(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 837 516 A1

# (12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
**26.09.2007 Bulletin 2007/39**

(51) Int Cl.:
***F02M 51/06*** *(2006.01)*

(21) Application number: **06270035.6**

(22) Date of filing: **23.03.2006**

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR**
Designated Extension States:
**AL BA HR MK YU**

(71) Applicant: **Delphi Technologies, Inc.**
**Troy, MI 48007 (US)**

(72) Inventor: **Farah, Philippe-Said**
**78600 Maisons-Laffitte (FR)**

(74) Representative: **Jones, Keith William**
**Murgitroyd & Company**
**Scotland House**
**165-169 Scotland Street**
**Glasgow G5 8PL (GB)**

## (54) Fuel valve actuator

(57) The invention relates to a fuel valve actuator for an engine. The actuator has an armature (26) movable to open and close the valve, a permanent magnet (28) which urges the armature (26) toward the closed position, biasing means which urges the armature (24) toward the open position, and an electromagnet (24) which produces a magnetic field that interferes with the magnetic field of the permanent magnet (28) in order to produce a resultant magnetic field which at least reduces the force provided by the permanent magnet on the armature (26). This provides a fast fuel valve actuator with a fast response time. A method of actuating a fuel valve is also provided.

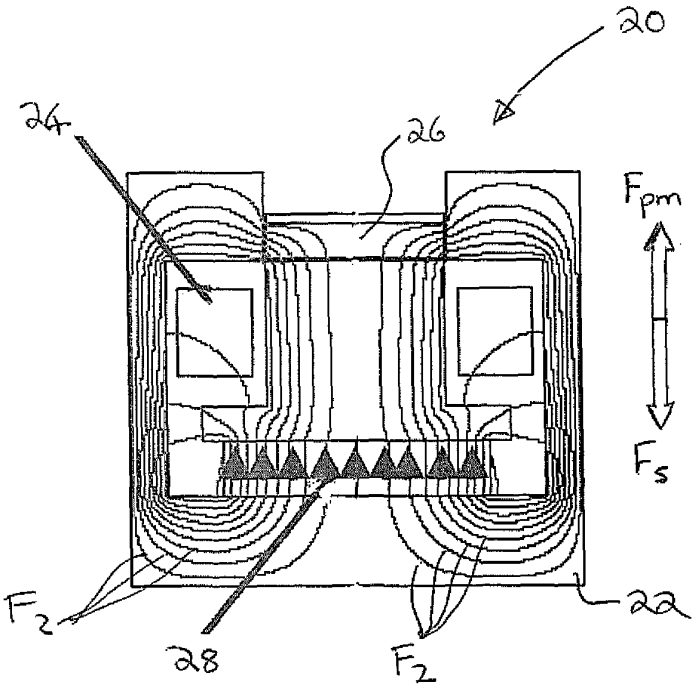


Fig. 2A

EP 1 837 516 A1

## Description

**[0001]** The present invention relates to a fuel value actuator, particularly, but not exclusively a fuel value actuator for use in direct injection automobile engines.

**[0002]** The fuel injection valves of automobile engines must open and close very quickly and reliably in order to ensure efficient engine operation. The rapid opening and closing of such valves is normally performed using a solenoid connected to the valve. The solenoid typically has an electromagnetic coil which may be successively energised and de-energised against the action of a return spring in order to cause an armature (and hence the valve) to move up and down in an opening / closing operation. In order to assist this movement, a spring is provided. When the electromagnetic coil is de-energised the force exerted by the spring causes the valve to return to the closed position.

**[0003]** A disadvantage of such systems is that the time taken for the valve to respond to each opening / closing signal (provided by the Engine Control Module) is often longer than desired. This is due to the amount of time required for the electromagnetic coil to build up the magnetic force required to overcome the force of the return spring.

**[0004]** According to a first aspect of the present invention, there is provided a fuel valve actuator comprising:-

an armature actuable between a first configuration which closes the valve to fuel flow and a second configuration which opens the valve to fuel flow;
a permanent magnet which urges the armature toward the closed configuration with a first force;
biasing means arranged to urge the armature toward the open configuration with a second force; and
an electromagnet for selectively producing a magnetic field which interferes with the permanent magnetic field in order to produce a resultant magnetic field which at least reduces the first force on the armature.

**[0005]** According to a second aspect of the present invention, there is provided a method of actuating a fuel valve comprising:-

providing an armature actuable between a first configuration which closes the valve to fuel flow and a second configuration which opens the valve to fuel flow;
holding the armature in the closed configuration with a first force using a permanent magnet;
urging the armature toward an open configuration with a second force using a resilient biasing means;
energising an electromagnet by passing a current there through in order to produce a magnetic field which at least reduces the first force on the armature such that the second force is greater than the first and the armature moves toward the open configuration.

**[0006]** Further aspects and advantages of the present invention will be apparent from the following description and from the claims.

**[0007]** Embodiments of the present invention will now be described, by way of example only, with reference to the following drawings, in which:-

Fig. 1 is a schematic illustration of a prior art electromagnetic actuator not in accordance with the present invention;
Fig. 2A is a schematic illustration of a first embodiment of the present invention in the de-energised configuration where magnetic flux lines produced by the permanent magnet are shown;
Fig. 2B is a schematic illustration of the apparatus of Fig. 2A in the energised configuration where the resulting magnetic flux lines from the energised electromagnet and the permanent magnet are shown; and
Fig. 3 is a schematic illustration of a second embodiment of the present invention.

**[0008]** A prior art fuel injector actuator 10 comprises a body 12 which houses an electromagnet coil 14 surrounding an armature 16. The armature 16 is connected to the value (typically the value pintle) such that when it moves the valve may be moved between an open and closed configuration. A return spring (not shown) also acts on the armature 16 in order to provide a force Fs which keeps the valve in the closed position when the electromagnet 14 is not energised. When the valve is to be opened, the electromagnet is energised (an electrical current is passed through it). This creates flux lines F1 as shown in Fig. 1 which collectively produce a magnetic force on the armature 16 in the direction Fm. As the electromagnetic coil 14 is energised it takes time for the magnetic force Fm to build up to a level which is capable of overcoming the return spring force Fs. Once the force from the electromagnetic coil 14 is greater than the spring force Fs, the valve opens. Up to this point, the valve remains closed and there is therefore a time delay from the moment the valve opening signal reaches the valve and the moment the valve opens. This is undesirable since it introduces a time-delay into a crucial phase of the injection sequence.

**[0009]** Referring to Fig. 2A a fuel value actuator according to the present invention will now be described. Fuel value actuator 20 comprises a body 22 which houses an electromagnet 24 surrounding an armature 26. A permanent magnet 28 is also provided which exerts a magnetic force Fpm that keeps the valve in the closed position when the electromagnet 24 is not energised. The permanent magnet 28 may have a magnetic flux density of around 1.2T. Resilient biasing means such as a spring (not shown) also acts on the armature 16. In contrast with the prior art fuel injector 10, this spring provides a force

Fs which tends to open the valve. The spring typically provides a force of around 25 Newton, although this may be adjustable.

**[0010]** In use, in the de-energised state, the force of the permanent magnet 28 Fpm acts against the force of the spring Fs. The permanent magnet should be chosen during manufacture to provide a force Fpm which is slightly greater than the force of the spring Fs in order to keep the valve in the closed position when the electromagnet is not energised. The magnetic force provided by the permanent magnet is depicted by flux lines F2 in Fig. 2A. These flux lines clearly pass through (and hence act upon) the armature 26.

**[0011]** When the fuel valve is to be opened, the electromagnet 24 is energised in response to a control signal. In the present embodiment the electromagnet 24 is energised with a current which provides around 650 AT for a coil of around 42 turns. This quickly creates flux lines which interfere with the flux lines F2 in order to arrive at the flux pattern depicted by flux lines F3 in Fig. 2B. The flux lines are created faster than in prior art systems due to the saturated magnetic field provided by the permanent magnet 28 which, upon application of a positive voltage to the electromagnet, allows current to build up quickly. The built up current creates a magnetic field opposed to the original one created by the permanent magnet. Importantly, flux lines F3 do not pass through the armature 26 and therefore do not act thereupon. This has the effect of temporarily reducing, if not cancelling, the force Fpm produced by the permanent magnet 28. As a result, the armature moves to the open position under the action of the spring Fs. The skilled reader will realise that the air gap between the electromagnet 24 and the armature 26 may be manipulated in order to achieve the desired magnetic force. In this regard, this air gap may typically be in the region of between 50 m and 100 m; however, other clearances could be used.

**[0012]** The above actuator does not suffer from the time delay between the moment the control signal arrives at the fuel actuator the moment and the valve opens. This is in part due to there being no build up of force required by the electromagnet to move the actuator since the actuator is actually moved by the spring force Fs.

**[0013]** Furthermore, when the valve is to be returned to the closed configuration the current in the electromagnet 24 can either be stopped (in which case the force of the permanent magnet 28 will close the valve) or can preferably, be re-versed in direction (in which case the armature will be positively urged toward the closed configuration by both the resulting magnetic field from the electromagnet and the closing force provided by the permanent magnet).

**[0014]** This allows the valve to be closed quickly as well as opening quickly. The overall response time of the valve is therefore greatly improved over the prior art.

**[0015]** Modifications and improvement may be made to the foregoing without departing from the scope of the invention, for example:-

In an alternative embodiment, as shown in Fig 3, the permanent magnetic 28A is provided annularly around the armature 26A. In this arrangement, the permanent magnet 28A typically has a magnetic flux density in the region of 0.5 - 0.6T. In this embodiment the flux concentration allows magnets having low residual induction properties to be used.

## Claims

1. A fuel valve actuator comprising:-

   an armature (26) actuable between a first configuration which closes the valve to fuel flow and a second configuration which opens the valve to fuel flow;
   a permanent magnet (28) which urges the armature (26) toward the closed configuration with a first force (Fpm);
   biasing means arranged to urge the armature (24) toward the open configuration with a second force (Fs); and
   an electromagnet (24) for selectively producing a magnetic field which interferes with the magnetic field of the permanent magnet (28) in order to produce a resultant magnetic field which at least reduces the first force (Fpm) on the armature (26).

2. A fuel valve actuator according to claim 1, wherein the biasing means comprises resilient biasing means.

3. A fuel valve actuator according to claim 2, wherein the resilient biasing means comprises a spring.

4. A fuel valve actuator according to any preceding claim, wherein the electromagnet (24) comprises coiled wires which, when energised, produce a magnetic field.

5. A method of actuating a fuel valve comprising:-

   providing an armature (26) actuable between a first configuration which closes the valve to fuel flow and a second configuration which opens the valve to fuel flow;
   holding the armature (26) in the closed configuration with a first force (Fpm) using a permanent magnet (28);
   urging the armature (26) toward an open configuration with a second force (Fs) using a resilient biasing means;
   energising an electromagnet (24) by passing a current there through in order to produce a magnetic field which at least reduces the first force (Fpm) on the armature (26) such that the second

force (Fs) is greater than the first force (Fpm) and the armature (26) moves toward the open configuration.

**6.** A method of actuating a fuel valve according to claim 5, wherein the magnetic field produced by the electromagnet (24) reduces the first force (Fpm) on the armature (16) to a value at or near zero.

**7.** A method of actuating a fuel valve according to any preceding claim, comprising de-energising the electromagnet (24) when the valve is toward the open configuration in order to cause the armature (26) to move back toward the closed configuration under the action of the first force (Fpm) provided by the permanent magnet (28).

**8.** A method of actuating a fuel flow valve according to either of claims 5 and 6, comprising reversing the energising current direction such that the armature (26) is positively urged toward the closed configuration by the electromagnet (28).

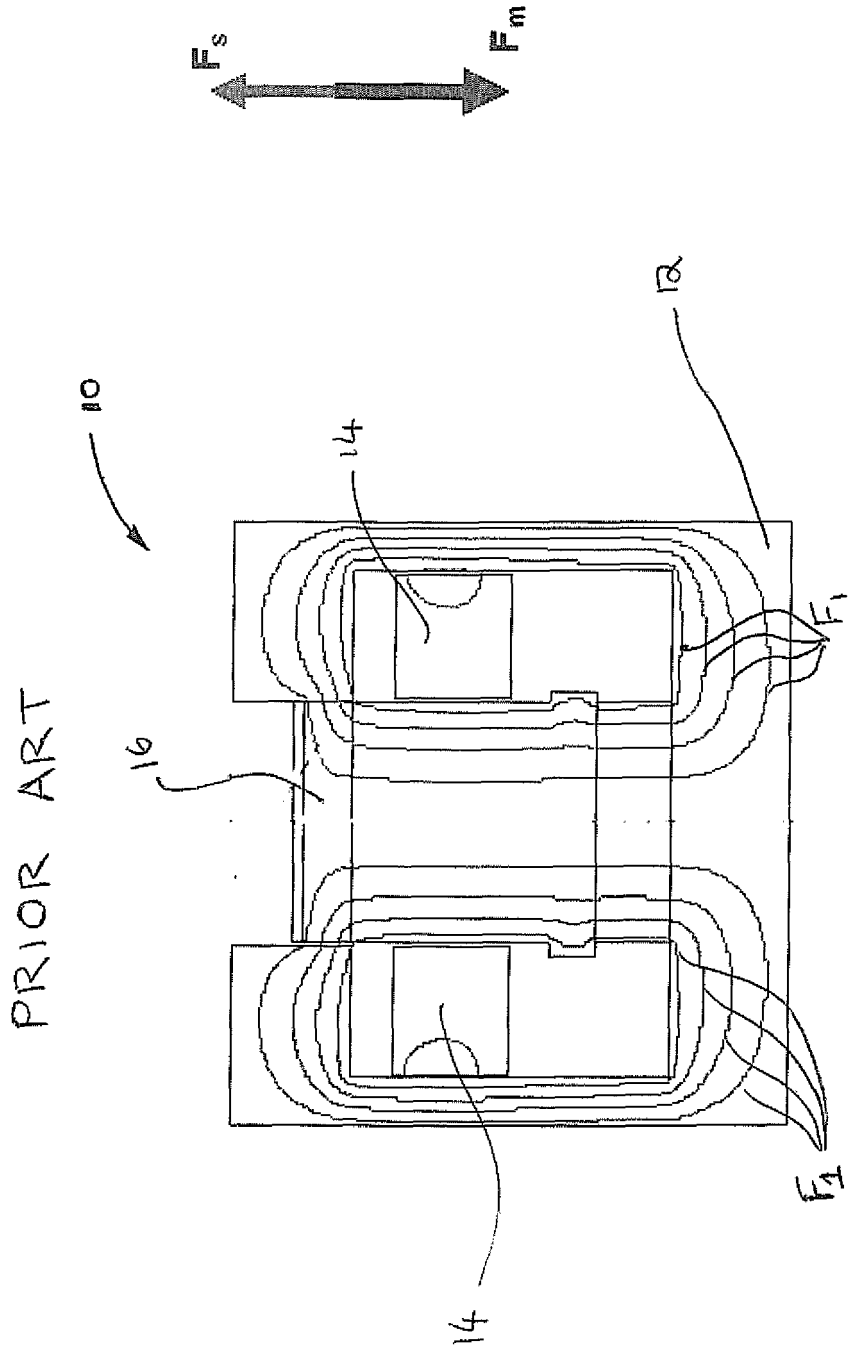


Fig. 1

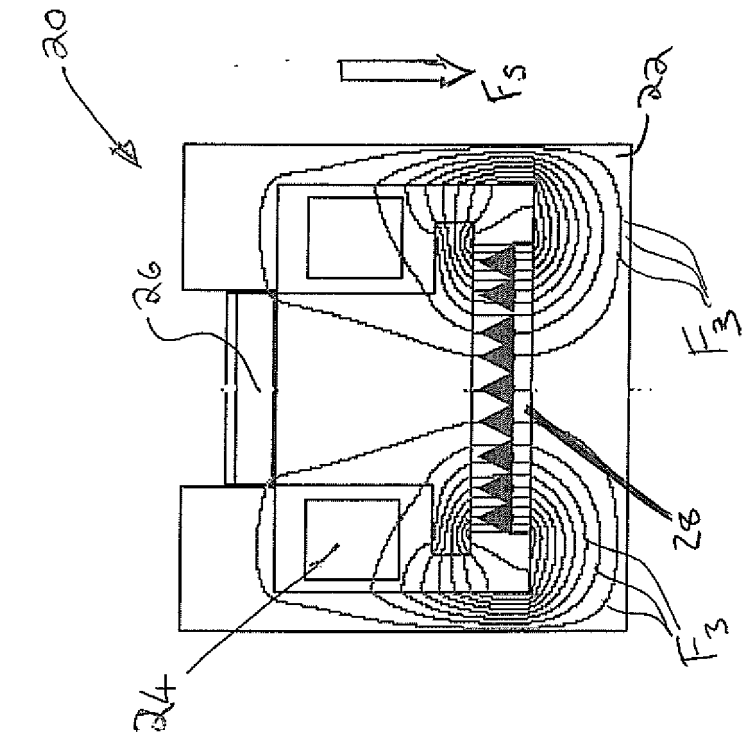


Fig. 2B

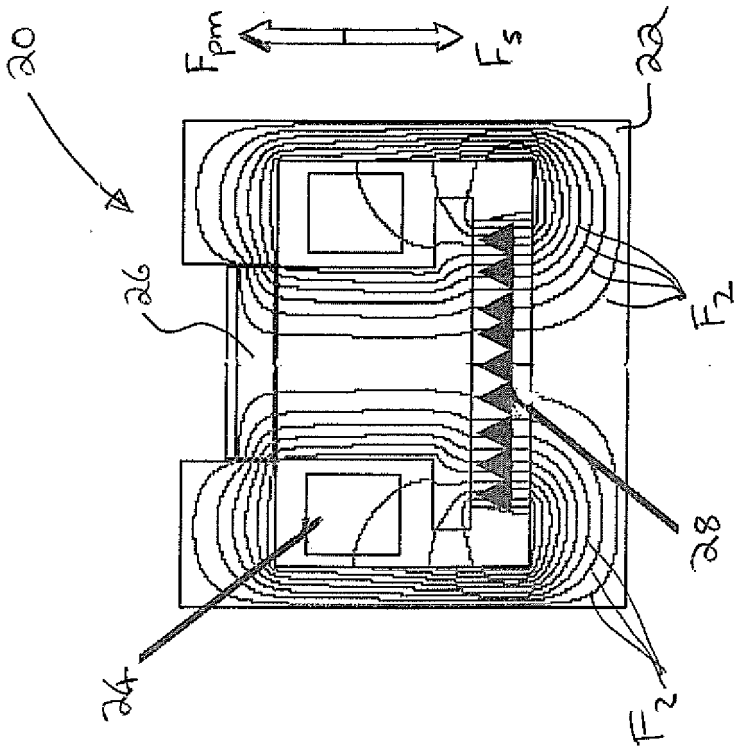


Fig. 2A

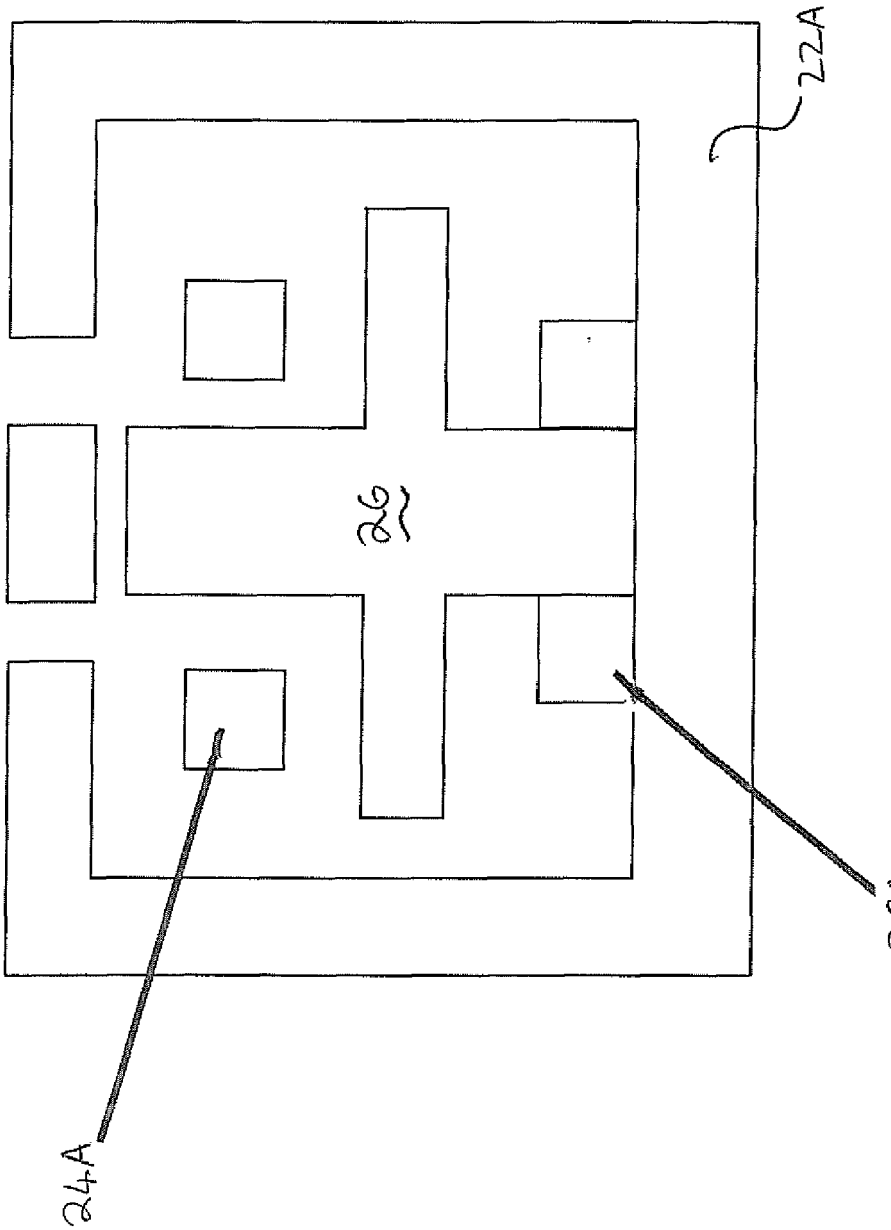


Fig. 3

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 06 27 0035

## 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 33 32 822 A1 (ROBERT BOSCH GMBH) 28 March 1985 (1985-03-28) * page 16, last paragraph - page 17, paragraph 2; figure 1 * ----- | 1-8 | INV. F02M51/06 |

TECHNICAL FIELDS SEARCHED (IPC)

F02M

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 8 August 2006 | Torle, E |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 06 27 0035

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

08-08-2006

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| DE 3332822 A1 | 28-03-1985 | JP 60060383 A | 06-04-1985 |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82