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(71) Applicant: **Mechadyne International Limited**
Kirtlington
Oxfordshire OX5 3JQ (GB)

(72) Inventor: **Lancefield, Timothy, Mark**
Shipston on Stour, Warwickshire CV36 5LZ (GB)

(74) Representative: **Harrison IP Limited**
Box Tree House
Northminster Business Park
York, Yorkshire YO26 6QU (GB)

(54) **Internal combustion engine**

(57) An internal combustion engine is disclosed having a crankshaft; at least one engine cylinder; a piston connected to the crankshaft and reciprocable within the cylinder to define a variable volume combustion chamber; at least two intake valves (34) and at least two exhaust valves (36) controlling the flow of gas into and out of the combustion chamber, respectively; a first camshaft (14) having fixed cam lobes (14a to 14h) for operating a first intake valve and a first exhaust valve of the cylinder, and a second camshaft (16) having cam lobes (16a to 16h) for operating a second intake valve and a second exhaust valve of the cylinder. The second camshaft (16) is an assembled concentric camshaft having an outer tube (32) and an inner shaft (30) that are rotatable relative to one another and two groups of cam lobes (16a to 16h) mounted for rotation with the outer tube and with the inner shaft, respectively; and a phase change mechanism (24) is connected to the assembled camshaft (16). In the invention, the first camshaft (14) is driven in fixed phase relationship to the crankshaft, and the phase change mechanism (24) has an input member (22) driven by the crankshaft and two output members each driving a respective one of the inner shaft (30) the outer tube (32) of the assembled camshaft (16), so as to enable the phase of the lobes rotatable with the outer tube and the phase of the lobes rotatable with the inner shaft to be varied relative to one another and relative to the crankshaft.

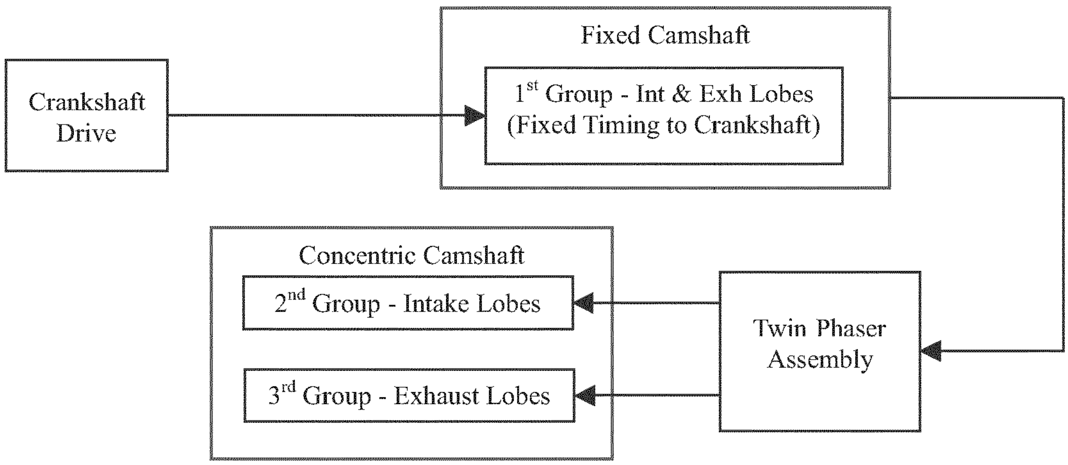

Fig. 5

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Description

Field of the invention

[0001] The present invention relates to an internal combustion engine having a crankshaft; at least one engine cylinder; a piston connected to the crankshaft and reciprocable within the cylinder to define a variable volume combustion chamber; at least two intake valves and at least two exhaust valves controlling the flow of gas into and out of the combustion chamber, respectively; a first camshaft having fixed cam lobes for operating a first intake valve and a first exhaust valve of the cylinder; and a second camshaft having cam lobes for operating a second intake valve and a second exhaust valve of the cylinder.

Background

[0002] The present applicants have previously proposed a camshaft design referred to herein as an assembled camshaft, which is also termed an SCP camshaft in some of the Applicants' earlier patents and applications such as GB 2433974. Such a camshaft has an outer tube and an inner shaft that can rotate relative to the outer tube. One set of cams is fixed to the outer tube and a second set is rotatably supported on the outer tube and connected to the inner shaft by means of pins that pass through elongated slots in the outer tube. By rotating the inner shaft relative to the outer tube, it is possible to change the relative phase of the two sets of cams.

[0003] Phase changing mechanisms, also referred to herein more briefly as a phasers, are also known in the art. Conventionally, the camshaft of a four-stroke engine, which rotates at half the speed of the engine crankshaft, is driven in a fixed phase to the crankshaft so that the valves always open and close at a fixed crank angle. The purpose of a phaser is to allow the opening and/or closing times of the valves to be changed, so as to vary the timing (or phase) of the intake and exhaust events relative to the angular position of the crankshaft and therefore to the axial position of the piston in the cylinder.

[0004] Vane-type phasers are well known, these being compact devices that can be mounted on the end of a camshaft. One such phaser is shown in EP 1828552. Such phasers have an input member, in the form of a gear or sprocket that is driven by the crankshaft through a belt, a chain or gears. The input member has arcuate chambers that receive vanes projecting radially from an output member. By controlling the flow of hydraulic fluid into the chambers on opposite sides of the vanes, the angular position of the output member can be adjusted relative to the input member.

[0005] Twin phasers are also known that have one input member and two output members. A twin phaser can be mounted on a concentric assembled camshaft so that each of the two sets of cam lobes can be varied in phase relative to the crankshaft independently of the other.

Known valve train configurations

[0006] US2010/0212625 has two assembled concentric camshafts each with a single phaser. One camshaft acts on two intake valves and the other on two exhaust valves. Each camshaft thus operates on a primary and a secondary valve serving the same function (intake or exhaust). By varying the phase of the secondary valve relative to the primary valve, the duration of the event can be changed to allow early opening of the exhaust valve (e.g. for increasing the energy transferred to the turbocharger or after-treatment system) or delayed closing of the intake valve (e.g. for improved volumetric efficiency or part load operation).

[0007] The closest prior art known to the Applicants is believed to be WO2011/010241. The latter application describes a twin phaser and a wide variety of configurations for phasing two groups of cam lobes. The twin phaser is configured such that the output from the first phaser is connected to the input of the second so that the first phaser can affect the timing of all the cam lobes and the second phaser affects the timing of the second set of lobes relative to the first.

Summary of the invention

[0008] According to the present invention, there is provided an internal combustion engine as hereinafter set forth in Claim 1 of the appended claims.

[0009] The engine of the invention differs from that shown in Figure 1E of WO2011/010241 in that there are three sets of cam lobes rather than two. A first set of cam lobes connected to the solid camshaft is operated in fixed phase relative to the engine crankshaft whilst the second and third sets of cam lobes mounted to the assembled concentric camshaft are adjustable independently of one another relative to the engine crankshaft.

[0010] The present invention offers the advantage that, though using only one phaser, it is possible to vary the total duration of both the intake and the exhaust events by advancing the opening time or delaying the closing time of an intake or exhaust event by altering the phase of the second intake or exhaust valve operated by the assembled camshaft.

Brief description of the drawings

[0011] The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a cylinder head of an engine embodying the invention,
Figure 2 is a plan view of the cylinder head in Figure 1,
Figure 3 is a section along the line III-III in Figure 2, the section plane passing through two intake valves,
Figure 4 is a section along the line IV-IV in Figure 2,

the section plane passing through two exhaust valves and

Figures 5 to 10 show schematically various possible configurations for deploying a twin phaser in valve train driving a fixed camshaft and an assembled camshaft

Detailed description

[0012] The engine cylinder head 10 shown in the drawings is that of a four-cylinder engine, or engine block, with four valves per cylinder. In a conventional gasoline engine, the two intake valves of each cylinder are arranged on one side of the cylinder head centre line 12 and the two exhaust valves on the opposite side of the centre line 12. In the present invention, however, one intake and one exhaust valve of each cylinder are arranged on one side of the centre line 12 while the other intake and the other exhaust valve of the cylinder are arranged on the opposite side of the centre line 12.

[0013] The engine has two overhead camshafts 14 and 16. The camshaft 14 is a solid shaft having eight lobes 14a to 14h which alternately act on intake and exhaust valves, that is to say the lobes 14a, 14c, 14e and 14g act on intake valves and the remaining lobes act on exhaust valves of the four cylinders.

[0014] The camshaft 14 has a drive pulley 18 at one end that is driven by the engine crankshaft by way of a toothed cam belt. The camshaft 14 rotates at exactly half the speed of the crankshaft and with a fixed phase so that the valves associated with the cam lobes 14a to 14h always open and close at fixed phase angles of the crankshaft.

[0015] At its opposite end from the drive pulley 18, the camshaft 14 is connected to a gear 20 that meshes with a second gear 22 of the same size and therefore rotates at the same speed. The gear 22 is connected to the input member of a twin phaser 24 serving to drive the second camshaft 16.

[0016] The second camshaft 16 is an assembled camshaft which, as is more clearly shown in Figures 3 and 4, comprises an inner shaft 30 and an outer tube 32. The inner shaft 30 is driven by one of two output members of the twin phaser 24 while the outer tube 32 is driven by the other output member of the twin phaser. In this way, both the inner shaft 30 and the outer tube 32 rotate at half the crankshaft speed but each of their phases may be varied by the twin phaser 24 relative to the crankshaft, independently of the phase of the other.

[0017] The assembled camshaft 16 once again has eight cam lobes, designated 16a to 16h. Of these, alternate lobes 16b, 16d, 16f and 16h, which in the illustrated embodiment all act on exhaust valves, are fast in rotation with the outer tube 32. This is most conveniently achieved by heat shrinking the lobes onto the outer tube 32 but other methods may be used. The remaining lobes 16a, 16c, 16e, and 16g, on the other hand, act on the intake valves and are fast in rotation with the inner shaft 30 of the assembled camshaft 16. As shown in Figure 2, each of the latter lobes has an axially extending collar connected to the inner shaft 30 by a radial pin, the latter passing through a tangentially elongated slot in the outer tube 32.

[0018] The intake and exhaust events of each cylinder are controlled by varying the phase of only one of the intake or exhaust valves (operated by the camshaft 16), while the phase of the other (operated by the camshaft 14) remains constant. Using only one twin phaser 24, the invention allows the commencement of any valve event (intake or exhaust) to be advanced or its termination retarded to enable a variety of valve control regimes to be implemented.

[0019] It should be noted that the invention is not dependent upon any particular design of twin phaser. WO2011/010241 shows a design having a first output that phases both sets of cams and a second output that phases the second set of cams relative to the first. Alternatively it would possibly be more advantageous to use a different design of twin phaser such as that shown in EP 1234954 where both output members are independently variable relative to the input member.

[0020] As can be seen from Figure 3 and 4, the distance between the rotational axes of the two camshafts 14 and 16 may in practice need to be greater than the distance between the intake valves 34 or the exhaust valves 36. The cam lobes of the respective cams may therefore act on the valves 34 or 36 by way of respective rockers 42 that contact the cam lobes via roller cam followers, with one end of each rocker 42 resting on a hydraulic lash adjuster 46 and the other end on the end of the associated poppet valve 34, 36.

[0021] There are various possibilities for the manner in which the twin phaser is deployed within the valve train, these being shown in Figure 5 to 10.

[0022] Figure 5 is a schematic representation of the configuration already described by reference to Figure 1 to 4. Here, the front end of the fixed camshaft is driven by the crankshaft, the twin phaser is located at the rear end of the assembled camshaft and is driven by the fixed camshaft.

[0023] In Figure 6, the twin phaser is located at the front end of the assembled camshaft and it driven directly by the crankshaft.

[0024] In Figure 7, the twin phaser is again positioned at the front end of the assembled camshaft but is driven by a secondary drive taken from the fixed camshaft.

[0025] In Figure 8, only the twin phaser is driven directly by the crankshaft and the fixed camshaft is camshaft is driven by a secondary drive taken from the input member of the twin phaser.

[0026] Figures 9 and 10 illustrate different possible internal constructions of the twin phaser. In Figure 9, the input member is connected to drive the two output members and directly whereas in Figure 10, the input member drives one of the output member, which in turn drives the other output member.

[0027] While the invention is not restricted as to the type of fuel burnt in the engine, the engine valve configuration required by the invention is currently only commonly used in diesel engines.

Claims

1. An internal combustion engine having:

   a crankshaft;
   at least one engine cylinder;
   a piston connected to the crankshaft and reciprocable within the cylinder to define a variable volume combustion chamber;
   at least two intake valves (34) and at least two exhaust valves (36) controlling the flow of gas into and out of the combustion chamber, respectively;
   a first camshaft (14) having fixed cam lobes (14a to 14h) for operating a first intake valve and a first exhaust valve of the cylinder, and
   a second camshaft (16) having cam lobes (16a to 16h) for operating a second intake valve and a second exhaust valve of the cylinder;
   characterised in that
   the second camshaft (16) is an assembled concentric camshaft having an outer tube (32) and an inner shaft (30) that are rotatable relative to one another and two groups of cam lobes (16a to 16h) mounted for rotation with the outer tube and with the inner shaft, respectively;
   a phase change mechanism (24) is connected to the assembled camshaft (16);
   the first camshaft (14) is driven in fixed phase relationship to the crankshaft, and
   the phase change mechanism (24) has an input member (22) driven, directly or indirectly, by the crankshaft and two output members each driving a respective one of the inner shaft (30) the outer tube (32) of the assembled camshaft (16), so as to enable the phase of the lobes rotatable with the outer tube and the phase of the lobes rotatable with the inner shaft to be varied relative to one another and relative to the crankshaft.

2. An engine as claimed in claim 1, wherein the first camshaft (14) and the second camshaft (16) are both coupled for rotation with the engine crankshaft by means of a drive belt or chain.

3. An engine as claimed in claim 1, wherein the second camshaft (16) is coupled for rotation with the engine crankshaft by means of the first camshaft (14).

4. An engine as claimed in claim 1, wherein the first camshaft (14) is coupled for rotation with the engine crankshaft by means of the input member of the phase change mechanism (24) mounted to the second camshaft (14).

5. An engine as claimed in any preceding claim, wherein the two output members of the phase change mechanism (24) are each independently directly driven by the input member of the phase change mechanism (Fig. 9).

6. An engine as claimed in any of claims 1 to 4, wherein a first output member of the phase change mechanism (24) is directly driven by the input member of the phase change mechanism and the second output member is driven by way of the first output member (Fig. 10).

7. An engine as claimed in any preceding claim, wherein the cam lobes of the first and second camshafts act on the engine valves by way of respective rockers (42).

8. An engine as claimed in claim 7, wherein each rocker (42) is pivotable relative to a cam follower and has one end acting on a valve (32,34) and the other resting on a hydraulic lash adjuster (46).

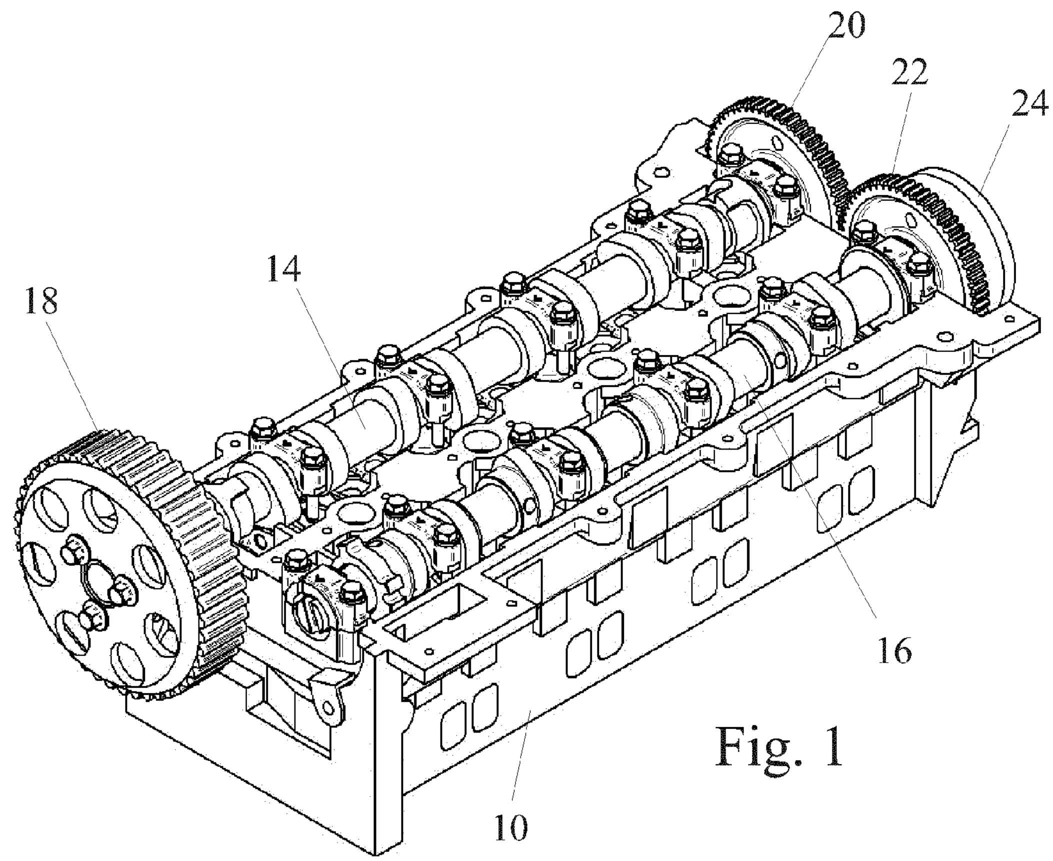
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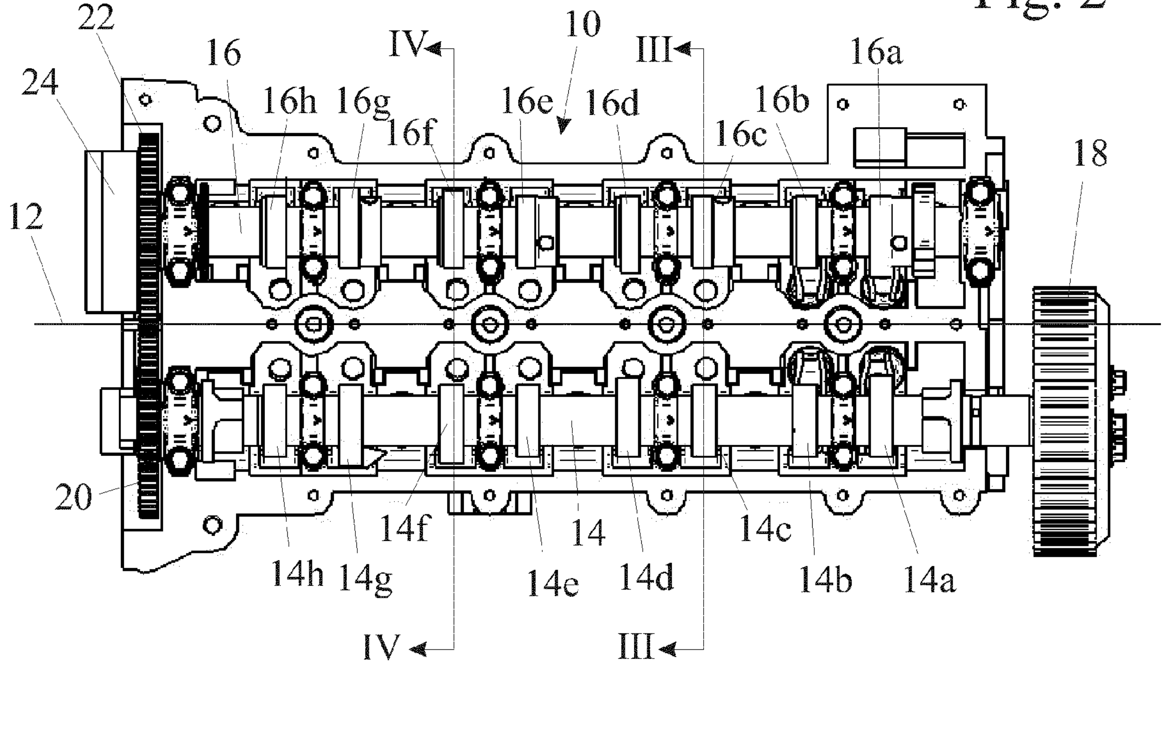
Fig. 1

Fig. 2


22
24
16
16h
16g
16f
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10
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16d
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16c
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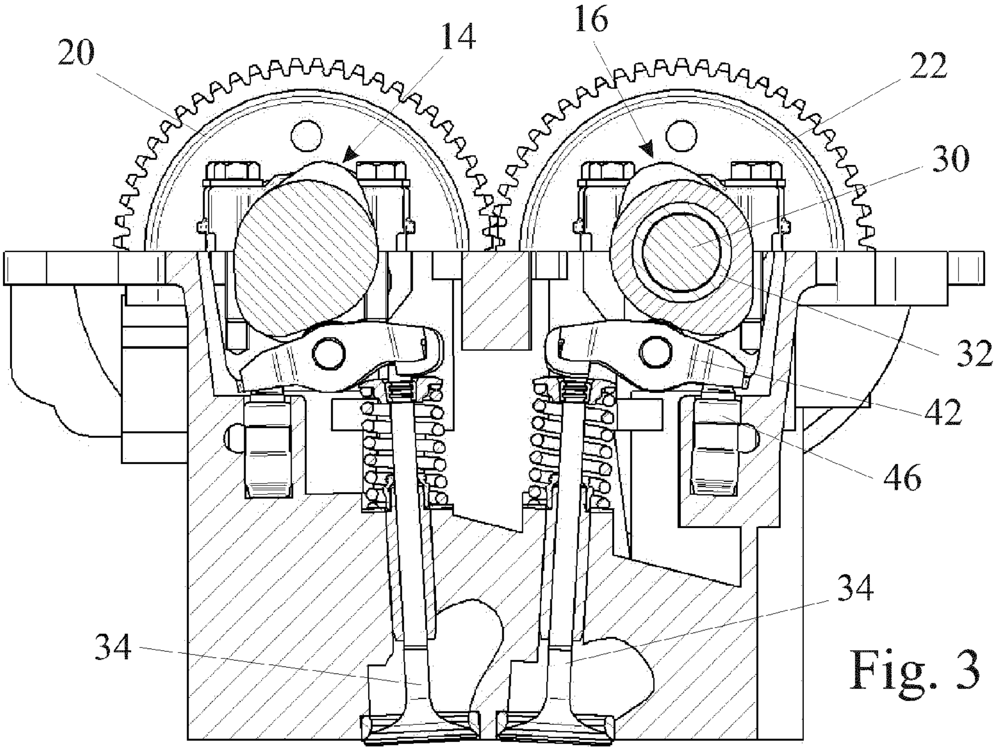

Fig. 3

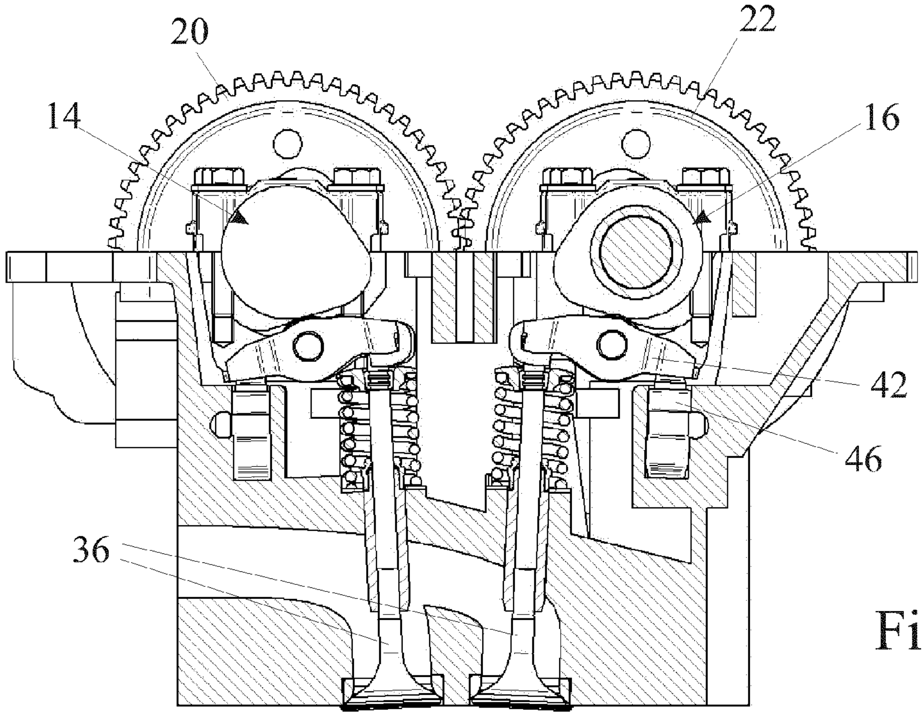

Fig. 4

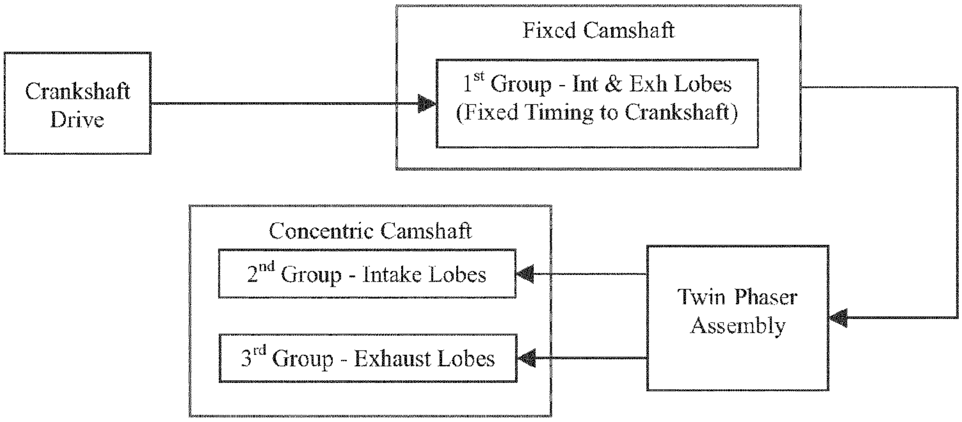

Fig. 5

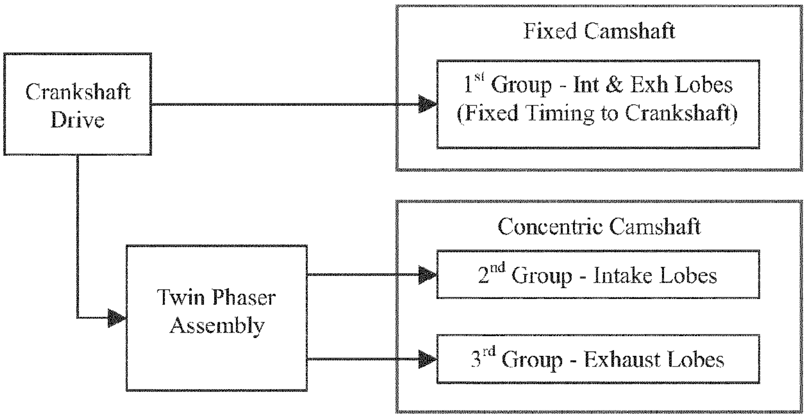

Fig. 6

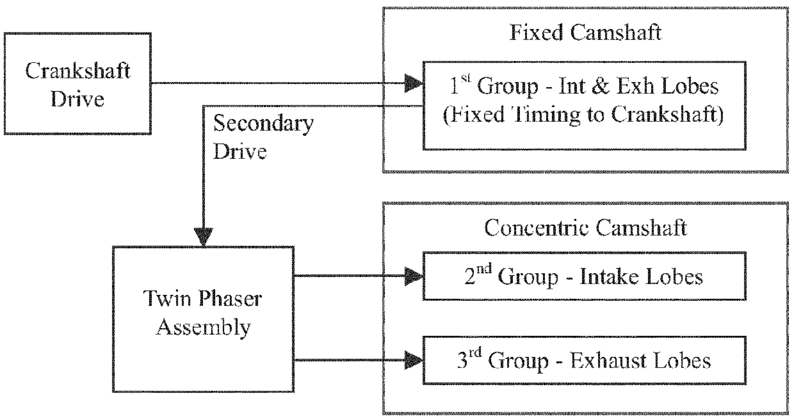

Fig. 7

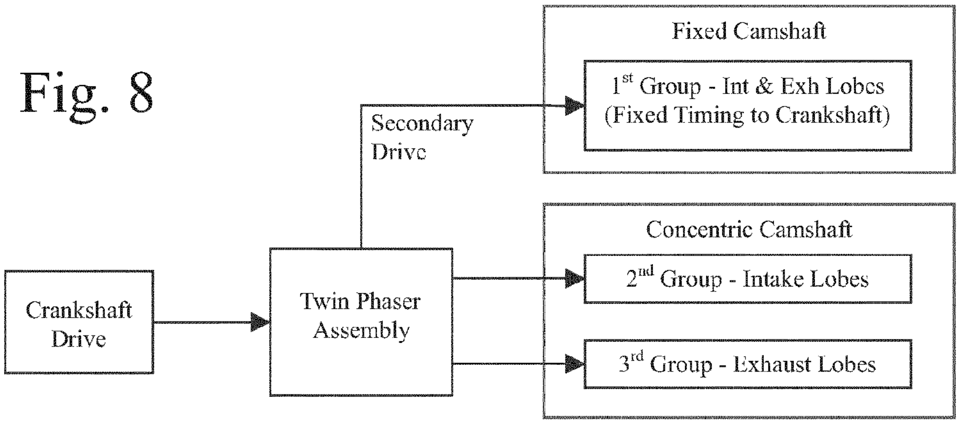

Fig. 8

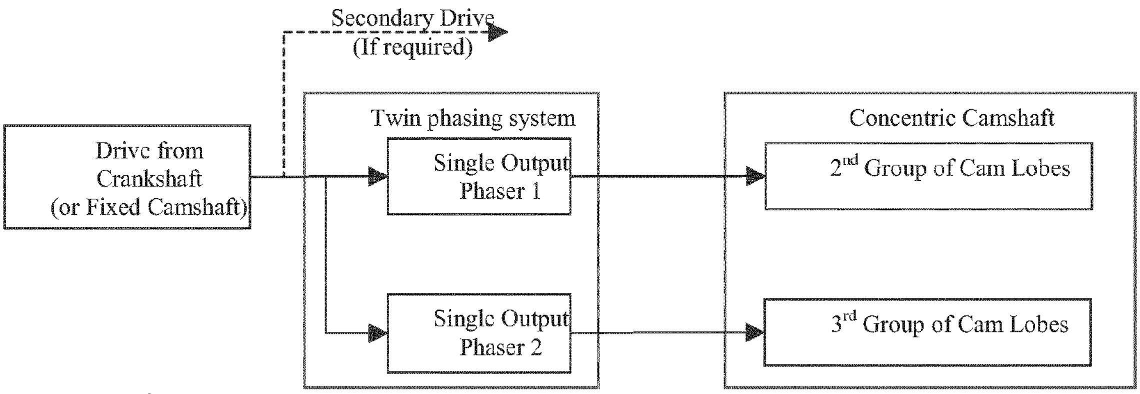

Fig. 9

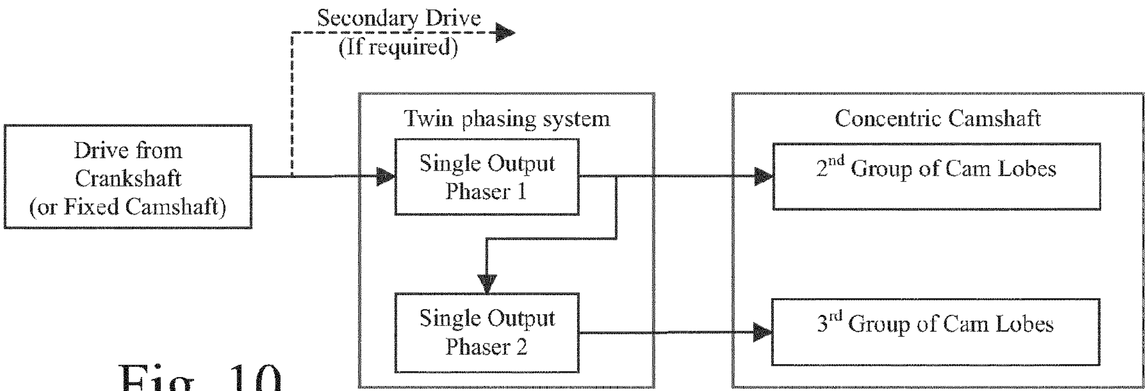

Fig. 10

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EUROPEAN SEARCH REPORT

Application Number
EP 14 15 7549

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	9 July 2014	Klinger, Thierry

CATEGORY OF CITED DOCUMENTS

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