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(71) Applicant: **ACHATES POWER, INC.** [US/US]; 4060 Sorrento Valley Boulevard, San Diego, CA 92121 (US).

(72) Inventors: **REDON, Fabien, G.**; 5043 Via Playa Los Santos, San Diego, CA 92124 (US). **VRSEK, Gary, A.**; 357 Lakeshore Pointe Drive, Howell, MI 48843 (US).

(74) Agent: **MEADOR, Terrance, A.**; Achates Power, Inc., 4060 Sorrento Valley Boulevard, San Diego, CA 92121 (US).

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: MECHANISM FOR VARYING CRANKSHAFT TIMING ON A BELT/CHAIN DRIVEN, DUAL CRANKSHAFT OPPOSED-PISTON ENGINE

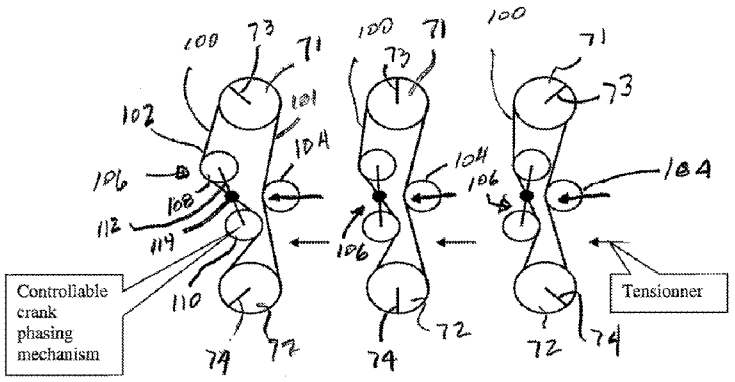

FIG. 2A FIG. 2B FIG. 2C

(57) Abstract: A mechanism for varying crankshaft timing on a belt/chain driven, dual crankshaft opposed-piston engine includes sprockets on corresponding ends of the two crankshafts, connected by a belt or chain which is tensioned by two or more tensioners. By changing the position of the tensioners the length of the two spans of the belt/chain are varied and thus the phase between the crankshafts is varied.

WO 2014/168864 A1

MECHANISM FOR VARYING CRANKSHAFT TIMING ON A BELT/CHAIN DRIVEN, DUAL CRANKSHAFT OPPOSED-PISTON ENGINE

PRIORITY

[0001] This application claims the benefit of and priority to US application 61/810,256, filed in the US Patent and Trademark Office on 9 April 2013.

BACKGROUND

[0002] The subject matter relates to a dual-crankshaft, opposed-piston engine with improvements for variable port timing. More particularly, the subject matter relates to an opposed-piston engine with two crankshafts coupled by a belt or chain, in which a timing control mechanism acts against the belt or chain to vary the timing of port operations in the engine.

[0003] In an opposed-piston engine, a pair of pistons is disposed for opposed sliding motion in the bore of at least one ported cylinder. Each cylinder has exhaust and intake ports, and the cylinders are juxtaposed and oriented with exhaust and intake ports mutually aligned. Each port is constituted of one or more arrays or sequences of openings disposed circumferentially in the cylinder wall near a respective end of the cylinder. The engine includes two crankshafts rotatably mounted at respective exhaust ends and intake ends of the cylinders, and each piston is coupled to a respective one of the two crankshafts. In a belt (or chain)-driven, dual crankshaft, opposed-piston engine, the two crankshafts are connected by a belt or chain. The reciprocal movements of the pistons control the operations of the ports. In this regard, each port is located at a fixed position where it is opened and closed by a respective piston at predetermined times during each cycle of engine operation. Those pistons that control exhaust port operation are termed "exhaust pistons" and those that control intake port operation are called "intake pistons".

[0004] Typically in opposed-piston engines the exhaust piston is phased in relation to the intake piston so as to enhance exhaust gas purging and scavenging during the later portion of the power stroke.

[0005] Piston phasing is normally fixed by positioning the exhaust piston connecting rod at some advanced angle on the crankshaft to which it is connected ("the exhaust crankshaft") ahead of the intake piston connecting rod position on the crankshaft to

which it is connected ("the intake crankshaft"). In such a configuration, as the pistons move away from top center (TC) positions after combustion, both ports (intake and exhaust) are closed by their respective pistons. As the pistons approach bottom center (BC) positions the exhaust port is opened first to begin exhaust gas purging and then the intake port opens some preset time later to allow pressurized air into the cylinder chamber to provide scavenging of the remaining exhaust gasses. As the pistons reverse direction, the exhaust port closes first, allowing pressurized air into the cylinder chamber through the still open intake port until it too closes and a compression cycle begins.

[0006] It is desirable to be able to control port phasing in an opposed-piston engine by relying on changing piston phasing in such a way as to dynamically adapt port opening and closing times to changing speeds and loads that occur during engine operation.

SUMMARY

[0007] This desirable objective is achieved in a belt (or chain)-driven, dual crankshaft, opposed-piston engine by tensioning the belt or chain that connects the two crankshafts by two or more tensioners. By changing the position of the tensioners, the lengths of two spans of the belt/chain are varied and thus the phase between the crankshafts is varied. Varying the phase between the crankshafts, in turn, varies the inter-piston phasing, thereby changing port phasing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a schematic diagram of a dual crankshaft opposed-piston engine.

[0009] FIGS. 2A-2C are schematic illustrations of an interlinked crankshaft system of a belt/chain drive, dual crankshaft, opposed-piston engine in which the two crankshafts are connected by a belt or chain engaged by two idlers, showing variable crankshaft phasing.

[0010] FIGS. 3A-3C are schematic illustrations of an interlinked crankshaft system of a belt/chain drive, dual crankshaft, opposed-piston engine in which the two crankshafts are connected by a belt or chain engaged by four idlers, showing variable crankshaft phasing.

[0011] FIG. 4 is a schematic illustration of an interlinked crankshaft system for a belt/chain drive, dual crankshaft, opposed-piston engine showing output shaft integration for the multi-idler configurations of FIGS. 2A-2C

[0012] FIG. 5 is a schematic illustration of an interlinked crankshaft system for a belt/chain drive, dua- crankshaft, opposed-piston engine showing output shaft integration for the multi-idler configurations of FIGS. 3A, 3B, and 3C.

SPECIFICATION

[0013] FIG. 1 illustrates a dual crankshaft opposed-piston engine 49 having at least one ported cylinder 50. For example, the engine may have one ported cylinder, two ported cylinders, three ported cylinders, or four or more ported cylinders. Each cylinder 50 has a bore 52 and exhaust and intake ports 54 and 56 formed or machined in respective ends thereof. The exhaust and intake ports 54 and 56 each include one or more circumferential arrays of openings in which adjacent openings are separated by a solid bridge. In some descriptions, each opening is referred to as a "port"; however, the construction of a circumferential array of such "ports" is no different than the port constructions shown in FIG. 1. Exhaust and intake pistons 60 and 62 are slidably disposed in the bore 52 with their end surfaces 61 and 63 opposing one another. The exhaust pistons 60 are coupled to a crankshaft 71, the intake pistons are coupled to the crankshaft 72. Although the figure shows the engine 49 in an essentially vertical orientation, this is for the sake of illustration only; in other aspects the engine could be disposed in other orientations than the vertical one shown.

[0014] When the pistons 60 and 62 of a cylinder 50 are at or near their TC positions, a combustion chamber is defined in the bore 52 between the end surfaces 61 and 63 of the pistons. Fuel is injected directly into the combustion chamber through at least one fuel injector nozzle 100 positioned in an opening through the sidewall of a cylinder 50.

[0015] FIGS. 2A-2C and 3A-3C show a dual crankshaft, opposed-piston engine, such as that shown in FIG. 1, equipped with a belt (or chain) 100 that couples the crankshafts 71 and 72. The belt 100 is engaged by spaced-apart tensioning idlers that are disposed on respective sides of a straight line connecting the axes of the crankshafts. The phasing between the crankshafts 71 and 72 is varied by controlling the movement of the tensioning idlers so as to vary the tension in the belt 100. By changing the positions of the tensioners, the lengths of two spans of the belt are varied and thus the phase

between the crankshafts is varied. Varying the phase between the crankshafts, in turn, varies the inter-piston phasing, thereby changing port phasing of the opposed-piston engine 49.

[0016] As seen in FIGS. 2A-2C, a tensioning idler 104 acts against a first span of the belt 100 and is spring-loaded in one direction indicated by the arrow so as to take up any slack in the belt 100. A second tensioning idler 106 acts against a second span of the belt 100. The second tensioning idler 106 is constituted of a pair of pulleys 108, 110 mounted at opposing ends of a pulley arm 112 pivoted at a point 114 fastened to the engine structure. The pulleys are in rolling contact with opposite sides of the second span of the belt 100. The pulley arm 112 is controlled by an actuator to pivot from one position to another in a predetermined arc. As the pulley arm 112 is pivoted, the pulleys 108 and 110 swing in opposing CW/CCW directions, thereby changing the length of travel of the belt 100. The changes in the length of travel cause the phase between the crankshafts to shift as indicated by the changes in position of the crankshaft timing lines 73 and 74.

[0017] As seen in FIGS. 3A-3C, two tensioning idlers 206 act against respective spans of the belt 100. Each of the tensioning idlers 206 is constituted of a pair of pulleys 208, 210 mounted at opposing ends of a pulley arm 212 pivoted at a point 214 fastened to the engine structure. The pulleys are in rolling contact with opposite sides of the respective spans of the belt 100. Each of the pulley arms 212 is controlled by an actuator to pivot from one position to another in a predetermined arc. As a pulley arm 212 is pivoted, the pulleys 208 and 210 swing in opposing CW/CCW directions, thereby changing the length of travel of the belt 100. The changes in the length of travel cause the phase between the crankshafts to shift.

[0018] With the layout shown in FIGS. 3A-3C, a belt tensioning idler 206 only needs to compensate for belt stretch and to maintain the tension. A shorter tensioning idler motion range facilitates the design of this component. The belt tension would be exercised between one side of the belt 100 and the other, instead of between the engine block and the belt 100 as in the embodiment of FIGS. 2A-2C.

[0019] Output shaft integration for the belt/chain drive, dual crankshaft embodiment of FIGS. 2A-2C is shown in FIG. 4, and output shaft integration for the belt/chain drive, dual crankshaft embodiment of FIGS. 3A-3C is shown in FIG. 5. Both of these figures presume that the crankshaft 71 is disposed above the crankshaft 72, and so, for the

purposes of these figures, the crankshaft 72 is referred to as the "lower" crankshaft. With each embodiment the belt drive is located on the opposite end from where the engine is connected to the crankshaft, allowing for easy belt replacement if necessary. In some aspects, if the engine power was connected to the lower crankshaft 72, the engine would sit too high and would not package well. However, as per FIGS. 4 and 5, the output is taken from a gear idler 300 connected to the lower crankshaft 72 which allows the engine to sit at the proper height and clear the vehicle components above the engine.

[0020] This last gear set before the transmission can be manipulated to adjust the output shaft speed with respect to the crankshaft of the engine allowing for further integration flexibility with the vehicle.

CLAIMS

1. A dual-crankshaft, opposed-piston engine (49), including one or more ported cylinders (50) that are juxtaposed and oriented with exhaust (54) and intake (56) ports mutually aligned, a pair of crankshafts (71, 72), each rotatably mounted at respective exhaust and intake ends of the cylinders, a pair of pistons (60, 62) is disposed for opposed sliding movement in the bore (52) of each cylinder, all of the pistons (60) controlling the exhaust ports (54) being coupled by connecting rods to the crankshaft (71) mounted at the exhaust ends of the cylinders, and all of the pistons (62) controlling the intake ports (56) being coupled by connecting rods to the crankshaft (72) mounted at the intake ends of the cylinders, characterized in that:

the two crankshafts (71, 72) are connected by a belt or chain (100), with opposing tensioning idlers (104, 106), (206) operatively engaging opposing lengths of the belt or chain, and at least one tensioning idler includes a pair of pulleys (108, 110), (208, 210) mounted at opposing ends of a centrally-pivoted pulley arm (112), (212).

2. The dual crankshaft, opposed-piston engine of claim 1, in which:

the tensioning idlers are disposed on respective sides of a straight line connecting the axes of the two crankshafts

a first tensioning idler (104) acts against a first span of the belt or chain (100) and is spring-loaded in a first direction so as to take up any slack in the belt 100;

a second tensioning idler (106) acts against a second span of the belt or chain (100); and

the second tensioning idler is constituted of a pair of pulleys (108, 110) mounted at opposing ends of a pulley arm (112) pivoted at a point (114) fastened to the engine structure.

3. The dual crankshaft, opposed-piston engine of claim 2, in which the pulleys (108, 110) are in rolling contact with opposite sides of the second span of the belt (100).

4. The dual crankshaft, opposed-piston engine of claim 1, in which:

the tensioning idlers (206, 206) are disposed on respective sides of a straight line connecting the axes of the two crankshafts

each tensioning idler (206) acts against a respective span of the belt or chain (100); and,

each tensioning idler is constituted of a pair of pulleys (208, 210) mounted at opposing ends of a pulley arm (212) pivoted at a point (214) fastened to the engine structure.

5. The dual crankshaft, opposed-piston engine of claim 4, in which the pulleys (208, 210) of each tension idler (206) are in rolling contact with opposite sides of a respective span of the belt or chain (100).

6. The dual crankshaft, opposed-piston engine of claims 1-5, in which the crankshafts include an upper (71) and a lower (72) crankshaft, and output to a transmission is taken from a gear idler (300) connected to the lower crankshaft.

7. The dual crankshaft, opposed-piston engine of claim 6, in which the gear idler (300) is connected to an end of the lower crankshaft (72) that is opposite to the end where the belt or chain (100) is connected.

8. A method for varying the timing of port operations of the dual crankshaft, opposed-piston engine of any one of claims 1-7 by pivoting at least one pulley arm (112, 212) from one position to another in a predetermined arc to thereby change the length of travel of the belt (100).

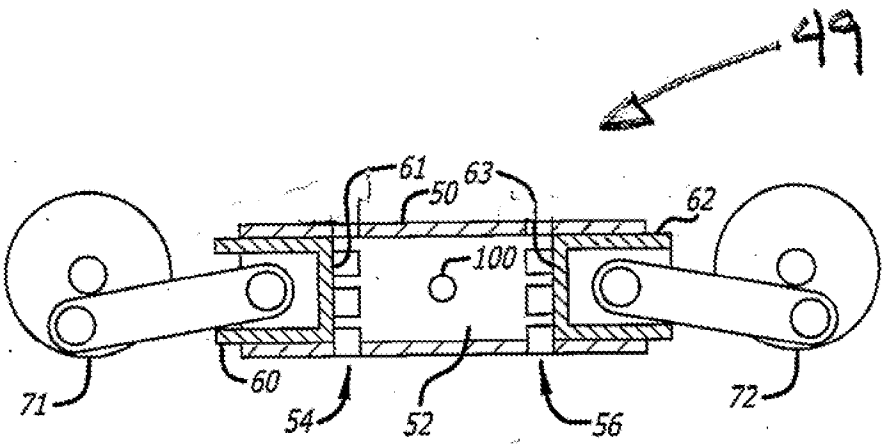

FIG. 1

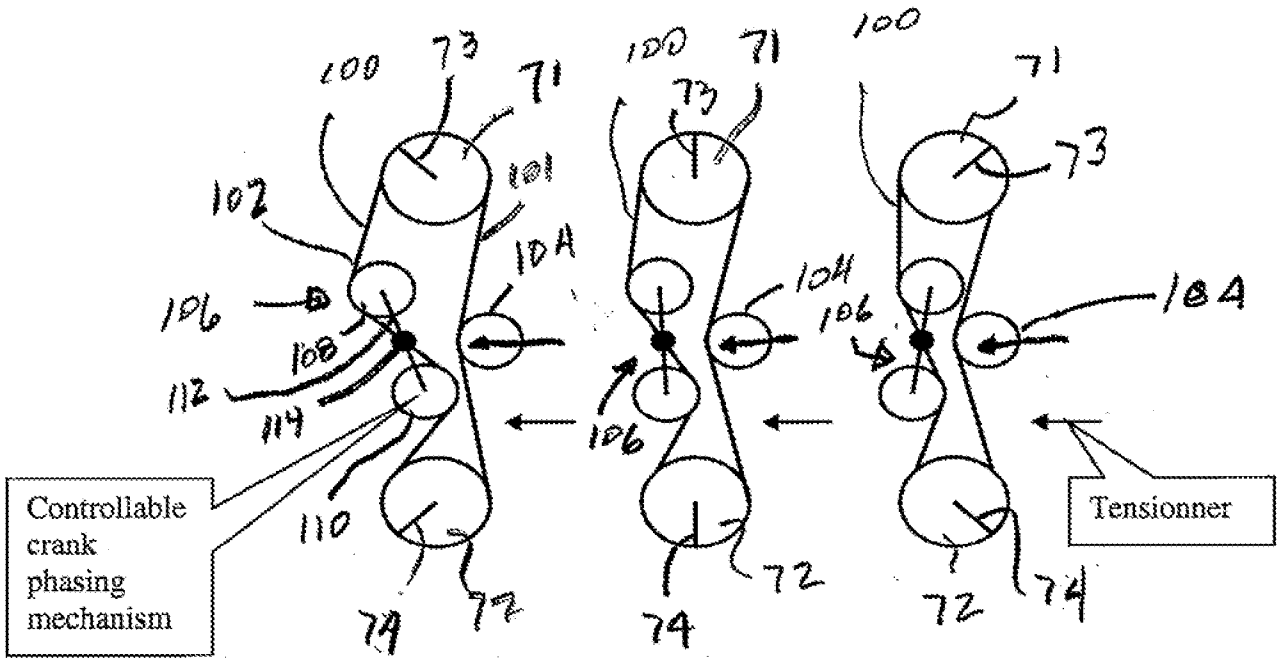

FIG. 2A FIG. 2B FIG. 2C

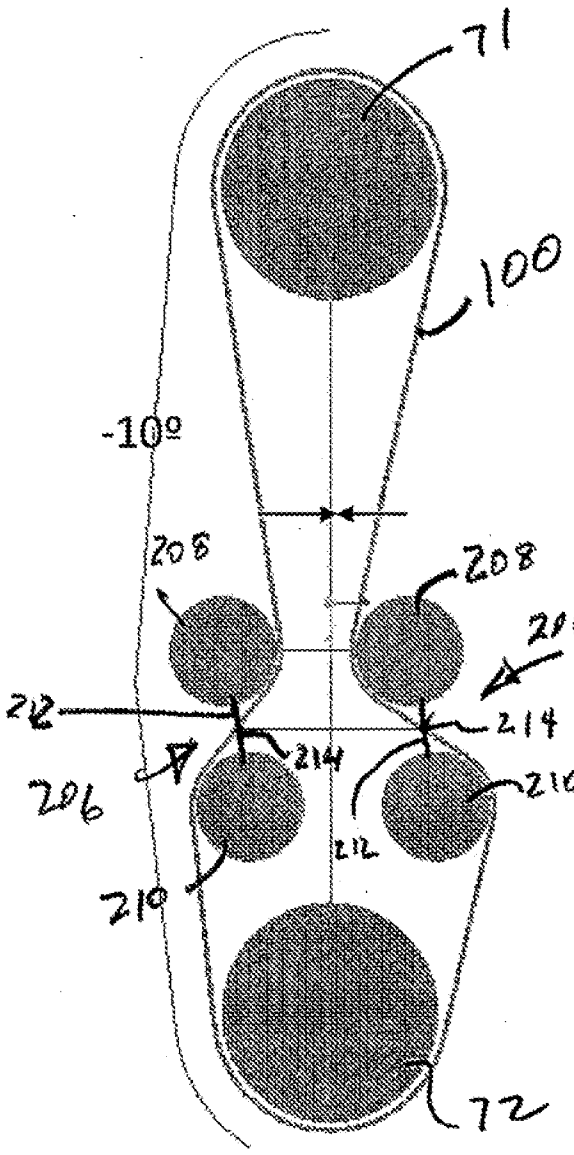

FIG. 3A

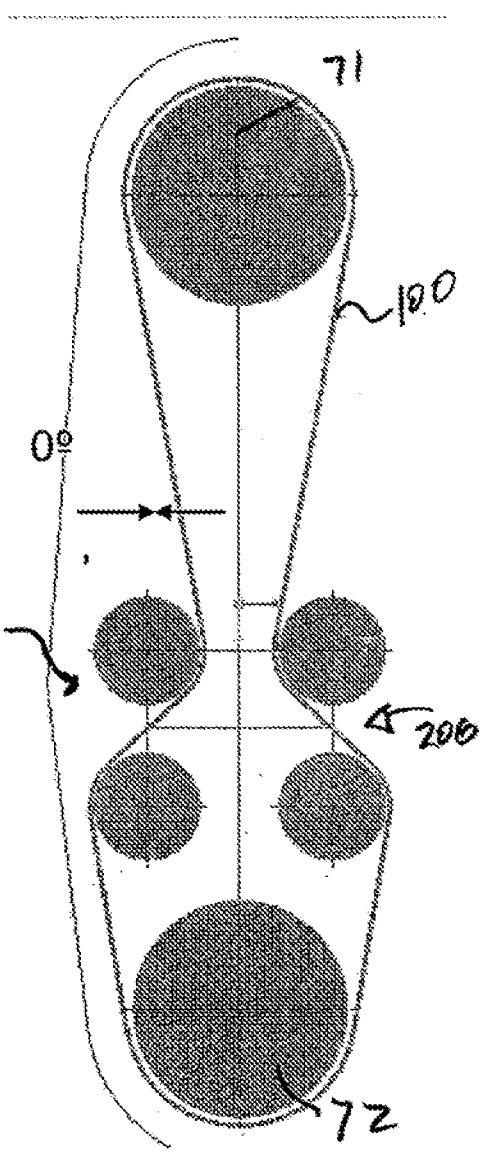

FIG. 3B

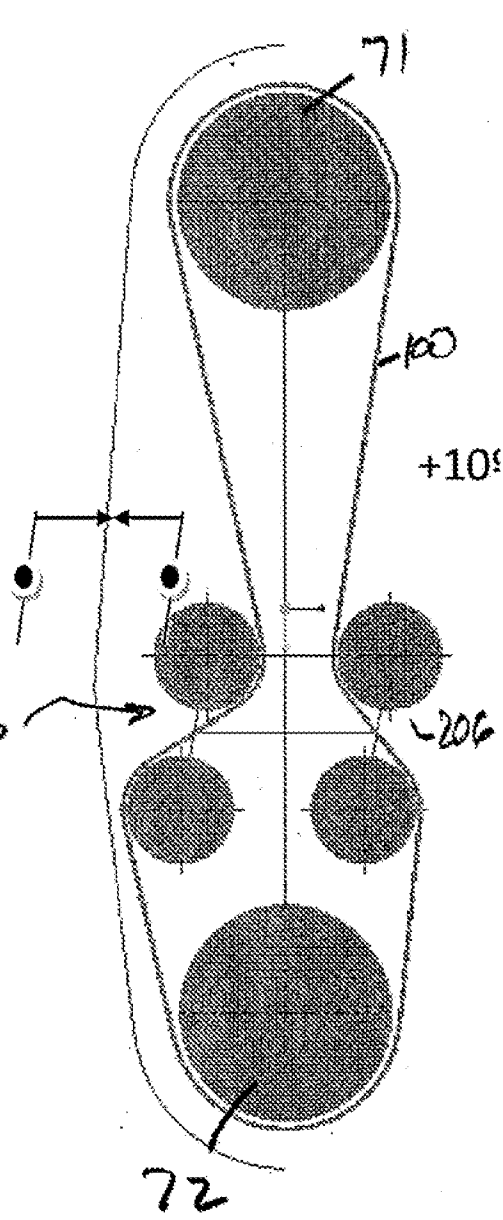

FIG. 3C

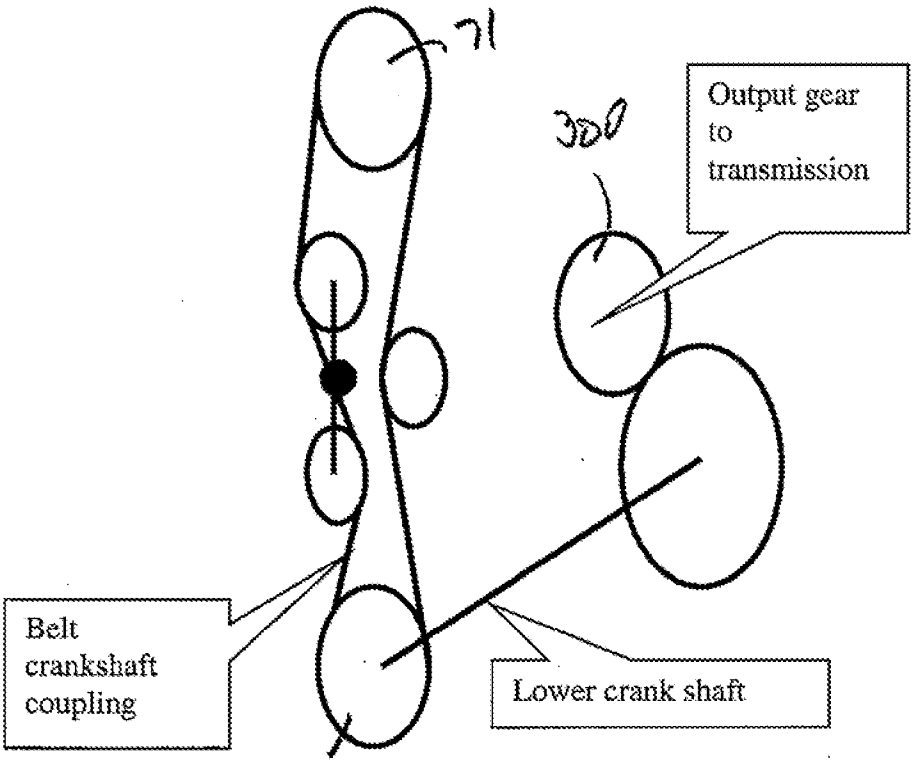
71
300
Output gear to transmission
Belt crankshaft coupling
Lower crank shaft
72

FIG. 4

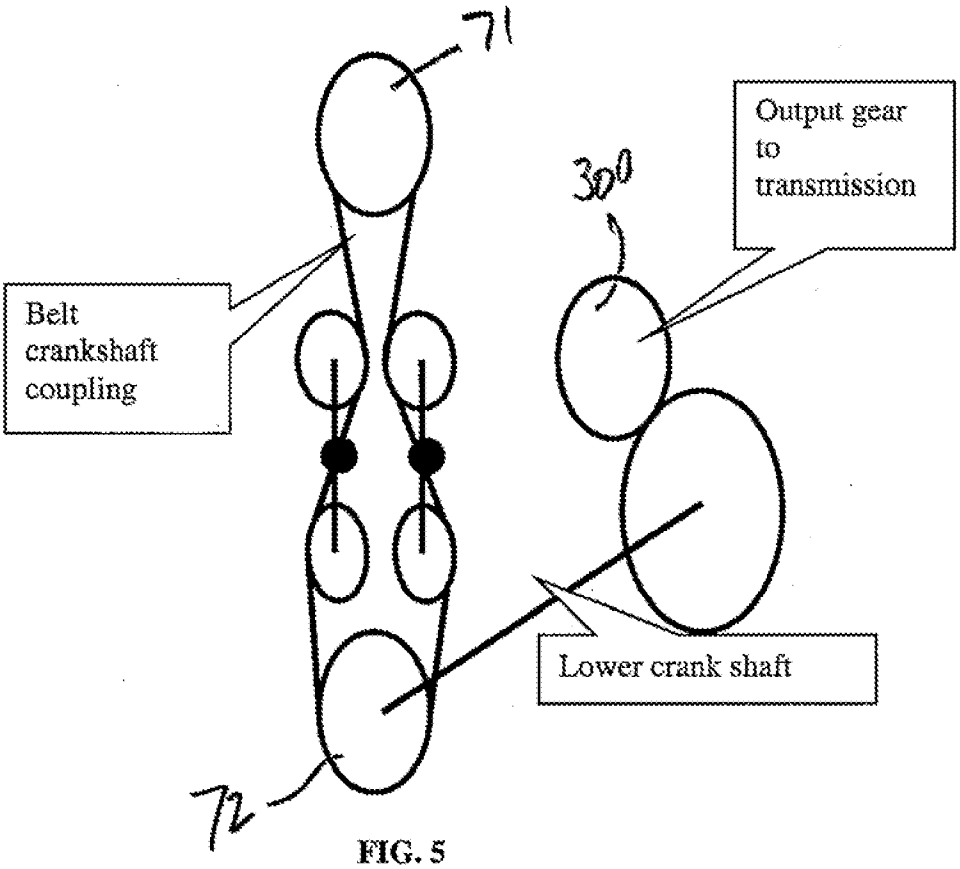
71
300
Output gear to transmission
Belt crankshaft coupling
Lower crank shaft
72

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/033151

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01B7/14 F02B75/28
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01B F02B F01L

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 practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2 401 188 A (PRINCE DAVID C) 28 May 1946 (1946-05-28) page 2, line 27 - line 34; figure 1	1,2,4,8 3,5-7
X	GB 280 412 A (STANLEY ALDER) 17 November 1927 (1927-11-17) page 1, line 35 - line 42; figure 1	1
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A	DE 616 451 C (RICHARD RIBBACK) 29 July 1935 (1935-07-29) figures 3-5	1

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent 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	Date of mailing of the international search report
30 July 2014	07/08/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Yates, John

1

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/033151

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 2012/285422 A1 (EXNER CHRISTINA [US] ET AL) 15 November 2012 (2012-11-15) paragraph [0022]; figure 4	1
Y	GB 2 339 257 A (PERKINS ENGINES CO LTD [GB]) 19 January 2000 (2000-01-19) abstract page 1, line 7 - line 15; claim 1; figures 3,4	3,5
Y	WO 95/18917 A1 (MADDEN STEPHEN KEITH [AU]) 13 July 1995 (1995-07-13) figure 3	3,5
Y	US 2005/274332 A1 (LEMKE JAMES U [US] ET AL) 15 December 2005 (2005-12-15) paragraph [0052]; figures 7a-7d	6,7

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/033151

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-8

   Dual crankshaft engine with belt drive tensioned by double pulley

1.1. claims: 1-5

   Constructional details of double pulley mechanism

1.2. claims: 6, 7

   Dual crankshaft engine having idler for output to transmission

1.3. claim: 8

   Dual crankshaft engine phase change

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2014/033151

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