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(54) Title: METHOD FOR PROVIDING VARIABLE COMPRESSION RATIO IN AN INTERNAL COMBUSTION ENGINE AND ACTUATOR FOR SAID METHOD

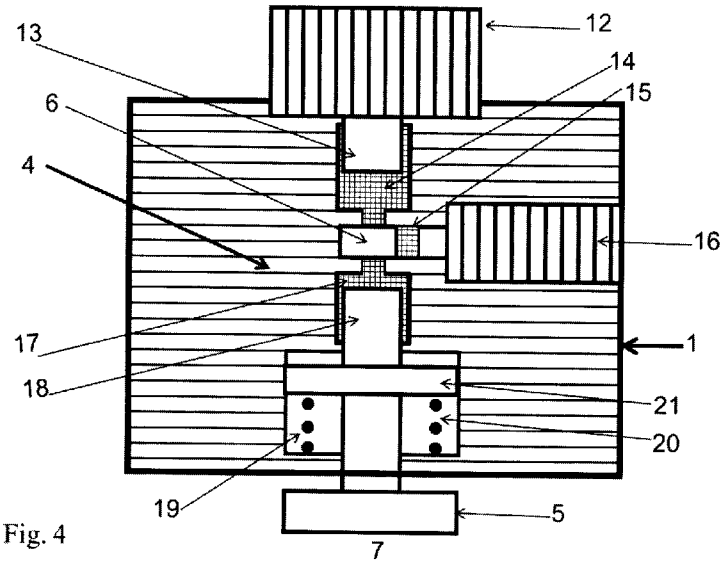

Fig. 4

(57) Abstract: In a combustion chamber of a piston combustion engine there is a displaceable piston that can be moved progressively up or down between an upper and a lower turning position. The displacement takes place via an electrically controlled step motor which is connected to the piston via a hydraulic link, including a hydraulic lock. The lock is deactivated during the displacement a certain number of steps up or down ordered by a motor control system, and when the displacement is ended, the lock is activated by said engine control system and the moving piston is locked in a certain position ordered by the motor control system.

[Continued on next page]

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Method for providing variable compression ratio in an internal combustion engine and actuator for said method

Technical area

The present invention relates to an increase of the efficiency coefficient in all types of piston combustion engines and further making it possible to minimize the creating of NOX (NitrogenOxides) in diesel engines.

Background

One problem to solve in today's diesel engines is to reduce emissions of nitrogen oxides, so-called NOx. A proposed solution is described, and referred to, in Swedish patent application no. 1500404-7 where the possibility of a variable compression ratio is a prerequisite. It can be seen from the proposal that the size of the combustion chamber needs to be controlled with great accuracy and then adapted to the volume of air supplied, in a preferred embodiment, via a freely controllable inlet valve during the intake stroke.

There are several proposed solutions for variable compression ratios, but only a few of them include that the combustion chamber, at least a substantial part of it, is present above the piston in the cylinder head. By placing the variable combustion chamber, from a size perspective view, in the cylinder head, simultaneously provides an efficiency enhancing solution for all types of piston combustion engines. The diesel engine which usually has a substantial part of the combustion chamber performed as a bowl in the piston can be said to cause the bowl to be moved from the piston to the cylinder head, which means that the combustion chamber size can be made variable.

Object of the invention

The object of the invention is to provide a solution to a variable compression ratio in a diesel engine which fulfil the severe and big demands which concerns the possibility to be able to vary the size of the combustion chamber with high accuracy and at the same time obtain a solution which can in princip be the same for all types of piston combustion engines. This object is obtained by the invention has been given the characterizing clauses mentioned in the claims mentioned after the description.

Description of the invention

A motor control system decides, for example based on the position of a gaspedal, a variety of actions, e.g. the amount of air to be supplied to the compression rate, the amount of fuel to be supplied and exactly when it is to be supplied, the size of the combustion chamber to provide optimum efficiency and the formation of a minimum of NOx, etc.

Herein, the invention is described only by showing how the regulation and control of the size of the combustion chamber is carried out by command and input from the engine control system, not the basis for these.

In the combustion chamber there is a movable piston that can be moved progressively upwards or downwards between an upper and a lower turning

position. The displacement takes place via an electrically controlled step motor which is connected to the piston via a hydraulic link, including a hydraulic lock. During the influence of a motor control system decided movement, a certain number of steps up or down, the lock deactivates and when movement is completed, the lock activates and the movable piston is locked in a certain position by the engine control system. During combustion and expansion stroke, the lock is activated which protects the step motor, its attachment and bearing from mechanical stress.

The lock is activated/deactivated by an electromagnet on input from the engine control system. The lock consists of a so-called pressure-relieved hydraulic lock, which on one hand reduces stress on the lock and also minimizes friction which facilitates activation/deactivation of the lock. The mentioned steps can be very small, millimeters, hundreds of millimeters, or less. At the same time, a step motor allows the movement to take place with high force, which is advantageous if there are combustion residues on the walls of the combustion chamber that must be overcome. Replacement of the piston occurs after the hydraulic lock is deactivated and easiest with the aid of a mechanical spring. Variations of the pressure in the combustion chamber cause the plunger to minimally move and preventing from being stuck.

A further description is made with the aid of figures as shown below.

Summary of Figures

Figure 1 shows schematically a section through the upper part of a diesel engine cylinder with cylinder head where the combustion chamber volume is adapted to small engine load and with the engine piston in its upper turning position after a compression stroke.

Figure 2 shows schematically a section through the upper part of a diesel engine cylinder with cylinder head where the combustion chamber volume is adapted for maximum engine load and with the motor piston in its upper turning position after a compression stroke.

Figure 3 shows schematically a section through the upper part of a diesel engine cylinder with cylinder head where the combustion chamber volume is adapted to medium-sized engine load and with the engine's piston in its upper turning position after a compression stroke

Figures 4 – 10 show schematically how an actuator 4 is deplacing a piston in a combustion chamber, ex.g. in a cylinder head of a diesel engine, shown in fig. 1-3, and makes the piston to take different positions in dependent of the motor load. It is stressed that the invention can be used with all types of piston combustion engines.

Fig. 1 shows a schematic view of a cylinder of a diesel engine with a cylinder head 1 and with a piston 2 mounted on a crank shaft 3. An actuator 4 with a a principal function according to the present invention is shown in fig. 4 – 10. A piston 5 can by an input from a motor control system, not shown, be controlled to take different positions in the combustion chamber 7 and thereby vary the volume on the portion under the piston , whereby an essential part of the combustion takes place when fuel is sprayed by the injector 9.

Said different positions are locked in a hydraulic circuit 6. An outlet valve 8 controlled by a cam shaft or by an actuator according to ex.g. patent (SE535886 C2, SE1100435A1) are schematically shown as well as an inlet valve 10, which preferably, but not necessary is opened and closed by an actuator on input from the control system of the engine, with a function according ex.g. any of said mentioned patents. An air mass meter 11 to measure the amount of air being introduced during the intake stroke through the inlet valve 10. The piston 2 is shown in upper turning position where it is prohibited to mechanically contact the cylinder head including the poppet valves 8, 10.

Fig. 2 shows the piston 5 in its upper position where the combustion chamber is at its maximum in size, and the engine can, but must not, be maximally loaded. Still can, as today more or less engine load be taken out depending how much fuel being injected, in such a case with the exhaust emission valid today. It may be advantageously having a little bowl in the piston where the bowl of today is situated, that is directely under the combustion chamber.

Fig. 3 shows a schematic view of the upper part of the cylinder of the engine with cylinder head where the volume of the combustion chamber is adapted to a middle big engine load and with the piston of the engine in its upper turning position after a compression stroke. In princip all air from the intake stroke is pressed into said volume. At the end of the compression stroke a suitable amount of fuel is injected to minimize NOx. Said activities are are controllably performed by the control system of the engine.

Fig. 4 display part of the cylinder 1 with an actuator 4 according to the invention having a step motor 12 with a vertical, upward or downward displaceable shaft 13 running in a chamber 14 filled with hydraulic fluid. Further, there is shown a hydraulic lock 6 consisting of a valve with an opening where the valve is horizontal, left or right, displaceable in chamber 14 or between chamber 14 and below chamber 17 via an electromagnet 16 or other type of electrical element , for opening and closing flow of hydraulic fluid between chamber 14 and a chamber 17 also filled with hydraulic fluid. Further, the piston 5 running in the combustion chamber 7 is shown, which in itself is shown in more detail in Figs. 1-3. The piston has a shaft 18 the upper part of which is present in the chamber 17 and displaceable disposed therein. A chamber 20 with a mechanical spring 19 which makes the piston 5 slidable upwardly by acting between the floor of the chamber and a flange 21 existing on the shaft 18. The valve with its aperture 15 can be displaced in both directions by a double acting electromagnet or in a direction via an electromagnet and in the other direction via a mechanical spring, not shown.

Fig. 5 shows the step motor 12 with the shaft 13 maximally displaced upwards and the piston 5 with the shaft 18 likewise is maximally displaced upwardly. The hydraulic lock with the valve 6 shifted to the right has shut the connection between the chambers 14 and 17. The step motor can not affect the piston 5 in this position.

Fig. 6 shows the hydraulic lock deactivated by the electromagnet repositioning the valve 6 to the left so that its opening 15 creates connection between the hydraulic fluid filled chambers 14 and 17.

Fig. 7 shows that the step motor 12 repositioned the shaft 13 downwardly, thereby pushing hydraulic fluid from the chamber 14 through the opening 15 in the valve 6 to the chamber 17 and thereby pushing the piston shaft 18 with the

piston 5 downwardly under compression of the spring 19. Thus the combustion chamber, not directly illustrated, decreases.

Fig. 8 shows the electromagnet 16 with the valve 6 in a position where the connection between the chambers 14 and 16 is switched of and hence the hydraulic lock is activated. The piston 5 can neither move upwards nor downwards.

Fig. 9 shows the hydraulic lock deactivated.

Fig. 10 shows a position where the step motor 12 has moved the shaft 13 upwards, whereby, by action of the spring 19, hydraulic fluid is pressed from the chamber 17 to 14 and the piston shaft 18 with its piston 5 has been moved upwards.

Actions undertaken by a man skilled in the art have not been described, as the hydraulic fluid is suitably engine oil, how the volume of hydraulic fluid is substantially kept constant, selection and placement of the engine control system, deciding the combustion chamber size, etc. An engine control system is obvious today and therefore it is not mentioned in the claims that the action of the electromagnet and step motor is controlled by the engine control system.

CLAIMS

1. A method to control the size of a combustion chamber (7) by an actuator (4) in the cylinder head (1) of a piston combustion engine, comprising a vertically displaceable piston (5), a chamber (20) with a piston associated shaft (18) having a flange (21) and a spring (19) in the chamber acting between the flange and the chamber floor to reposition the piston (5) in the upward direction, the actuator further comprising two chambers (14) and (17) filled with hydraulic fluid and separated by a valve (16) with an opening (15), wherein the valve being horizontally repositionable via an electromagnet (16), the actuator further comprising a step motor (12) and a shaft (13) vertically displaceable by said step motor in the chamber (14) , **characterized in** that to have the size of the combustion chamber changed the valve is displaced by the electromagnet is so that its opening connects the two chambers.

2. A method according to claim 1, **characterized in** that when the shaft (13) is displaced downwardly by the step motor, hydraulic fluid is forced from the chamber (14) to the chamber (17), wherein the shaft (18) with its piston (5) are displaced downwardly with its piston (5) compressing the spring (19) while reducing the size of the combustion chamber until the repositioning of the shaft (12) is ended.

3. A method according to claim 1 or 2, **characterized in** that when the repositioning of the shaft (13) ends, the valve is displaced with its opening so that the opening no longer connects the two chambers whereby the piston (5) is no longer displaceable.

4. A method according to claim 1, **characterized in** that when the shaft (13) by the step motor is moved upwards, the hydraulic fluid is forced from the chamber (17) to the chamber (14) by the action of the spring (19) on the flange (21) of the shaft (18), wherein the piston (5) is moved upward at the same time as the spring (19) expands in that the size of the combustion chamber increases until displacement of the shaft (13) has come to an end.

5. A method according to claim 1 or 4, **characterized in** that when the displacement of the shaft (13) ends, the valve is displaced with its opening so that the opening no longer connects the two chambers whereby the piston (5) is no longer displaceable.

6. An actuator comprising a combustion chamber (7), a vertically displaceable piston (5), a chamber (20) with a piston associated shaft (18) with a flange (21), a spring (19) between the flange and the chamber floor , two hydraulic fluid chambers (14) and (17), a valve (16) with an opening (15), an electromagnet (16), a step motor (12), a shaft (13) displaceable in the chamber (14)), **characterized in** that to have the size of the combustion chamber changed the valve is displaced so that its opening connects the two chambers.

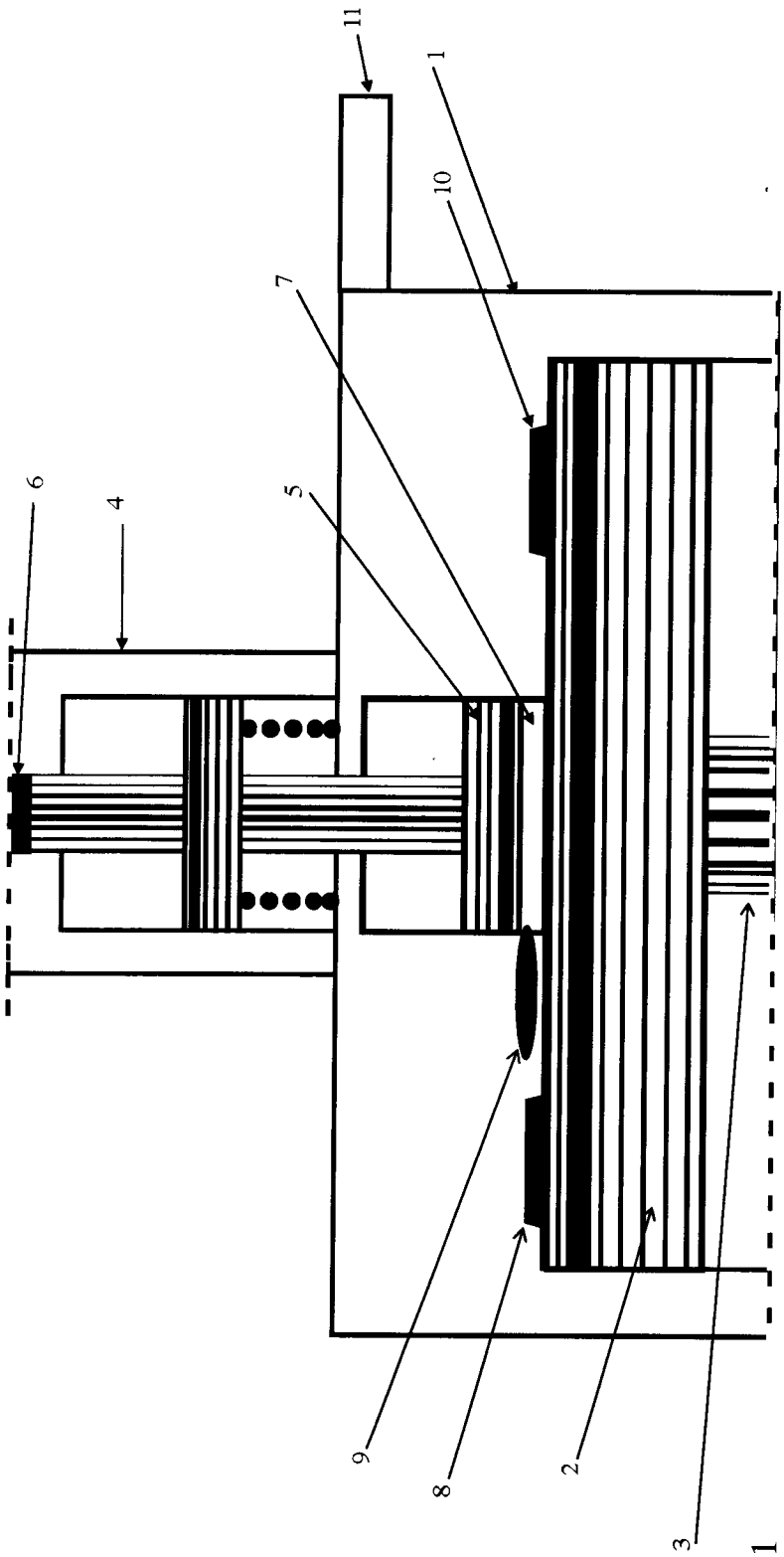

Fig. 1

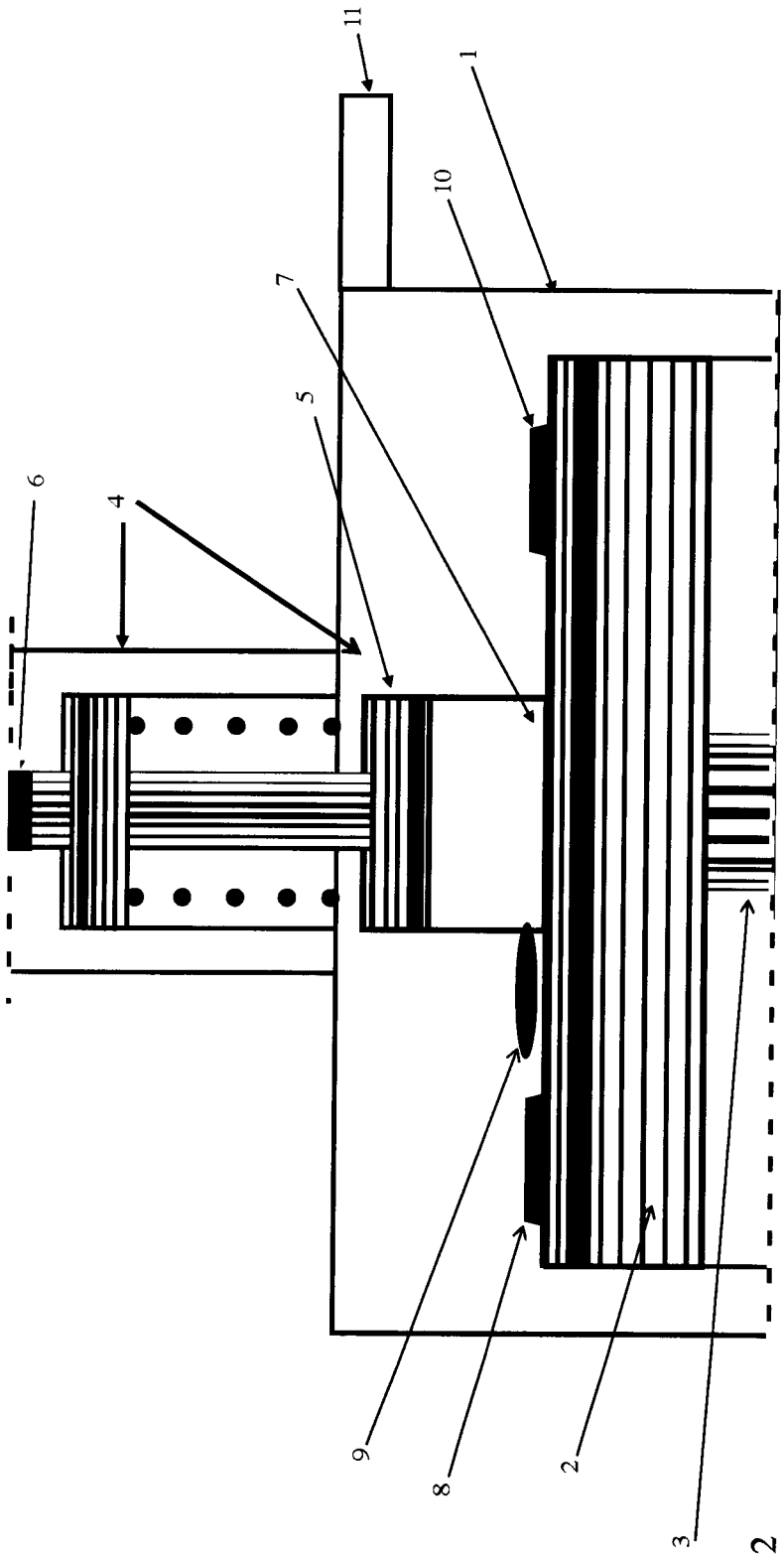

Fig. 2

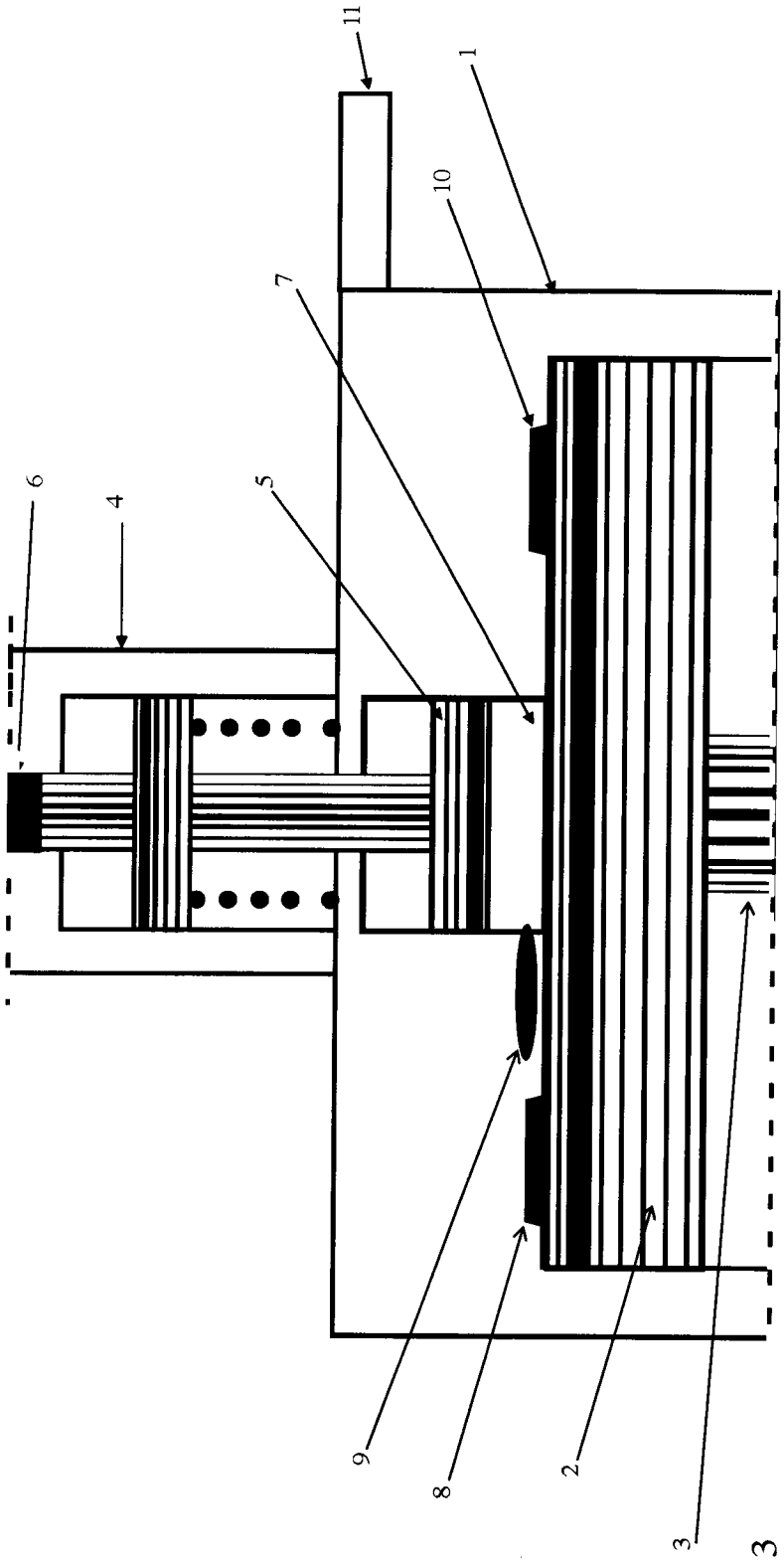

Fig. 3

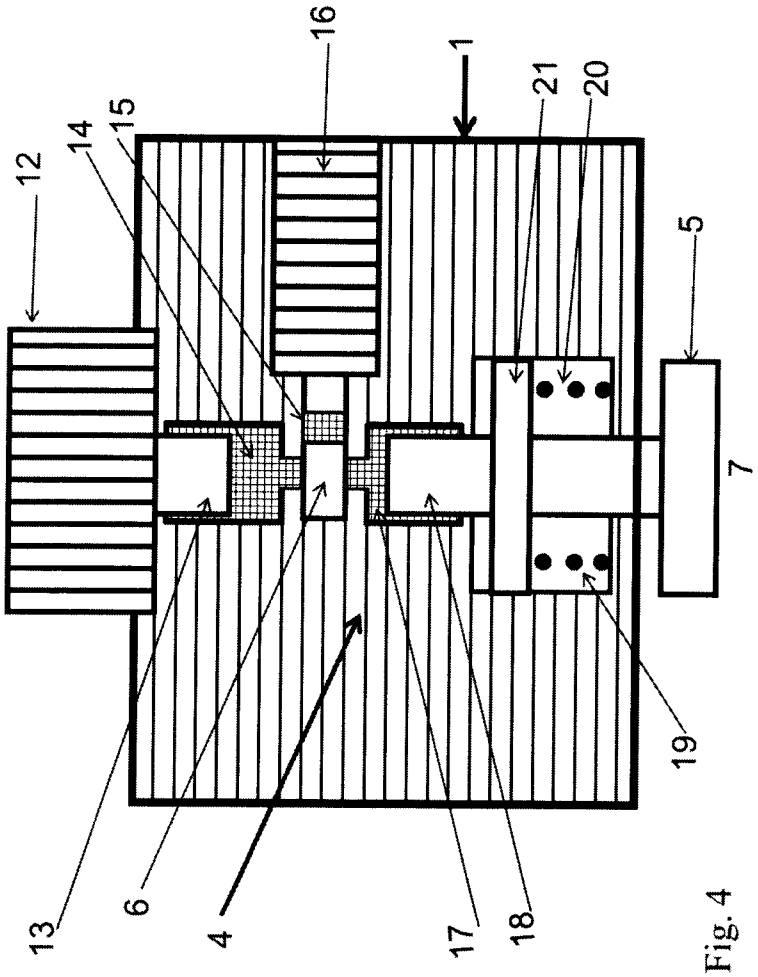

Fig. 4

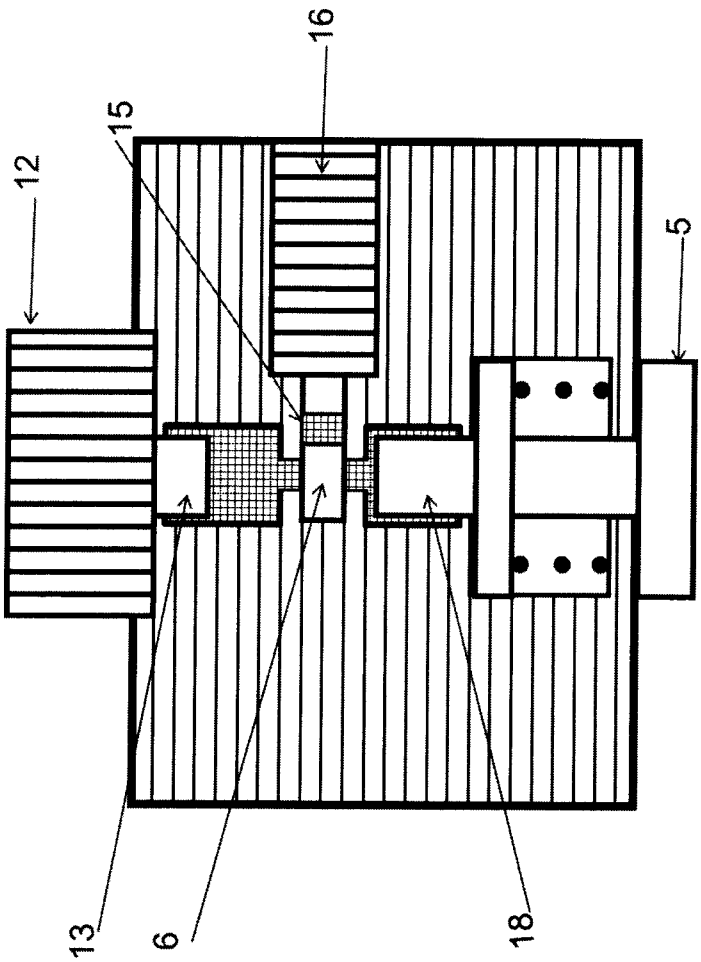

Fig. 5

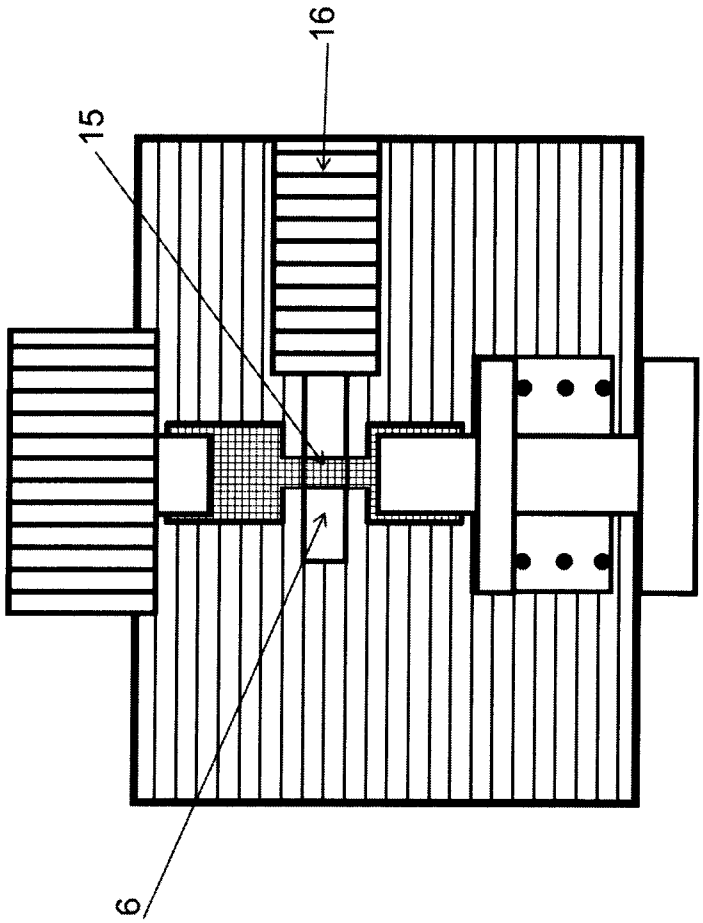

Fig. 6

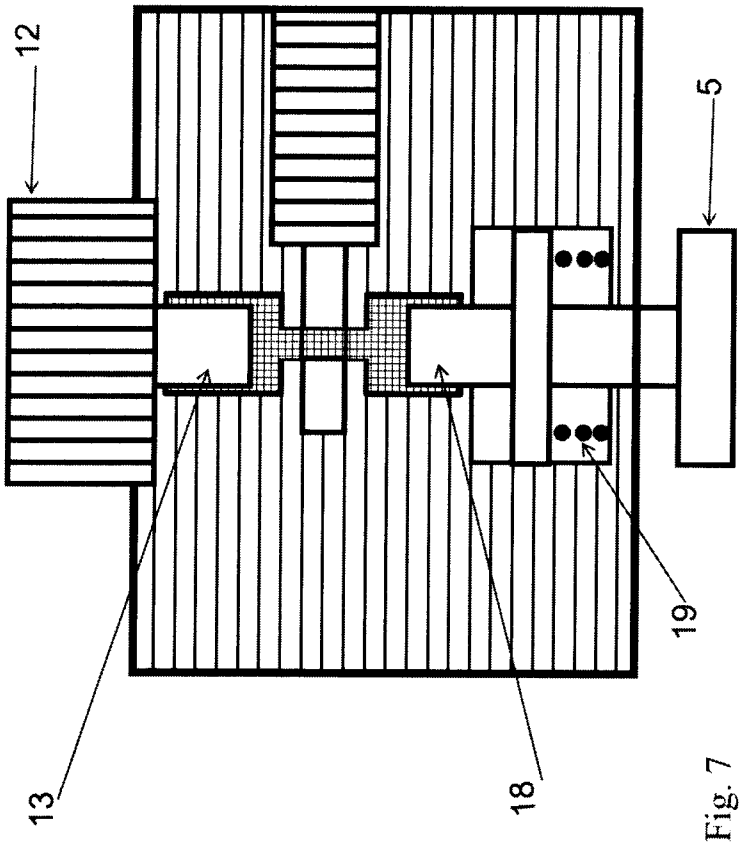

Fig. 7

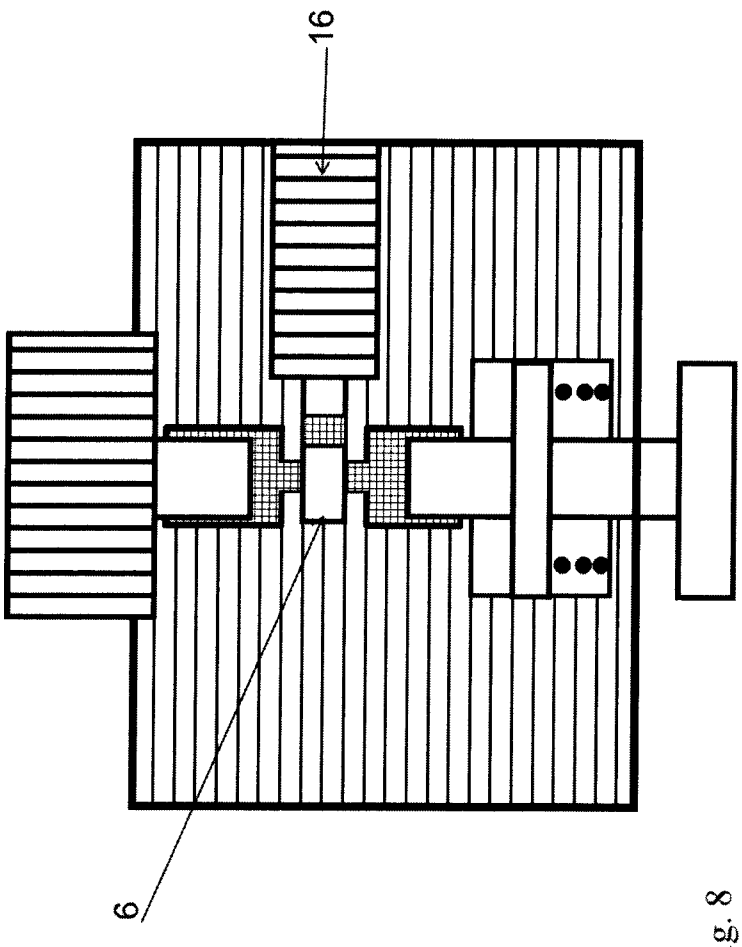

Fig. 8

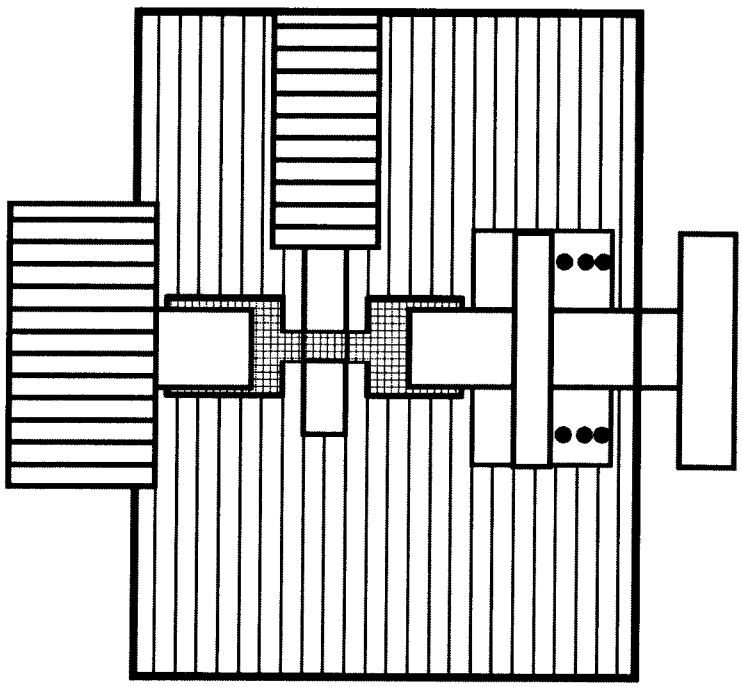

Fig. 9

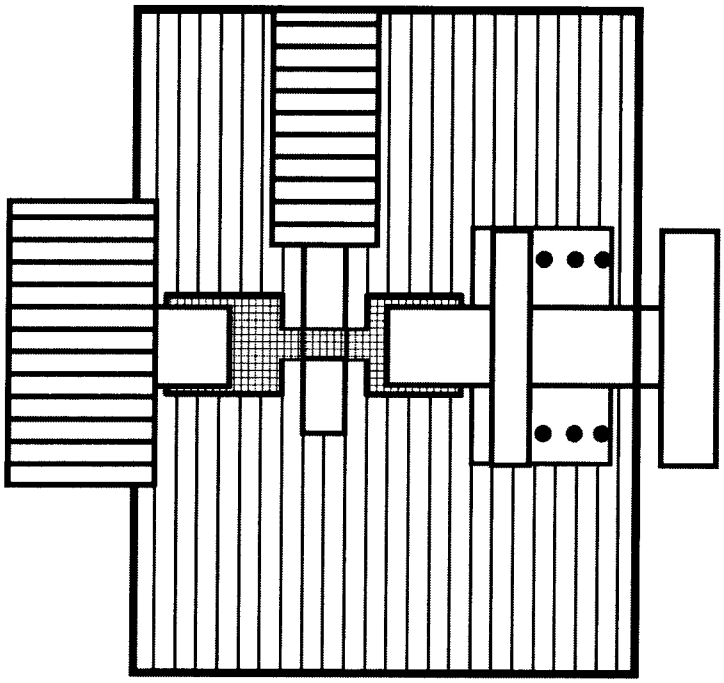

Fig. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2017/000049

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: F02B, F02D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20090223491 A1 (SYED AHMED ET AL), 10 September 2009 (2009-09-10); abstract; paragraph [0036]; figures 1, 5 --	1-6
A	US 20100294244 A1 (FAVENNEC GWENNAEL ET AL), 25 November 2010 (2010-11-25); abstract; paragraph [0050]; figure 2 --	1-6
A	US 20110197859 A1 (WILSON KELCE S), 18 August 2011 (2011-08-18); abstract; paragraphs [0022]-[0027]; figures 1-3 --	1-6
A	US 20040159292 A1 (LAWRENCE KEITH E ET AL), 19 August 2004 (2004-08-19); paragraphs [0064]-[0068], [0084]; figure 11 --	1-6

☒ 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
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"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
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"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
07-03-2018	07-03-2018

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2017/000049

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.

International application No.
PCT/SE2017/000049

Continuation of: second sheet

International Patent Classification (IPC)

F02B 75/04 (2006.01)
F02D 15/04 (2006.01)

US	20090223491	A1	10/09/2009	CN	101970831	A	09/02/2011
				EP	2265808	A2	29/12/2010
				WO	2009109924	A3	26/11/2009
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				FR	2902145	A1	14/12/2007
				JP	2009540187	A	19/11/2009
				WO	2007141434	A1	13/12/2007
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				CN	100394000	C	11/06/2008
				DE	10354842	A1	26/08/2004
				US	7055469	B2	06/06/2006