



(51) International Patent Classification:

F02B 37/04 (2006.01) *F02B 33/06* (2006.01)
F02B 29/08 (2006.01)

(21) International Application Number:

PCT/FI2017/050258

(22) International Filing Date:

11 April 2017 (11.04.2017)

(25) Filing Language:

Finnish

(26) Publication Language:

English

(30) Priority Data:

20160094 11 April 2016 (11.04.2016) FI

(72) Inventor; and

(71) Applicant : JANHUNEN, Timo [FI/FI]; Perustie 10 A9,
00330 Helsinki (FI).

(74) Agent: SEPO LAINEN OY; Itämerenkatu 3 A, 00180
Helsinki (FI).

(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, DJ, 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, KH, KN,
KP, KR, KW, 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.

(84) 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,
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))
- 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: METHOD FOR USING A COMBUSTION ENGINE AND COMBUSTION ENGINE ASSEMBLY

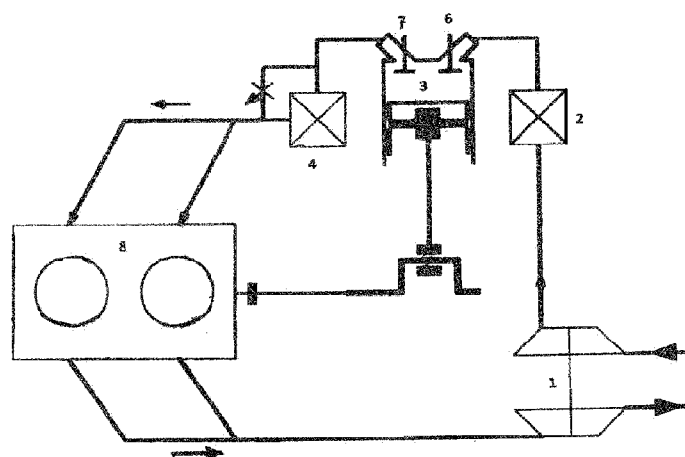


FIGURE 2

(57) Abstract: Method and internal-combustion engine arrangement, which comprises an internal-combustion engine (8) comprising at least one cylinder and piston, which is arranged to operate according to the split-cycle principle, a turbocharger (1) connected to the exhaust side of the engine for compressing the air with the aid of the exhaust gases of the internal-combustion engine (8) in the first stage, a first intercooler (2) for cooling the compressed air, and a mechanical compressor (3) for further compressing the aid in the second stage, a second intercooler (4) for cooling the compressed air, and in which the output of the mechanical compressor (3) can be regulated according to the air requirement of the engine (8). The air thus compressed and cooled is led to the cylinder (cylinders) of the engine (8) with the aid of its (their) extremely fast intake-air valve system (5) as the engine's piston moves towards its upper dead centre.



Method for Using a Combustion Engine and Combustion Engine Assembly

Field of technology

[0001] The present invention relates to a method for reducing throttling losses in the
5 gas exchange of an internal-combustion engine.

BACKGROUND

[0002] In piston engines the gas exchange in the cylinders is based on the vacuum and excess pressure created by the movement of the piston and the correctly timed opening and closing of the valves. Normally, the output of an internal-combustion engine is
10 regulated by throttling the intake-air port. This leads to throttling losses and a reduction in efficiency, particularly on part-load of the engine. A usual method for reducing the throttling losses of an internal-combustion engine is to close the intake valve earlier or later than normal. Thus losses can be partly reduced and the part-load efficiency of the engine increased. Nevertheless, losses remain and the part-load efficiency of the engine is not the
15 best possible. In direct-injection engines, both petrol and diesel, throttling of the intake port can be omitted on part load, but this leads to a lower average cylinder temperature and thus to higher CO, HC, and particle emission, due to the high air factor.

SUMMARY OF THE INVENTION

[0003] The invention is defined according to the characteristics of the independent
20 Claims. Some particular characteristics are described in the dependent Claims.

[0004] According to the first characteristic of the invention, an internal-combustion engine comprising at least one cylinder and piston is operated according to the split-cycle principle, in such a way that air is compressed in the first stage with the aid of the engine's exhaust gases using a turbocharger, the compressed air is cooled and is further compressed
25 in the second stage using a mechanical compressor, the compressed air is cooled and the output of the mechanical compressor is regulated according to the engine's air requirement. Then the compressed and cooled air is led to the engine's cylinder with the aid of an extremely fast intake-air valve arrangement 5, (Figures 1 and 2) as the engine's piston moves towards its top dead centre.

[0005] According to the second characteristic of the invention, the air is compressed in the second stage using a mechanical adjustable piston compressor.

[0006] According to the third characteristic of the invention, the output of air of the adjustable piston compressor is regulated by controlling its intake-air valves according to
5 the early intake valve close method.

[0007] According to the fourth characteristic of the invention, the output of air of the adjustable piston compressor is regulated by controlling its intake-air valves according to the late intake valve close method.

[0008] According to the fifth characteristic of the invention, the output of air of the adjustable piston compressor is regulated by altering the timing of its intake and exhaust-
10 air valves.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 shows the operating principle of a split-cycle internal-combustion
15 engine.

[0010] Figure 2 shows a device, with the aid of which at least some embodiments of the invention can be implemented.

EMBODIMENTS

20 [0011] DEFINITIONS

[0012] In this context, the term split-cycle engine refers to a piston engine, in which the exchange of gas in the cylinder takes place during one rotation of the crankshaft under the control of valves and part of the work of compressing the intake air is done by a compressor external to the engine, according to Figure 2.

25 [0013] The term early intake valve close method refers to the closing of the intake valve before the end of the intake stroke.

[0014] The term late intake valve close method refers to keeping the intake valve open partly during the compression stroke, in such a way that part of the air in the cylinder flows back into the intake-air port.

[0015] The present method is based on a new type of engine, which is shown in
5 Figures 1 and 2. The engine is a so-called "split-cycle" type engine 8, in which part of the compression work of the engine 8 has been transferred to a separate compressor 3, according to Figures 1 and 2. The engine's intake-air gas exchange is based on the stages: compressing of the air using a turbocharger 1, cooling in an intercooler 2, further compression using a piston compressor 3, cooling in a second intercooler 4, and the
10 engine's 8 extremely rapid intake-air valve arrangement 5. The functioning of this gas-exchange arrangement has been proven by engine tests and CFD simulation (see e.g.: www.aumet.fi).

[0016] The engine's work cycle is shown in Figure 1. It begins with injection of the ignition fuel (at about the upper dead centre of the piston) into a hot, compressed fuel-air
15 mixture (Figure 1, item 1) and the subsequent combustion and work stroke. After this, the engine's exhaust valve opens and the exhaust stroke follows (Figure 1, item 2), when the piston pushes the combustion gases out of the cylinder and into the exhaust port. After that, fuel is injected into the hot, internal combustion gas (Figure 1, item 3). After this, the air that has been compressed by the piston compressor (3) and intercooled (intercooler 4,
20 Figure 2) is led with the aid of a rapid intake-air valve arrangement (5), (Figure 1, item 4) into the engine's cylinder as its piston moves towards its upper dead centre. After this, the air-fuel mixture created is compressed at the upper dead centre of the piston (Figure 1, item 5),

[0017] If it is desired to keep the engine's fuel and air mixture ratio, the lambda, in
25 an optimal range to achieve a good efficiency, to reduce nitrogen oxides and particles and the engine's other detrimental emissions, and to permit the good further processing of exhaust gases, it must be possible to regulate the amount of air produced by the compressor 3. In the embodiment of Figure 2, this is done by adjusting the opening and closing of the intake valves of the compressor 6, according to the so-called "early intake valve close", or
30 "late intake valve close" method. Ready components (see supercharging-turbocharger) are available of the market for implementing the method. In the same way, the opening and closing of the compressor's exhaust valve 7 should be controlled in order to achieve an

optimal result. Ready components for this are available on the market. The optimal opening and closing point of both the intake and exhaust valves is optimized using software known in the field for the case-specific adjustment of the valves, and also various pressure and other sensors can be used, as is the practice in the field. The pressure level of the compressor, which is significantly lower than that of the engine, makes this adjustment easy to implement.

[0018] The compressor's valves 6 and 7 are forced-acting disc valves, similar to those in a car's engine, because self-acting compressor valves do not generally operate at a speed of more than 3000 rpm and their flow-efficiency is poorer than that of disc valves. The valves' camshafts are adjusted so that the valves open at the right time, as described above. The advantage of a mechanical valve mechanism is that, if the valves' camshaft followers are roller followers, they return most of the valves' opening work to the camshafts. This is not the case e.g. in hydraulic systems, such as, e.g. Fiat Multiair.

[0019] The engine intake-air gas-exchange system described here regulates the amount of air coming to the engine, without throttling losses, and thus permits a high engine efficiency and low emissions, even on part load. The solution described is completely new in the field and permits the an engine to always operate at an optimal operating point, irrespective of the load.

[0020] The engine's (8) operating principle is shown in Figure 1, in which item 4, the intake of intake air, shows the rapid gas exchange taking place in the engine's cylinder with the aid of an extremely fast intake-air valve arrangement 5. As can be seen from the engine's gas exchange picture 2, the air (gas) coming to the engine 8 is first compressed in a turbocharger 1, after which the air is cooled in an intercooler 2 and is then led to a compressor 3, the output of which can be regulated and the compressed air then led to an intercooler 4 and then to the engine's cylinder (Figure 1, intake-air intake, item 4) with the aid of the engine's extremely fast intake-air valve arrangement 5, while the engine's piston moves towards its upper dead centre.

[0021] The invention comprises, among others, the following embodiments:

[0022] Method for minimizing the throttling losses of the gas exchange of an internal-combustion engine, which comprises a so-called. "spit-cycle" gas-exchange system, according to Figures 1 and 2, on the intake-air side of the engine 8, which is based

on the following stages: turbocharger 1, intercooler 2, mechanical compressor 3, intercooler 4, and the engine's extremely fast intake-air valve system 5. The air output of the mechanical compressor (3) can be regulated according to the engine's requirement, without throttling losses.

- 5 **[0023]** Method, in which its mechanical, adjustable compressor (3) is a piston compressor.

[0024] Method, in which the regulation of its piston compressor 3 is based on the so-called "early intake valve close" method and the control of its intake 6 and exhaust 7 valves for achieving the said adjustment .

- 10 **[0025]** Method, in which the regulation of its piston compressor 3 is based on the so-called "late intake valve close" method and the control of its intake 6 and exhaust 7 valves for achieving the said adjustment.

- [0026]** Method, in which the timing of the valves 6 and 7 of its piston compressor 3 is altered as required, to be able to minimize the throttling losses of the gas exchange of the
15 internal-combustion engine.

INDUSTRIAL APPLICABILITY

- [0027]** The invention can be applied in internal-combustion engines.

CLAIMS:

1. Method for operating an internal-combustion engine (8), comprising at least one cylinder and piston, according to the split-cycle principle, in such a way that the engine's intake air is compressed in the first stage with the aid of the internal-combustion engine's exhaust gases in a turbocharger (1), the compressed air is cooled and further compressed in a second stage using a mechanical compressor (3), the compressed air is cooled and the output of the mechanical compressor (3) is regulated according to the engine's (8) air requirement, and the compressed and cooled air is taken to the engine's cylinder with the aid of its extremely fast intake-air valve arrangement (5) as the engine's piston moves towards its upper dead centre.
2. Method according to Claim 1, in which the air is compressed in a second stage using a mechanical adjustable piston compressor (3).
3. Method according to Claim 2, in which the output of air of the adjustable piston compressor (3) is regulated by controlling its intake-air valves (6) according to the early intake valve close method.
4. Method according to Claim 2, in which the output of air of the adjustable piston compressor (3) is regulated by controlling its intake-air valves (6) according to the late intake valve close method.
5. Method according to any of the above Claims, in which the output of air of the adjustable piston compressor (3) is regulated by altering the timing of its intake and exhaust valves (6, 7).
6. Internal-combustion engine arrangement, which comprises an internal-combustion engine (8) comprising at least one cylinder and piston (8), which is arranged to operate according to the split-cycle principle, a turbocharger (1) connected to the exhaust side of the engine for compressing the air in the first stage with the aid of the exhaust gases of the internal-combustion engine (8), a first intercooler (2) for cooling the compressed air, and a mechanical compressor (3) for further compressing the air in the second stage, a second

intercooler (4) for cooling the compressed air, and in which the output of the mechanical compressor (3) can be regulated according to the air requirement of the engine (8).

7. Arrangement according to Claim 6, in which the mechanical compressor is an adjustable
5 piston compressor.

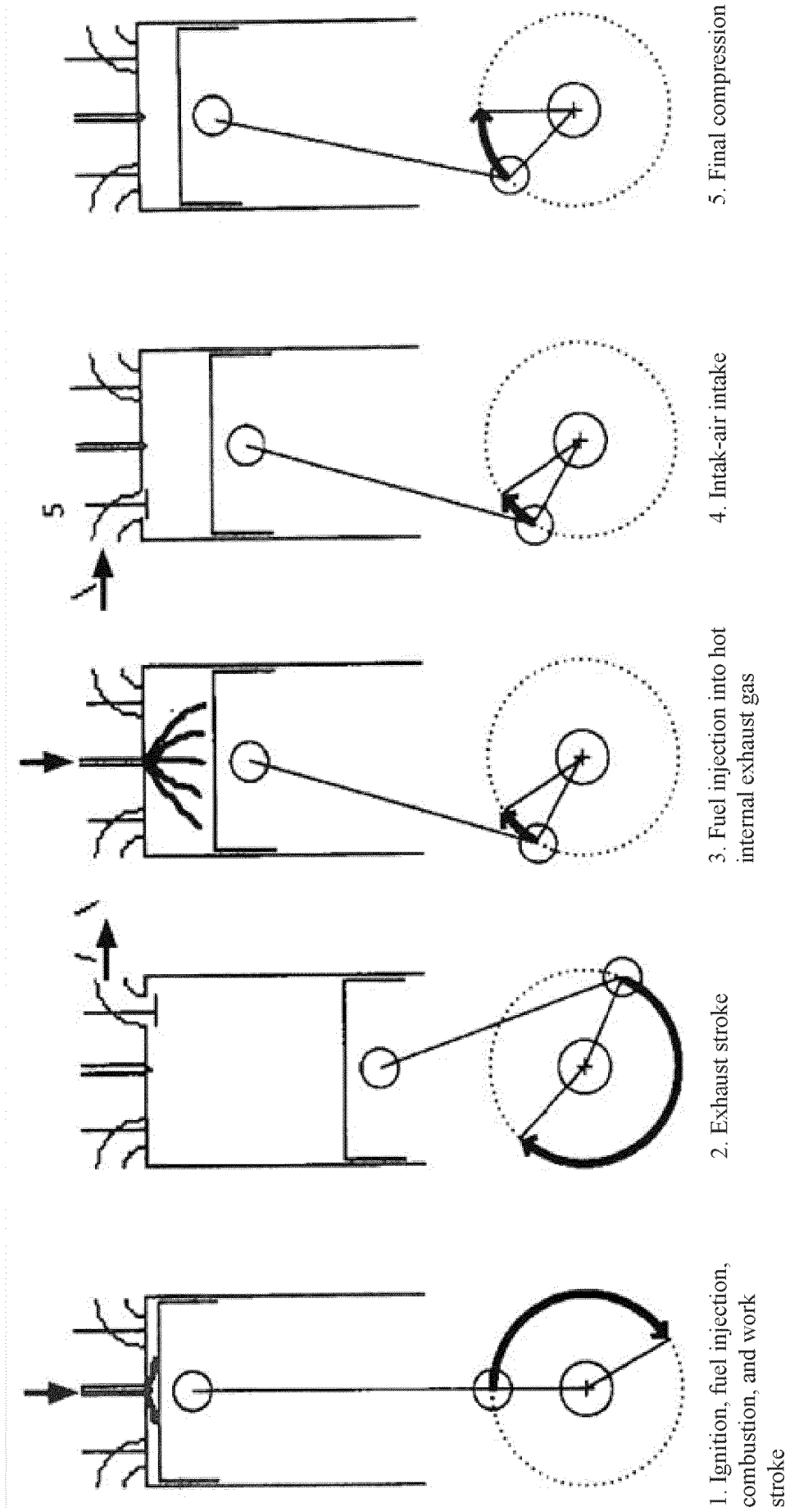


FIGURE 1

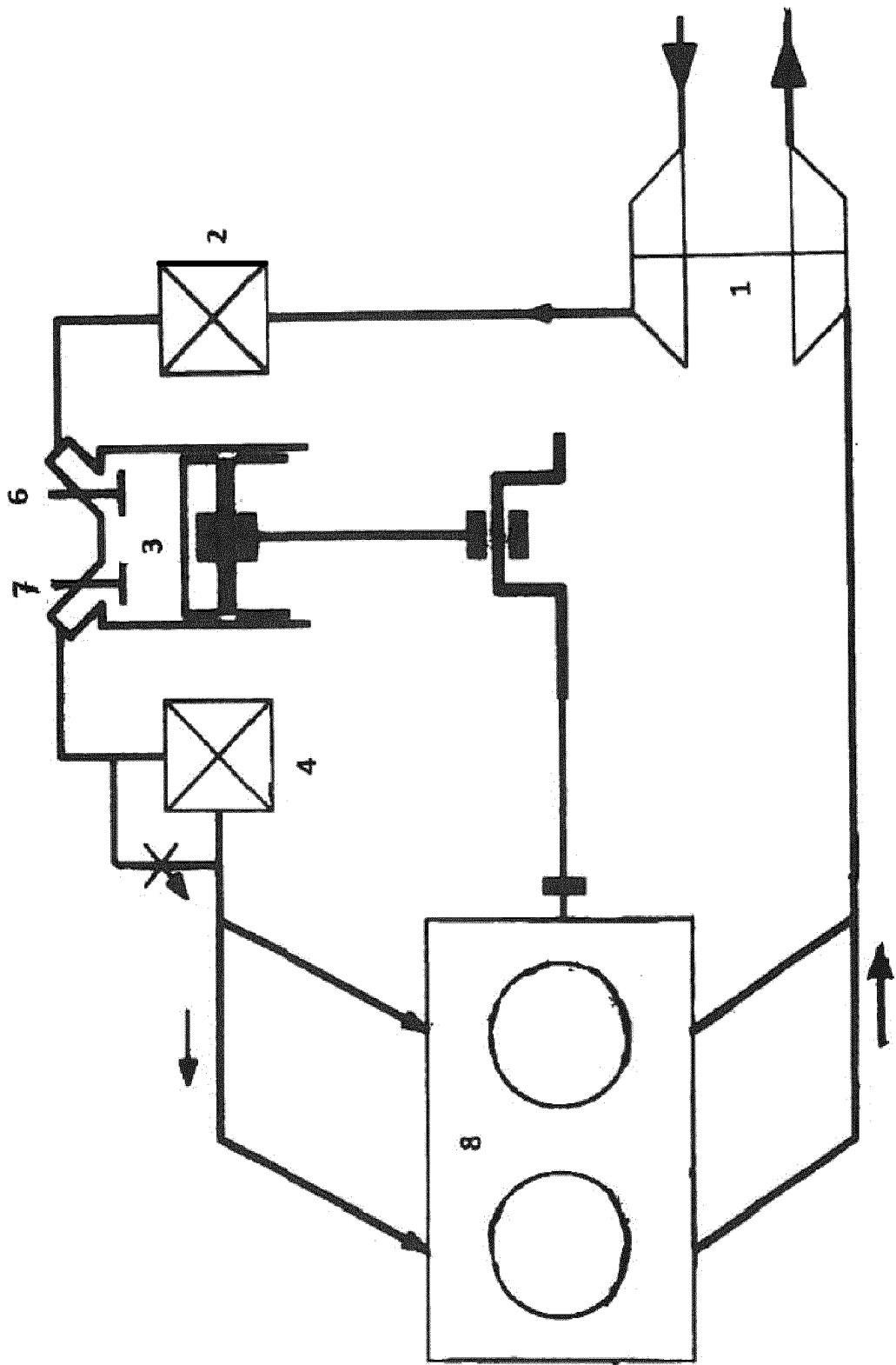


FIGURE 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2017/050258

A. CLASSIFICATION OF SUBJECT MATTER

INV. F02B37/04 F02B29/08 F02B33/06
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)

F02B F02M

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 2015/136071 A1 (DORTCH JR RICHARD W [US]) 21 May 2015 (2015-05-21)	1,2,6,7
Y	figures 1,3 paragraph [0016] paragraph [0022] - paragraph [0025] -----	3-5
Y	US 2012/073551 A1 (BRANYON DAVID P [US] ET AL) 29 March 2012 (2012-03-29) paragraph [0055] - paragraph [0069]; figures 1, 3 -----	3-5



Further documents are listed in the continuation of Box C.



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

1 August 2017

Date of mailing of the international search report

09/08/2017

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

Kołodziejczyk, Piotr

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/FI2017/050258

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015136071 A1	21-05-2015	AU 2014352881 A1	12-05-2016
		CA 2928863 A1	28-05-2015
		CN 105745414 A	06-07-2016
		EP 3058192 A1	24-08-2016
		HK 1221496 A1	02-06-2017
		JP 6110996 B2	05-04-2017
		JP 2016537557 A	01-12-2016
		KR 20160085889 A	18-07-2016
		US 2015136071 A1	21-05-2015
		US 2017022908 A1	26-01-2017
		WO 2015077496 A1	28-05-2015

US 2012073551 A1	29-03-2012	AU 2011305396 A1	01-11-2012
		CA 2802522 A1	29-03-2012
		CL 2012003150 A1	04-01-2013
		CN 102959195 A	06-03-2013
		EP 2619427 A1	31-07-2013
		JP 2013533424 A	22-08-2013
		KR 20130018889 A	25-02-2013
		RU 2013109014 A	27-10-2014
		TW 201233889 A	16-08-2012
		US 2012073551 A1	29-03-2012
		WO 2012040431 A1	29-03-2012
		ZA 201208068 B	26-06-2013
