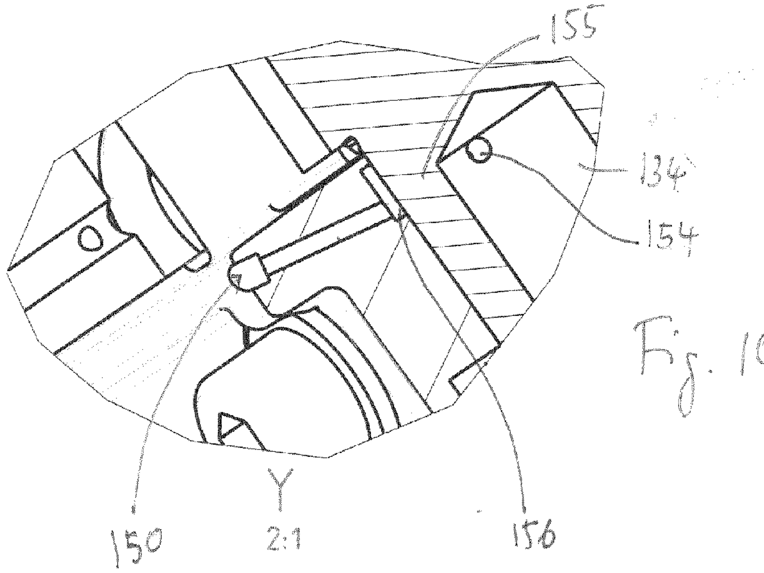
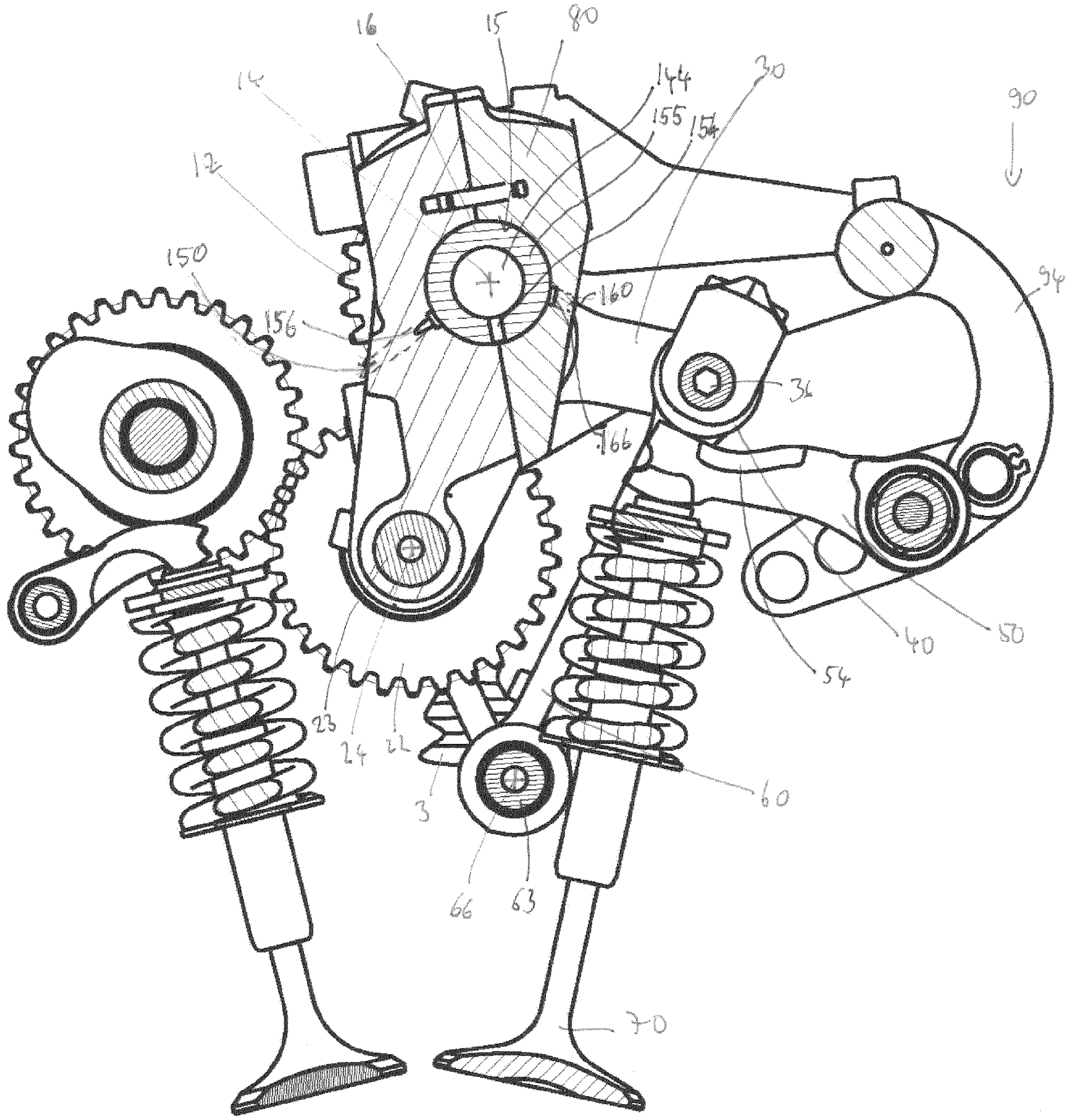


Fig. 10b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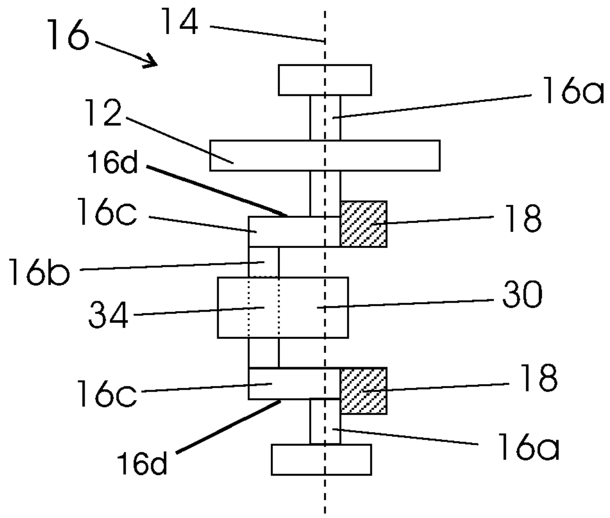
E-E

Fig. 11

Fig. 12



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EUROPEAN SEARCH REPORT

Application Number
EP 18 19 4801

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	14 March 2019	Aubry, Yann

2

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