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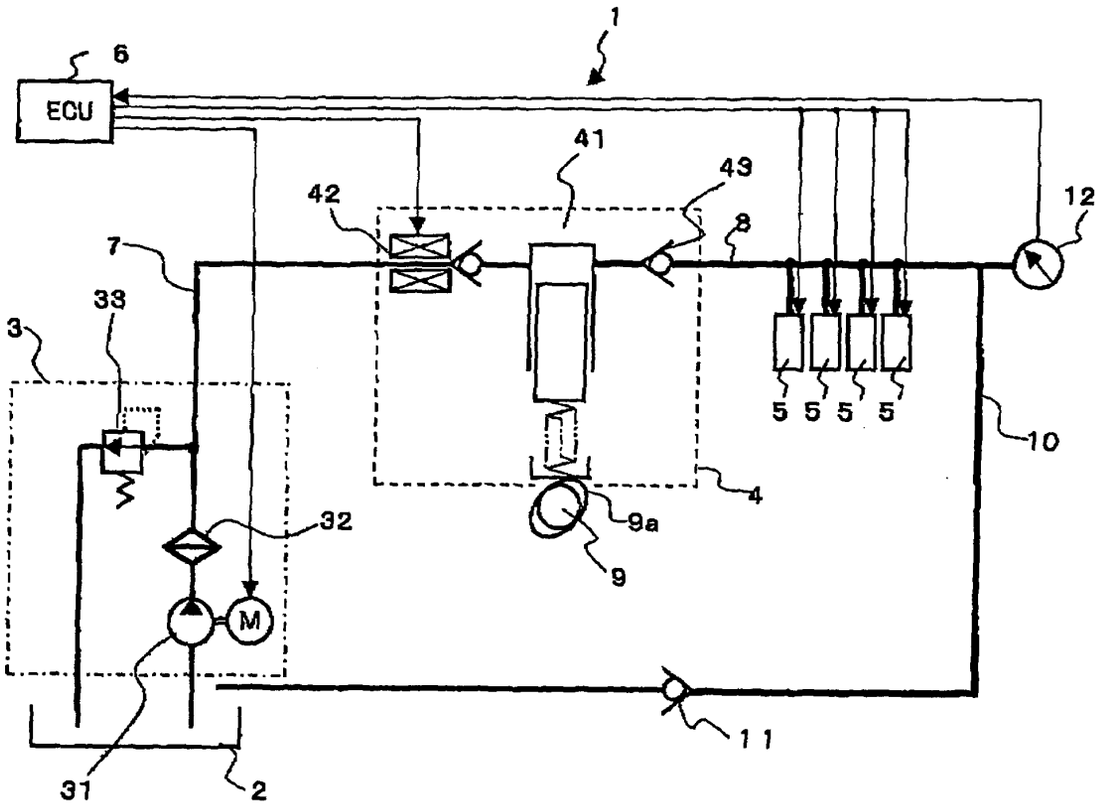
(54) Fuel pump

(57) In a fuel pump (4), two independent seal members (44,45) are disposed to seal a clearance between an inner surface (411a) of a cylinder (411) and an outer surface (412a) of a plunger (412). At least a sliding portion of the seal member (45) with the plunger (412), being closer to a pressure chamber (413) among two seal members (44,45), is made of abrasion resistance material.

FIG. 1



EP 1 355 059 A2

Description

Field of the Invention

[0001] The present Invention relates to a fuel pump that supplies pressurized fuel to an internal combustion engine and in particular, to a technology of improving a seal performance of the fuel pump with regard to lubricant and fuel therein.

background of the Invention

[0002] In an internal combustion of a cylinder-direct-fuel injection type that directly injects fuel into a cylinder, a pressure of the fuel supplied from a fuel tank to a fuel injector needs to be pressurized to a sufficiently high pressure (for example, 3-12 Mpa) by a fuel pump. Accordingly, a mechanical fuel pump connected to a camshaft is used along with the pump. This mechanical fuel pump, in general, includes a pump-driving cam mounted to a camshaft for opening and closing an intake valve or an exhaust valve and pressurizes fuel therein by reciprocating a plunger in a cylinder by rotation of the camshaft.

[0003] A Japanese Unexamined Patent Publication No. 8 - 68370 has disclosed the mechanical fuel pump where a seal member contacts an outer surface of a plunger with a lip portion thereof to prevent lubricant for sliding the plunger from mixing with the fuel.

Summary of the Invention

[0004] Since the above earlier fuel pump has one single seal member to prevent mixing the lubricant with the fuel, the fuel pump has the following problems when applied to an engine with a high engine output and a large exhaust amount.

[0005] In the engine with the high engine output and the large exhaust amount, a plunger-stroke amount needs to increase corresponding to an increase of a fuel-flow amount required for the engine. As a result, a distance of a sliding movement of a plunger-outer surface to a seal member becomes longer and therefore, durability of the seal member needs to improve further.

[0006] A flow of the lubricant and the fuel is mostly prevented by the seal member. However, a preciously small amount thereof is left as a thin liquid film between the plunger-outer surface and the seal member and when a plunger reciprocates, this preciously small amount thereof passes through the seal member. Accordingly, when the plunger-stroke amount increases, a region where the lubricant directly contacts the fuel is enlarged, thereby promoting mixing the lubricant with the fuel. As a result of mixing the lubricant with the fuel, the lubricant mixed with the fuel bums and therefore, an exhaust gas emission deteriorates or the lubricant is diluted by the fuel mixed, thereby worsening a lubrication performance thereof.

[0007] One aspect of the present invention, in view of the foregoing problems, provides a fuel pump where even when a stroke length of a plunger in a fuel pump increases, durability of a seal member does not deteriorate and mixing lubricant with fuel is properly prevented.

[0008] Therefore, the present invention provides a fuel pump that pressurizes fuel and supplies a pressurized fuel to an internal combustion engine, comprising:

a cylinder;
a pressure chamber defined in an end side of the cylinder;
a plunger that is slidably inserted into the cylinder, the plunger pressurizing the fuel in the pressure chamber by reciprocal thereof;
a first seal member that seals a clearance between an inner surface of the cylinder and an outer surface of the plunger; and
a second seal member that is situated closer to the pressure chamber than the first seal member, the second seal member sealing the clearance between the inner surface of the cylinder and the outer surface of the plunger, wherein an abrasion resistance material is used for at least a portion of the second seal member in whose portion the second seal member slides with the plunger.

[0009] The other aspects and features of this invention will become understood from the following description with accompanying drawings.

Brief Explanation of the drawings

[0010] Fig. 1 is a schematic structural view of a fuel supply apparatus in an internal combustion engine which a fuel pump according to the invention is applied to.

[0011] Fig. 2 is a structural view of a high-pressure-fuel pump of a first embodiment according to the invention.

[0012] Fig. 3 is a fragmentary view of explaining an operation of a first seal member and a second seal member in relation to lubricant and fuel movement in a clearance defined between an inner surface of a cylinder and an outer surface of a plunger.

[0013] Fig. 4 is a structural view of a high-pressure-fuel pump of a second embodiment according to the invention.

[0014] Fig. 5 is a structural view of a high-pressure-fuel pump of a third embodiment according to the invention.

[0015] Fig. 6 is an enlarged view of A-portion in Fig. 5 showing the first seal member for lubricant formed of a seal lip structure.

Detailed Description of the Preferred Embodiments

[0016] Fig. 1 is a schematic structural view of a fuel supply apparatus in an internal combustion engine which a fuel pump according to the invention is applied to. Fig. 2 is a structural view of a high-pressure-fuel pump of a first embodiment according to the invention. As shown in Fig.1, the fuel supply apparatus comprises a fuel tank 2, a low-pressure-fuel pump unit 3, a high-pressure-fuel pump 4, an injector 5, and an engine control unit (ECU) 6. Low-pressure-fuel pump unit 3 and high-pressure fuel pump 4 are connected by a low-pressure-fuel passage 7, and high-pressure-fuel pump 4 and injector 5 are connected through a high-pressure-fuel passage 8.

[0017] Low-pressure-pump unit 3 is disposed in fuel tank 2, including a feed pump 31, a fuel filter 32, and a low-pressure-pressure regulator 33. Feed pump 31 discharges fuel in fuel tank 2 and fuel filter 32 percolates the fuel discharged from feed pump 31. Low-pressure-pressure regulator 33 bypasses low-pressure-fuel passage 7 and adjusts a pressure of the fuel discharged from feed pump 31 to a certain pressure (low pressure).

[0018] High-pressure-fuel pump 4 pressurizes the fuel adjusted by low-pressure-fuel pump unit 3 to a sufficiently high pressure for supply to injector 5, including, as shown in Fig. 1 and 2, a pump body 41, an electromagnetic control valve 42, and a discharge check valve 43.

[0019] Pump body 41 is mounted to a cylinder head of the engine, including a cylinder 411, a cylindrical plunger 412 slidably inserted into cylinder 411, and a pressure chamber 413 that is defined by an inner wall surface forming an upper closed end of cylinder 411 and a crest surface of plunger 412.

[0020] Plunger 412 is disposed forming a predetermined insert clearance between an outer surface 412a of plunger 412 and an inner surface 411a of cylinder 411 and a bottom end thereof is connected to a lifter 414. Lifter 414 is regularly forced against a camshaft 9 (for example, an intake valve-driving or an exhaust valve-driving camshaft) having a pump-driving cam 9a by a return spring 415, Rotation of camshaft 9 causes plunger 412 to reciprocate in the Arrow Y - Y' direction of Fig. 2 and to pressurize fuel introduced to pressure chamber 413.

[0021] Pressure chamber 413 is connected to a fuel supply passage 417 through one connection portion 416 and connected to a fuel discharge passage 419 through the other connection portion 418. Fuel supply passage 417 is connected to low-pressure-fuel passage 7 and fuel discharge passage 419 is connected to high-pressure-fuel passage 8. Connection passage 416 that connects pressure chamber 413 to fuel supply passage 417 is opened and closed by electromagnetic control valve 42. A valve body 422 changes from a valve closed position where valve body 422 is seated by spring force of a return spring 421 to a valve opened position to which valve body 422 is moved against return spring 421 by energizing a solenoid 423 of electromagnetic control valve 42.

[0022] On the other hand, Connection passage 418 that connects pressure chamber 413 to fuel discharge passage 419 is opened and closed by discharge check valve 43. A valve body 432 changes from a valve closed position where valve body 432 is pushed against connection passage 418 by spring force of return spring 431 of discharge check valve 43 to a valve opened position to which valve body 432 is moved against return spring 431 due to fuel pressure in pressure chamber 413 being higher than fuel pressure in high-pressure-fuel passage 8.

[0023] In the embodiment, two independent seal members are disposed in an open end side of cylinder 411 (opposite side to pressure chamber 413) for sealing a clearance between inner surface 411 a of cylinder 411 and outer surface 412a of plunger 412. One of the two seal members disposed to the side of pump-driving cam 9a is a seal member 44 for lubricant (first seal member) mainly preventing leakage of the lubricant introduced into the pump for lubricating pump-sliding portions and the other thereof disposed to the side of pressure chamber 413 is a seal member 45 for fuel (second seal member) mainly preventing leakage of the fuel.

[0024] A distance L between seal member 44 for lubricant and seal member 45 for fuel is set longer than a stroke amount (length) of plunger 412 reciprocated by rotation of camshaft 9. A rigid seal material made of abrasion resistance material (for example, fluorine resin) is preferably used as both seal member 44 and seal member 45 and in the embodiment, heat resistance and abrasion resistance Teflon (registered trade mark) is used only for seal member 45 for fuel (Teflon is used as an entire material of seal member 45 or as a partial coating portion such as a sliding portion).

[0025] The reason Teflon is used only for seal member 45 for fuel is that (1) seal member 45 is under more severe condition due to seal member 45 being exposed directly to high pressure of pressure chamber 413, and (2) a seal material made of Teflon is in general expensive, but a rigid seal material can be used for both seal members 44, 45.

[0026] A space 46 that is defined by inner surface 411a of cylinder 411, outer surface 412a of plunger 412, seal member 44, and seal member 45 is connected to a return passage 60 that returns extra fuel in the pump to fuel tank 2. Thereby the pressure taking place in space 46 can be escaped.

[0027] A first fuel reservoir 48 is defined on the side of pressure chamber 413 of seal member 45 by inner surface 411 a of cylinder 411, outer surface 412a of plunger 412, and seal member 45. First fuel reservoir 48 is connected to the return passage 60 through second connection passage 49. This causes the pressure taking place in pressure chamber 413 by reciprocal of plunger 412 to be lowered and not to be conveyed di-

rectly to seal member 45, as well as to be returned to fuel tank 2 without the fuel staying In first fuel reservoir 48.

[0028] A second fuel reservoir 50 that has a wider clearance in the diameter direction between cylinder 411 and plunger 412 than the other insert clearance therebetween is defined on a sliding portion of cylinder 411 and plunger 412, being closer to the side of pressure chamber 413 than first fuel reservoir 48. Second fuel reservoir 50 is connected to fuel supply passage 417 through a third connection passage 51. This causes the pressure taking place in pressure chamber 413 by reciprocal of plunger 412 to be escaped, as well as the fuel to recirculate. Second fuel reservoir 50 is formed by disposing a groove on inner surface 411a of cylinder 411 and/or outer surface 412a of plunger 412.

[0029] Back in Fig. 1, injector 5 is disposed for each cylinder of the engine, is controlled to be opened in response to a pulse signal sent from ECU 6 in a predetermined injection timing and injects fuel-pressure adjusted fuel into a combustion chamber of each cylinder. If the fuel pressure becomes high due to failure of fuel supply apparatus 1, the fuel is returned to fuel tank 2 through a relief passage 10 and a relief valve 11. ECU 6 executes a predetermined calculation processing based upon input signals from various sensors including fuel pressure sensor 12 disposed in high-pressure-fuel passage 8 and executes various controls such as a fuel injection control.

[0030] An operation of fuel supply apparatus 1 as described above will be explained. The fuel in fuel tank 2 is adjusted to a predetermined low pressure by low-pressure-fuel pump unit 3 and sent out to low-pressure fuel passage 7.

[0031] During an intake stroke wherein plunger 412 goes down based upon a profile of pump-driving cam 9a (direction of Arrow Y' in Fig. 2), electromagnetic valve 42 is controlled to be opened by ECU 6 (power supply to solenoid 423). This causes the fuel sent out to low-pressure fuel passage 7 to be introduced to pressure chamber 413 through fuel supply passage 417. At this moment, the fuel pressure in high-pressure-fuel passage 8 is higher than the fuel pressure introduced to pressure chamber 413 and therefore, discharge check valve 43 is in a closed position.

[0032] On the other hand, during a discharge stroke wherein plunger 412 goes up based upon the profile of pump-driving cam 9a (direction of Arrow Y in Fig. 2), electromagnetic valve 42 is controlled to be closed by ECU 6 (to stop power supply to solenoid 423). An amount of the fuel discharged from high-pressure-fuel pump 4 is adjusted by adjusting valve-closing timing of electromagnetic valve 42. After electromagnetic valve 42 is closed, the fuel introduced into pressure chamber 413 is pressurized accompanied by raising plunger 412. When the fuel pressure in pressure chamber 413 is higher than the fuel pressure in high-pressure-fuel passage 8, discharge check valve 43 is opened to discharge the high-pressure fuel, which then, is sent out to injector 5 through high-pressure-fuel passage 8.

[0033] During this discharge stroke, the pressure occurring in pressure chamber 413 is released to fuel supply passage 417 or the return passage that has a lower pressure respectively through third connection passage 51 or second connection passage 49. Accordingly, the entirety of the pressure occurred is not transmitted to seal member 45 passing through the insert clearance between cylinder 411 and plunger 412.

[0034] Outer surface 412a of plunger 412 slides with the seal members by reciprocating movement of plunger 412. However, since two independent seal members that are seal member 44 for lubricant and seal member 45 for fuel are provided, seal performance can improve by using the seal material suitable for each purpose thereof. And also each seal member does not slide being immersed in both lubricant and fuel, thereby making a long life thereof.

[0035] Further, since in the embodiment, seal member 45 for fuel that is subjected to a direct influence of the pressure occurring in pressure chamber 413 is made of a rigid seal using an abrasion resistance material, durability of seal member 45 can be maintained. Accordingly, if a stroke amount of plunger 412 becomes longer, a good seal performance can be maintained for a long time.

[0036] When plunger 412 reciprocates, most of the lubricant and the fuel are respectively stopped by seal member 44 for lubricant and seal member 45 for fuel. However, the lubricant is left as a thin film between outer surface 412a of plunger 412 and seal member 44 and on the other hand, the fuel is left as a thin film between outer surface 412a of plunger 412 and seal member 45, Therefore, a very slight amount of the lubricant and the fuel moves from the outside of space 46 to the inside thereof accompanied by reciprocal of plunger 412.

[0037] In the embodiment, a distance L between seal member 44 and seal member 45 is longer than a stroke amount of plunger 412, causing the region in which the lubricant and the fuel pulled into space 46 mix directly to be minimized.

[0038] During an intake stroke wherein plunger 412 goes down, as shown in Fig. 3 (a), the fuel is pulled in space 46, as well as the lubricant and the fuel existing in space 46 are taken out. During a discharge stroke wherein plunger 412 goes up, as shown in Fig. 3 (b), the lubricant is pulled in space 46, as well as the lubricant and the fuel existing in space 46 are taken out. If space 46 is closed up tightly, when an amount of the lubricant and the fuel pulled in space 46 become larger than an amount thereof taken out from space 46 due to variations in seal performance and viscosity change, the pressure in space 46 rises up to give an abnormal force on seal member 44 and seal member 45 and as a result, as shown in Fig. 3 (c), the seal members are deformed in the outside direction of space 46 or broken, thereby damaging seal performance.

[0039] In the embodiment, however, space 46 is connected to the return passage 60 through first connection passage 47 so that the pressure occurring in space 46 escapes to prevent an abnormal pressure from being provided on seal member 44 and seal member 45. Accordingly, durability of seal member 44 and seal member 45 can improve.

[0040] As described above, according to a fuel pump of the embodiment, even when applied to an engine with a high output and a large exhaust capacity, a stable, good seal performance of seal members is maintained for a long period of time and mixing lubricant with fuel is minimized.

[0041] In the above explanation, space 46 is connected to the return passage 60 through first connection passage 47, but, not limited to the return passage, space 46 may be connected to a passage the pressure of which is lower than in space 46.

[0042] Fig. 4 is a structural view of a high-pressure-fuel pump according to a second embodiment. The second embodiment differs in that first and second connection passages 47, 49 are made convergent and are thereafter connected to the return passage (not shown) from the first embodiment and has the same construction with the first embodiment in the other elements and has the same effects with the first embodiment.

[0043] Fig. 5 is a structural view of a high-pressure-fuel pump according to a third embodiment. The third embodiment differs in that a seal member having a seal lip structure is used as a seal member 44' for lubricant and there is no first connection passage 47 therein from the first and second embodiments (the same construction in other elements).

[0044] Seal member 44' for lubricant having the seal lip structure comprises, as shown in Fig. 6 (a), a seal lip 441 made of rubber and a hold member 442 for holding the seal lip wherein hold member 442 is fixed into inner surface 411 a of cylinder 411 by pressure and the like, or as shown in Fig. 6 (b), comprises a seal lip 443 with no hold member having a X-type shape lacking one piece thereof wherein seal lip 443 is Inserted into a groove 411b formed in an inner surface of cylinder 411. Ether type thereof may be used. A surface of the seal lip (441 or 443), at least a portion thereof sliding with outer surface 412a of plunger 412 is preferably coated with heat resistance and abrasion resistance material such as Teflon.

[0045] Seal lip 441, or 443, as shown in Fig. 6 (a), (b), extends slantingly in the direction of lubricant side (in the direction of pump-driving cam 9a side) and contacts outer surface 412a of plunger 412. Accordingly, the pressure in space 46' defined by inner surface 411 a of cylinder 411, outer surface 412a of plunger 412, seal member 44' having a seal lip structure, and seal member 45 can be easily escaped.

[0046] Therefore, when the pressure in space 46' closed rises up, seal lip 441 or 443 of seal member 44' is temporarily deformed, thereby escaping the pressure to avoid deformation of seal member 45 for fuel. After the pressure is escaped, seal lip 441 or 443 is returned back to the former shape and continues to maintain a stable, good seal performance.

[0047] In the embodiment, it is explained that space 46' is closed up tightly (namely where there is no first connection passage 417), but space 46' may be connected to a passage such as the return passage the pressure of which is lower than in space 46' in the same as in the first and second embodiments.

[0048] This application claims priority to Japanese Patent Application No. 2002-118424 filed April 19, 2002. The entire disclosure of Japanese Patent Application No. 2002 - 118424 is hereby incorporated herein by reference.

[0049] While only selected embodiments have been chosen to illustrate the present invention, it will be apparent to those skilled in the art from this disclosure that various changes and modifications can be made herein without departing from the scope of the invention as defined in the appended claims.

[0050] Furthermore, the foregoing description of the embodiments according to the present invention is provided for illustration only, and not for the purpose of limiting the invention as defined by the appended claims and their equivalents. Moreover, features of the different embodiments may be combined.

Claims

1. A fuel pump (4) that pressurizes fuel and supplies a pressurized fuel to an internal combustion engine comprising:

   a cylinder (411);
   a pressure chamber (413) defined in an end side of the cylinder (411);
   a plunger (412) slidably inserted into the cylinder (411), the plunger (412) pressurizing the fuel in the pressure chamber (413) by reciprocal of the plunger (412);
   a first seal member (44) that seals a clearance between an inner surface (411a) of the cylinder 411 and an outer surface (412a) of the plunger (412); and
   a second seal member (45) disposed closer to the pressure chamber (413) than the first seal member (44), the second seal member (45) sealing the clearance between the inner surface (411a) of the cylinder (411) and the outer surface (412a) of the plunger (412) wherein at least a sliding portion of the second seal member (45) with the plunger (412) is made of abrasion resistance material.

2. A fuel pump (4) according to claim 1, wherein a distance between the first seal member (44) and the

second seal member (45) is longer than a stroke amount of the plunger (412).

3. A fuel pump (4) according to claim 1 or 2, wherein a space (46) defined by the inner surface (411a) of the cylinder (411), the outer surface (412a) of the plunger (412), the first seal member (44), and the second seal member (45) is connected to a passage a pressure of which is lower than a pressure in the space (46).

4. A fuel pump (4) according to claim 3, wherein the passage is a return passage (60) that returns an extra remaining fuel back to a fuel tank (2).

5. A fuel pump (4) according to any of claim 1 - 4, wherein the abrasion resistance material is made of Teflon.

6. A fuel pump according to any of claim 1 - 5, wherein at least the first seal member (44') out of the first seal member (44') and the second seal member (45) has a seal lip structure where a front end of the first seal member (44') is in contact with the outer surface (412a) of the plunger (412).

FIG. 1

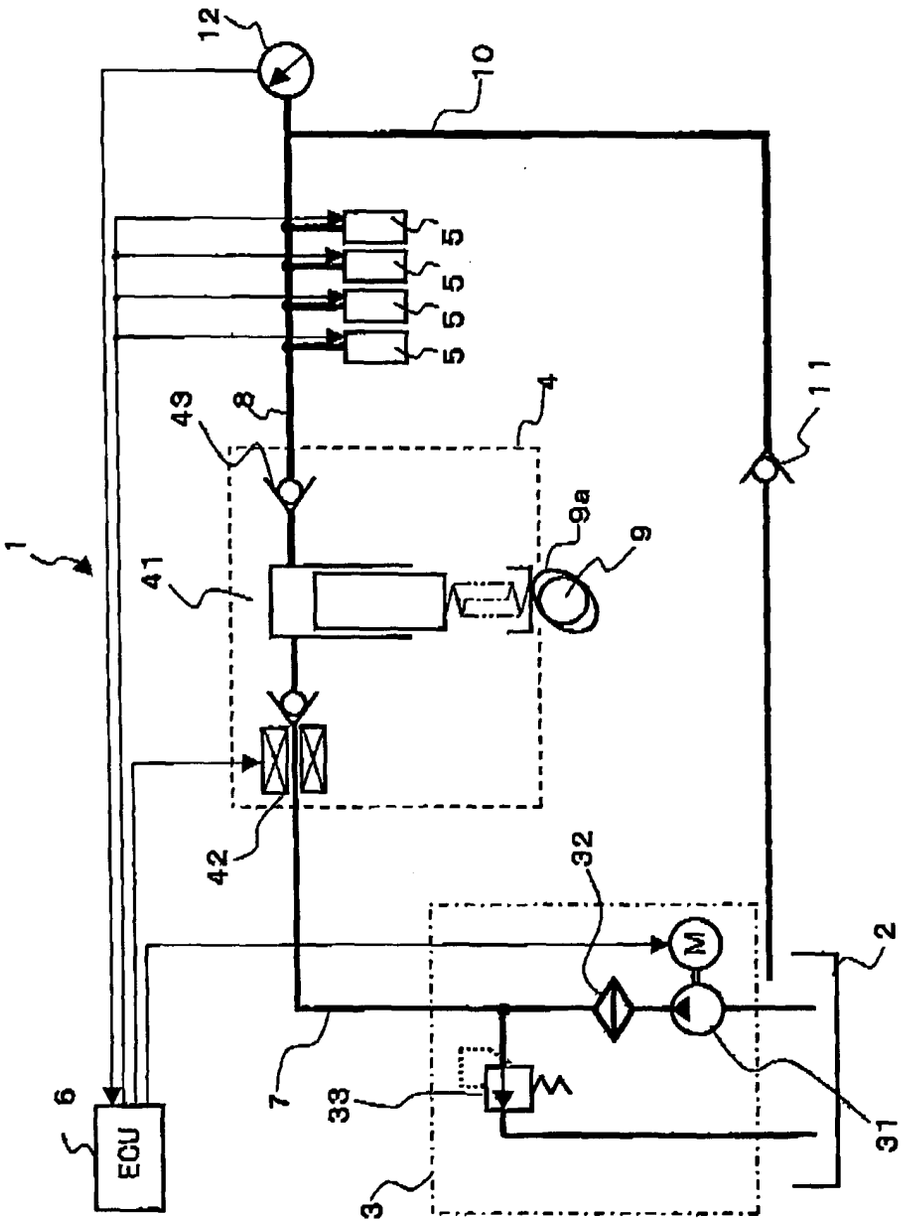


FIG. 2

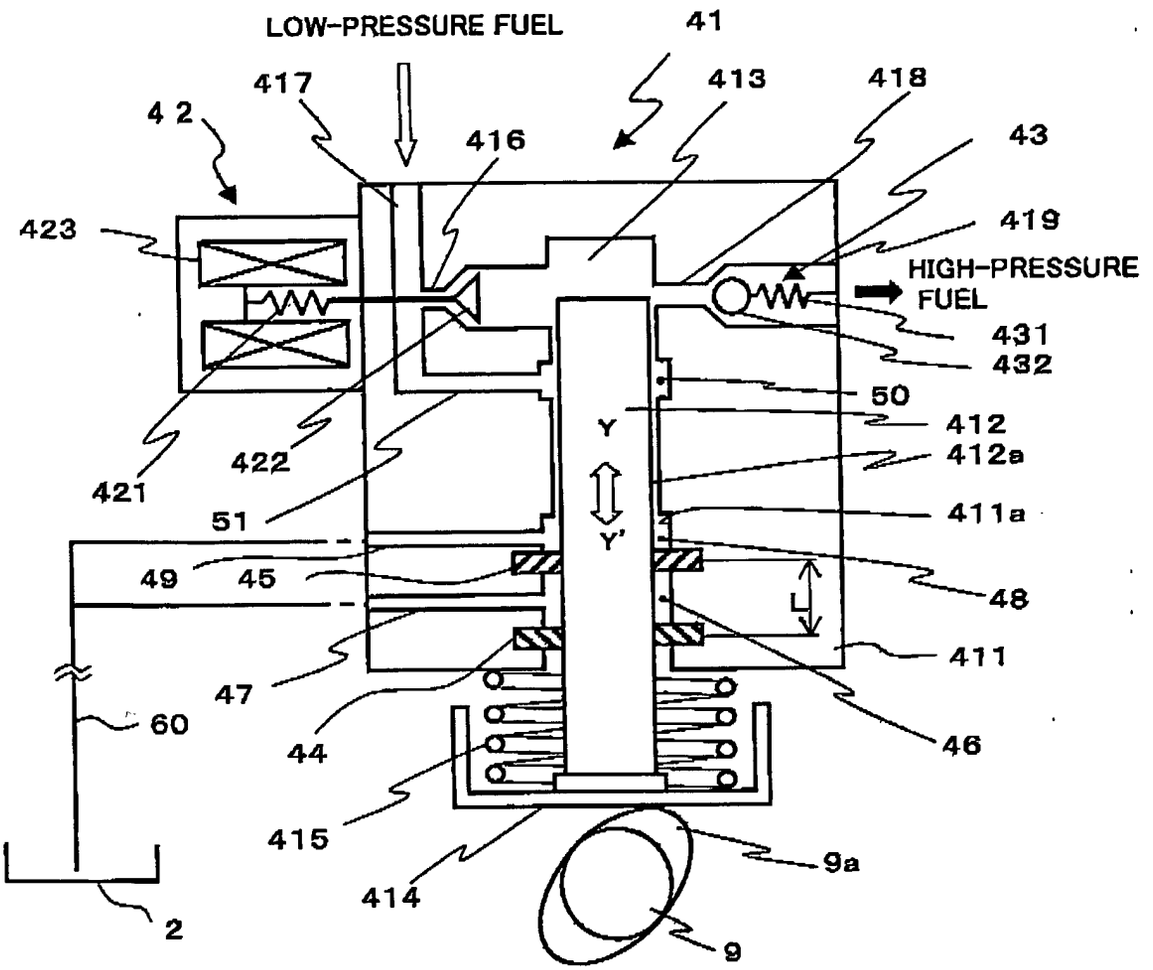

LOW-PRESSURE FUEL
41
417
413
418
42
416
43
423
419
HIGH-PRESSURE FUEL
431
432
50
412
Y
412a
422
421
411a
51
Y'
49
45
48
L
411
47
60
46
44
415
9a
414
2
9

FIG. 3

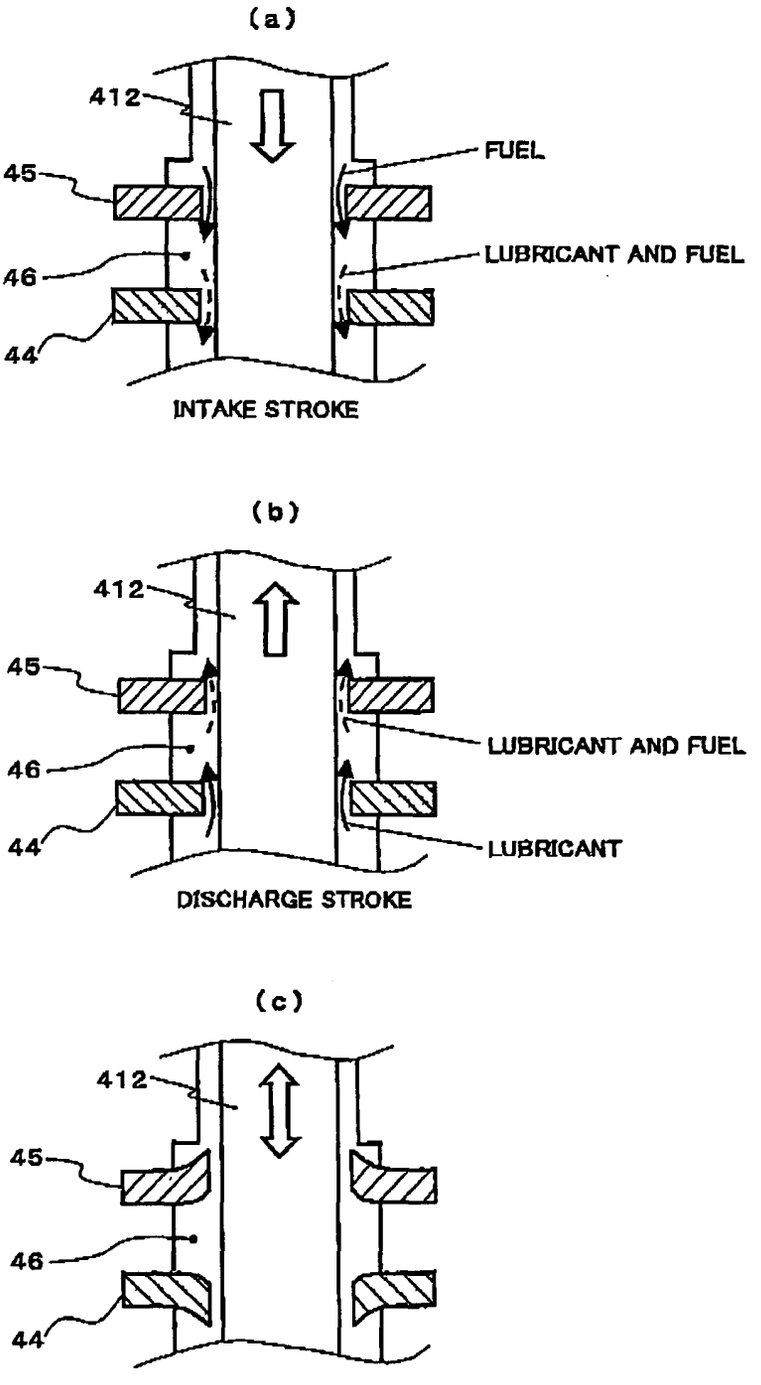

(a)
412
FUEL
45
LUBRICANT AND FUEL
46
44
INTAKE STROKE
(b)
412
45
LUBRICANT AND FUEL
46
44
LUBRICANT
DISCHARGE STROKE
(c)
412
45
46
44

FIG. 4

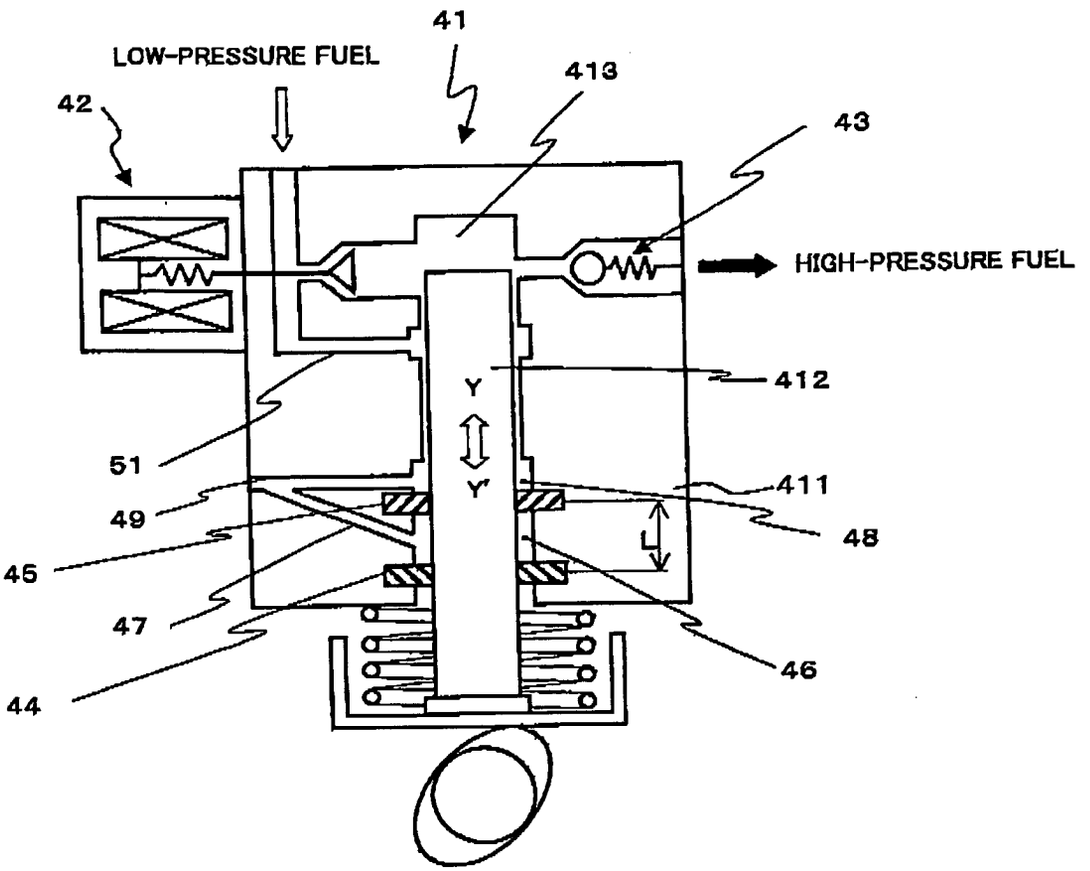

41
LOW-PRESSURE FUEL
413
42
43
HIGH-PRESSURE FUEL
412
Y
Y'
51
411
49
48
45
L
47
46
44

FIG.5

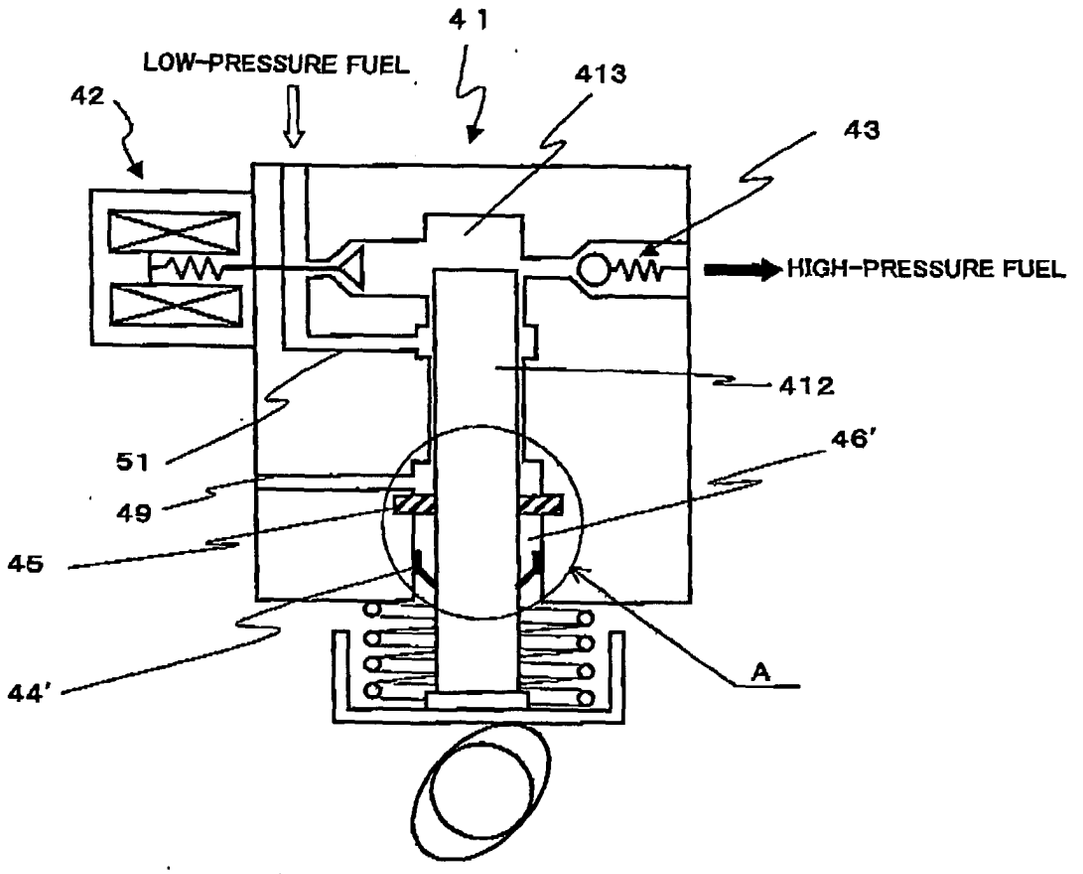
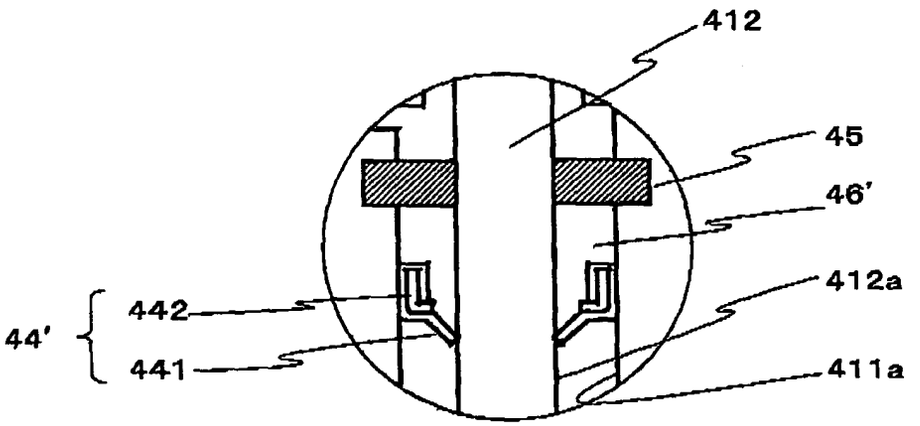

41
LOW-PRESSURE FUEL
413
42
43
HIGH-PRESSURE FUEL
412
51
46'
49
45
44'
A

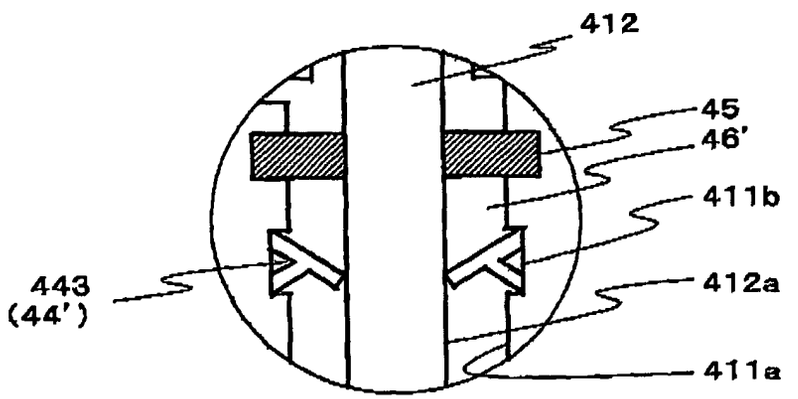
FIG. 6

(a)



ENLARGEMENT OF A-PORTION IN FIG. 5

(b)



ENLARGEMENT OF A-PORTION IN FIG. 5