



(51) International Patent Classification:

F02D 41/14 (2006.01) *F02D 13/02* (2006.01)
F02D 41/32 (2006.01) *F02D 19/10* (2006.01)
F02D 41/00 (2006.01)

(21) International Application Number:

PCT/FI2015/050601

(22) International Filing Date:

14 September 2015 (14.09.2015)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

20145833 23 September 2014 (23.09.2014) FI

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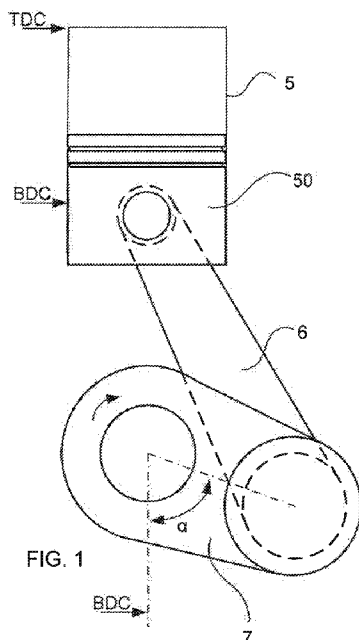
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(81) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

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(54) Title: METHOD IN OPERATING AN INTERNAL COMBUSTION PISTON ENGINE



(57) Abstract: Method in operating an internal combustion four-stroke piston engine comprising, - a number of cylinders (5) each comprising a cylinder head and a cylinder wall, a piston (50) is movable in a reciprocating manner between a top dead center (TDC) and a bottom dead center (BDC) inside the cylinder (5) defining a combustion chamber, - the piston (50) is connected via a connecting rod (6) to a crankshaft (7), wherein the reciprocating movement of the piston (50) is converted to a rotating movement of the crankshaft (7), - a valve mechanism controls an intake valve opening and closing timing in relation to the crankshaft angle, - the intake valve timing is adapted to be changed in relation to the engine load, - on a low load situation a fuel amount to be fed is adapted to the low load power need and the intake valve closing timing is adapted such that the intake valve is closed at the crankshaft angle of 70° to 55° before the bottom dead center (BDC) so that air-fuel equivalence ratio lambda is kept below 2.0.



SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG). **Published:**

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

Method in operating an internal combustion piston engine

TECHNICAL FIELD

[001] The invention concerns in general the technology of internal combustion engines, such as large turbo charged piston engines. In particular the invention
5 concerns the way in which the air to fuel ratio is controlled during certain operating conditions.

[002] In more detail, the present invention concerns a method in operating an internal combustion four-stroke piston engine comprising,
10 - a number of cylinders each comprising a cylinder head and a cylinder wall, a piston is movable in a reciprocating manner between a top dead center (TDC) and a bottom dead center (BDC) inside the cylinder defining a combustion chamber,
- the piston is connected via a connecting rod to a crankshaft, wherein the reciprocating movement of the piston is converted to a rotating movement of the
15 crankshaft,
- a valve mechanism controls an intake valve opening and closing timing in relation to the crankshaft angle,
- the intake valve timing is adapted to be changed in relation to the engine load.

20 BACKGROUND OF THE INVENTION

[003] With modern large internal combustion engines it is necessary that the emissions are kept within certain rather low limits at all running situations. These large engines are typically used in power plants, on sea going vessels etc., generally at demanding power supplying applications. These engines are
25 designed to run at a certain nominal load thus producing a constant power. However there are situations, where the load is not at the nominal load but the load is much lower. Also in these situations the emissions must be kept under the limits.

[004] A state of the art document WO2012072864 A1 discloses a method for
30 controlling the operation of an internal combustion engine comprising at least two operating modes. In a first operating mode, the intake valve (3) is closed at a first predetermined crank angle, in accordance with a Miller cycle, before the piston reaches bottom dead center during the intake stroke for reducing pres-

sure in the cylinder, and fuel is injected using first fuel injection means optimized for large amounts of fuel. In a second operating mode the intake valve is closed at a second predetermined crank angle, in accordance with conventional intake valve closing timing, after or slightly before the piston has passed
5 bottom dead center, and fuel is injected using second fuel injection means optimized for small amounts of fuel.

[005] Another state of the art document US2009222194 A1 discloses a Miller cycle combustion engine capable of operating on multiple fuel types, and a method of operating the engine, is provided. The engine includes a fuel type
10 determiner to determine the fuel type, and a compression adjustor to adjust the compression of a first cylinder of the engine to match the requirement of the determined fuel type. The compression adjustor is a variable valve timing system that provides a maximum compression when a fuel type requiring maximum compression is determined, and that advances or retards the opening of
15 the intake valve to provide lower compression when a fuel type requiring lower compression is determined.

SUMMARY OF THE INVENTION

[006] The following presents a simplified summary in order to provide a basic understanding of some aspects of various invention embodiments. The summary is not an extensive overview of the invention. It is neither intended to
20 identify key or critical elements of the invention nor to delineate the scope of the invention. The following summary merely presents some concepts of the invention in a simplified form as a prelude to a more detailed description of exemplifying embodiments of the invention.

25 [007] According to the present invention, on a low load situation a fuel amount to be fed is adapted to the low load power need and the intake valve closing timing is adapted such that the intake valve is closed at the crankshaft angle of 70° to 55° before bottom dead center (BDC) so that air-fuel equivalence ratio lambda is kept below 2.0.

30 [008] It is understood that the primary cause of too high THC (total hydrocarbon) emissions at low load in lean burn gas engines (a Spark Gas or a Dual Fuel) is too high lambda, resulting incomplete combustion. It may cause quenching, slow burning, incomplete ignition and various other issues that can be seen as incomplete burning at the combustion. Test results have shown

that lambda below 2.1 produces acceptably low levels of THC and CO. However, at low loads (0-50%) the engines are practically run at a lambda of 2.2 up to even 2.5. This is because, especially at very low load, with this type of engine intended for power supplying purposes for an electric power network, it is complicated to reduce the engine airflow enough even by opening the turbocharger wastegate to the maximum. Also, at 30-50% load, the exhaust gas temperature after turbocharger may become a limiting factor. The exhaust temperature may rise too high and it shortens the life time of the components in contact with the high temperature exhaust gas.

10 [009] According to an implementation of the invention it is provided a high Miller like camshaft, for example a Miller 70, to reduce the engine airflow and thus lambda, and then operate the engine in VIC (variable intake valve closing) mode always at high loads to reach the desired "nominal" Miller timing (such as 55). This is kind of a reverse of conventional VIC use, where it is used at
15 low loads instead, mainly in diesel engines.

[010] A benefit of this method is an optimal lambda at low load. The applicant has achieved test results showing the method to effectively reduce THC and CO emissions by even 92-94%. This would eliminate the need for an after-treatment system, skip firing, air by-pass etc. unless they are also needed at
20 full load. The method is especially useful for Spark Gas power plants that are used for secondary or even tertiary frequency control, where a genset may need to operate extended periods at low loads.

[011] The exemplary embodiments of the invention presented in this patent application are not to be interpreted to pose limitations to the applicability of the
25 appended claims. The verb "to comprise" is used in this patent application as an open limitation that does not exclude the existence of also unrecited features. The features recited in depending claims are mutually freely combinable unless otherwise explicitly stated.

[012] The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The invention itself,
30 however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[013] Fig. 1 illustrates an engine with a piston at crank shaft angle of 70 deg before BDC,

5 Fig. 2 illustrates an engine with a piston at crank shaft angle of 55 deg before BDC,

Fig. 3 illustrates an engine with a piston at crank shaft angle at the BDC.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[014] In fig 1 it is shown an internal combustion four-stroke piston engine comprising,

- 10 - a number of cylinders 5 (only one shown here) each comprising a cylinder head and a cylinder wall, a piston 50 is movable in a reciprocating manner between a top dead center TDC and a bottom dead center BDC inside the cylinder 5 defining a combustion chamber,
- the piston 50 is connected via a connecting rod 6 to a crankshaft 7, wherein
- 15 the reciprocating movement of the piston 50 is converted to a rotating movement of the crankshaft 7. In the fig. 1 the crank shaft angle is 70° before the BDC. Practically this is about the first position where the inlet valve can be closed in order to reduce the air intake to the cylinder. In figure 1 it is not shown that a valve mechanism controls an intake valve opening and closing
- 20 timing in relation to the crankshaft angle, and that the intake valve timing is adapted to be changed in relation to the engine load. The engine should comprise a variable inlet valve closing (VIC) system that is used for adapting the timing of the inlet valve closing. Thus the intake valve closing is transferred towards lower limit when the engine load increases.

- 25 [015] Further according to the method on a low load situation a fuel amount to be fed is adapted to the low load power need and the intake valve closing timing is adapted such that the intake valve is closed at the crankshaft angle α of 70° to 55° before the bottom dead center (BDC) so that air-fuel equivalence ratio lambda is kept below 2.0. By using parameters within these ranges the applicant has achieved even 92-94% reduction of THC and CO emissions based
- 30 on results of a laboratory engine. Thus the intake valve is closed before bottom dead center to reduce the air intake in the low load situation.

[016] According to a preferred embodiment the lambda in use in low load power mode is kept within range of 1.6 to 2.0. This range keeps the emissions

at low level and also keeps the exhaust temperature in check. The actual optimal range of lambda depends on some other parameters also, thus the range need to be determined on tests.

5 [017] Here in this description the low load situation is considered to be within a range of 0 – 50% of the nominal maximum load of the engine. The method has been developed for certain engine types, here the engine is a dual fuel or a spark gas engine. For precautionary measure if the exhaust gas temperature after a turbocharger approaches an upper limit, the intake valve timing is adapted to close the intake valve earlier. Thus the method can be also
10 adapted for controlling the running conditions of the engine.

[018] In fig. 2 it is shown that the crank shaft angle α is 55° before the BDC. Practically this is about the last feasible position where the inlet valve can be closed in order to effectively reduce the air intake to the cylinder so that it has the intended effect on the low load power situation. This method is also usable
15 on DF engines, where it would be able to easily pass the wanted THC marine cycle emission limit or even go much lower. According to an embodiment of the operation parameters usable, it is noted that at the 50% engine load the optimal closing angle is 55° on crankshaft angle.

[019] For reference, in fig. 3 the piston 50 has been shown to be at crank shaft
20 angle $\alpha 0^\circ$ i.e. to be in the BDC. Here both the upper part of the piston and crank shaft 7 are indicated with an arrow to be in BDC. The same reference signs are used in fig. 1 and fig. 2.

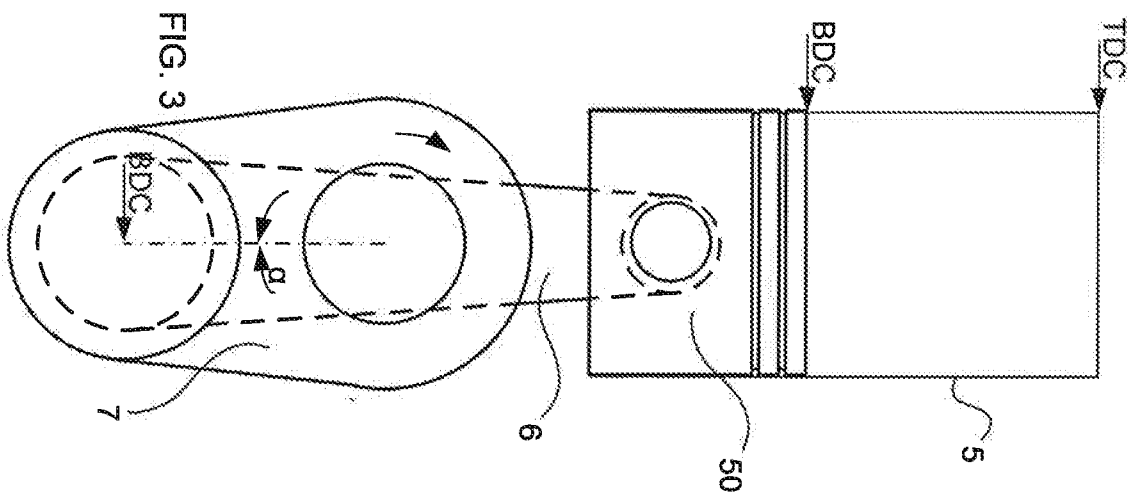
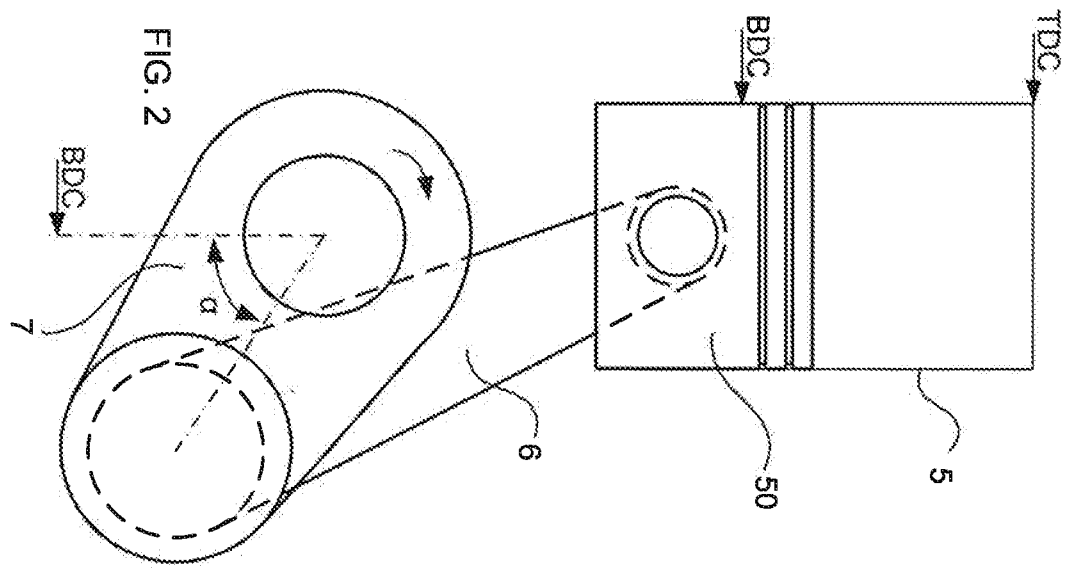
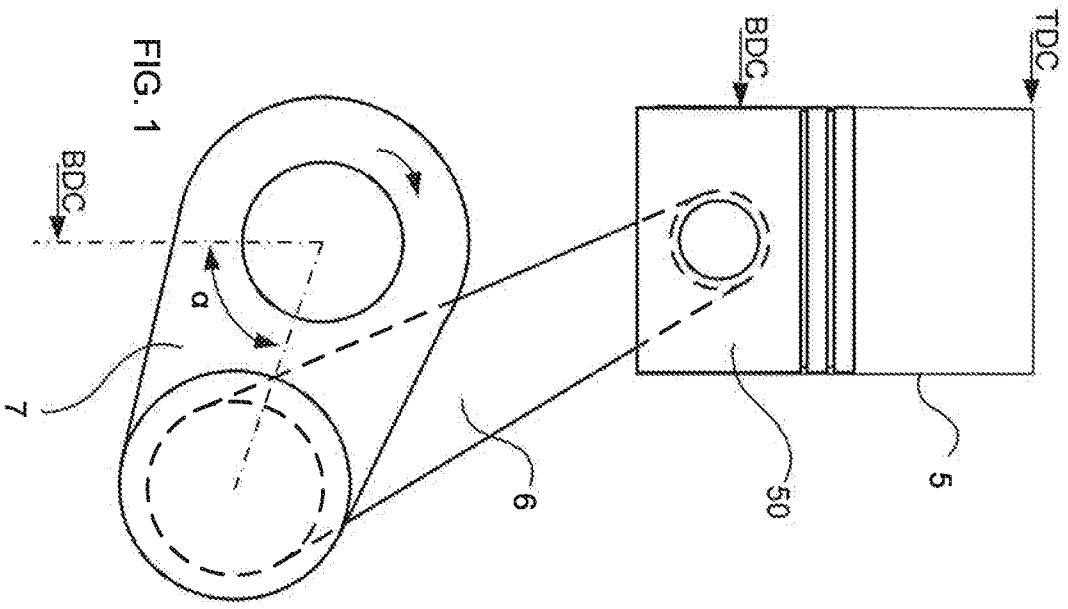
[020] For example, if some marine products use of this kind of method instead of skip-firing, which is not feasible with small cylinder numbers, the use of pre-
25 sent would bring very effective way to achieve improved emission results.

[021] Variations and modifications to the embodiments described above are possible without departing from the scope of the amended claims. For example, instead of VIC, some other kind of variable intake valve timing system could be used.

Patent claims

1. Method for operating an internal combustion four-stroke piston engine, the engine comprising
- a number of cylinders (5) each comprising a cylinder head and a cylinder wall,
 - a piston (50) that is movable in a reciprocating manner between a top dead center (TDC) and a bottom dead center (BDC) inside the cylinder (5) defining a combustion chamber,
 - a connecting rod (6) and a crankshaft (7), the piston (50) being connected via the connecting rod (6) to the crankshaft (7) for converting the reciprocating movement of the piston (50) to a rotating movement of the crankshaft (7), and
 - a valve mechanism for controlling intake valve opening and closing timing in relation to the crankshaft angle,
- the intake valve timing being adapted to be changed in relation to the engine load,
- characterized** in that
- on a low load situation a fuel amount to be fed is adapted to the low load power need and the intake valve closing timing is adapted such that the intake valve is closed at the crankshaft angle (α) of 70° to 55° before the bottom dead center (BDC) so that air-fuel equivalence ratio lambda does not exceed 2.0.
2. The method according to the patent claim 1, **characterized** in that the lambda is kept within range of 1.6 to 2.0.
3. The method according to the patent claim 1, **characterized** in that the low load situation is 0 – 50% of the nominal maximum load of the engine.
4. The method according to the patent claim 1, **characterized** in that the intake valve is closed before bottom dead center to reduce the air intake in the low load situation.
5. The method according to the patent claim 1, **characterized** in that the engine is a dual fuel or a spark ignition gas engine.
6. The method according to the patent claim 1, **characterized** in that if the exhaust gas temperature after a turbocharger approaches a predetermined upper limit, the intake valve timing is adapted to close the intake valve earlier.

7. The method according to the patent claim 6, **characterized** in that the engine comprises a variable inlet valve closing (VIC) system that is used for adapting the timing of the inlet valve closing.
8. The method according to the patent claim 1, **characterized** in that the intake valve closing is transferred towards lower limit when the engine load increases.
9. The method according to patent claims 1 and 8, **characterized** in that at the 50% engine load the closing angle is 55° on crankshaft angle (α).



INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2015/050601

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02D41/14 F02D41/32 F02D41/00 F02D13/02 F02D19/10
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)
F02D

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	US 6 039 026 A (SHIRAISHI TAKUYA [JP] ET AL) 21 March 2000 (2000-03-21)	1-5,8,9
Y	abstract; claims 1,2,8; figures 1,6,10 column 3 - column 4 column 6, line 38 - column 7, line 5 column 8, line 44 - line 62 column 9, line 55 - line 63	6,7
Y	DE 10 2011 122442 A1 (VOLKSWAGEN AG [DE]) 27 June 2013 (2013-06-27)	6,7
A	paragraph [0007]; claims 1,7,8,10 paragraph [0010] - paragraph [0011] paragraph [0018] - paragraph [0021] paragraph [0029] - paragraph [0030] paragraph [0034] - paragraph [0035]	1-5,8,9
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Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search 17 December 2015	Date of mailing of the international search report 04/01/2016
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Rocabruna Vilardell
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INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2014/044388 A1 (DAIMLER AG [DE]) 27 March 2014 (2014-03-27) the whole document	1-9
A	----- US 2009/173319 A1 (KOCH THOMAS [DE]) 9 July 2009 (2009-07-09) the whole document	1-9
A	----- WO 01/40642 A1 (NISSAN MOTOR [JP]; ARAI MASAHIRO [JP]; NAGAISHI HATSUO [JP]) 7 June 2001 (2001-06-07) the whole document	1-9
A	----- EP 0 953 750 A2 (NISSAN MOTOR [JP]) 3 November 1999 (1999-11-03) the whole document	1-9

INTERNATIONAL SEARCH REPORT

Information on patent family members

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