(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 899 591 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
31.03.2010 Bulletin 2010/13

(21) Application number: **05768132.2**

(22) Date of filing: **05.07.2005**

(51) Int Cl.:
F02B 75/16 *(2006.01)* ***F02B 67/04*** *(2006.01)*

(86) International application number:
PCT/EP2005/007977

(87) International publication number:
WO 2007/003217 (11.01.2007 Gazette 2007/02)

(54) A 4-STROKE, MONO-CYLINDER, LIQUID-COOLED, INTERNAL COMBUSTION ENGINE, IN PARTICULAR FOR MOTORCYCLES OR QUADS

FLÜSSIGKEITSGEKÜHLTER 4-TAKT-MONOZYLINDER-VERBRENNUNGSMOTOR, INSBESONDERE FÜR MOTORRÄDER ODER QUADS

MOTEUR À COMBUSTION INTERNE MONOCYLINDRIQUE À QUATRE TEMPS ET REFROIDISSEMENT PAR LIQUIDE, EN PARTICULIER POUR MOTOCYCLETTES OU QUADS

(84) Designated Contracting States:
AT DE ES FR IT

(43) Date of publication of application:
19.03.2008 Bulletin 2008/12

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EP 1 899 591 B1

Description

[0001] The present invention relates to monocylinder, liquid cool internal combustion engines, and more particularly to such an engine equipped with a multifunctional balance shaft used to not only control engine vibration, but also to directly drive at least the camshaft and the water-pump of a coolant circuit. Thus it can lend itself to both auto-ignition combustion engines or to spark-ignition engines for such applications as motorcycles, quads or karts.

[0002] A balance shaft, in its simplest form, is simply an eccentric weighted shaft which offsets the vibrations of unbalanced engines.

These balance shafts are found in most internal combustion engines, but applicable to any internal combustion engine, which due to their design have an inherent first and second order vibration that cannot be eliminated no matter how well balanced the internal components may be. The reciprocating movement of the pistons and connecting rods, combined with the rotation of the crankshaft generate inertial forces that act on the engine block and causes it to vibrate in various modes. The most significant forces arise once or twice per crankshaft revolution, and are known as first engine order and second engine order forces.

The first order vibrations are totally unbalanced and stem from the reciprocating movement of the piston as they change direction at top dead centre and bottom dead centre.

This has led to the basic concept behind balance shafts, which is to have equally sized and phased eccentric weights such that the inertial reaction to their counter-rotation produces a net force equal to but 180° out of phase to the 1st order vibration of the basic engine, thereby cancelling it.

[0003] An engine according to the préambule of claim 1 is known from EP1221560

[0004] The object of the invention is to reduce the overall weight and increase the overall compactness of such an engine by repositioning and combining elements of a traditional engine, specifically through the use of a multifunctional balance shaft.

The present invention proposes to do this by altering the common balance shaft such that it may be positioned more advantageously to save space and such that it reduces intermediate parts. It does this by itself driving the camshaft(s) via a timing belt or chain (for spark ignition engines), and also directly driving a water pump shaft and impeller (for liquid-cooled engines) thereby reducing the number of parts in an engine, and consequently weight and complexity, and by inference reliability.

[0005] Conventional balance shafts generally need relatively large volume space envelopes, which prevent them from easily fitting compactly in a crank case chamber. They generally have one eccentric weight positioned in the middle, and normally also integrally, to the balance shaft. Driving gears and sprockets located on the balance shaft, such as those needed for the balance shaft to be driven from the crankshaft, are separate elements normally fixed during assembly. Differently, our invention tightly integrates inside the crank case chamber, very close to the crankshaft, such that it takes up minimal room but also brings numerous further advantages such as quieter running and needing fewer parts.

It is important to reduce the number of parts as this leads to more compact and light engines, and increases the power to weight ratio and engine response. A solution to this is to design parts such that they fulfil more than a singular end function.

[0006] In a 4-stroke, monocylinder, liquid cooled, internal combustion engine comprising a single piston able to reciprocate within a single cylinder and connected by a connecting rod to a crankshaft rotatable about a first transverse axis and driving a balance shaft carrying at least one balance weight in rotation about a second transverse axis parallel to said first axis and at least one camshaft for actuating a valve train by means of a timing chain, the invention achieves this object for a multifunctional balance shaft by providing that the balance shaft is driven from the crankshaft through a 1:1 gearing ratio, inside the crankcase chamber, and that said balance shaft also drives directly the valve train and a water pump of a coolant circuit.

In the interest of weight, it has been provided that said balance shaft is hollow to save weight at the negligible detriment of strength and stiffness, and that it also has on one end portion of said balance shaft an integral sprocket for driving the timing chain and an integral pinion to be driven by the crankshaft, and that said pinion contains the same amount of teeth as said sprocket.

Furthermore, between said sprocket and pinion, a hardened cylindrical surface has been provided to be in direct rolling contact with rolling members of one of the main bearings supporting said balance shaft, on one axial end portion of said balance shaft.

To further save weight and combine functions, the pinion has at least one, but preferably a plurality, of holes positioned a symmetrically on the side surface of the pinion such as to achieve a quasi-integral balance weight. A further independent eccentric weight is added on the opposite end portion to said sprocket. This eccentric weight is fixed between a second main balance shaft bearing, which itself is fixed against an abutment, and the extremity of the shaft normally containing a washer and nut.

Inside said hollow end portion of said balance shaft, is fitted a mounting bush which serves to position and fix, by means of a pin, the shaft driving the waterpump impeller such that the balance shaft and the waterpump rotate on a common axis.

The water pump has traditionally been a separate element directly driven by either the oil pump shaft or the crankshaft through gears or chains. Integrating the water pump on the balance shaft reduces the number of parts and further simplifies engine construction.

[0007] As a consequence of such an architecture, the balance shaft can be advantageously positioned in a lateral direction in the horizontal plane, substantially parallel to the axis of the crankshaft and longitudinally as close to the crankshaft rotating envelope (defined by outside diameter of the crankshaft) as would allow, which itself is a function of the bore and stroke ratio. The vertical position can be set such as to minimise the distance from the balance shaft to the camshafts while still maintaining direct meshing contact between these gears, in order to optimise the length of the timing belt or chain, and consequently to reduce wear.

It can be placed in the vertical direction as high as possible, with a tradeoff for the size of the connecting gears (affecting compactness), and the length of the timing belt or chain between the camshafts and the balance shaft. I.e. the block deck height and the headface to cam centre line are reduced to shorten the chain. The connecting rod can be kept as short as possible while still clearing the crankshaft external diameter - to aid in the overall strategy of reducing overall external dimensions of the engine.

[0008] The balance shaft is directly connected to the crankshaft thorough two gears with an equal amount of teeth. These gears are so positioned as to be next to two bearings to reduce the bending moments transmitted from one shaft to the other, and consequently onto the camshafts and valve train. In this way wear on the camshafts is greatly reduced as is the accuracy of the timing mechanism.

[0009] Through these gears the balance shaft rotates at an equal rotational speed but opposite rotational direction than the crankshaft such that the first engine order vibrations may be greatly reduced. As the gear on the crankshaft meshing with that of the balance shaft is positioned inside the crankcase chamber, rather than outside and connected via belts or chains, gear noise can be greatly reduced.

[0010] To assist a more complete understanding of the invention a specific embodiment in accordance with the invention is presented in more detail below with reference to accompanying drawings, in which:

Figure 1 shows the right side view of an embodiment of the engine;

Figure 2 shows the left side view of an embodiment of the engine;

Figure 3 shows an 3D view of the internal non-structural components of the engine;

Figure 4 shows a sectional view of the engine through a central longitudinal plane;

Figure 5 shows the right side of the engine with the clutch, water-pump impeller and cover removed

Figure 6 is a sectional view of the crank case chamber cut between the centre of the crankshaft and the centre of the balance shaft, and

Figures 7a and 7b are a 3D views of the integral balance shaft (Fig. 7a), and the shaft fitted with the balance weight and mounting bush (Fig. 7b)

[0011] This embodiment is one of a mono-cylinder internal combustion, spark ignition, liquid-cooled engine. Figure 1 and 2 shows the right and left side view respectively of a particular embodiment of the engine. Clearly visible are the crankcase chamber block 1 and the cylinder head block 2. The clutch cover 3 and the generator 4 cover are visible, as well as the pinion gear 5 connected internally via the clutch to the crankshaft.

[0012] Figure 3 shows the internal non-structural dynamic components of the engine. The ignition coil 6 is visible at the top fitted in a substantially vertical direction, substantially parallel to the central axis of the cylinder 7 and the movement traversed by the piston 8. In the front and behind the sparkplug 9 body are fitted, in a substantially transverse direction perpendicularly to the vertical and longitudinal axes, two camshafts 10 controlling the valve trains 11 and four spring loaded valves, consisting of two intake valves 12a and two exhaust valves 12b. The two camshafts 10 are connected via a timing chain or belt 13 to a balance shaft 14, itself directly connected to a crankshaft 15 via an integral gear 16. The crankshaft 15, balance shaft 14 and camshafts 10 are rotating substantially parallel to each other about a transverse axis. A connecting rod 17 links the rotational movement of the crankshaft 15 into substantially vertical reciprocating movements of the piston 8 guided inside the cylinder 7 (shown in fig 4).

Two chain guides 18 and a tensioner 19 are fitted to guide and to appropriately tension the timing chain 13 on the upstream and downstream length of chain 13. The tensioner 19 is connected to the front guide 18, in the return (cam to crank) feed to the engine. Conventionally this chain tensioner 19 is found at the back of the engine, however due to the camshafts 10 rotating directly off the balance shaft 14 rather than off the crankshaft 15, the chain 13 feed originates from the opposite direction of the engine, and hence the slack part of the engine chain is on the front side of the engine.

The water-pump impeller 20 is seen directly connected to the balance shaft 14, as is its support bearing 21, such that they share the same transverse axis of rotation.

[0013] On either transverse sides of the engine are positioned the generator 22 and clutch mechanisms 23. The clutch 23 is driven directly off a small pinion gear 24 on the crank shaft 15, and the generator 22 is directly connected to the crankshaft 15.

[0014] Figure 4 shows a transverse sectional view of the left side of the engine cut through a middle plane corresponding to the mating plane of the two crankcase halves, the left half 25 and the right half 26, such that only the left crankshaft half 25 is visible (refer to Fig 6). The intake 27 and exhaust 28 ports in the cylinder head 2 are clearly visible as well as the piston 8, connecting rod 17 and crankshaft 15 at the 'Top Dead Centre (TDC) ' position inside the cylinder block 7, meaning that the piston head 8 is at the top of its travel and the connecting rod 17 is aligned in a substantially vertical direction. The cooling channels 30 in the cylinder block in the vicinity of the combustion chamber 31 are also evident.

What is particularly evident on this drawing is the very close positioning of the balance shaft 14 relative to the crankshaft 15. Balance shaft 14 is positioned in a transverse direction substantially parallel to the crankshaft 15 axis of rotation, as close as geometry would allow in a longitudinal direction, and in the vertical direction slightly higher than the crankshaft 15 axis of rotation to allow direct meshing of gears 16, 32 while minimising the length of the timing chain 13. Gear 16 is integral with crankshaft 15, while gear 32 is integral with the balance shaft 14 in a 1:1 ratio.

[0015] Figure 5 shows a right side view of the engine with the external cover removed and the clutch mechanism 23 and water pump impeller 20 not shown. The chain 13 and chain guides 18 are clearly visible linking the camshaft pulleys 33 to the balance shaft 14, but peculiarly to this engine, the chain tensioner 19 is on the front side of the engine. The tensioning bolt 34 can be seen connecting the chain guide 18 on the return side of the engine such that when the bolt 34 is tightened it pushes the chain guide 18 inwards so as to impart a suitable tension in the timing chain13.

[0016] Figure 6 is a sectional view of the crankcase 1 passing through the centre of the balance shaft 14 normal to the longitudinal axis. As can be seen from the small clearances around the components, especially around the crankshaft 15, everything has been tightly integrated to produce as compact an engine as possible.

The crankcase 1 is constructed of two halves 25, 26 split down the middle through a longitudinal plane, and the balance shaft 14 is positioned between these two halves, in a transverse direction substantially parallel to the crankshaft 15 axis of rotation. The generator 22 is in line with crankshaft 15 axis of rotation on the left side. On the other end of the crankshaft 15 is positioned the clutch mechanism 23.

The balance shaft 14 is a one-piece hollow construction 29' to save weight and reduce its first moment of inertia and thus also contribute to fast response times in engine acceleration and is supported by a ball bearing 35 and a needle bearing 36. The needle bearing 36 is positioned on a hardened surface 37 between the crankshaft pinion gear 32 and the timing chain sprocket 38 on one end portion of the shaft 14. The rollers of the needle bearing 36 are in direct rolling contact with the hardened surface 37.

Inside this enclosed hollow end section 29 of the shaft 14 is fitted a bush 39 used to position and drive the water pump impeller shaft 40. The water pump shaft 40 fits inside this bush 39 and is fixed in place by a pin 41 positioned transversely through the water pump shaft 40 and into the wall of the bush 39. This pin 41 also serves to transmit torque to the impeller 20. The water pump shaft 40 is supported by a ball bearing 21 and fixed in place by two circlips 42 adjacent to the bearing 21. Between the water pump shaft bearing 21 and the impeller 20 are two sealing rings 43 to prevent coolant ingress into the crank case chamber 1, or conversely engine oil to leak out of the engine and mix with the coolant.

On the other end portion of the balance shaft 14 is fitted an eccentric balance weight 44, rotating in a separate compartment 45 to the main crank case chamber 1, whose geometry and weight is chosen so as to cancel out the free forces of the first engine order. The balance weight 44 is positioned next to the second ball bearing support 35 such as to reduce the flex of the balance shaft 14 caused by having a weight in rotation at high speeds. The balance shaft 14 transverse position is controlled by the balance weight 44 and the ball bearing 35, which is itself positioned against an abutment 46 machined on the shaft 14. The balance shaft 14 and balance weight 44 are fixed by a nut 47 and washer 48 on the extremity of the shaft 14.

The crankshaft 15 has an integral gear 16 to drive the balance shaft 14 positioned next to one of its two main support bearings 49. This arrangement of placing a gear next to a support serves to reduce the transmitted stress and strain exerted by the combustible gases on the crankshaft 15 so that the camshafts 10 have less flex and thus will not influence camshaft timing, making the valves 12 more precise.

[0017] Figures 7a and 7b illustrate in detail the balance shaft 14. Figure 7a shows the one piece construction of the balance shaft 14, and Fig. 7b the balance shaft 14 fitted with the balance weight 44 fixed in place with a washer 48 and nut 47 as well as the mounting bush 39 and pin 41 in the other end portion of the shaft 14.

[0018] The balance shaft 14 construction is essentially a one piece, hollow construction primarily to save weight and thus reduce first moment of inertia and increase engine response. One extremity of the shaft 14 has a thread 50 for fixing a nut onto, a spline profile groove 51 for rotationally fixing the eccentric balance weight 44, a surface 52 for attaching a ball bearing 35, then an abutment as support 46.

The other extremity has first a sprocket 38 for driving the timing chain 13 then, moving inwards, a hardened surface 37 for positioning a needle support bearing 36, then a gear 32 for the transmission of torque from the crankshaft. The driving gear 32 has the same number of teeth as the sprocket 38.

The driving gear 32 also has a number of holes 53 machined into the side surface which serves as a small internal balance weight and to lighten the overall rotational mass.

At this end of the shaft 14, inside the enlarged hollow tubular end portion 29 is fitted by interference a bush 39 used to position and fix the water pump impeller 20.

The shaft 40 of the water pump 20 is positioned inside this bush 39 and fixed in place with a pin 41 through the transverse side of the water pump shaft 40 and into the bush housing 39. This enables the transmission of the torque to the water pump impeller 20 and ensures the water pump 20 is always circulating coolant when the engine is operational.

Claims

1. A 4-stroke, mono-cylinder, liquid cooled, internal combustion engine comprising:

- a single piston (8) able to reciprocate within a single cylinder (7) and connected by a connecting rod (17) to a crankshaft (15) rotatable about a first transverse axis,
- a balance shaft (14) carrying at least one eccentric weight and directly driven in rotation about a second transverse axis parallel to said first transverse axis, said balance shaft (14) driving a coolant pump of a cooling circuit, and
- at least one camshaft (10) for actuating at least one valve train, wherein said balance shaft (14) is directly driven from said crankshaft (15) through a 1:1 gearing ratio, and **characterised in that** said balance shaft (14) further drives directly said camshaft (10) by means of a timing chain or belt (13).

2. An engine as in the preceding claim, wherein said balance (14) shaft is hollow.

3. An engine as in any of the preceding claims, wherein said balance shaft (14) further comprises an integral sprocket for driving the timing chain or belt (13) and an integral pinion to be driven by the crankshaft.

4. An engine as in any of the preceding claims, wherein said balance shaft (14) rotates about main support bearings, and has a hardened cylindrical surface in direct rolling contact with rolling members of one of the main support bearings.

5. An engine as in claims 3 and 4, wherein said hardened surface is positioned between said sprocket and said pinion.

6. An engine as in any of claims 3-5, wherein said sprocket, and pinion are positioned together at one end portion of the shaft.

7. An engine as in claims 3-6, wherein said pinion has at least one hole on its surface.

8. An engine as in any of the preceding claims 3-7, wherein the eccentric weight is fitted on the balance shaft on the opposite end portion to said sprocket.

9. An engine as in any of the preceding claims, wherein said balance shaft (14) comprises a means of fixing said eccentric weight, and comprises an abutment on the inner side of said means of fixing.

10. An engine as in any of the preceding claims, wherein the coolant pump is driven directly by said balance shaft (14) on a common axis.

11. An engine as in claims 2-10, wherein an impeller (20) of the coolant pump is fitted coaxially inside the hollow end portion of the balance shaft by means of a mounting bush.

Patentansprüche

1. Flüssigkeitsgekühlter Vier-Takt-Monozylinder-Verbrennungsmotor, umfassend:

einen einzelnen Kolben (8), der zur Hin- und Herbewegung innerhalb eines einzelnen Zylinders (7) in der Lage ist und durch ein Pleuel (17) mit einer Kurbelwelle (15) verbunden ist, welche um eine erste transversale Achse drehbar ist,
eine Ausgleichswelle (14), welche zumindest ein exzentrisches Gewicht trägt und direkt um eine zweite transversale Achse rotierend angetrieben wird, welche parallel zur ersten transversalen Achse ist, wobei die Ausgleichswelle (14) eine Kühlmittelpumpe eines Kühlkreises antreibt, und
zumindest eine (10) zum Betätigen von zumindest einem Ventiltrieb, wobei
die Ausgleichswelle (14) direkt von der Kurbelwelle (15) über ein Übertragungsverhältnis 1:1 angetrieben wird, und **dadurch gekennzeichnet, dass**
die Ausgleichswelle (14) ferner direkt die Nokkenwelle (10) mittels einer Steuerkette oder eines Riemens (13) antreibt.

2. Motor nach dem vorhergehenden Anspruch, wobei die Ausgleichswelle (14) hohl ist.

3. Motor nach irgendeinem der vorhergehenden Ansprüche, wobei die Ausgleichswelle (14) ferner ein integriertes Ritzel zum Antrieb der Steuerkette oder des Riemens (13) und ein integrales Zahnrad zum Antrieb durch die Kurbelwelle umfasst.

4. Motor nach irgendeinem der vorhergehenden Anspruche, wobei sich die Ausgleichswelle (14) um Haupttraglager dreht und eine gehärtete zylindrische Oberfläche in direktem Wälzkontakt mit Wälzelementen von einem der Haupttraglanger aufweist.

5. Motor nach Anspruch 3 und 4, wobei die gehärtete Oberfläche zwischen dem Ritzel und dem Zahnrad positioniert ist.

6. Motor nach irgendeinem der Ansprüche 3 bis 5, wobei das Ritzel und das Zahnrad zusammen an einem Endabschnitt der Welle positioniert sind.

7. Motor nach Anspruch 3 bis 6, wobei das Zahnrad zumindest ein Loch auf seiner Oberfläche aufweist.

8. Motor nach irgendeinem der vorhergehenden Ansprüche zu bis 7, wobei das exzentrische Gewicht auf der Ausgleichsewelle auf dem gegenüberliegenden Endabschnitt bezüglich des Ritzels befestigt ist.

9. Motor nach irgendeinem der vorhergehenden Ansprüche, wobei die Ausgleichswelle (14) ein Mittel zum Fixieren des exzentrischen Gewichts umfasst, und ein Widerlager auf der inneren Seite des Mittels zum Fixieren umfasst.

10. Motor nach irgendeinem der vorhergehenden Ansprüche, wobei die Kühlmittelpumpe direkt durch die Ausgleichswelle (14) auf einer gemeinsamen Achse angetrieben wird.

11. Motor nach Ansprüchen 2 bis 10, wobei ein Impeller (20) der Kühlmittelpumpe koaxial in dem hohlen Endabschnitt der Ausgleichswelle mittels einer Anbringungsbuchse befestigt ist.

Revendications

1. Moteur à combustion interne à quatre temps, monocylindrique, à par liquide comprenant :

   - un seul piston (8) capable d'effectuer un mouvement alternatif dans un seul cylindre (7) et relié par une bielle (17) à un vilebrequin (15) pouvant tourner autour d'un premier axe transversal,
   - un arbre d'équilibrage (14) supportant au moins un poids excentrique et entraîné directement en rotation autour d'un deuxième axe transversal parallèle audit premier axe transversal, ledit arbre d'équilibrage (14) entraînant une pompe à eau d'un circuit de refroidissement, et
   - au moins un arbre à cames (10) pour actionner au moins un dispositif de commande des soupapes, dans lequel

   ledit arbre d'équilibrage (14) est entraîné directement par ledit vilebrequin (15) sur un rapport de démultiplication 1:1, et **caractérisé en ce que** ledit arbre d'équilibrage (14) entraîne en outre directement ledit arbre à cames (10) au moyen d'une chaîne ou d'une courroie de distribution (13).

2. Moteur selon la revendication précédente, dans lequel ledit arbre d'équilibrage (14) est creux.

3. Moteur selon l'une quelconque des revendications précédentes, dans lequel ledit arbre d'équilibrage (14) comprend en outre une roue dentée intégrée pour entraîner la chaîne ou la courroie de distribution (13) et un pignon intégré devant être entraîne par le vilebrequin.

4. Moteur selon l'une quelconque des revendications précédentes, dans lequel ledit arbre d'équilibrage (14) tourne autour de paliers principaux de support, et a une surface cylindrique trempée en contact roulant direct avec des éléments roulants de l'un des paliers principaux de support.

5. Moteur selon les revendications 3 et 4, dans lequel ladite surface trempée est positionnée entre Mite roue dentée et ledit pignon.

6. Moteur selon l'une quelconque des revendications 3 à 5, dans lequel ladite roue dentée et ledit pignon sont positionnés ensemble à une portion d'extrémité de l'arbre.

7. Moteur selon les revendications 3 à 6, dans lequel ledit pignon a au moins un trou sur sa surface.

8. Moteur selon l'une quelconque des revendications 3 à 7 précédentes, dans lequel le poids excentrique est placé sur l'arbre d'équilibrage sur la portion d'extrémité opposée à ladite roue dentée.

9. Moteur selon l'une quelconque des revendications précédentes, dans lequel ledit arbre d'équilibrage (14) comprend un moyen de fixation dudit poids et comprend une butée sur le côté intérieur dudit moyen de fixation.

10. Moteur selon l'une quelconque des revendications précédentes, dans lequel la pompe à eau est entraînée directement par ledit arbre d'équilibrage (14) sur un axe commun.

11. Moteur les revendications 2 à 10, dans lequel une turbine (20) de la pompe à eau est installée de manière coaxiale à l'intérieur de la portion d'extrémité creuse de l'arbre d'équilibrage au moyen d'une bague de montage.

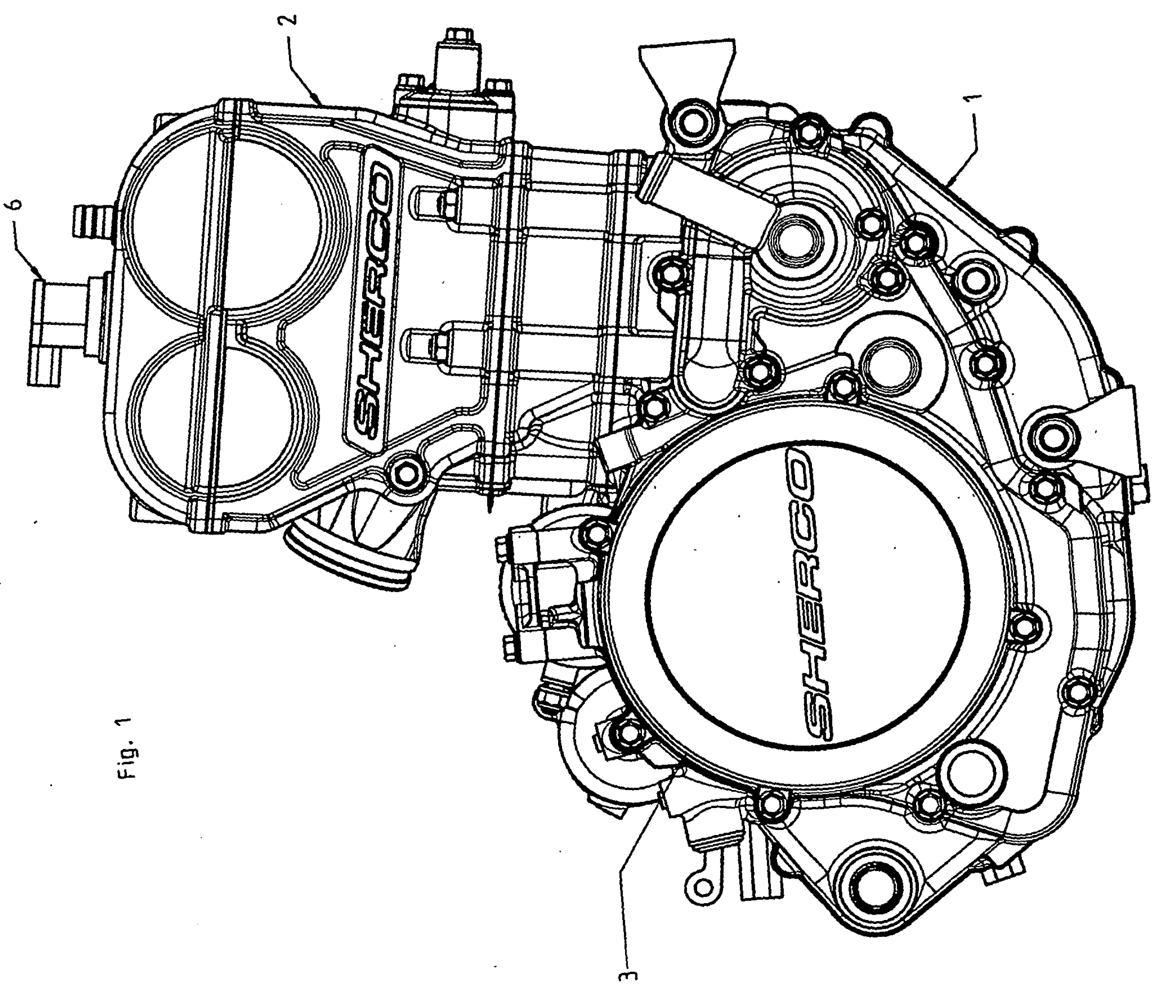
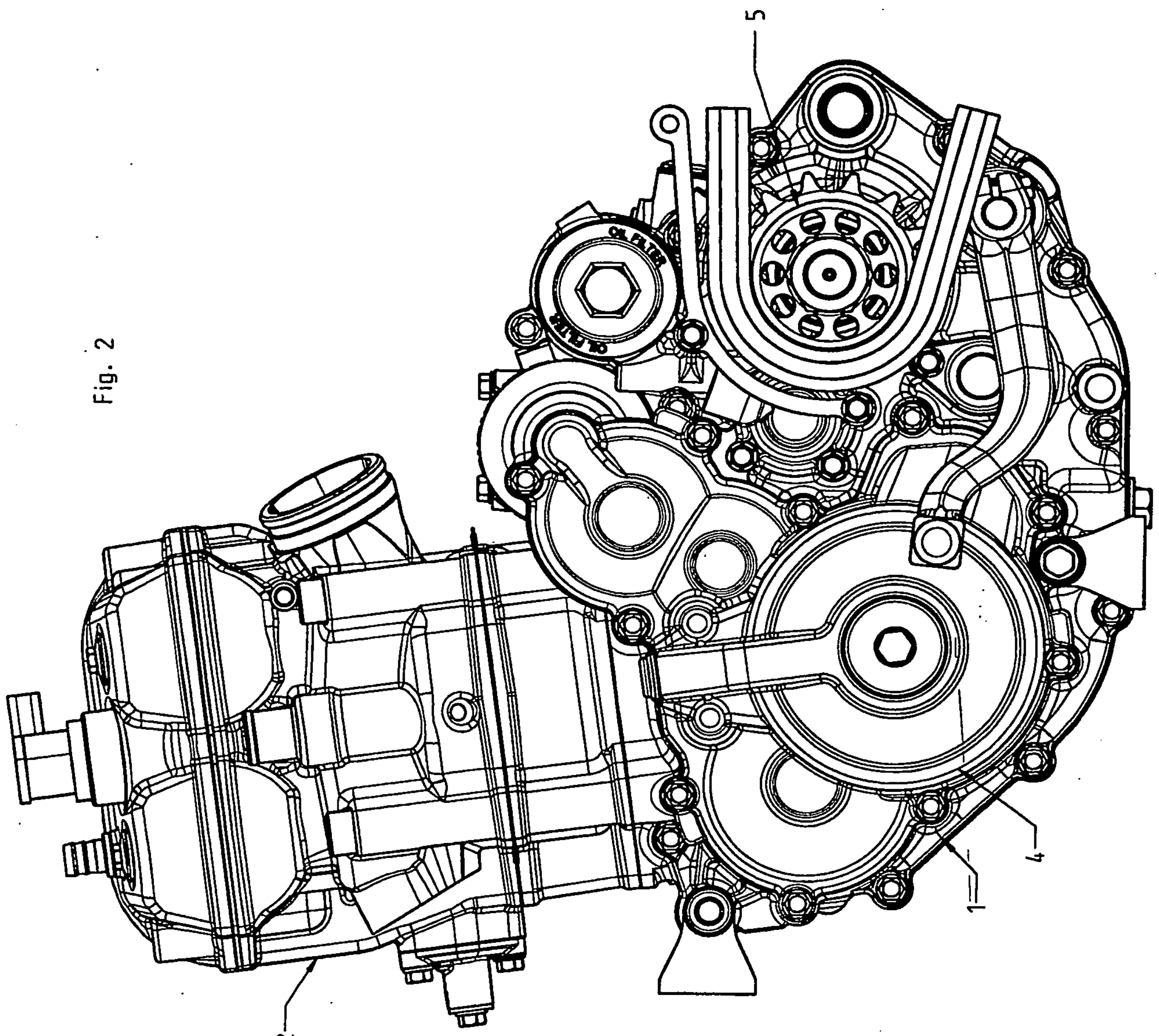


Fig. 1

Fig. 2



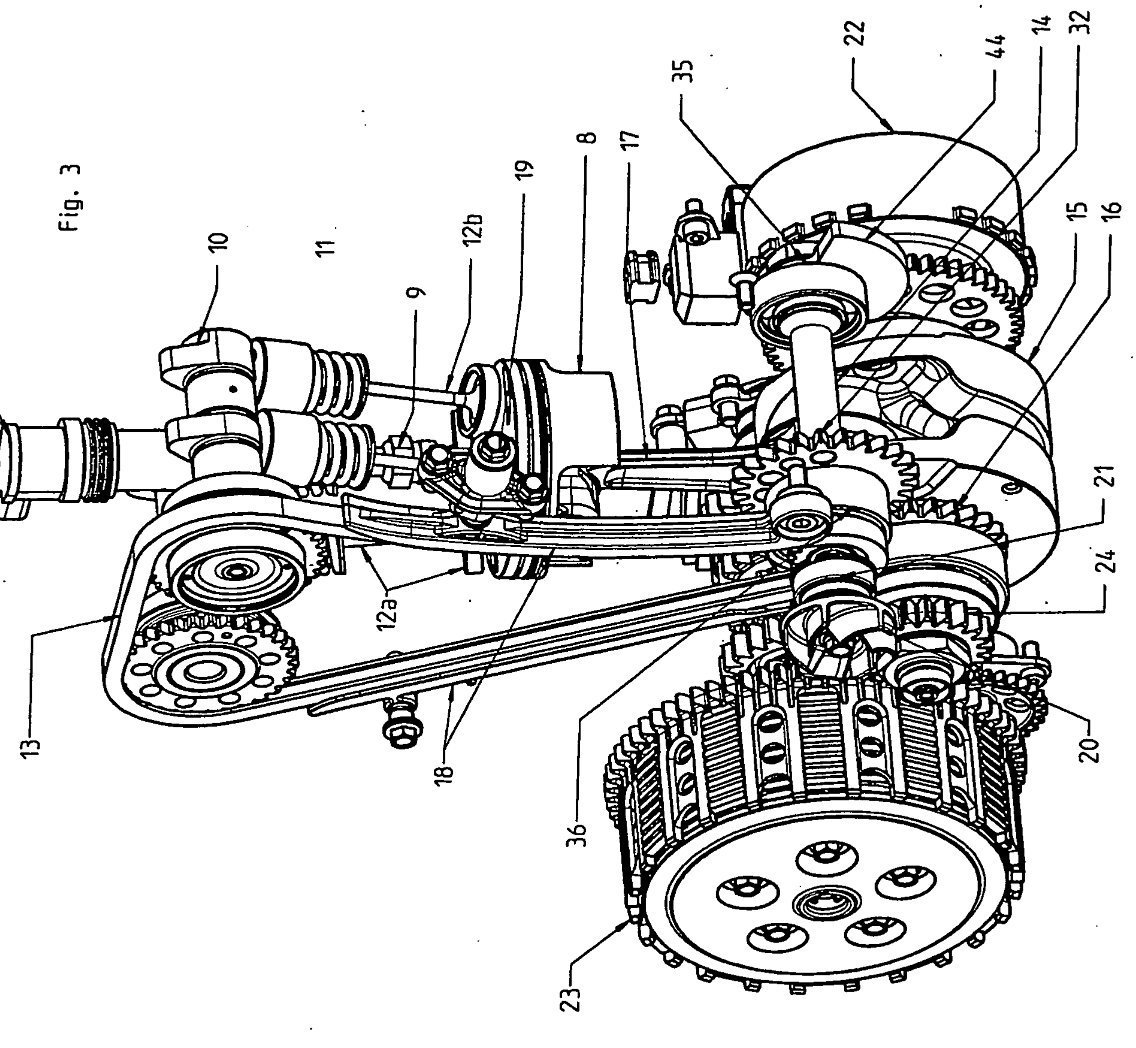


Fig. 3

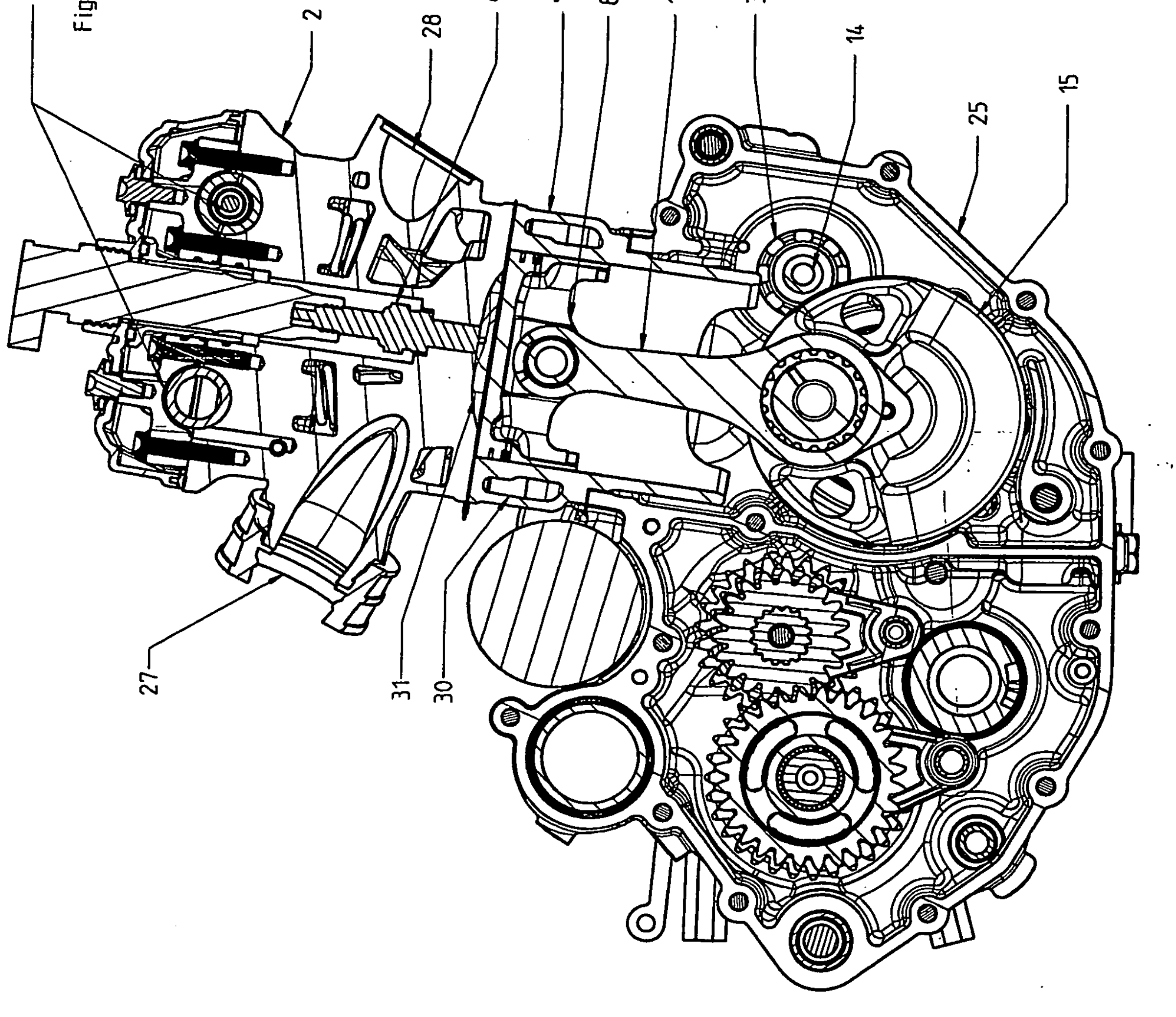


Fig.4

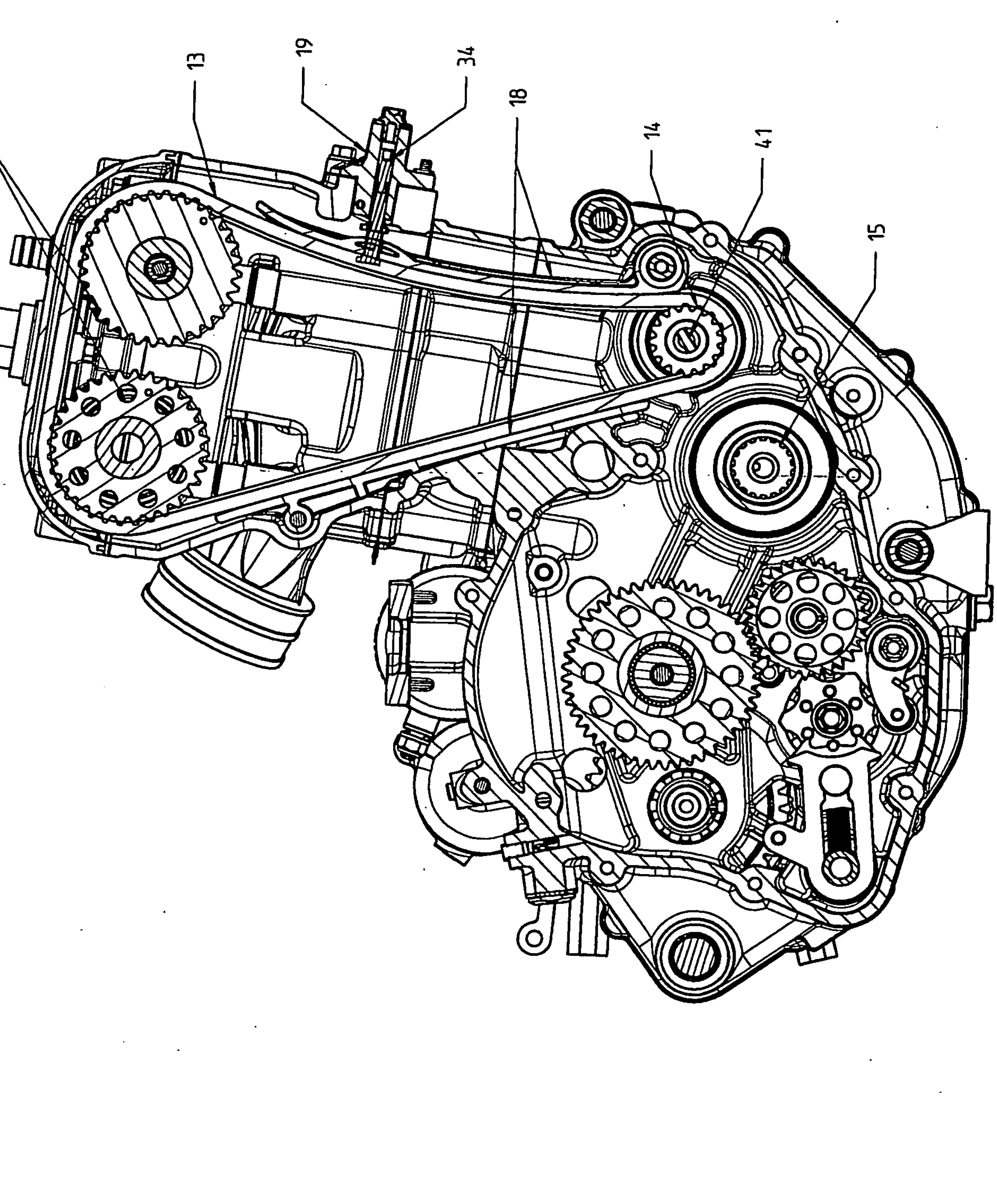


Fig. 5

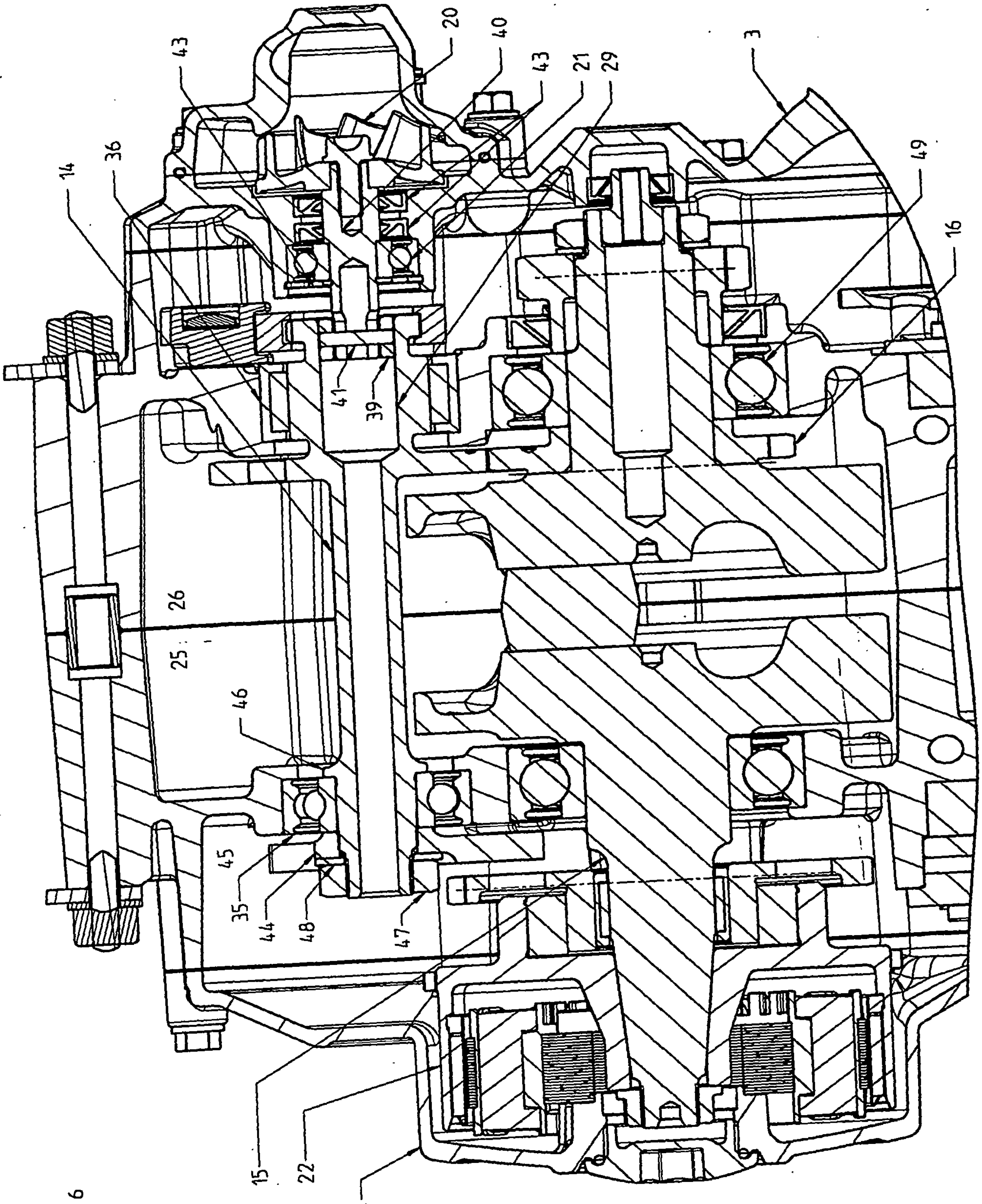


Fig. 6

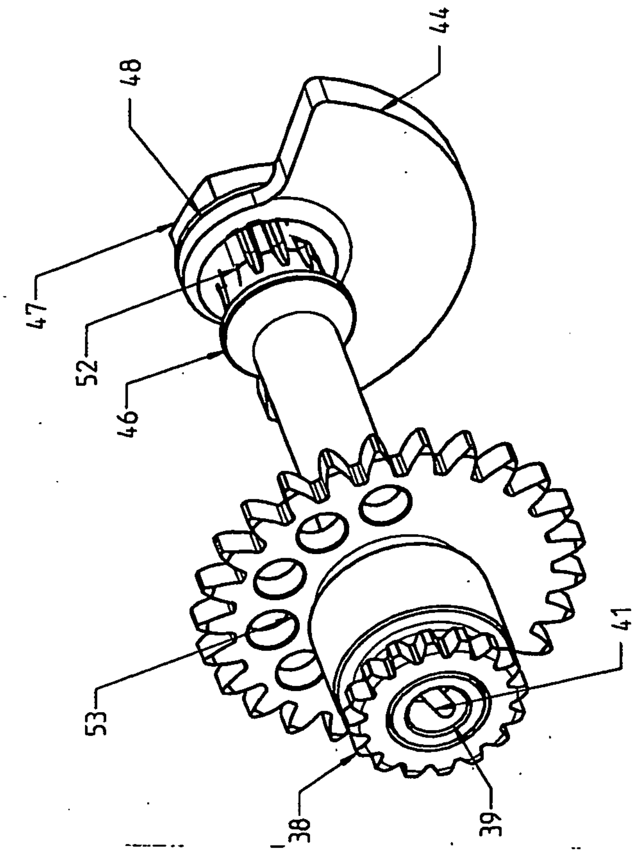


Fig.7b

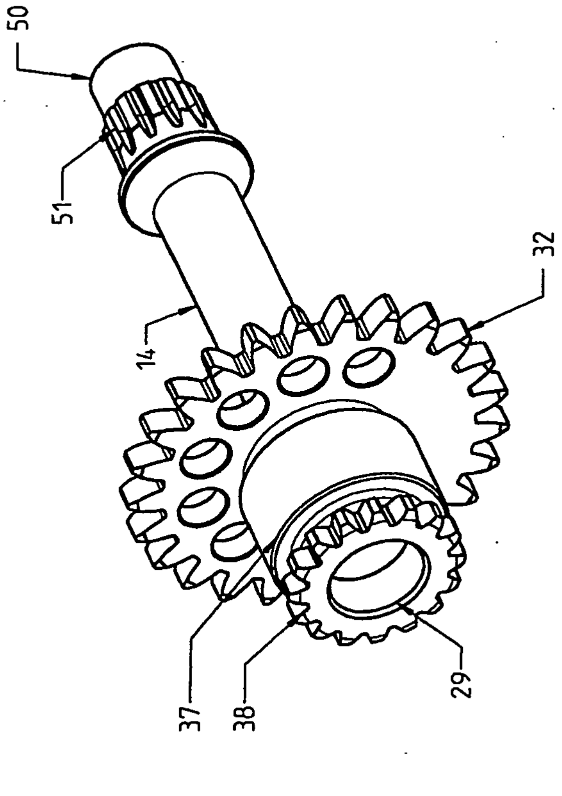


Fig.7a

REFERENCES CITED IN THE DESCRIPTION

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