

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
5 January 2006 (05.01.2006)

PCT

(10) International Publication Number  
**WO 2006/000832 A1**

- (51) International Patent Classification<sup>7</sup>: **F01L 1/34**, 1/047
- (21) International Application Number:  
PCT/GB2005/050078
- (22) International Filing Date: 2 June 2005 (02.06.2005)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
0414514.0 29 June 2004 (29.06.2004) GB

SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(71) Applicant (for all designated States except US): **MECHADYNE PLC** [GB/GB]; Park Farm Estate, Kirtlington Oxfordshire OX5 3JQ (GB).

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

(72) Inventors; and  
(75) Inventors/Applicants (for US only): **LANCEFIELD, Timothy, Mark** [GB/GB]; Shirley Farm Little Wolford, Shipston on Stour Warwickshire CV36 5LZ (GB). **LAWRENCE, Nicholas** [GB/GB]; 8 Mallard Drive, Buckingham Buckinghamshire MK18 1GJ (GB).

**Declaration under Rule 4.17:**

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

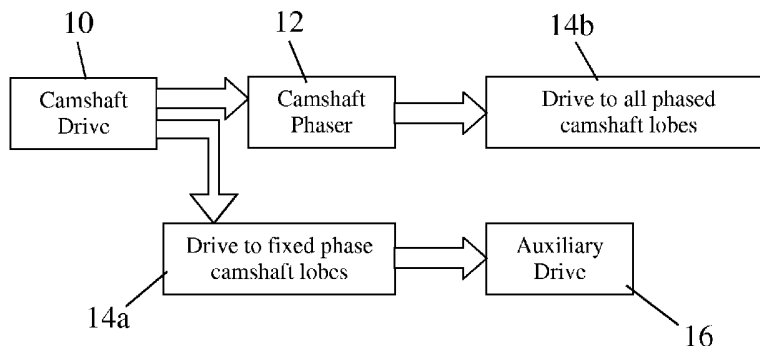
(74) Agents: **MESSULAM, Alec, Moses** et al.; 43-45 High Road, Bushey Hertfordshire WD23 1EE (GB).

**Published:**

— with international search report

[Continued on next page]

(54) Title: ENGINE WITH VARIABLE VALVE TIMING



(57) Abstract: An engine is described having a crankshaft and a camshaft formed of two concentric rotary members 50, 52 at least one of which carries a group of cams 54. A transmission train drives one of the rotary members 52 in fixed phase relationship with the crankshaft and a phaser 12 serves to enable the phase of the other rotary member 50 to be varied dynamically relative to the phase of the crankshaft and the first rotary member 52. The invention uses the unphased rotary member 52 to drive an auxiliary device 16, such as a diesel pump, so that the reaction torque of the auxiliary device 16 does not affect the operation of the phaser 12.

WO 2006/000832 A1



---

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

**ENGINE WITH VARIABLE VALVE TIMING**Field of the invention

5           The present invention relates to an internal combustion engine having a phase change mechanism for varying the opening and closing times of the engine valves during the engine operating cycle, that is to say for varying the phase of the cams acting on the valves in relation to the phase of  
10 the engine crankshaft.

Background of the invention

          Regardless of whether one wishes to operate an engine  
15 for maximum output power, best fuel economy or minimum emissions, the optimum setting of the valve timing will depend on operating conditions, such as speed and load. It has long been recognised therefore that it is desirable to be able to alter the phase of the cams of an engine relative  
20 to the crankshaft to suit the prevailing operating conditions.

          To this end, there have previously been proposed numerous phase change mechanisms, herein termed phasers, to  
25 rotate the cams relative to the crankshaft while the engine is in operation.

          Some internal combustion engine layouts use the rear end, i.e. the non-driven end, of the camshaft to drive  
30 auxiliary devices. Some of these devices, such as the high-pressure common rail pumps found in diesel engines, require a high drive torque. This presents a problem when implementing a variable valve timing strategy because it requires the phaser to produce sufficient output torque not  
35 only to vary the phase of the cams but also to drive the auxiliary device.

- 2 -

As an example, some auxiliary devices require a drive torque of up to 40Nm, but, if the phaser runs on engine oil pressure, it may only be able to supply 5Nm. The phaser will therefore be unable to control camshaft phase angle, and the high reaction torque will simply push the phaser to the end of its adjustment range.

#### Summary of the invention

10 With a view to mitigating the foregoing problem, the present invention provides an engine having a crankshaft, a camshaft formed of two concentric rotary members at least one of which carries a group of cams, a transmission train connected to drive a first of the rotary members in fixed  
15 phase relationship with the crankshaft, and a phaser for enabling the phase of the second of the rotary members to be varied dynamically relative to the phase of the crankshaft and the first rotary member, characterised in that an auxiliary device is connected to be driven by torque  
20 transmitted from the crankshaft through the first rotary member of the camshaft.

A camshaft for use in a multi-cylinder engine and having two rotary members in the form of an inner shaft  
25 which is surrounded by an outer tube carrying at least some of the cams, is known in the prior art, an example being found in EP-A-1 234 954. The present invention uses such a two-part camshaft to overcome the problem encountered in the prior art, by transmitting torque to the auxiliary device  
30 through a rotary member of the camshaft that is not driven by a phaser.

In one embodiment of the invention, the outer tube is fast in rotation with all the cams of the camshaft.

35

In an alternative embodiment of the invention, the camshaft is formed with two groups of cams, one of the

- 3 -

groups being fast in rotation with the outer tube and the other group being coupled to the inner shaft by means of pins extending into the inner shaft through circumferentially elongated slots in the outer tube.

5

The invention may also be used in an engine having two camshafts, in which case several possibilities present themselves. In particular, the second camshaft may be a solid (one-piece) camshaft driven either directly or through a phaser by one of the rotary members of the first camshaft. As a further possibility, the second camshaft may itself comprise two rotary members at least one of which carries a group of cams, wherein one of the rotary members of the second camshaft is driven in synchronism with one of the rotary members of the first camshaft and the second rotary member of the second camshaft is driven by means of a phaser that enables the relative angular position of the two rotary members of the second camshaft to be varied dynamically, so as to allow the phase of at least some of the cam lobes on the second camshaft to be altered with respect to the crankshaft.

10  
15  
20

#### Brief description of the drawings

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

Figure 1 is a schematic representation of a flow path to transmit torque from the crankshaft through a camshaft to an auxiliary device such as a diesel fuel pump,

30

Figure 2 is a similar representation of a torque flow path in an embodiment of the invention,

Figures 3 and 4 are sections through different two-part camshafts that may be used in implementing the invention,

35 and

- 4 -

Figures 5 and 6 are schematic representations of the torque flow paths of two further embodiments of the invention.

5 Detailed description of the preferred embodiments

In Figure 1, a camshaft drive 10 transmits torque to a one-piece camshaft 14 through a phaser 12. The camshaft drive 10 consists of the engine crankshaft and transmission  
10 train made up of cogs, a belt or a chain that connects a pulley on the crankshaft to the phaser 12. Different types of phaser 12 are known in the prior art and the choice of phaser is not of fundamental importance to the present invention. Essentially, the phaser 12 acts dynamically to  
15 shift the phase of the camshaft relative to the engine crankshaft. It can derive its power from an external source, such as a pressurised hydraulic fluid supply or it may rely on the reversal of the reaction torque of the valve train. In the ensuing description, it will be assumed that the  
20 phaser is a hydraulically powered so-called vane-type phaser.

If the camshaft 14 were to be coupled at its rear end to an auxiliary device 16, such as a diesel fuel pump, that  
25 presents a high reaction torque, the phaser 12 would not have the power to overcome the reaction torque of the auxiliary device 16 and would become ineffective. For this reason, in a conventional variable phase valve timing system, one could not use the camshaft to power auxiliary  
30 devices and another way had to be found to transmit torque from the crankshaft to the auxiliary device.

In the present invention, as represented in Figure 2, the camshaft 14 is separated into two rotary members, namely  
35 a first rotary member 14a driven by the crankshaft and driving any unphased cams, and a second rotary member 14b which drives all the phased cams, that it is to say the cams

- 5 -

of which the phase is to be varied relative to the crankshaft. As only the second rotary member 14b lies in the torque output path of the phaser 12, the phaser 12 only has to overcome the reaction torque of the valve train and it is not required to overcome the reaction torque of the auxiliary device 16.

Figures 3 and 4 show two different two-part camshafts that may be employed in the invention. They differ from one another in that in the case of Figure 3, all the cams are phased and in Figure 4 only some of the cams are phased.

In Figure 3, the camshaft has an outer tube 50 journaled in bearings (not shown) in the cylinder head. The outer tube 50 acts as the phased rotary member 14b and carries all the cams 54, all of which are therefore phased. The outer tube supports an inner shaft 52, corresponding to the unphased rotary member 14a, which serves to transmit torque to the auxiliary device 16, shown as being a diesel pump.

The camshaft of Figure 4 once again comprises a journaled outer tube 60 supporting an inner shaft 62. In this case, however, only some of the cams 64 are mounted on the outer tube 60 in the same way as the cams 54 in Figure 3 and rotate with it. The remaining cams 66 can rotate about the outer tube 60 and are coupled instead for rotation with the inner shaft 62 by means of pins 68 that pass through tangentially elongated slots in the outer tube 60. To avoid the pins passing through cam lobes, each of the cams 66 that rotate with the shaft 62 is formed with an annular extension 66a which receives the pin 68. Figure 4 shows the auxiliary device 16 being driven by the inner shaft 62, but in this embodiment, it is also possible to use either the outer tube 60 to transmit torque to the auxiliary device. In some cases the latter approach may be advantageous because the outer

- 6 -

tube 60 has the greater torsional rigidity and because it is directly supported in bearings.

5 The phaser 12 shown in Figure 3 and 4, is a vane-type phaser with one driven member, in the form of a camshaft pulley that is rotated by the crankshaft and two drive members. One of the drive members is directly coupled to the driven member, i.e. the camshaft pulley so that its phase does not vary in relation to the engine crankshaft.

10

The second drive member of the phaser 12 is connected to a vane rotor carrying vanes that act in the same way as the pistons of hydraulic jacks. As hydraulic fluid is supplied to working chambers on the opposite sides of the vanes, the phase of the vane rotor is shifted in relation to the drive pulley. The vane rotor of the phaser is used to drive the phased member 14b of the camshaft 14, being the outer tube 50 in the embodiment of Figures 3 and 4.

20 In the case of an engine with a single camshaft, the camshaft of Figure 4 allows phase shifting of the intake cams without affecting the phase of the exhaust cams.

The invention can also find application in engines having separate intake and exhaust camshafts. In such a case it is not necessary to resort to the more complex camshaft construction of Figure 4 and all the cams of any one of the camshafts can be carried by the outer tube 14b.

30 Figure 5 differs from Figure 2 in that the unphased rotary member 14a of the first camshaft 14 is connected to drive a second, conventional, one-piece camshaft 30. In this case, the phase of the cams carried by the camshaft 30 is fixed relative to the engine crankshaft and torque can be transmitted to auxiliary devices 16 from the rotary member 14a of the first camshaft 14 and/or from the second camshaft 30.

35

- 7 -

Figure 6 is a variation on the valve train shown in Figure 5 and differs from it in that the engine has a further phaser 42 arranged between the unphased rotary member 14a of the first camshaft 14 and the second camshaft 30. In this case, the second camshaft 30 may either be a solid one-piece camshaft or a camshaft constructed in the manner shown in Figures 3 and 4. As with the embodiment shown in Figure 5, torque may be transmitted to two auxiliary devices 16a and 16b, the torque to the second device 16b being taken either from the unphased rotary member of the first camshaft 14, as illustrated, or from unphased rotary member of the second camshaft 30 if the latter is constructed in the manner illustrated in Figures 3 and 4.

15

- 8 -

**CLAIMS**

1. An engine having a crankshaft, a camshaft (14) formed of two concentric rotary members (50,52) at least one of which carries a group of cams (54), a transmission train connected to drive a first of the rotary members in fixed phase relationship with the crankshaft, and a phaser (12) for enabling the phase of the second of the rotary members to be varied dynamically relative to the phase of the crankshaft and the first rotary member, characterised in that an auxiliary device (16) is connected to be driven by torque transmitted from the crankshaft through the first rotary member of the camshaft.

2. An engine as claimed in claim 1, wherein the engine is a multi-cylinder engine and wherein the two rotary members consist of an inner shaft and a outer tube surrounding the inner shaft.

3. An engine as claimed in claim 2, wherein the outer tube is fast in rotation with all the cams of the camshaft.

4. An engine as claimed in claim 2, wherein the camshaft is formed with two groups of cams, one of the groups being fast in rotation with the outer tube and the other group being coupled to the inner shaft by means of pins extending into the inner shaft through circumferentially elongated slots in the outer tube.

5. An engine as claimed in any preceding claim, wherein the engine has two camshafts, the second camshaft being a solid camshaft driven in synchronism with one of the rotary members of the first camshaft.

6. An engine as claimed in any of claims 1 to 4, wherein the engine has two camshafts, the second camshaft

- 9 -

being a solid camshaft coupled by means of a second phaser to one of the rotary members of the first camshaft.

7. An engine as claimed in any of claims 1 to 4,  
5 wherein the engine has two camshafts and the second camshaft comprises two rotary members at least one of which carries a group of cams, wherein one of the rotary members of the second camshaft is driven in synchronism with one of the rotary members of the first camshaft and the second rotary  
10 member of the second camshaft is driven by means of a phaser that enables the relative angular position of the two rotary members of the second camshaft to be varied dynamically, so as to allow the phase of at least some of the cam lobes on the second camshaft to be altered with respect to the  
15 crankshaft.

8. An engine as claimed in claims 5 to 7, wherein the second camshaft is used to provide an unphased drive to an auxiliary device driven by torque transmitted by the  
20 crankshaft through the second camshaft.

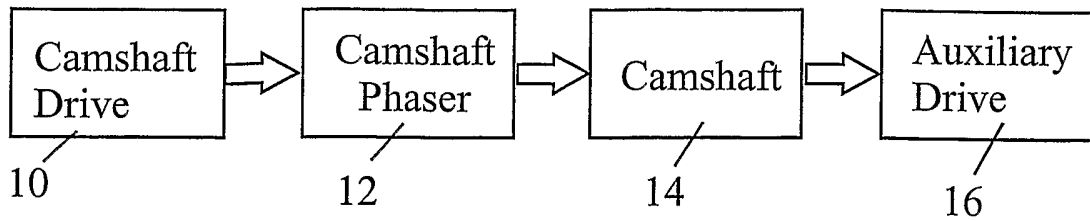


Fig. 1

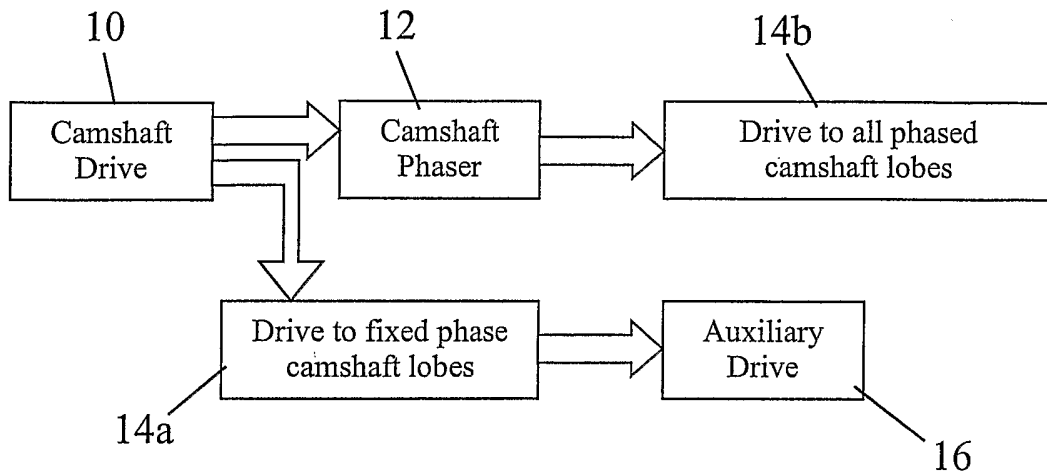


Fig. 2

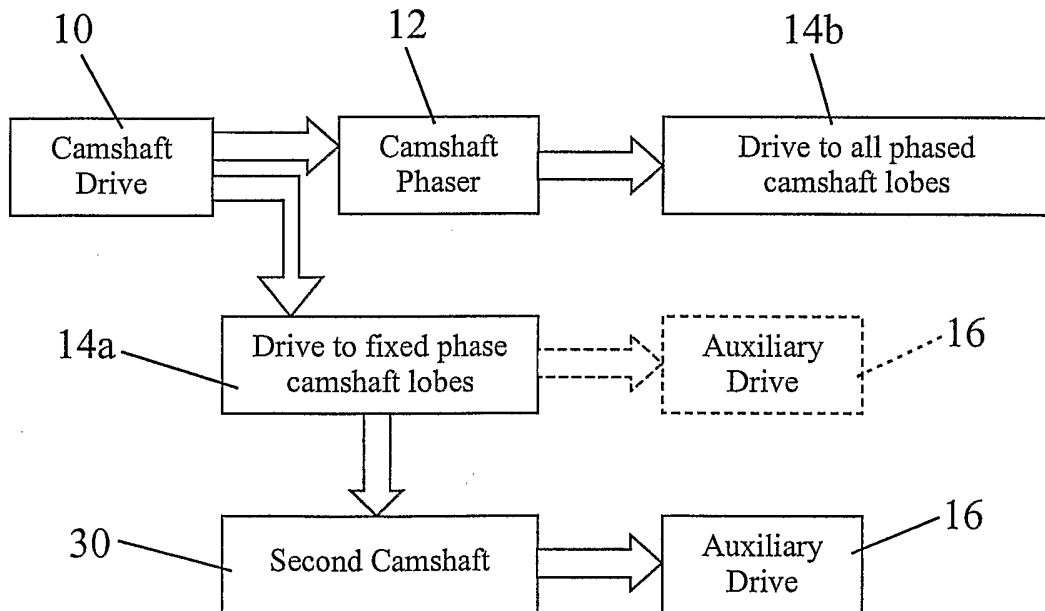


Fig. 5

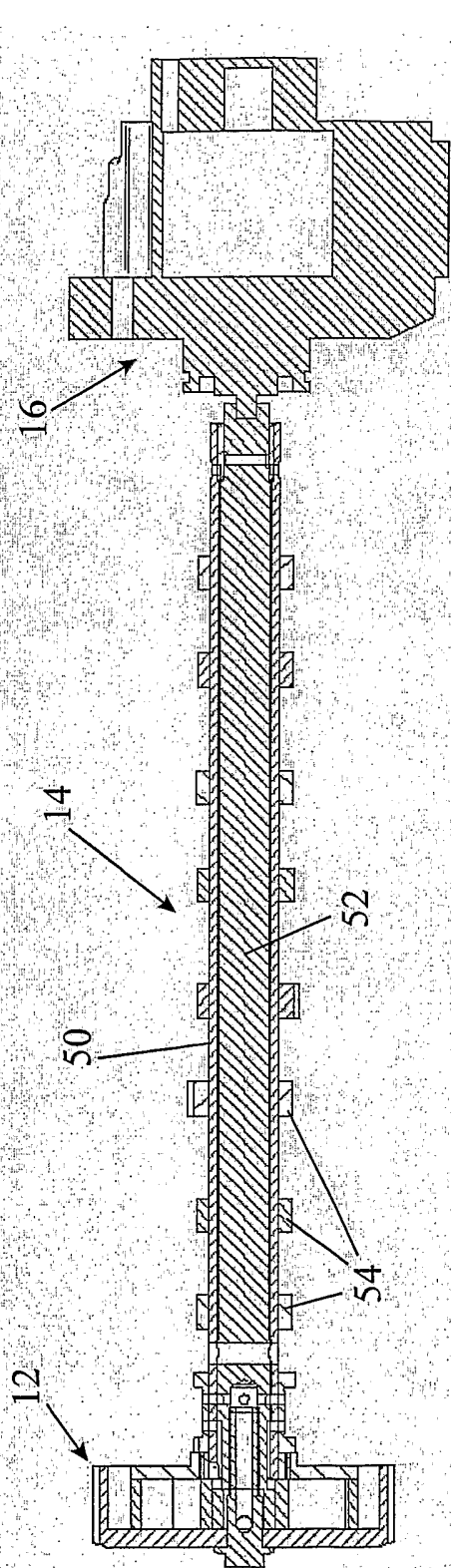


Fig. 3

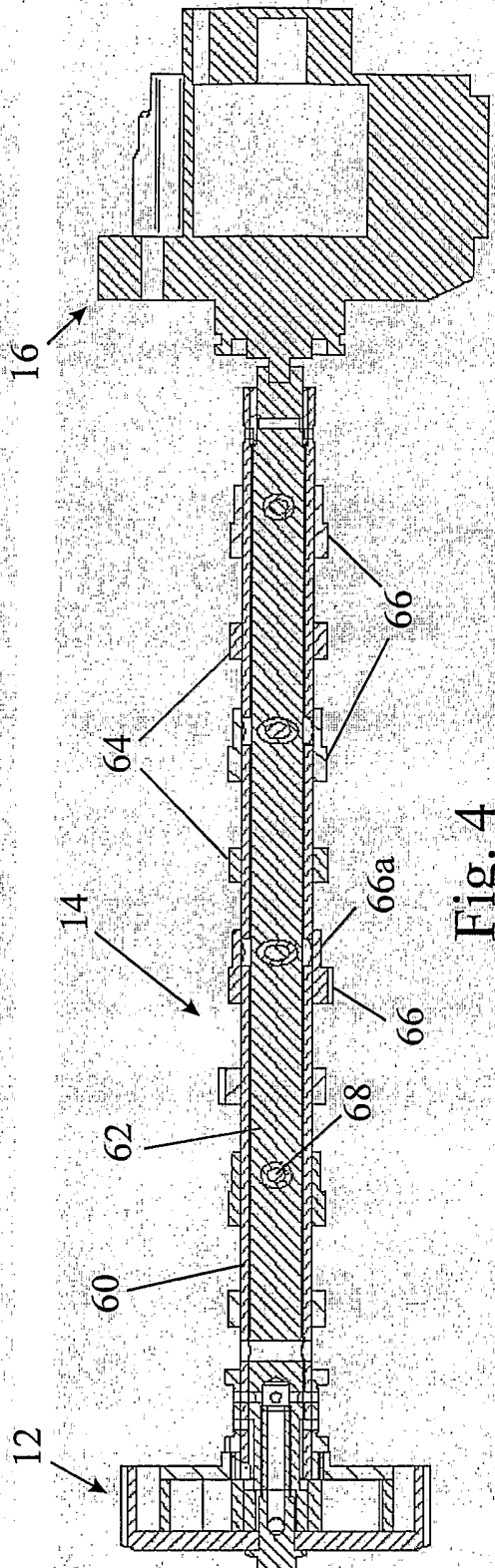


Fig. 4

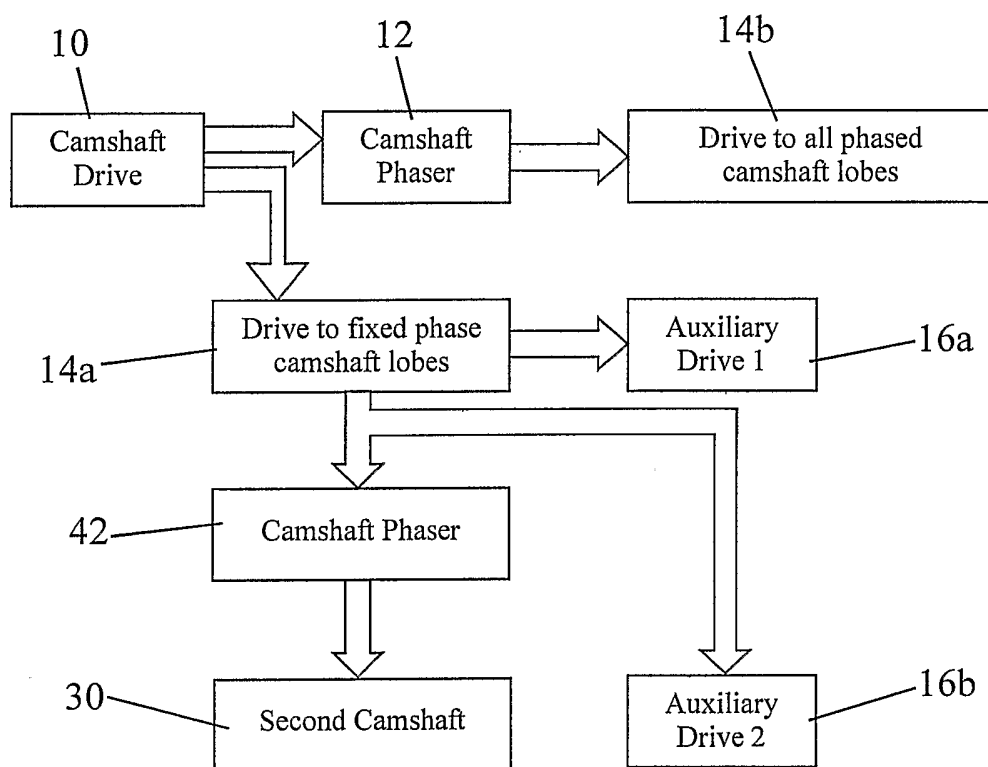


Fig. 6

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/GB2005/050078

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC 7 F01L1/34 F01L1/047				
According to International Patent Classification (IPC) or to both national classification and IPC				
<b>B. FIELDS SEARCHED</b>				
Minimum documentation searched (classification system followed by classification symbols) IPC 7 F01L F02B				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched				
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal, WPI Data, PAJ				
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>				
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
A	EP 1 234 954 A (MECHADYNE PLC) 28 August 2002 (2002-08-28) cited in the application paragraph '0001! paragraph '0014! paragraph '0022! figures 1,4	1,2,4,5, 7		
A	US 5 564 380 A (KOBAYASHI ET AL) 15 October 1996 (1996-10-15) column 1, lines 8-11 column 6, lines 19-52 figures 9-13	1-3		
----- -/--				
<input checked="" type="checkbox"/> Further documents are listed in the continuation of box C.				
<input checked="" type="checkbox"/> Patent family members are listed in annex.				
° Special categories of cited documents :				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none; vertical-align: top;">                     "A" document defining the general state of the art which is not considered to be of particular relevance                      "E" earlier document but published on or after the international filing date                      "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)                      "O" document referring to an oral disclosure, use, exhibition or other means                      "P" document published prior to the international filing date but later than the priority date claimed                 </td> <td style="width: 50%; border: none; vertical-align: top;">                     "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention                      "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone                      "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.                      "&amp;" document member of the same patent family                 </td> </tr> </table>			"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family			
Date of the actual completion of the international search  <div style="text-align: center; font-weight: bold;">30 August 2005</div>		Date of mailing of the international search report  <div style="text-align: center; font-weight: bold;">05/09/2005</div>		
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer  <div style="text-align: center; font-weight: bold;">Paquay, J</div>		

# INTERNATIONAL SEARCH REPORT

International Application No <b>PCT/GB2005/050078</b>
--

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2 349 157 A (FORD HENRY ET AL) 16 May 1944 (1944-05-16) page 1, column 1, lines 1-3 page 2, column 2, lines 40-44 page 3, column 1, lines 3-12 figures 1-5 -----	1
A	DE 39 34 848 A1 (INGELHEIM, GRAF VON, PETER, 8309 AU, DE) 25 April 1991 (1991-04-25) column 1, lines 3-7 column 3, lines 2-61 figure 1 -----	1,2,4-6
A	US 5 165 303 A (RIEMSCHEID ET AL) 24 November 1992 (1992-11-24) column 1, lines 8-14 column 2, lines 47-50 column 2, lines 60-65 column 5, line 38 - column 6, line 15; figures 1-4 -----	

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No  
PCT/GB2005/050078

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1234954	A	28-08-2002	GB 2369175 A EP 1234954 A2 US 2002059910 A1	22-05-2002 28-08-2002 23-05-2002
US 5564380	A	15-10-1996	JP 8068340 A	12-03-1996
US 2349157	A	16-05-1944	NONE	
DE 3934848	A1	25-04-1991	NONE	
US 5165303	A	24-11-1992	DE 3921923 A1 DD 296332 A5 ES 2024896 A6 FR 2649443 A1 GB 2233734 A JP 3111607 A US 5577420 A DE 3943427 C1	17-01-1991 28-11-1991 01-03-1992 11-01-1991 16-01-1991 13-05-1991 26-11-1996 04-04-1991