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(54) **DUAL CAMSHAFT PHASER**

(57) A dual phaser is disclosed for use with an internal combustion engine having a crankshaft and a valve train that includes a first and a second group of cam lobes, wherein the phase of the cam lobes in each group is adjustable, independently of the phase of the cam lobes

of the other group, relative to the phase of the crankshaft. The dual phaser has an electric first phaser for acting on the first group of cam lobes and a hydraulic second phaser for acting on the second group of cam lobes.

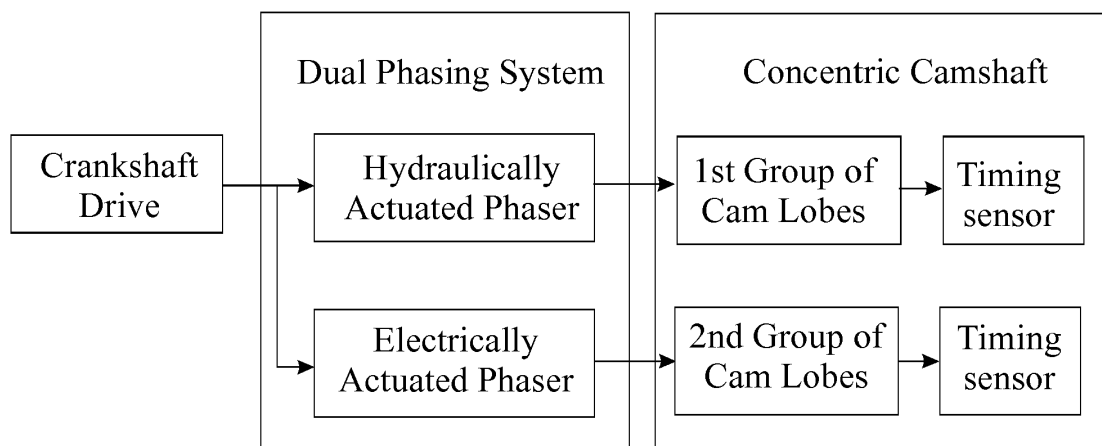


Fig. 1

Description

Field of the disclosure

[0001] The present invention relates to a phasing system for acting on two groups of cam lobes of a valve train of an internal combustion engine to change the phases of each of the two groups of lobes independently of one another relative to the phase of the engine crankshaft. Such a system is herein referred to as a dual phaser.

Background

[0002] The use of phasing systems, or phasers, is becoming increasingly widespread on both gasoline and diesel engines. In the past, hydraulically operated phasers (also herein termed hydraulic phasers) have offered a compact and cost effective solution. However, more recently, electrically operated phasers (also herein termed E-phasers), have become popular due to the functional advantages that they offer. These include:

- Faster response time,
- More consistent response times over all engine operating conditions, particularly low temperatures when oil viscosity reduces the performance of hydraulic phasers, and
- Reduced oil consumption and oil pump power consumption.

[0003] An E-phaser generally consists of two main components, namely a gear set or harmonic drive that is mounted to the engine camshaft, and an electric motor for adjusting the E-phaser which is mounted to a stationary part of the engine, and positioned coaxially with the camshaft. There may be a drive coupling (Oldham coupling) to allow for any small eccentricity between the motor and the camshaft. Phase is adjusted using an E-phaser by varying the speed of the electric motor relative to that of the camshaft. If the motor speed is synchronised with camshaft speed then the phasing setting is maintained. Reducing the motor speed relative to the camshaft will cause the phaser to move in one direction, increasing the motor speed will cause the phaser to move in the other direction. A typical example of an E-phaser is to be found in US Patent 8,682,564,

[0004] In some variable valve systems, such as that shown in EP 1417399, a phasing system is used to adjust the valve lift profile characteristics. In such a system, operation of the phaser affects engine power output and the faster response of an E-phaser would offer driveability advantages.

[0005] Many engines are now being designed with multiple phasers, and in some cases two phasers are required to act on the same camshaft. It may be, for example, that one phaser is required to control valve lift while

the other is required to change the valve timing relative to the crankshaft.

[0006] Hydraulic dual phasers have previously been proposed in EP 1234954 that could be used in such applications. However, the known hydraulic dual phasers, when used to control valve lift, may not offer the desirable fast response of an E-phaser.

[0007] Combining two independent E-phasers into a single unit is not practicable because only one electric motor can be mounted on the engine adjacent to the end of the camshaft. It would be possible to have two separate E-phasers mounted at opposite ends of the same camshaft, but this requires packaging space to be available at both ends of the camshaft and would significantly reduce the natural resonant frequency of the camshaft drive system.

Summary

[0008] According to the present invention, there is provided a dual phaser for use with a reciprocating piston engine having a crankshaft and a valve train that includes a first and a second group of cam lobes wherein the phase of the cam lobes in each group is adjustable, independently of the phase of the cam lobes of the other group, relative to the phase of the crankshaft, the dual phaser having an electric first phaser for acting on the first group of cam lobes and a hydraulic second phaser for acting on the second group of cam lobes.

[0009] The dual phaser of the invention includes an E-phaser that can be used to act on cam lobes that affect event duration and valve lift, such control benefiting from a rapid response time. The dual phaser additionally incorporates a hydraulic phaser that can be used to provide valve timing control where response time is not critical. The invention thus provides a hybrid dual phaser, which offers the advantages of both types of phasers, while still being constructed as a single compact unit that can be mounted on a single end of the camshaft.

Brief description of the drawings

[0010] Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of a first embodiment of the invention, the diagram showing two torque flow paths from the engine crankshaft through a dual phaser to two groups of cam lobes acting on the intake and/or exhaust valves of the engine, Figure 2 is an exploded view from the front of a dual phaser according to the first embodiment of the invention, Figure 3 is an exploded view from the rear of the dual phaser shown in Figure 2, Figure 4 shows a section through the dual phaser of Figures 2 and 3,

Figure 5 shows an alternative section through the dual phaser of Figures 2 and 3,

Figure 6 is a block diagram similar to that of Figure 1 showing two torque flow paths from the engine crankshaft through a dual phaser of a second embodiment of the invention,

Figure 7 is an exploded view from the front of a dual phaser in accordance with the second embodiment of the invention, in which the hydraulic phaser is exploded, Figure 8 is an exploded view of the embodiment shown in Figure 7, in which the hydraulic phaser is assembled,

Figure 9 is a sectional view of the dual phaser of Figures 7 and 8,

Figure 10 is an isometric view of the dual phaser of Figures 7 to 9 in a fully assembled state, and

Figure 11 is a block diagram similar to that of Figures 1 and 6, showing two torque flow paths from the engine crankshaft through a dual phaser of a third embodiment of the invention.

Detailed description of the drawings

[0011] Figures 1, 6 and 11 demonstrate the three possible configurations for transmitting torque through a dual hybrid phaser to two groups of cam lobes of a concentric camshaft. Such a camshaft comprises a hollow outer tube carrying one group of cam lobes that are fast in rotation with the tube. The tube also carries a second group of lobes that can rotate relative to the tube and are connected by means of pins passing through circumferentially elongated slots in the tube for rotation with an inner shaft rotatably supported within the outer tube.

[0012] In the first embodiment of the invention, both the hydraulic and the electric phaser are connected directly to the engine crankshaft and drive a respective one of the two groups of cam lobes. An example of such a hybrid dual phaser will be described below by reference to Figures 2 to 5.

[0013] In the second embodiment of Figure 6, the hydraulic phaser is driven directly by the crankshaft and drives the first group of cam lobes. The electric phaser is driven from the output of the hydraulic phaser and drives the second group of cam lobes. An example of such a hybrid dual phaser will be described below by reference to Figures 7 to 10.

[0014] In the third embodiment of Figure 11, the electric phaser is driven directly by the crankshaft and drives the first group of cam lobes. The hydraulic phaser is driven from the output of the electric phaser and drives the second group of cam lobes.

[0015] In the following description, the construction and method of operation of vane-type hydraulic phasers and motor driven electric phasers will be assumed to be known and will not therefore be described in detail. In each case, the phaser has a stator and a rotor that can be rotated relative to one another to bring about a change of phase between the driving element and the driven el-

ement. In the case of a hydraulic phaser, the phase change is brought about by changing the volume of working chambers defined between the rotor and the stator and in the case of an electric phaser the phase change is brought about by an electric motor that rotates the rotor and stator relative to one another.

[0016] Figures 2 and 3 shows an exploded view of a hybrid dual phaser mounted to the front end of a concentric camshaft 10, having an outer tube 12, a first group of cam lobes 14 mounted for rotation with the outer tube 12 and a second group of cam lobes 16 (only one visible in Figures 2 and 3) connected by pins 18 for rotation with the inner shaft 20 of the concentric camshaft 10, as shown in the sections of Figures 4 and 5.

[0017] The hybrid dual phaser comprises a hydraulic phaser 22 that comprises a stator 24 and a rotor 26 and is actuated via oil feeds passing from at least one of the camshaft bearings into the phaser. The stator 24 has teeth 28 to enable it to be driven by way of a toothed belt or chain from the engine crankshaft. The rotor 26 is secured for rotation with the outer tube 12 of the assembled camshaft 10 thereby enabling the phase of the first set of lobes 14 of camshaft to be changed relative to the crankshaft.

[0018] The stator 24 of the hydraulic phaser can be seen in Figure 2 to have five axially projecting fixing bolts 30 that are received in five threaded holes 32 in the stator 34 of the electric phaser 36, which also acts as one of the end plates enclosing the working chambers of the hydraulic phaser 22. Thus drive from the crankshaft is transmitted without any phase change directly to the stator 34 of the electric phaser 36 via the stator of the hydraulic phaser 22.

[0019] The rotor 38 of the phaser 36 is rotated relative to the stator 34 by an electric motor 40 to which it is connected by means of a first drive coupling 42. A second drive coupling 44 connects the rotor 38 of the electric phaser 36 for rotation with the inner shaft 20 of the concentric camshaft 10, thereby allowing the phase of the second set of cam lobes 16 of the camshaft to be varied relative to the phase of the crankshaft independently of the phase of the first set of cam lobes 14.

[0020] A bolt 50, in screw threaded engagement with the inner shaft 20 serves to secure the rotor of the electric phaser to the front end of the drive shaft 20.

[0021] The embodiment of Figures 7 to 10 is generally similar to that of Figures 2 to 5. To avoid repetition of the description, like components have been allocated like reference numerals. The main difference resides in the fact that fixing bolts 30' transmitting driving torque to the stator of the electric phaser 36 are connected to the rotor 26 rather than the stator 24 of the hydraulic phaser 22 so that hydraulic phaser changes the phase of the both sets of cam lobes 14 and 16 relative to the crankshaft and the electric phaser changes the phaser of the two sets of cam lobes 14 and 16 relative to one another, independently of their phase relative to the engine crankshaft.

[0022] The exploded view of the hydraulic phaser in Figure 7 shows that the stator 24 defines five arcuate chambers, each of which is divided into two opposing working chambers by a respective one of five vanes 52 that form part of the rotor of the hydraulic phaser. The fixing bolts 30' in the case of the second embodiment are connected to these vanes 52 rather than to the stator 24.

[0023] Figures 9 and 10 also show timing rings that are secured to the hybrid phaser to allow the phase of the two sets of cam lobes 14 and 16 to be determined. A first timing ring 60 is mounted on the stator of the electric phaser. This allows the phase of the first set of cam lobes 14 to be sensed as the rotor of the hydraulic phaser is connected to drive both the first set of cam lobes 14 and the stator 32 of the electric phaser.

[0024] The phase of the second set of cam lobes 16 is sensed using a second timing ring 64 that is rotatably mounted on the outer tube 12 of the concentric camshaft and, like the second set of cam lobes 16, is connected by a pin 66 passing through a tangentially elongated slot to the inner shaft of the concentric camshaft.

[0025] The design of a hybrid dual phaser in accordance with the third embodiment of the invention described above will be clear to a person skilled in the art as the distinction in the operating principle from second embodiment can readily be appreciated from comparison of figure 11 with figure 6. The design may essentially be the same as that shown in Figure 9, save that the stator of the electric phaser would be coupled to the crankshaft instead of the stator of the hydraulic phaser and the stator of the hydraulic phaser would be connected for rotation in phase with the rotor of the electric phaser.

[0026] Though the invention has been described herein by reference to a hybrid dual phaser mounted on one end of a concentric camshaft, it should be clear that the phaser could also find use in an engine having two separate solid camshafts and the drive to the second set of cam lobes could be transmitted through a chain, a toothed belt, or meshing gear wheels.

Claims

1. A dual phaser for use with an internal combustion engine having a crankshaft and a valve train that includes a first and a second group of cam lobes wherein the phase of the cam lobes in each group is adjustable, independently of the phase of the cam lobes of the other group, relative to the phase of the crankshaft, the dual phaser having an electric first phaser for acting on the first group of cam lobes and a hydraulic second phaser for acting on the second group of cam lobes.
2. A dual phaser as claimed in claim 1, wherein an electric motor arranged substantially coaxially with the camshaft controls the electric first phaser.

3. A dual phaser as claimed in claim 1 or 2, wherein the hydraulic second phaser is actuated via oil feeds passing from at least one of the camshaft bearings into the phaser.
4. A dual phaser as claimed in any preceding claim, wherein the twin phaser is mounted to a concentric camshaft having the two groups of cam lobes mounted coaxially.
5. A dual phaser as claimed in any of claims 1 to 3, wherein the twin phaser is mounted to drive two groups of cam lobes mounted on separate parallel camshafts.
6. A dual phaser as claimed in any preceding claim, wherein both the electric first phaser and the hydraulic second phaser have inputs operative to rotate in synchronism with the crankshaft and each of the two groups of cam lobes is connectable to an output of a respective one of the two phasers.
7. A dual phaser as claimed in any one of claims 1 to 5, wherein the hydraulic second phaser has an input operative to rotate in synchronism with the crankshaft and an output connected for rotation with an input of the electric first phaser and with one of the two groups of cam lobes, the other of the two groups of cam lobes being connected for rotation with an output of the electric first phaser.
8. A dual phaser as claimed in any one of claims 1 to 5, wherein the electric phaser has an input operative to rotate in synchronisation with the crankshaft and an output connected for rotation with an input of the hydraulic phaser and with one of the two groups of cam lobes, the second of the two groups of cam lobes being connected for rotation with an output of the hydraulic phaser.
9. A dual phaser as claimed in any preceding claim, wherein a timing wheel is mounted to rotate in synchronism with the input of at least one of the phasers.
10. A dual phaser as claimed in any preceding claim, wherein timing wheels are provided for sensing the phases of the two groups of cam lobes.

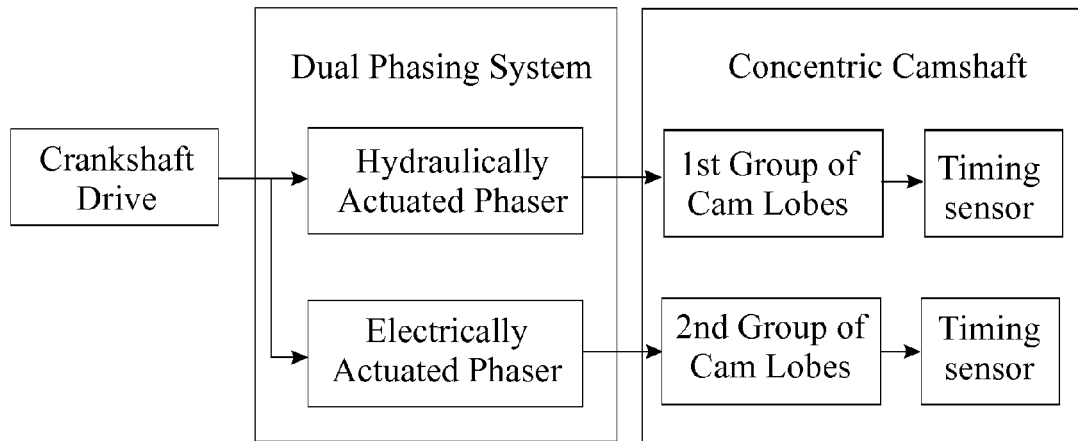


Fig. 1

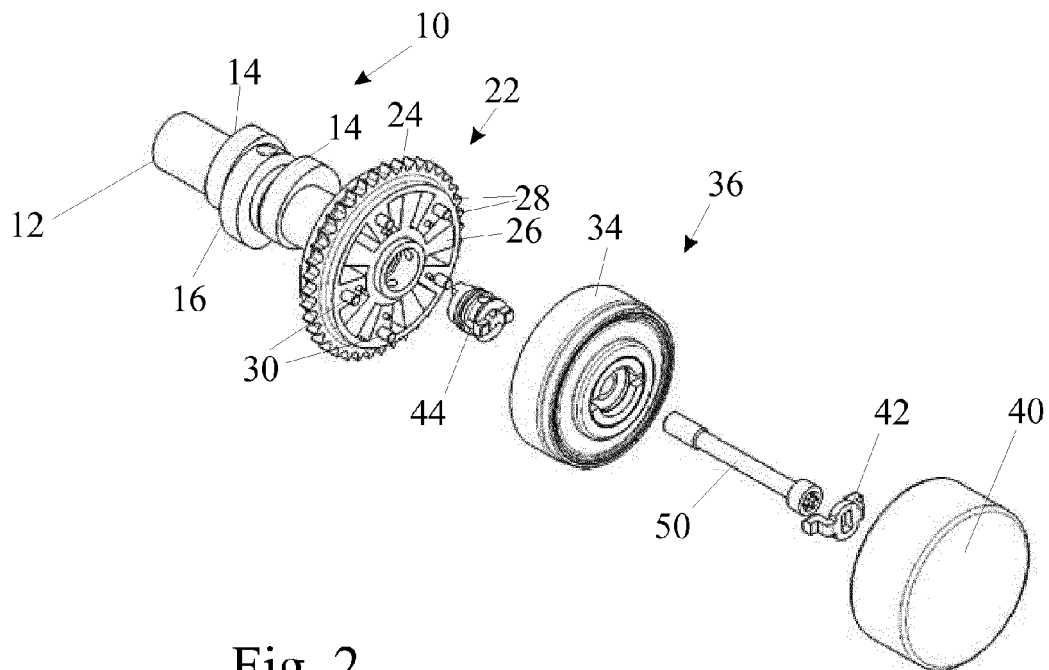


Fig. 2

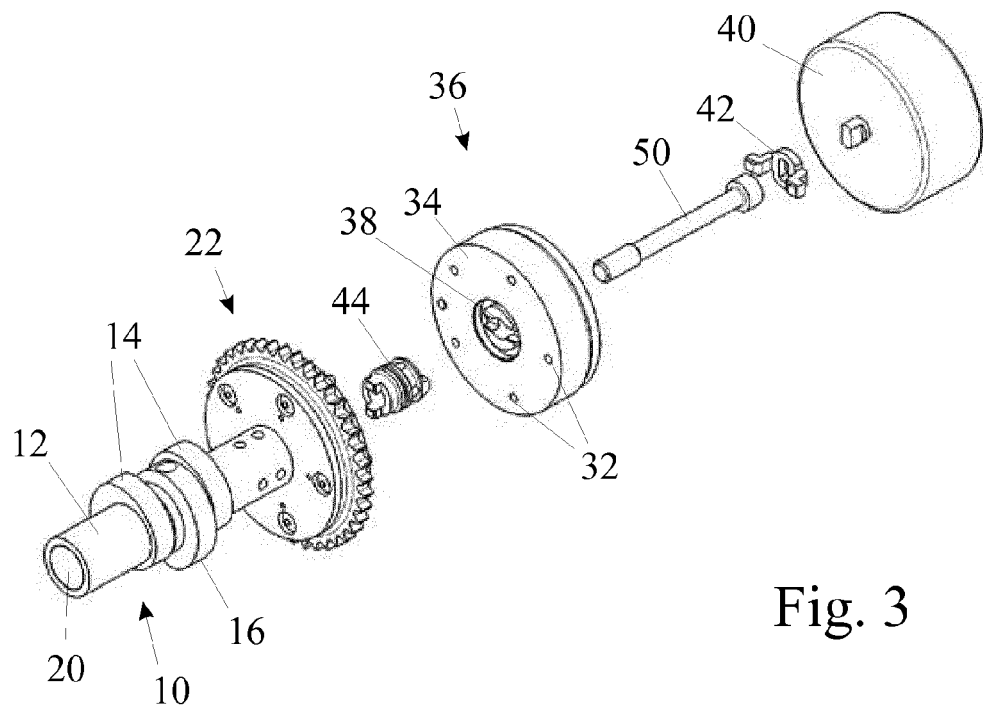


Fig. 3

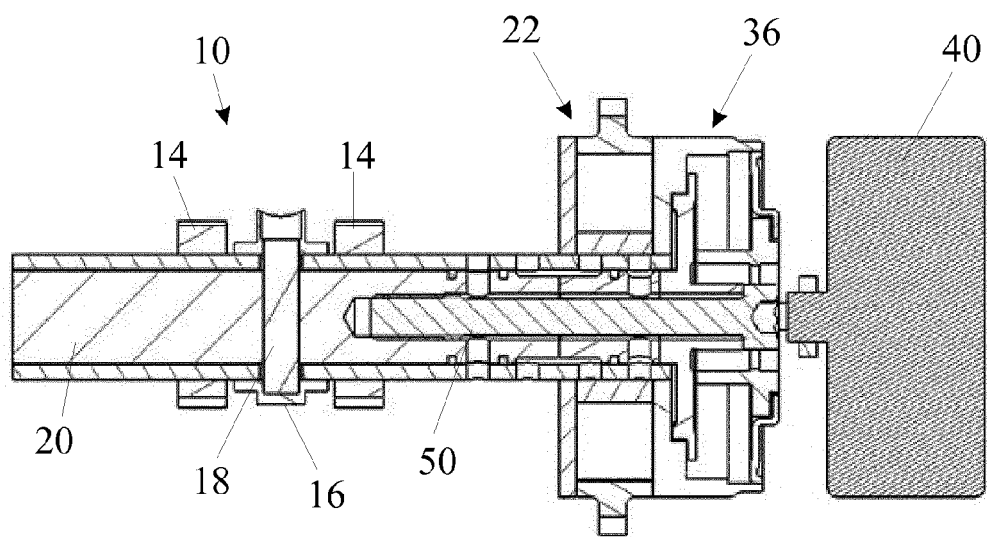


Fig. 4

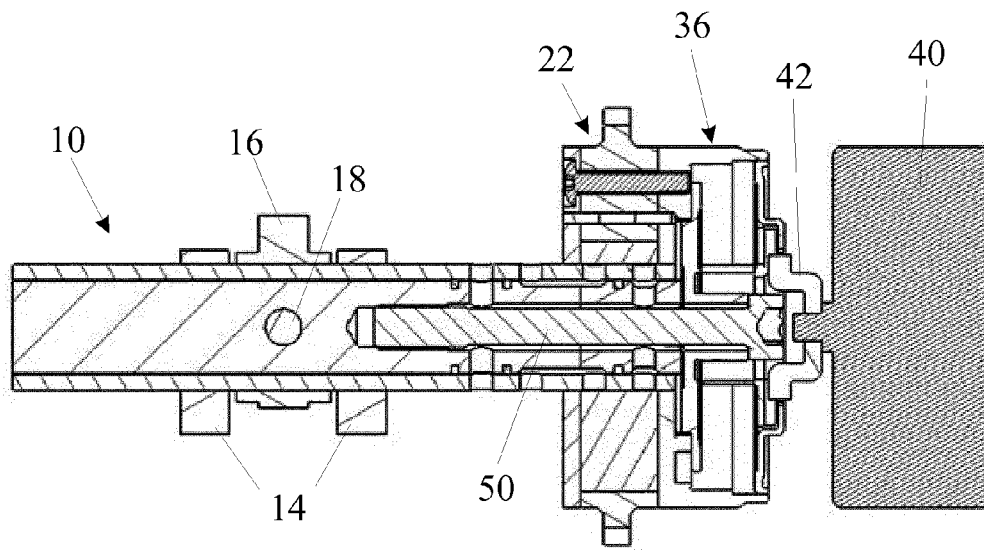


Fig. 5

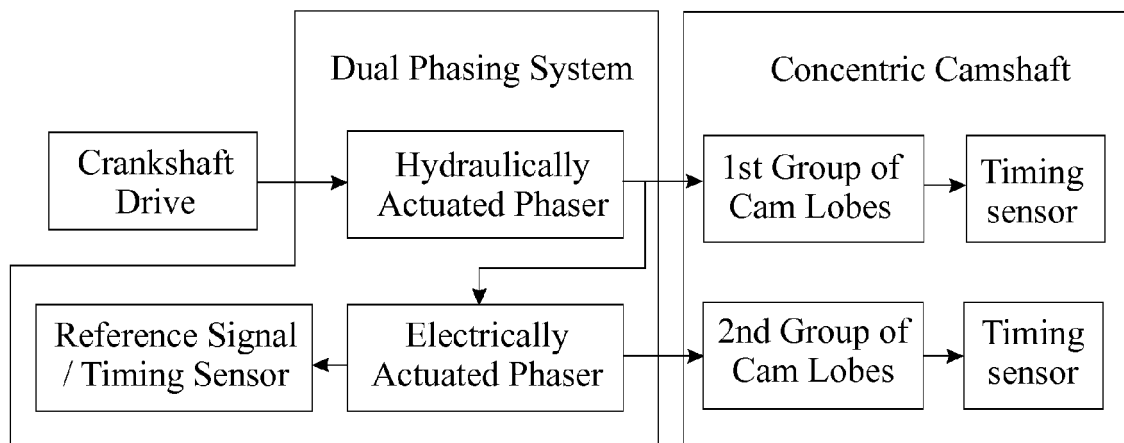


Fig. 6

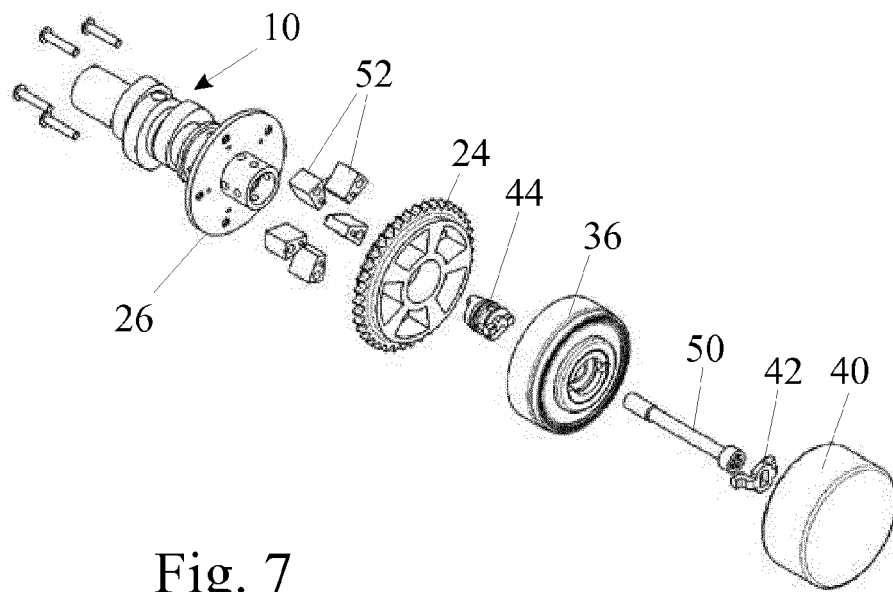


Fig. 7

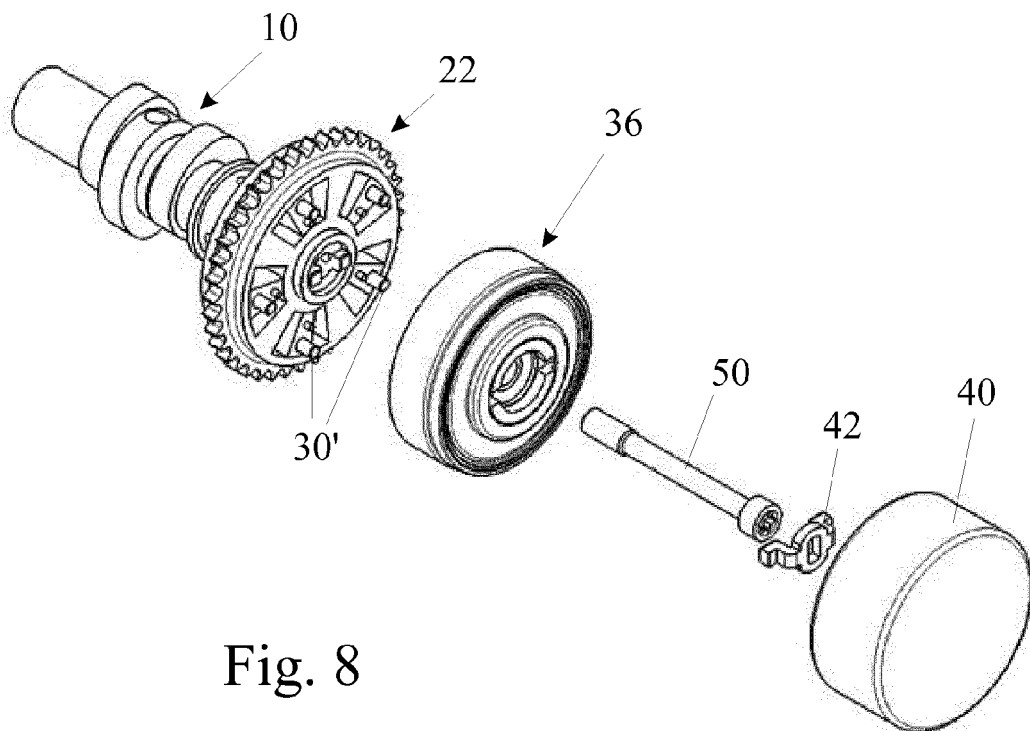


Fig. 8

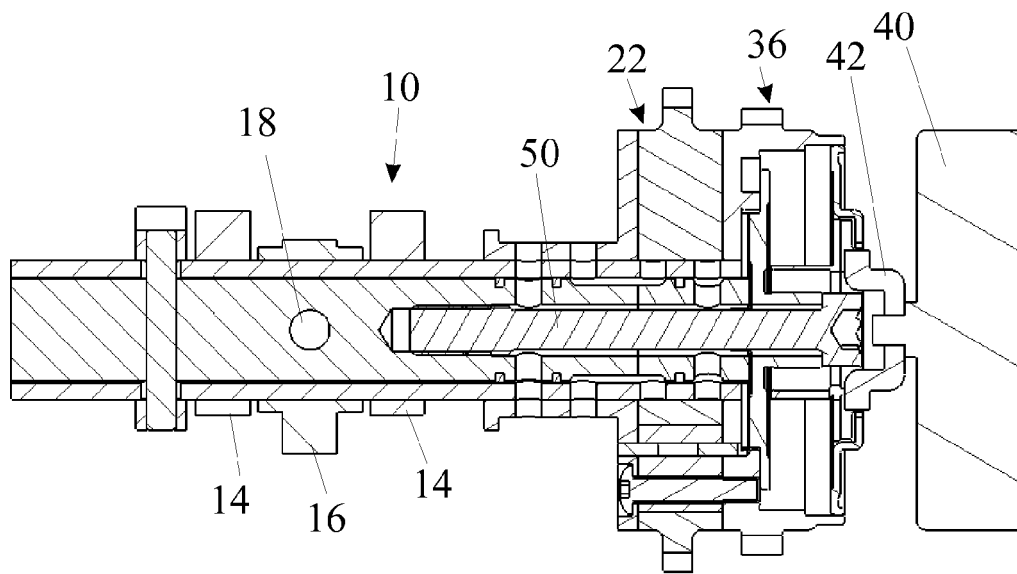


Fig. 9

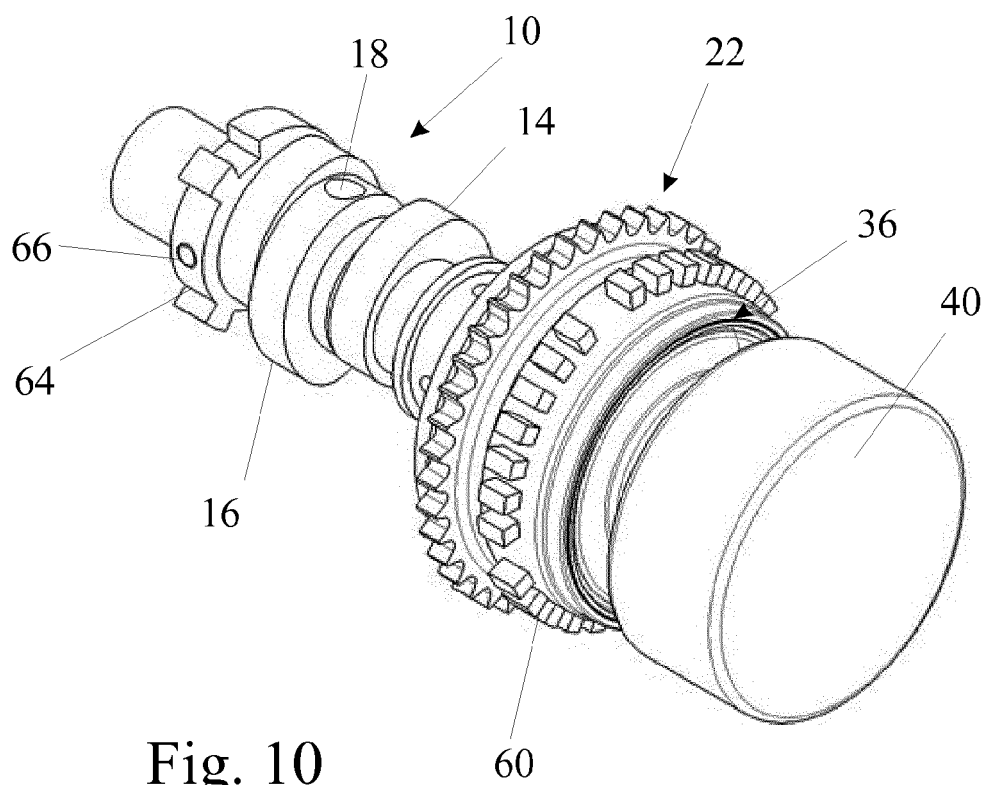


Fig. 10

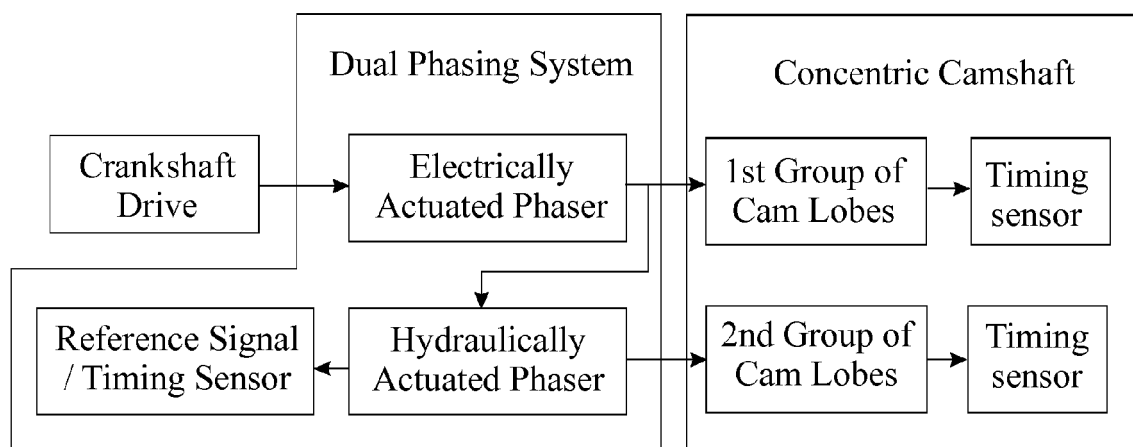


Fig. 11



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 Application Number
 EP 15 18 4962

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 11 February 2016	Examiner Klinger, Thierry
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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