May 28, 1946. D. C. PRINCE 2,401,188

INTERNAL-COMBUSTION ENGINE WITH VARIABLE COMPRESSION RATIO

Filed March 1, 1943 2 Sheets-Sheet 1

Fig. 1.

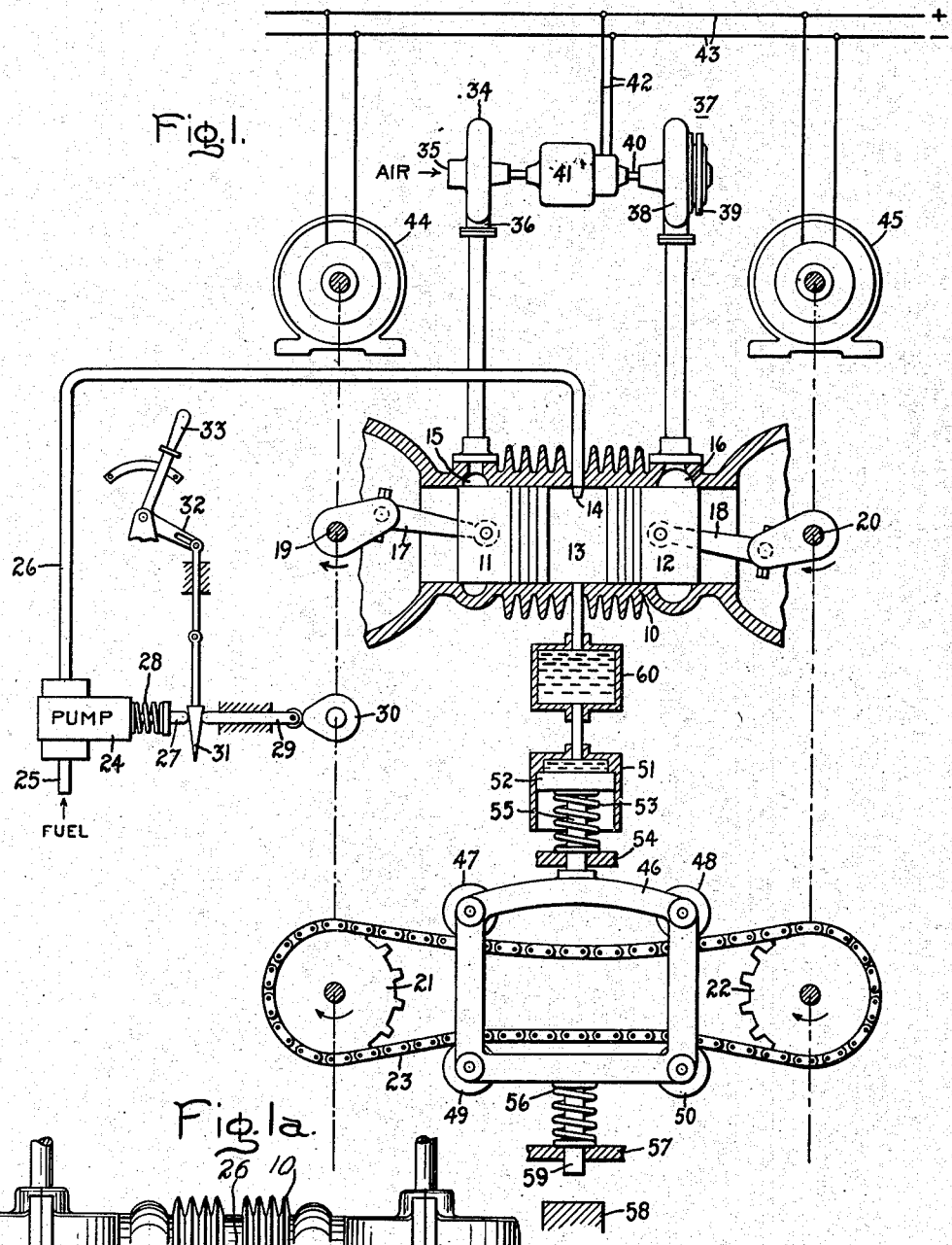
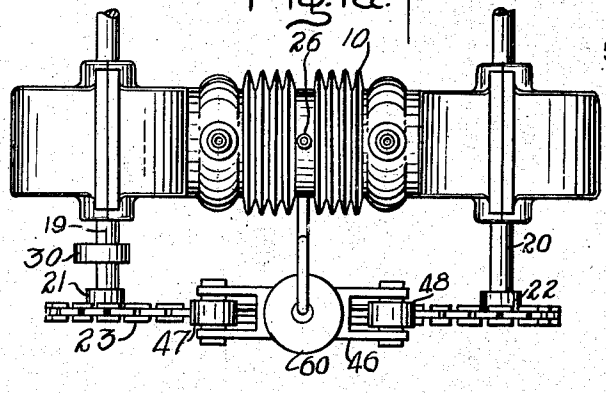



Fig. 1a.



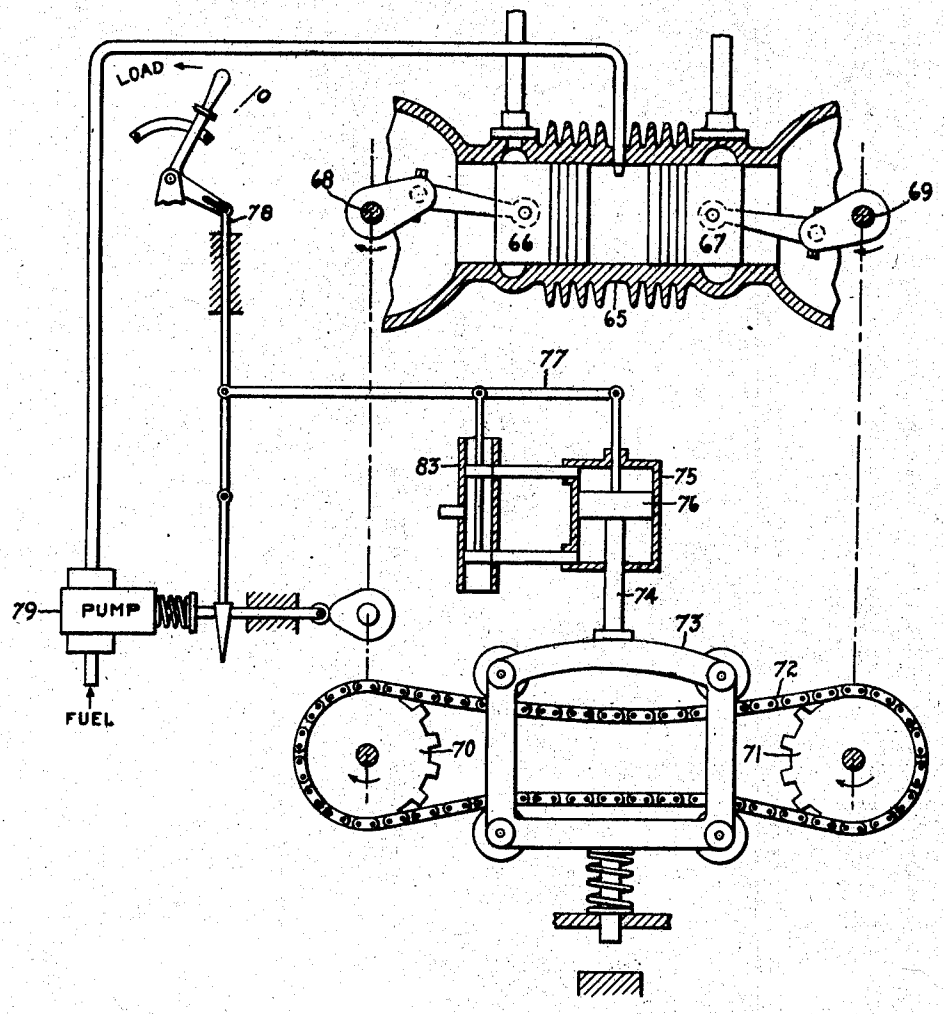

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Fig. 2.




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# UNITED STATES PATENT OFFICE

2,401,188

## INTERNAL-COMBUSTION ENGINE WITH VARIABLE COMPRESSION RATIO

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7 Claims. (Cl. 123—48)

The present invention relates to internal combustion engines with variable compression ratio of the type having a pair or pairs of pistons with a common combustion chamber for each pair and separate drive or crank shafts connected to the pistons of each pair together with means for adjusting the angular relation of the drive or crank shafts.

One object of my invention is to provide an improved construction and arrangement of the above type of combustion engines. Another object of my invention is to provide an improved mechanism for controlling engines with variable ratio compression whereby better efficiency and economy are obtained.

This is accomplished in accordance with my invention by an arrangement including means for controlling the compression ratio in response to load changes on the engine to operate the engine at high compression ratio during starting and at low load and at low compression ratio when the engine is hot and carrying high load.

For a better understanding of what I believe to be novel and my invention, attention is directed to the following description and the claims appended thereto in connection with the accompanying drawings.

In the drawings Fig. 1 illustrates diagrammatically a supercharged internal combustion engine of the solid fuel injection type such as a Diesel engine embodying my invention, Fig. 1*a* is an assembly view of certain parts of Fig. 1, and Fig. 2 illustrates a modification according to my invention.

The arrangement comprises a cylinder 10 with a pair of opposed pistons 11, 12 disposed therein and forming between them a common combustion and compression space 13 to which fuel is supplied by means including a nozzle 14. The left-hand portion of the cylinder 10 forms a supply port 15 for compressed air and the right-hand portion of the cylinder 10 forms an exhaust port 16 through which gases may be discharged from the cylinder. The pistons 11, 12 are connected by rods 17 and 18 respectively, to separate drive shafts 19 and 20 respectively. The compression ratio in an arrangement of this kind depends on the phase relation between the pistons 11 and 12, maximum compression ratio being obtained when the pistons are in synchronism, that is, reach simultaneously their inner dead-center positions. In order to maintain certain phase relationships between the pistons 11, 12 means are provided for interconnecting the shafts 19 and 20. This is accomplished in the present instance by sprockets 21 and 22 secured to the shafts 19 and 20 respectively and connected by a chain 23.

Fuel is forced through the aforementioned nozzle 14 by means of a fuel pump 24 which has an inlet conduit 25 for connection to a source of fuel and a discharge conduit 26 connected to the nozzle 14. The pump is of the reciprocating type with a plunger 27 biased outward by a spring 28 and actuated by means of an actuating rod 29 from a cam 30 fastened to the drive shaft 19. A wedge 31 is interposed between the pump plunger 27 and the actuating rod 29 and may be positioned by means including a bell crank 32 with a handle 33 to vary the fuel supply. In the position shown the fuel supply is at a minimum and may be increased upon counterclockwise turning movement of the bell crank 32.

Air under pressure is supplied to the cylinder 10 through the port 15 by means of a blower 34 having an inlet 35 for receiving air from the atmosphere and an outlet 36 connected to the port 15. The blower 34 is driven by an exhaust gas operated turbine 37 which has a nozzle box 38 connected to receive gases exhausted from the port 16 of the cylinder 10 and a bucket wheel 39 secured to a shaft 40 for driving the blower 34. An electric machine 41 is provided with its rotor secured to the shaft 40 and its stator connected by conductors 42 to a power line 43. Other electrical machines 44 and 45 are mechanically connected to the drive shafts 19 and 20 respectively and electrically connected to the line 43.

During operation compressed air for maintaining combustion is supplied to the cylinder 10 from the blower 34, the supply being controlled by movement of the piston 11. After combustion of the fuel supplied through the nozzle 14 burned gases are discharged through the port 10, the discharge being controlled by the piston 12. The exhaust gases are utilized to operate the turbine 37 for driving the blower 34, and also the machine 41 which latter during normal operation acts as a generator supplying electric energy to the line 43. Likewise, the machines 44 and 45 act normally as generators for converting mechanical energy in the drive shafts 19, 20 into electrical energy and supplying it to the line 43. At low engine speed and during starting the machine 41 acts as a motor fed from the line 43 and aiding the turbine 37 to drive the blower 34.

During starting when the engine is cold and also at low engine speed a high compression ratio is necessary to assure ignition. At high engine speed and high load output it is desirable to re-

duce the compression ratio in the interest of best efficiency and economy. Also, lower compression ratio reduces the wear and tear on the engine. Finally, if the engine is supercharged at a low compression ratio it can handle a great deal more air. Hence, more fuel can be burned, and the output can be materially increased without the drawback of maximum pressure ratio during normal operation. This is accomplished in accordance with my invention by the provision of means for automatically varying the angular relation between the shafts 19 and 20 in response to load changes on the engine. To this end I provide a mechanism for turning the sprockets 21, 22 in opposite directions in response to load changes on the engine. The mechanism diagrammatically shown in the drawings includes a rectangular frame or support 46, with rollers 47, 48, 49 and 50 rotatably supported on the frame. The rollers 47, 48 engage the upper side of the upper portion of the chain 23, and the rollers 49, 50 engage the lower side of the lower portion of the chain 23. The sprockets 21, 22 as indicated by arrows rotate normally in clockwise direction and their angular relation is normally fixed by their connection through the chain 23. Downward movement of the frame 46 tends to aid the clockwise rotation of the sprocket 21 and at the same time tends to retard or counteract the rotation of the sprocket 22. Thus, by forcing the frame 46 downward the angular relation between the sprockets 21, 22 and accordingly the pistons 11, 12 may be changed to reduce the ratio of compression in the cylinder 10.

Upon downward movement of the frame 46 both pistons 11, 12 are moved to the right substantially equal amounts and no change of compression between them takes place in this instance. This applies only to the particular position shown and not to the relative position in which maximum compression is reached, that is, in which the two pistons are nearest to each other. In the position shown both pistons are moving towards the center, that is, towards their inner dead-center positions. If now piston 11 is moved to the right by clockwise turning movement of the sprocket 21 the piston 11 will reach its dead-center position earlier. On the other hand, if piston 12 is also moved to the right, that is, away from its dead-center position, it will reach such dead-center position later. Hence, if one piston reaches the dead-center position earlier and the other one later, the phase angle between the pistons must increase and the compression or the compression ratio consequently must decrease.

Upward movement of the frame 46 likewise causes a change of the compression ratio except that in this case the sprocket 21 is retarded and the sprocket 22 is accelerated, causing a phase displacement of the pistons in a direction opposite of that accomplished upon downward movement of the frame 46. In one case the piston 11 reaches its dead-center position first and in the other case the piston 12 reaches its dead-center position first. According to my invention, the adjustment is made in one side of the condition for which the pistons arrive simultaneously at their upper dead-center. If the pistons do not arrive simultaneously the compression ratio is reduced regardless of which piston arrives at dead-center first. When the pistons are not perfectly synchronized the exhaust and intake ports are not simultaneously uncovered by their respective pistons. If the pistons are dephased to reduce the compression ratio the dephasing is preferably in the direction to advance the relative phase of the piston uncovering the exhaust port. This permits high pressure gas to exhaust before the intake port is opened.

In the arrangement shown in Fig. 1 vertical movement of the frame 46 is accomplished by means responsive to changes of the pressure in the cylinder 10. This means includes a cylinder 51 with a piston 52 biased upward by a compression spring 53 engaging at its upper end the piston 52 and at its lower end a fixed support 54. The piston 52 has a stem 55 secured to the frame 46. The lower portion of the frame is supported by another compression spring 56 engaging at its upper end the frame and at its lower end another fixed support 57. Downward movement of the frame is limited by a stop 58 cooperatively associated with a projection 59 secured to the frame 46. The pressure chamber formed above the piston 52 communicates with the compression space 13 through a vessel 60. This vessel and the pressure chamber in the cylinder 51 are preferably filled with a liquid such as oil to dampen the transmission of pressure variations during each cycle of the engine. During operation increase of the mean pressure in the compression space 13 due to increase in load on the engine causes downward movement of the frame 46, thereby increasing the phase angle between the shafts 19 and 20 to reduce the compression ratio of the engine. Similarly, a decrease in compression effects upward movement of the piston 52 by action of the springs 53 and 56 to reduce the angular displacement of the shafts 19, 20 and thereby to increase the compression ratio of the engine. The springs 53 and 56 are preferably so proportioned that the compression ratio will not be reduced until the explosion pressure in the engine exceeds a predetermined pressure required for ignition and maximum efficiency. Any higher pressure with its associated higher temperature would cause losses due to excessive radiation and disassociation of gases. The effect of disassociation is to prevent actual combustion from taking place during part of the power stroke and power that would otherwise be generated by complete combustion is therefore lost.

The arrangement of Fig. 2 comprises a cylinder 65 corresponding to the cylinder 10 of Fig. 1 and including two opposed pistons 66, 67 connected to drive shafts 68, 69 respectively corresponding to the drive shafts 19, 20 of Fig. 1 and connected by sprockets 70, 71 and a chain 72. The angular relation between the drive shaft 68, 69 may be varied by positioning of a frame 73 engaging the chain 72 and corresponding to the frame 46 of Fig. 1. The frame 73 together with the chain 72 and the sprockets 70, 71 broadly constitute gear means for varying the angular relation between the shafts 68, 69. Whereas in the arrangement of Fig. 1 the frame 73 is moved in response to changes of the mean pressure in the engine cylinder, in the arrangement of Fig. 2 such movement of the frame 73 is accomplished in response to changes of the fuel supply to the cylinder 65. To this end the frame 73 is connected to a stem 74 of a hydraulic motor 75 having a piston 76 connected to the stem 74 and to the right-hand end of a floating follow-up lever 77. The left-hand end of the lever 77 is pivoted to a rod 78 for controlling the operation of a fuel pump 79 corresponding to the pump 24 of Fig. 1. An intermediate point of the

lever 77 is connected to a pilot valve 83 for controlling the supply of operating fluid under pressure to the hydraulic motor 75. With this arrangement upward movement of the rod 78 to increase the fuel supply causes clockwise turning movement of the lever 77 whereby the pilot valve 83 is moved upward and fluid under pressure is supplied to the upper side of the piston 76 and discharged from the lower side thereof, resulting in downward movement of the piston 76 and the frame 73 to decrease the compression ratio of the engine. Similarly, downward movement of the rod 78 to decrease the fuel supply to the engine causes counterclockwise turning movement of the lever 77 about its right-hand end and downward movement of the pilot valve to increase the supply of fluid under pressure to the lower side of the piston 76 and to discharge fluid under pressure from the upper side thereof, resulting in upward movement of the piston 76 and the frame 73 to reduce the compression ratio of the engine. Upon movement of the piston 76 the pilot valve 83 is restored to its normal line in line position.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Internal combustion engine arrangement comprising cylinder means having a supply and an exhaust port, two pistons disposed in the cylinder means and forming a common compression space therewith, separate drive shafts connected to the pistons, gear means for connecting the drive shafts to maintain certain angular relations between them, and means responsive to changes of the mean pressure in the cylinder means to vary the angular relation between the drive shafts and in order to reduce compression ratio with increasing mean pressure and vice versa.

2. Internal combustion engine arrangement comprising cylinder means having a supply and an exhaust port, two pistons disposed in the cylinder means and forming a common compression space therewith, means for supplying fuel to the compression space, separate drive shafts connected to the pistons, sprockets secured to the drive shafts and connected by chain means, and means responsive to changes of fuel supply cooperatively associated with the chain means to vary the angular relation between the drive shafts in order to reduce compression ratio with increased fuel supply and vice versa.

3. Internal combustion engine arrangement comprising a cylinder, two opposed pistons in the cylinder, separate drive shafts connected to the pistons, means including a pump actuated from one of the drive shafts for supplying fuel under pressure to the combustion spaced formed between the pistons, means for controlling the fuel supply, separate sprockets secured to the drive shafts and a chain connecting the sprockets to maintain certain angular relations between the drive shafts, means cooperatively associated with the chain to vary the angular relation of the drive shafts, and means responsive to load changes on the engine for controlling the last named means.

4. Internal combustion engine arrangement comprising a cylinder, two opposed pistons in the cylinder forming a combustion space between them, separate drive shafts connected to the pistons, means including a pump actuated from one of the drive shafts for supplying fuel under pressure to the combustion space, means for controlling the fuel supply, separate sprockets secured to the drive shafts and a chain connecting the sprockets to maintain certain angular relations between the drive shafts, means cooperatively associated with the chain to vary the angular relation of the drive shafts, and a hydraulic motor having a pressure chamber communicating with the compression space to actuate the last named means in order to reduce the compression ratio with increasing load above a predetermined explosion pressure and vice versa.

5. Internal combustion engine arrangement comprising a cylinder having a supply port and an exhaust port, opposed pistons movable in the cylinder and controlling said ports, separate drive shafts connected to the pistons, means for supplying fuel to the combustion chamber formed between the pistons comprising a reciprocating pump actuated from one of the drive shafts, means for controlling the pump to vary the fuel supply, gear means connecting the drive shafts to maintain certain angular relations between them, and means for controlling the gear means to vary the angular relation between the drive shafts in order to reduce the compression ratio in response to movement of the pump control means comprising a hydraulic motor having a piston connected to the gear means and a pilot valve for the motor connected to the pump control means.

6. Internal combustion engine arrangement according to claim 1 including a gas turbine having an inlet connected to the exhaust port, a blower driven by the gas turbine and connected to the supply port, separate generators driven from the drive shafts, an electric line connected to the generators, and an electric motor connected to the electric line for driving the blower during starting and adapted to be driven by the gas turbine and operated as a generator during normal operation.

7. Internal combustion engine arrangement comprising cylinder means having a supply and an exhaust port, two pistons disposed in the cylinder means and forming a common compression space therewith, separate drive shafts connected to the pistons, gear means for connecting the drive shafts to maintain certain angular relations between them, and means responsive to load changes on the engine to vary the angular relation between the drive shafts in order to reduce the compression ratio with increasing load and vice versa, electric generator means driven from the drive shafts, a motor connected to the generator means, and a blower driven by the motor for supplying air under pressure to the supply port.

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