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(54) **Fuel injector**

(57) The armature of a solenoid actuated fuel injector comprises an upper armature part (7) and a lower armature part (8), each armature part being independently moveably guided on the pintle (1). Biasing means (11) are provided between the upper and lower armature parts (7,8) biasing the upper and lower armature parts away from one another, the biasing means (11) biasing the upper armature part (7) towards an upper stop (9) provided on the pintle (1) and biasing the lower armature part (8) towards a lower stop (10) provided on the pintle (1).

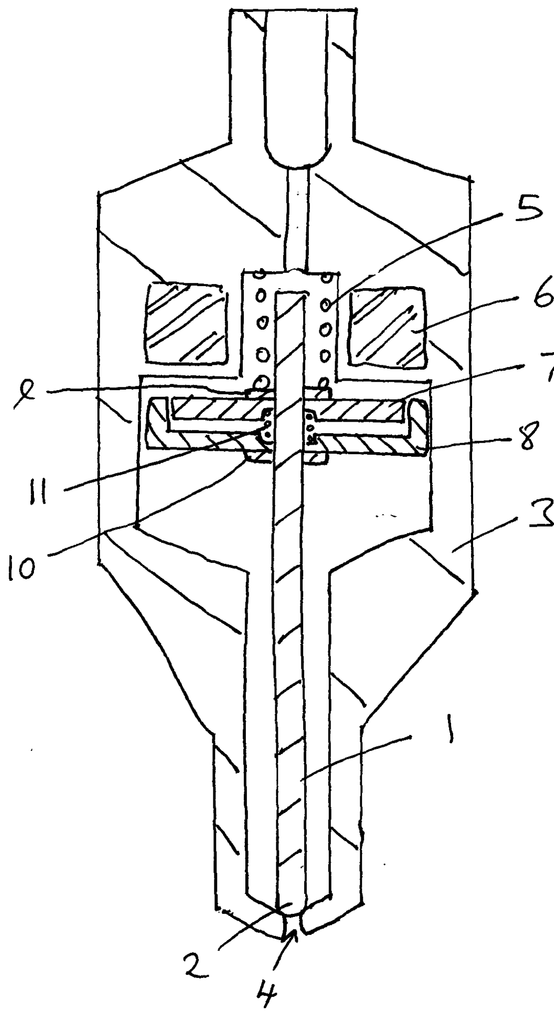

Fig.2

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Description

[0001] The present invention relates to a fuel injector and in particular to a fuel injector having improved means for eliminating valve bounce.

[0002] Modern direct injection gasoline engines require fuel injectors to operate under extreme conditions of temperature and pressure and with high fuel pressures. Furthermore, the fuel injector must open and close very rapidly in order to provide the high linear range required in modern engine applications.

[0003] A particular problem with known solenoid actuated fuel injectors when operated at high speed is valve bounce. When closing the injector at high speed, the impact of the pintle head against the valve seat can be substantial due to the large mass of the armature connected to the pintle and the force exerted on the pintle by the return spring. Due to the elasticity of the valve surfaces and the stiffness of the pintle the pintle head tends to rebound from the valve seat causing the injector to re-open. Such valve bounce causes one or more unmetered after injections of fuel delivery after injector closing, as shown in Fig 1. This problem is particularly acute in high pressure applications.

[0004] Known attempts to reduce valve bounce in solenoid actuated fuel injectors are disclosed in US 2002/0063173 and US 6,367,769. In each case, limited axial movement of the armature with respect to the pintle is permitted and controlled by resilient means, such as a spring or elastomeric member, to damp the movement of the armature with respect to the pintle. Such methods can prevent valve bounce and require accurate control of squeeze film damping gaps between the facing surfaces of the moving parts of the injector in order to be effective.

[0005] According to the present invention there is provided a fuel injector for an internal combustion engine, the injector comprising an injector body having a tip portion defining a spray aperture; a pintle extending within the tip portion for axial movement between an open position and a closed position, the pintle having a head portion engageable with a valve seat to close the spray aperture when the pintle is in its closed position; means being provided for urging the pintle towards its closed position; and solenoid means for selectively moving the pintle into said open position; said solenoid means comprising an electromagnetic coil and a moveable armature capable of being acted upon by the coil to urge the pintle towards its open position; wherein the armature comprises an upper armature part and a lower armature part, each armature part being independently moveably guided on the pintle, biasing means being provided between the two armature parts biasing the upper and lower armature parts away from one another, the biasing means biasing the upper armature part towards an upper stop provided on the pintle and biasing the lower armature part towards a lower stop provided on the pintle.

[0006] The present invention will now be described, by way of example, with reference to the accompanying drawing, in which:

Fig 1 is graph of pintle displacement against time for a known solenoid actuated fuel injector demonstrating the effect of valve bounce;

Fig 2 is a sectional view of solenoid actuated fuel injector according to an embodiment of the present invention;

Fig 3 is a graph of displacement against time for the valve head of the pintle of the injector of Fig 2.;

Fig 4 is a graph of displacement against time for the upper armature part of the injector of Fig 2, and;

Fig 5 is a graph of displacement against time for the lower armature part of the injector of Fig 2.

[0007] A fuel injector according to a preferred embodiment of the present invention, as illustrated in Fig 2, includes a pintle 1 having a valve head 2 at a distal end thereof, the pintle 1 being axially moveable within an injector body 3 between a closed position wherein the valve head 2 abuts a valve seat to close a spray aperture 4 in an injector tip and an open position wherein the valve head 2 is spaced from the valve seat to permit high pressure fluid to be ejected through the spray aperture 4. A return spring 5 biases the pintle 1 to its closed position and a solenoid, comprising an electromagnetic coil 6 mounted within the injector body 3 and a two part armature mounted on the pintle 1, is selectively actuable to move the pintle 1 to its open position against the return spring 5.

[0008] The armature comprises an upper armature part 7 and a lower armature part 8, each armature part 7,8 being independently slidably mounted on the pintle 1 for limited axial movement with respect to the pintle 1 between fixed upper and lower stops 9,10 located on the pintle 1. A compression spring 11 is located between the upper and lower armature parts biases the upper and lower armature parts away from one another whereby the spring 11 biases the upper armature part 7 against the upper stop 9 and the lower armature part 8 against the lower stop 10.

[0009] The lower armature part 8 is cup shaped, an outer region of the lower armature part 8 surrounding the upper armature part 7 to bring the lower armature part 7 into the magnetic field of the coil 6.

[0010] The two part armature of the present invention provides a three mass system (i.e. the pintle, lower armature part and upper armature). The lower armature part 7 behaves like a downwardly biased single part armature while the upper armature part 8 behaves like an upwardly biased single part armature.

[0011] The two part armature arrangement provides three squeeze file damping gaps that can provide damping to eliminate valve bounce, namely a gap between the upper armature part 7 and the upper stop 9, a gap between the lower armature part 8 and the lower stop 10 and a gap between co-operating contact faces of the upper and lower armature parts. Each of these gaps can be optimised to tune the opening and closing behaviour of the injector.

[0012] While in the embodiment shown in Fig 2 a single compression spring 11 is shown between the upper and lower armature parts, in an alternative embodiment (not shown) separate upper and lower springs might be provided on opposite sides of a central stop or collar fixed on the pintle between the upper and lower armature parts. With such arrangement the biasing force applied to the respective upper and lower armature part can be independently selected to provide the desired characteristics.

[0013] Fig 3 illustrates the movement of the valve head 2 of the pintle 1 when the solenoid is operated to deliver a predetermined amount of fuel to the combustion chamber of an internal combustion engine. Fig 4 illustrates the movement of the upper armature part 7 of the injector during the same time interval while Fig 5 illustrates the movement of the lower armature part 8 during said time interval.

[0014] As shown in Fig 5, when the solenoid coil 6 is initially energised at point A, the lower armature part 8 initially begins to move towards the upper armature part 7. The upper armature part 7 and the pintle 1 initially remain in their at rest positions due to the action of the return spring 5.

[0015] When the lower armature part 8 impacts the upper armature part 8, the force of attraction of the solenoid coil 6 and the inertia of the lower armature part 8 are sufficient to overcome the return spring 5 and the pintle 1, along with upper and lower armature parts 7,8, rapidly moves to it fully open position during the time interval between points B and C.

[0016] The solenoid remains energised for a period of time (between points C and D) to deliver a predetermined volume of fuel through the spray aperture 4.

[0017] Once the injection period is commanded to end (at point D), the solenoid coil 6 is de-energised and the magnetic field generated by the solenoid coil rapidly breaks down. The spring force of the return spring 5 now urges the pintle 1 and the upper and lower armature parts away from the coil 6 until the valve head 2 impacts the valve seat. During this period, the greater strength of the return spring 5 compared to the compression spring 11 between the upper and lower armature parts and the inertia of the lower armature part retains the lower armature part 8 in contact with the upper armature part 7.

[0018] Upon impact of the valve head 2 of the pintle 1 with the valve seat, a point E, the upper and lower armature parts 7,8 effectively decouple from the pintle 1 and continue to move away from the upper stop 9 of the pintle 1 towards the lower stop 10 (represented by the negative displacement shown in Figs 4 and 5). Therefore the inertia of the armature has no effect on the valve head 2 and a major cause of valve bounce is avoided.

[0019] After the closure of the valve at point E, the upper and lower armature parts 7,8 continue to move downwardly until the lower armature part 8 impacts the lower stop 10 at point F. The spring 11 then enhances the rebound of the upper armature part back up towards the upper stop 9 until the upper armature part returns to its at rest position at point G.

Claims

1. A fuel injector for an internal combustion engine, the injector comprising an injector body (3) having a tip portion defining a spray aperture (4) ; a pintle (1) extending within the tip portion for axial movement between an open position and a closed position, the pintle (1) having a head portion (2) engageable with a valve seat to close the spray aperture (4) when the pintle (1) is in its closed position; means (5) being provided for urging the pintle towards its closed position; and solenoid means for selectively moving the pintle (1) into said open position; said solenoid means comprising an electromagnetic coil (6) and a moveable armature capable of being acted upon by the coil (6) to urge the pintle (1) towards its open position; wherein the armature comprises an upper armature part (7) and a lower armature part (8), each armature part being independently moveably guided on the pintle (1), biasing means (11) being provided between the upper and lower armature parts (7,8) biasing the upper and lower armature parts away from one another, the biasing means (11) biasing the upper armature part (7) towards an upper stop (9) provided on the pintle (1) and biasing the lower armature part (8) towards a lower stop (10) provided on the pintle (1).

2. A fuel injector as claimed in claim 1, wherein the biasing means (11) comprises a single compression spring.

3. A fuel injector as claimed in claim 1, wherein the biasing means (11) comprises upper and lower compression springs, said upper and lower springs being arranged co-axially on the pintle (1) and being separated by a fixed stop or collar provided on the pintle (1), the upper spring acting on the upper armature part (7) and the lower spring acting on the lower armature part (8).

4. A fuel injector as claimed in any preceding claim, wherein lower armature part (8) is substantially cup shaped, at least a portion of the outer region of the lower armature part (8) surrounding the upper armature part (7) to bring the lower armature part (7) into the magnetic field of the coil (6).

5. A fuel injector as claimed in any preceding claim wherein predefined squeeze film damping gaps are provided between the upper armature part (8) and the upper stop (9), between the lower armature part (8) and the lower stop (10) and between the upper and lower armature parts respectively.

6. A fuel injector as claimed in any preceding claim, wherein the upper armature part (7) is formed from a non-magnetic material.

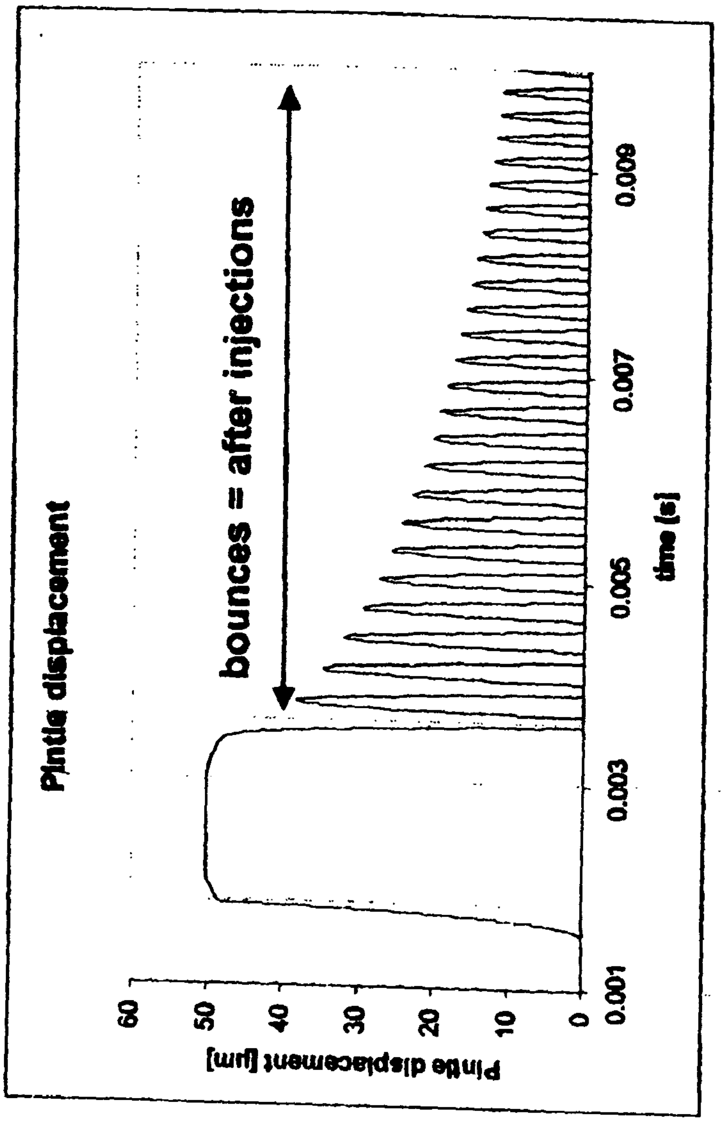
Pintle displacement
bounces = after injections
Pintle displacement [µm]
60
50
40
30
20
10
0
0.001
0.003
0.005
0.007
0.009
time [s]

Fig. 1

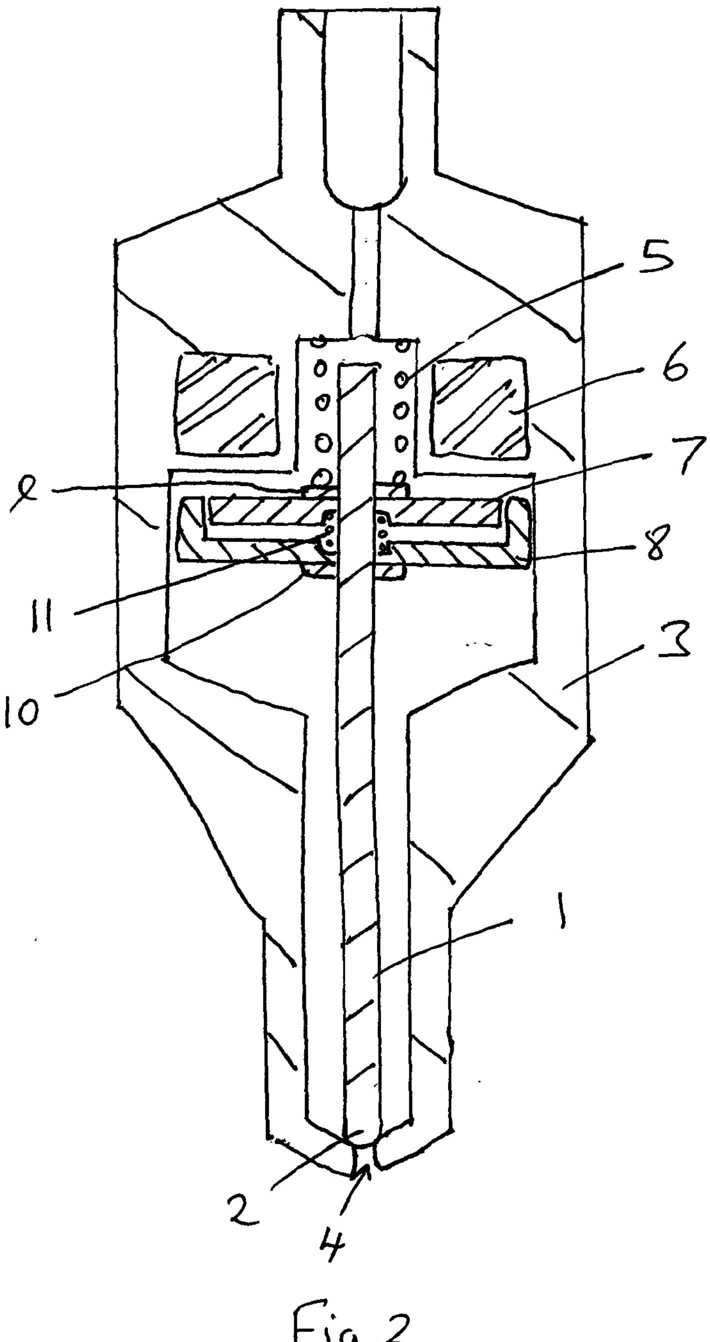

Fig.2

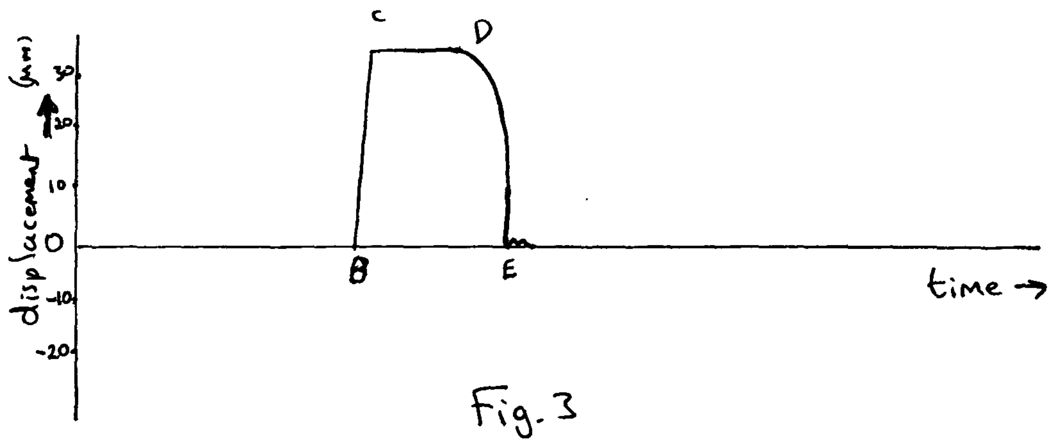

Fig. 3

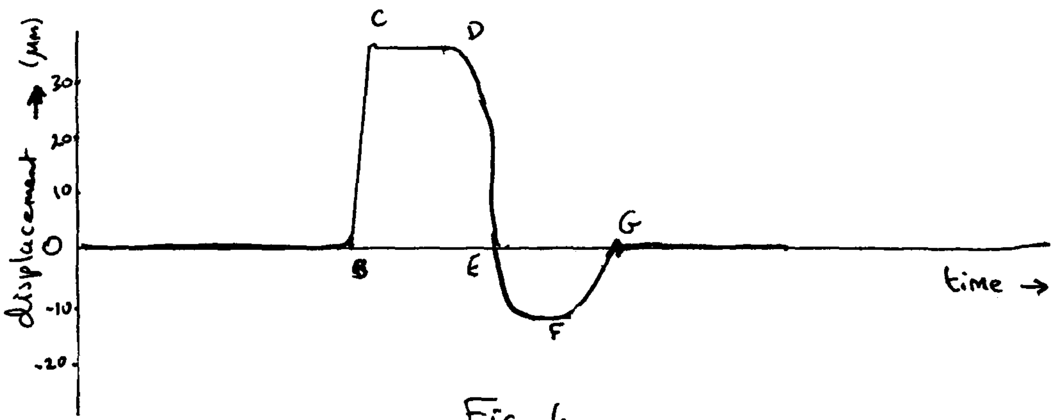

Fig. 4

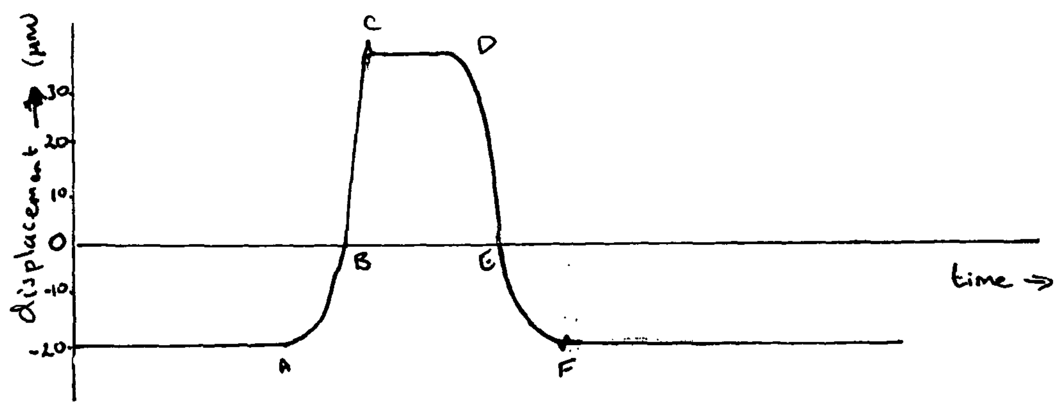

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 05 25 8059

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	EP 1 259 729 A (ROBERT BOSCH GMBH) 27 November 2002 (2002-11-27) * paragraphs [0011], [0018], [0019], [0021]; figure 5 *	1,2,5	INV. F02M51/06
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A	EP 1 137 877 A (ROBERT BOSCH GMBH) 4 October 2001 (2001-10-04) * paragraphs [0020], [0025] - [0027]; figures 2,3 *	1-6	
			TECHNICAL FIELDS SEARCHED (IPC)
			F02M

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	16 May 2006	Jucker, C

CATEGORY OF CITED DOCUMENTS

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