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(54) **Anti-bounce mechanism for fuel injectors**

(57) A solenoid actuated valve assembly (130) includes a pintle (132) having a valve (136) that seals against a valve seat (118), an armature (134) slidably positioned on the pintle (132), a first (138) and a second (140) armature stopper that allow and limit axial movement of the armature (134) relative to the pintle (132), a primary spring (160) providing a biasing down force to the pintle (132) and to the armature (134), and a secondary spring (162) providing a smaller biasing down force to the armature (134) only. The anti-bounce mechanism for solenoid actuated fuel injectors reduces valve bounce and the impact load between the valve seat (118) and the valve (136) while at the same time enabling the reduction of the pintle (132) opening time. The anti-bounce mechanism utilizes the separation of the moving masses of the armature (134) and the pintle (132), a biased armature, as well as hydraulic damping and suction mechanisms in combination.

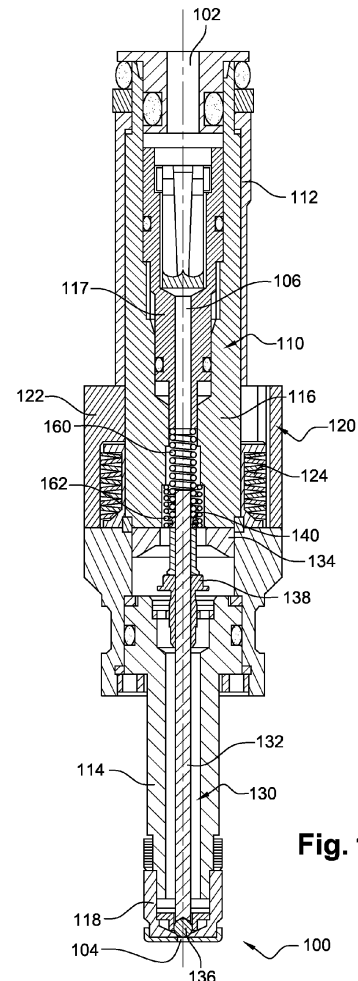


Fig. 1

Description

TECHNICAL FIELD

[0001] The present invention relates to fuel injectors for delivery of fuel to the combustion chamber of an internal combustion engine; more particularly, to solenoid actuated fuel injectors; and most particularly, to an anti-bounce mechanism for such fuel injectors.

BACKGROUND OF THE INVENTION

[0002] It is most desirable, in a modern internal combustion engine, to precisely control the flow of fuel to the combustion chamber, in order to meet performance requirements as well as emission regulations. Fuel injection arrangements may be divided generally into multi-port fuel injection, wherein fuel is injected into a runner of an air intake manifold ahead of a cylinder intake valve, and direct injection, wherein fuel is injected directly into the combustion chamber of an engine cylinder, typically during or at the end of the compression stroke of the piston. Direct injection is designed to allow greater control and precision of the fuel charge to the combustion chamber, resulting in better fuel economy and lower emissions. This is accomplished by enabling the combustion of a precisely controlled charge of fuel under various operating conditions. Direct injection is also designed to allow higher compression ratios, delivering higher performance with lower fuel consumption compared to other fuel injection systems

[0003] Current high pressure direct injection fuel injectors typically use either inwardly opening valves (nozzle type or multi-hole director type) in conjunction with solenoid actuation or outwardly opening valves using piezo-electric actuation. The piezo-electric actuated injector has demonstrated the highest potential for reducing fuel consumption, but the cost of the piezo-stack and driver is currently prohibitive for high volume applications.

[0004] In contrast to piezo-electric operated, solenoid actuated fuel injectors are much cheaper to produce, but known solenoid actuated fuel injectors currently cannot provide the same level of performance as piezo-electric actuated devices, mainly due to the lower opening force achievable by electromagnetic solenoid actuators and the slower rise of operating force over time. Generally, a solenoid actuated fuel injector incorporates a solenoid armature located between the pole piece of the solenoid and a fixed valve seat, wherein the armature operates a movable valve assembly. Electromagnetic fuel injectors of the pulse-width type meter fuel per electric pulse at a rate proportional to the width of the electric pulse. In a normally closed injector, when an injector is de-energized, its moveable valve assembly is released from one stop position and accelerated by a spring towards the opposite stop position, located at the valve seat. The distance in which the valve assembly travels from its upper position with solenoid energized to the valve-seated po-

sition constitutes the stroke of the injector.

[0005] A particular problem with known solenoid actuated fuel injectors when operated at high speed is valve bounce. As applied to fuel injectors, the term "bounce" refers to the condition where the movable valve assembly bounces off the valve seat one or more times after initial impact. When closing the injector at high speed, the impact of the pintle head (valve) against the valve seat can be substantial due to the relatively large mass of the armature connected to the pintle opposite from the pintle head and due to the force exerted on the pintle by the return spring. Due to the elasticity of the sealing surfaces, after making initial contact with its seat, the valve tends to rebound from the valve seat, causing the injector to reopen. Such valve bounce is generally undesirable because it can cause unwanted fuel injections in the form of unmetered after-injections of fuel delivery after initial injector closing. Such unmetered after-injections may have a deleterious effect on emissions and fuel economy since the additional unmetered amounts of fuel supplied by the after-injections may not be fully combusted.

[0006] This problem is particularly acute in direct injection injectors because direct injection typically requires a relatively high fuel pressure to operate against the internal pressures developed inside the combustion chamber. For example, a direct injection gasoline injector requires a pressure as high as 1700 psi or higher to operate while a typical port fuel injector requires only a pressure of approximately 60 psi to operate. These higher operational and combustion chamber pressures require the exertion of higher magnetic and spring forces on the valve assembly for proper operation. In turn, the higher forces result in greater valve bounce. Also, since the opening and closing times of a direct injection fuel injector must be less than in multi-port fuel injectors in order to meet minimum and maximum flow requirements, valve bounce in a direct injector is greater.

[0007] In addition, the impact force of the reciprocating valve assembly on the valve seat must be minimized to avoid excessive seat and valve wear during the lifetime of the fuel injector and to minimize valve leakage.

[0008] Currently, squeeze film damping is utilized in solenoid actuated fuel injectors to reduce valve bounce and impact force by carefully controlling the gap between the armature and the surfaces in which the armature comes in contact with during its stroke. Such gaps are required to be controlled to about 20 μm . Manufacturing and adjusting such air gaps have proven to be very expensive and difficult to control, particularly when coefficients of thermal expansion of the various components are taken into consideration.

[0009] Other prior art dampening methods employ a dampening device, for example a disk spring or an elastic cushion such as a rubber ring, positioned between the armature and the pintle to reduce bounce of the valve at the valve seat. The device allows some movement of the armature relative to the pintle for energy adsorption. While in this case the valve wear and bounce may be

reduced, the speed at which the valve can open is not optimized.

[0010] In addition, the stroke through which the movable valve assembly operates also affects the amount of valve bounce. The accuracy at which the pole piece and the fixed valve seat can be positioned relative to each other and the consistency at which the valve assembly stroke can be set is therefore important.

[0011] What is needed in the art is a solenoid actuated fuel injector that can be operated under relatively high pressure with minimum or no valve bounce and that achieves the same performance as a piezo-electric actuated device.

[0012] It is a principal object of the present invention to greatly reduce valve bounce in a fuel injector and to reduce the impact load between valve and valve seat.

[0013] It is a further object of the invention to reduce the valve opening time of a solenoid actuated fuel injector without employing a higher magnetic force.

SUMMARY OF THE INVENTION

[0014] The present invention proposes a solenoid actuated valve assembly, comprising:

a pintle including a valve for mating with a valve seat; an armature slidably positioned on said pintle opposite from said valve;

a first armature stopper and a second armature stopper both rigidly attached to said pintle at a distance from each other and configured to allow axial movement of said armature relative to said pintle;

a primary spring providing a first biasing force to said pintle and to said armature when said armature is in contact with said second armature stopper; and

a secondary spring providing a second biasing force to said armature only, wherein said second biasing down force is lower than said first biasing down force.

[0015] Briefly described, an anti-bounce mechanism for solenoid actuated fuel injectors in accordance with the invention greatly reduces the occurrence of valve bounce and the impact load between the valve seat and the valve while at the same time reducing the valve opening time. The anti-bounce mechanism utilizes the separation of the moving masses of the armature and the pintle, a biased down armature, as well as squeeze damping and hydraulic suction mechanisms in combination.

[0016] In the case of an inwardly opening fuel injector, the armature is designed to axially slide over the pintle. The movement of the armature is limited by first and second armature stoppers attached to the pintle.

[0017] A secondary spring being set to a lower force than the primary spring of the fuel injector is utilized to permit acceleration of the armature during the opening phase of the fuel injector prior to movement of the pintle by the armature, which reduces the opening time of the injector.

[0018] In the closing direction, since the armature can move independently, the armature continues a downward movement after the valve initially contacts the seat. The continued downward motion of the armature makes a delayed contact with the first armature stopper and acts against an upwards motion of the valve as the valve rebounds from the valve seat. Furthermore, since the armature is moving in the fuel passage and, therefore in a fluid, a hydraulic suction force acts between the armature and the second armature stopper and a squeeze dampening force acts between the armature and the first armature stopper during the continued downward motion of the armature at valve closing.

[0019] According to other features of the present invention:

- said primary spring is captured between said second armature stopper and a housing of said solenoid actuated valve assembly;
- said secondary spring is captured between said armature and a housing of said solenoid actuated valve assembly;
- said armature has a generally cylindrical shape;
- said armature includes a center aperture that slidably receives an outer circumferential surface of said pintle, said center aperture is configured to guide a reciprocating axial movement of said armature on said pintle;
- at least one of said first armature stopper and said second armature stopper is joined with said pintle by press fitting and subsequent welding;
- said first armature stopper includes a radially extending shoulder that faces said armature;
- it includes a solenoid assembly, wherein said armature moves from said first armature stopper towards said second armature stopper against said second biasing down force of said secondary spring upon activation of said solenoid assembly, and wherein said armature makes contact with said second armature stopper and said pintle is configured to move together with said armature against the combined first and second biasing down forces of said primary and said secondary spring;
- it includes a solenoid assembly, wherein after deactivation of said solenoid assembly said primary spring pushes said pintle and said armature concurrently until said valve contacts said valve seat, wherein said armature continues to travel downwards, and wherein said armature contacts said first armature stopper;
- said armature, first armature stopper and second armature stopper are configured to provide a hydraulic suction force between said armature and said second armature stopper, and a squeeze dampening force between said armature and said first armature stopper.

[0020] The present invention also proposes a solenoid

actuated fuel injector, comprising:

a valve assembly including a pintle and an armature slidably positioned on said pintle wherein a moving mass of said armature is separated from a moving mass of said pintle;

a solenoid assembly including a pole piece configured to provide an axial movement of said valve assembly, said pole piece enclosing a flow passage and limiting travel of said valve assembly in a first direction;

a lower housing including a valve seat that sealingly receives a valve of said pintle, said valve seat limiting travel of said valve assembly in a second direction; a primary spring biasing said pintle in a direction to move said valve toward said valve seat; and a secondary spring biasing said armature away from said pole piece, wherein a bias force of said primary spring and a bias force of said secondary spring move said valve of said pintle toward said valve seat.

[0021] According to other features of the fuel injector according to the present invention:

- a first armature stopper and a second armature stopper are both rigidly attached to said pintle and at a distance from each other and configured to limit said axial movement of said armature relative to said pintle;
- said primary spring is positioned between an armature stopper and a fluid tube that is enclosed by said pole piece;
- said secondary spring is positioned between said armature and said pole piece;
- a travel distance of said armature between a first and a second armature stopper is smaller than a length of a stroke of said pintle;
- said fuel injector is an inwardly opening fuel injector;
- said armature includes a plurality of through holes that enable flow of a fluid through said armature, and said fluid creates a hydraulic suction force between said armature and a second armature stopper and a squeeze dampening force between said armature and a first armature stopper;

[0022] The present invention also proposes a method for reducing valve bounce in solenoid actuated fuel injectors, comprising the steps of:

separating a moving mass of an armature from the moving mass of a pintle;

providing a biasing force with a primary spring to said armature and to said pintle;

providing a biasing force with a secondary spring to said armature only; and

limiting axial movement of said armature relative to said pintle by fixedly connecting a second armature stopper and a first armature stopper to said pintle.

[0023] According to other features of the method according to the present invention:

- it further comprises the steps of:

activating a solenoid;

moving said armature away from said first armature stopper against said biasing force of said secondary spring;

contacting said second armature stopper with said armature; and

causing said pintle to move upwards together with said armature against the combined biasing forces of said primary and said secondary spring until full stroke of said pintle is reached;

- it further comprises the steps of:

deactivating a solenoid;

biasing said pintle and said armature concurrently downwards with said primary spring until a valve of said pintle contacts a valve seat; and continuing downwards movement of said armature until said armature contacts said first armature stopper.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a cross-sectional view of an inwardly opening solenoid actuated fuel injector, in accordance with the invention;

FIG. 2 is a cross-sectional view of a valve assembly of the inwardly opening fuel injector, in accordance with the invention; and

FIG. 3 is a graph illustrating armature and pintle movement of the solenoid actuated fuel injector in accordance with the present invention.

[0025] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplification set out herein illustrates a preferred embodiment of the invention, in one form, and such exemplification is not to be construed as limiting the scope of the invention in any manner.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] Referring to FIG. 1, a solenoid actuated fuel injector 100 (inwardly opening-type shown) extends axially from a fuel inlet 102 to a fuel outlet 104 and includes a fuel delivery metering assembly 110 and a solenoid assembly 120. Fuel injector 100 may be, for example, an injector for direct injection.

[0027] Assembly 110 includes the moving compo-

nents and fuel containing components of injector 100, such as an upper housing 112, a lower housing 114, a pole piece 116 positioned between upper housing 112 and lower housing 114, and a valve assembly 130. A fuel tube 117 is positioned within upper housing 112 and may be at least partially surrounded by pole piece 116. A valve seat 118 may be integrated or attached to lower housing 114 proximate to fuel outlet 104. Valve seat 118 may be, for example, a beveled circular seat. Fuel tube 117, lower housing 114, and pole piece 116 enclose a fuel passage 106.

[0028] Solenoid assembly 120 includes an actuator housing 122, a coil assembly 124, and an electrical connector (not shown). Solenoid assembly 120 surrounds pole piece 116.

[0029] Valve assembly 130, shown in detail in FIG. 2, includes a pintle 132 and an armature 134 and is positioned within lower housing 114 such that a reciprocating movement of valve assembly 130 is enabled. Pintle 132 includes at one end a valve 136 that may have, for example, the geometric shape of a ball. Valve 136 functions as a reciprocally actuated valve and seals against valve seat 118, for example, in a circular sealing area. Armature 134 is slidably positioned on pintle 132 proximate an end opposite to valve 136. When valve assembly 130 is installed in injector 100, armature 134 is positioned adjacent pole piece 116. Valve assembly 130, including pintle 132, armature 134 and valve 136, constitutes the moving mass of fuel injector 100. By permitting slidable movement of armature 134 on pintle 132, the moving mass of armature 134 is separated from the moving mass of pintle/valve 132/136. The reciprocating movement of valve assembly 130 is actuated by solenoid assembly 120 to regulate the fuel flow through fuel outlet 104. Solenoid actuated fuel injector 100 may be a pulse-width type.

[0030] As can be seen in FIG. 1 and in detail in FIG. 2, armature 134 has a generally cylindrical shape, axially extends from a top surface 142 to a bottom surface 144, and includes a larger diameter section 146 that extends from top surface 142 and a smaller diameter section 148 that terminates at bottom surface 144. A center aperture 150, extending from top surface 142 to bottom surface 144, is configured to closely but slidably be received over an outer circumferential surface of pintle 132. Center aperture 150 is designed to guide reciprocating axial movement of armature 134 on pintle 132 without significant tilting about pintle axis 133. Armature 134 further includes a plurality of flow holes 154 that permit the flow of fuel through armature 134. While armature 134 is shown in FIGS. 1 and 2 to include larger diameter section 146 and smaller diameter section 148, other geometric configurations are possible.

[0031] Armature 134 is positioned on pintle 132 between a first armature stopper 138 and a second armature stopper 140. First armature stopper 138 and second armature stopper 140 are rigidly attached to pintle 132 at a distance 152 from each other. Distance 152 constitutes the distance in which armature 134 may move, ax-

ially, between first armature stopper 138 and second armature stopper 140. First armature stopper 138 and second armature stopper 140 may be joined with pintle 132, for example, by press fitting with subsequent welding. Distance 152 may be chosen based on an intended application of injector 100. First armature stopper 138 may include a radially extending shoulder 158 that faces bottom surface 144 of armature 134.

[0032] Preferably pintle 132 extends beyond top surface 142 of armature 134 and beyond second armature stopper 140. The extending section of pintle 132 receives a primary spring 160 and a secondary spring 162. Primary spring 160 preferably surrounds pintle 132 and is captured between second armature stopper 140 and fuel tube 117. Secondary spring 162 preferably surrounds primary spring and second armature stopper 140 and is captured between top surface 142 of armature 134 and a step integral with pole piece 116.

[0033] Primary spring 160 provides a downward biasing force to pintle 132 and to armature 134 when armature 134 is in contact with second armature stopper 140, while secondary spring 162 provides a downward biasing force to armature 134 only. Secondary spring 162 preferably exerts a lower force on the armature than primary spring 160 exerts on pintle 132.

[0034] Again referring to FIG. 1, when fuel injector 100 is closed as shown (solenoid de-energized), valve assembly 130 is in a lower position where valve 136 seals against valve seat 118 due to the biasing forces of primary spring 160 and secondary spring 162. In the position shown, armature 134 is in contact with first armature stopper 138. During the opening event of injector 100 (solenoid energized), armature 134 starts moving up from the lower position against the biasing force of secondary spring 162. When armature 134 first makes contact with second armature stopper 140, the impact with second armature stopper 140 transmits an impulse to pintle 132 causing pintle 132 to accelerate quickly in the valve opening direction. Armature 134 and pintle 132 then move upward together against the combined biasing forces of secondary spring 162 and primary spring 160 until the full pintle stroke is reached after top surface 142 of armature 134 contacts pole piece 116. Note that the length of the pintle stroke may be larger than the length that armature 134 is able to move between first armature stopper 138 and second armature stopper 140.

[0035] Referring to FIG. 3, a graph 200 illustrates the movement of armature 134 and pintle 132 in curves 206, 208 and 210. Compared to a typical fixed armature-pintle assembly as illustrated in curves 202 and 204, the opening time of pintle 132 can be reduced in accordance with the invention due to the initial acceleration of armature 134 prior to an upward movement of pintle 132. Calculations illustrate in FIG. 3, based on the direct injector design shown in FIG. 1, that the ballistic time of pintle 132 may be reduced by about 80 μ s from about 144 μ s of a prior art fixed valve assembly. Reducing the ballistic time of pintle 132 extends the linear range of fuel injector

100 during the opening event and enables a more precise control of flow at a low fuel flow rate. The calculations for graph 200 have been based on an armature/pintle mass of about 5 gram, an average magnetic force of about 60 N, a valve stroke of about 50 μm , and an axial moving distance of armature 134 between second armature stopper 140 and first armature stopper 138 of about 50 μm . In the example shown, the set force of primary spring 160 was about 20 N, and the set force of secondary spring 162 was about 5 N.

[0036] During the closing event of injector 100 (solenoid de-energized), primary spring 160 pushes pintle 132 and armature 134 down concurrently, once armature 134 contacts second armature stopper 140. During continued downward movement of valve assembly 130, top surface 142 of armature 134 stays in contact with second armature stopper 140. When valve 136 contacts valve seat 118, pintle 132 comes to a sudden stop while armature 134 continues to travel further down toward first armature stopper 138.

[0037] Accordingly, when pintle 132 attempts to rebound from seat 118 upon valve 136 making initial contact with seat 118, armature 134 continues downward to impact first armature stopper 138, thereby inhibiting pintle 132 from rebounding.

[0038] Since armature 134 moves within fuel passage 106, and therefore within a fluid, fluid engulfs the surfaces contacted by the armature. Thus, a hydraulic suction force is created between top surface 142 of armature 134 and second armature stopper 140 when armature 134 first starts to separate from the second armature stopper under the force of the secondary spring and the armature inertia. Top surface 142 of armature 134 and the surface of second armature stopper 140 that is in contact with armature 134 in the open position are preferably flat surfaces. When the solenoid is first de-energized, and pintle 132 begins to move toward seat 118 under the force of primary spring 160, top surface 142 of armature 134 remains engaged with second armature stopper 140. Then, when valve 136 first contacts seat 118, armature 134 continues its downward travel and surface 134 begins to separate from upper armature stopper 140. Fluid fills the space between the adjacent surfaces of armature 134 and upper armature stopper 140 creating a hydraulic suction force, thereby slowing the downward acceleration of the armature as it moves toward first armature stopper 138.

[0039] When armature 134 nears contact with first armature stopper 138, the force of armature 134 acting against the first armature stopper may be dampened by squeezing the fluid out from between bottom surface 144 of armature 134 and shoulder 158 of first armature stopper 138. The squeeze dampening force assists in stabilizing the armature on the first stopper without bounce. Due to the biasing down force of secondary spring 162, armature 134 stays in contact with first armature stopper 138 until the start of the next opening event.

[0040] If the masses of the pintle and armature, spring

forces, seat material and surface areas and finishes of the armature contact surfaces are controlled in an optimal way, valve bounce may be completely eliminated. Various characteristics, including but not limited to, the distance 152 between second armature stopper 140 and first armature stopper 138, the roughness of top surface 142 of armature 134 and of the contact surface of second armature stopper 140, the surface areas of top surface 142, bottom surface 144, the contact surface of second armature stopper 140, and of shoulder 158 of first armature stopper 138, may be adjusted, for example through computational modulation, to control valve bounce of valve assembly 130.

[0041] While the anti-bounce mechanism in accordance with the invention has been described for inwardly opening fuel injectors, the same principals may be applicable to outwardly opening fuel injectors.

[0042] While the anti-bounce mechanism as described above may be especially useful for application in direct injection fuel systems due to the relatively high fuel pressure of such systems, it may be applicable to other fuel systems operating at lower fuel pressures, such as multi-port injection fuel systems.

[0043] While the invention has been described by reference to various specific embodiments, it should be understood that numerous changes may be made within the spirit and scope of the inventive concepts described. Accordingly, it is intended that the invention not be limited to the described embodiments, but will have full scope defined by the language of the following claims.

Claims

1. A solenoid actuated valve assembly (130), comprising:
 - a pintle (132) including a valve (136) for mating with a valve seat (118);
 - an armature (134) slidably positioned on said pintle (132) opposite from said valve (136);
 - a first armature stopper (138) and a second armature stopper (140) both rigidly attached to said pintle (132) at a distance from each other and configured to allow axial movement of said armature (134) relative to said pintle (132);
 - a primary spring (160) providing a first biasing force to said pintle (132) and to said armature (134) when said armature (134) is in contact with said second armature stopper (140); and
 - a secondary spring (162) providing a second biasing force to said armature (134) only, wherein said second biasing down force is lower than said first biasing down force.
2. The valve assembly (130) of Claim 1, wherein said primary spring (160) is captured between said second armature stopper (140) and a housing (112) of

said solenoid actuated valve assembly (130).

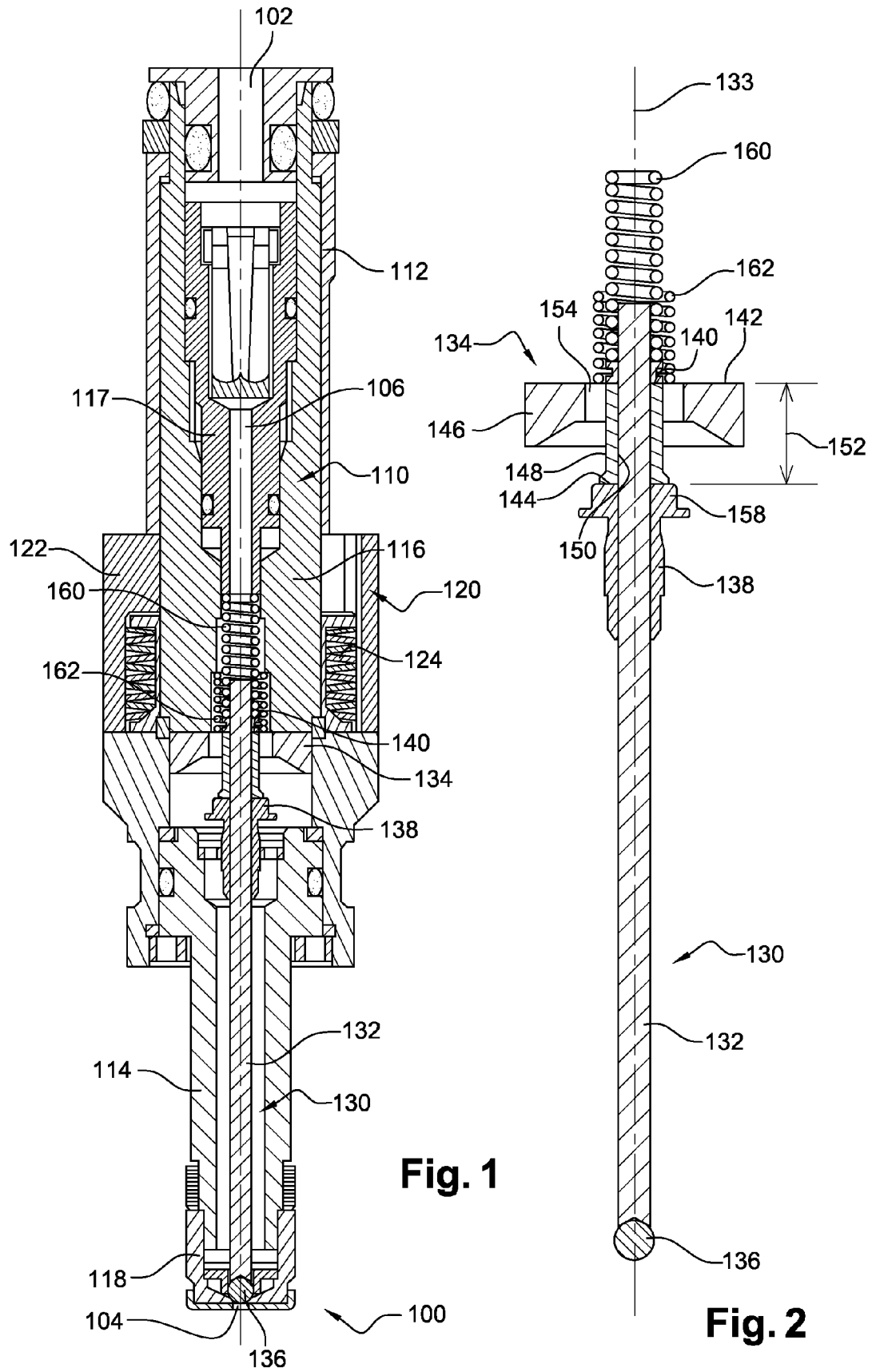
3. The valve assembly (130) of Claim 1 or 2, wherein said secondary spring (162) is captured between said armature (134) and a housing (112) of said solenoid actuated valve assembly (130). 5
4. The valve assembly (130) of anyone of Claims 1 to 3, wherein said armature (134) has a generally cylindrical shape. 10
5. The valve assembly (130) of anyone of Claims 1 to 4, wherein said armature (134) includes a center aperture (150) that slidably receives an outer circumferential surface of said pintle (132), wherein said center aperture (150) is configured to guide a reciprocating axial movement of said armature (134) on said pintle (132). 15
6. The valve assembly (130) of anyone of Claims 1 to 5, wherein at least one of said first armature stopper (138) and said second armature stopper (140) is joined with said pintle (132) by press fitting and subsequent welding. 20
7. The valve assembly (130) of anyone of Claims 1 to 6, wherein said first armature stopper (138) includes a radially extending shoulder (158) that faces said armature (134). 25
8. The valve assembly (130) of anyone of Claims 1 to 7, further including a solenoid assembly (120), wherein said armature (134) moves from said first armature stopper (138) towards said second armature stopper (140) against said second biasing down force of said secondary spring (162) upon activation of said solenoid assembly (120), and wherein said armature (134) makes contact with said second armature stopper (140) and said pintle (132) is configured to move together with said armature (134) against the combined first and second biasing down forces of said primary (160) and said secondary (162) spring. 30
9. The valve assembly (130) of anyone of Claims 1 to 8, further including a solenoid assembly (120), wherein after deactivation of said solenoid assembly (120) said primary spring (160) pushes said pintle (132) and said armature (134) concurrently until said valve (136) contacts said valve seat (118), wherein said armature (132) continues to travel downwards, and wherein said armature (132) contacts said first armature stopper (138). 35
10. The valve assembly (130) of anyone of Claims 1 to 9, wherein said armature (134), first armature stopper (138) and second armature stopper (140) are configured to provide a hydraulic suction force be- 40

tween said armature (134) and said second armature stopper (140), and a squeeze dampening force between said armature (134) and said first armature stopper (138).

11. A solenoid actuated fuel injector (100), comprising:

a solenoid actuated valve assembly (130) according to anyone of claims 1 to 10, including a pintle (132) and an armature (134) slidably positioned on said pintle (132) wherein a moving mass of said armature (134) is separated from a moving mass of said pintle (132);
 a solenoid assembly (120) including a pole piece (116) configured to provide an axial movement of said valve assembly (130), said pole piece (116) enclosing a flow passage (106) and limiting travel of said valve assembly (130) in a first direction;
 a lower housing (114) including a valve seat (118) that sealingly receives a valve (136) of said pintle (132), said valve seat (118) limiting travel of said valve assembly (130) in a second direction;
 said primary spring (160) biasing said pintle (132) in a direction to move said valve (136) toward said valve seat (118); and
 said secondary spring (162) biasing said armature (134) away from said pole piece (116), wherein a bias force of said primary spring (160) and a bias force of said secondary spring (162) move said valve (136) of said pintle (132) toward said valve seat (118).

12. The fuel injector (100) of Claim 11, wherein said primary spring (160) is positioned between an armature stopper (140) and a fluid tube (134) that is enclosed by said pole piece (116). 45
13. The fuel injector (100) of Claim 11 or 12, wherein a travel distance of said armature (134) between a first (138) and a second (140) armature stopper is smaller than a length of a stroke of said pintle (132). 50
14. The fuel injector (100) of anyone of Claims 11 to 13, wherein said armature (134) includes a plurality of through holes (154) that enable flow of a fluid through said armature (134), and wherein said fluid creates a hydraulic suction force between said armature (134) and a second armature stopper (138) and a squeeze dampening force between said armature (134) and a first armature stopper (140). 55



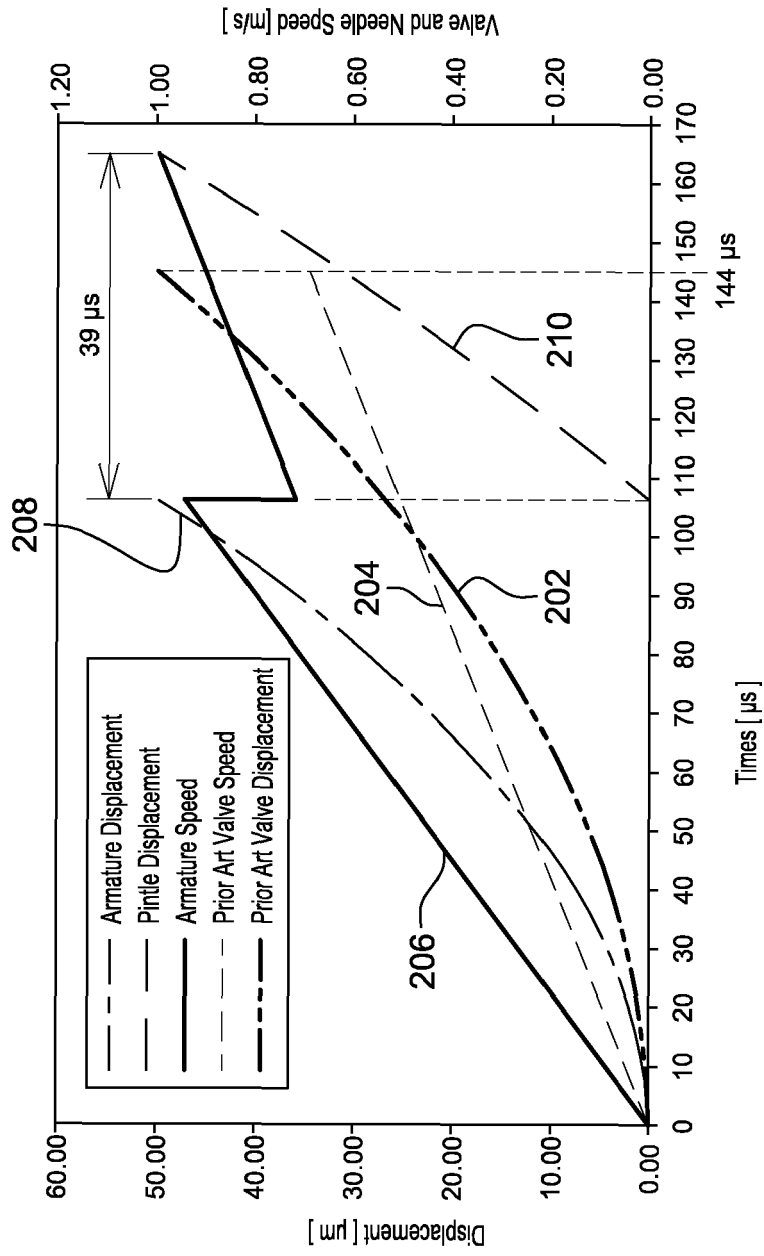


Fig. 3

200



EUROPEAN SEARCH REPORT

Application Number
EP 09 17 9022

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 102 56 661 A1 (BOSCH GMBH ROBERT [DE]) 17 June 2004 (2004-06-17) * page 3, paragraph 0019 - page 3, paragraph 0025; figures 1,2 * -----	1-14	INV. F02M51/06 ADD. F02M63/00
X	WO 02/068811 A1 (BOSCH GMBH ROBERT [DE]; REITER FERDINAND [DE]) 6 September 2002 (2002-09-06) * page 3, line 22 - page 5, line 36 * -----	1,2,4-14	
X	DE 198 16 315 A1 (BOSCH GMBH ROBERT [DE]) 14 October 1999 (1999-10-14) * page 6, line 24 - page 7, line 38; figure 2 * -----	1,2,4-14	
			TECHNICAL FIELDS SEARCHED (IPC)
			F02M
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 27 April 2010	Examiner Etschmann, Georg
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