United States Patent [19]

Kent

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[54] **METHOD OF MAKING A FUEL INJECTOR**

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[73] Assignee: **Brico Engineering Limited,** Warwickshire, England

[22] Filed: **Dec. 15, 1972**

[21] Appl. No.: **315,430**

Related U.S. Application Data

[62] Division of Ser. No. 171,472, Aug. 13, 1971, Pat. No. 3,773,265.

[52] **U.S. Cl.**..... **29/156.7 R,** 29/157.1 R, 29/445, 29/446, 29/526, 251/357

[51] **Int. Cl.**..... **B21k 1/20,** B23p 13/00

[58] **Field of Search**.... 29/445, 446, 157.1 R, 156.7, 29/526; 239/412, 533, 585; 251/356, 357 X, 358

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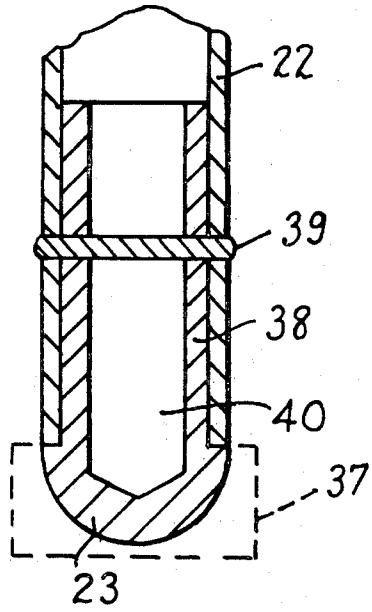
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[57] **ABSTRACT**

An electromagnetic fuel injector for a fuel injection system is provided with a solenoid winding which, when fed with electrical operating current, produces a saturated magnetic field in at least part of a magnetic circuit, which field is used to attract a member controlling the valve means of the injector and hence the fuel flow. The valve means may include a plunger having a tip portion of a plastics or rubber-like material to engage the valve seat. Methods of attaching the tip portion to the plunger are also described.

4 Claims, 3 Drawing Figures



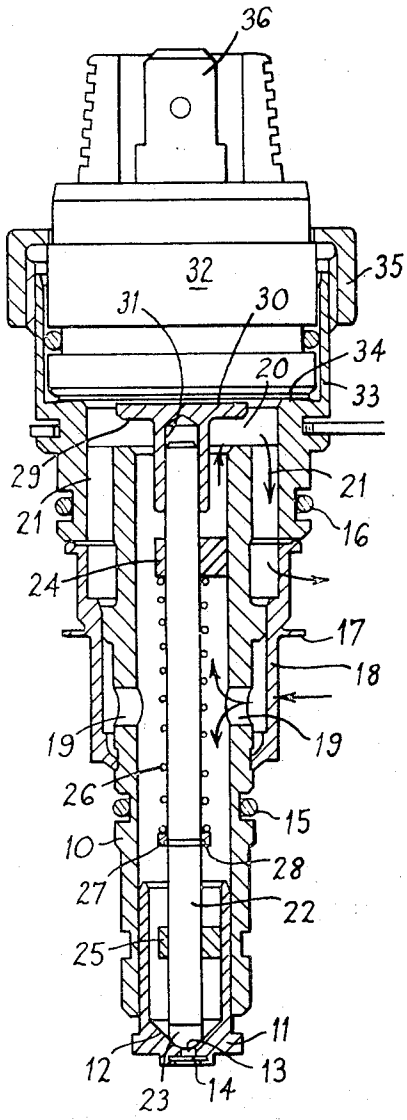


Fig.1

Fig.2

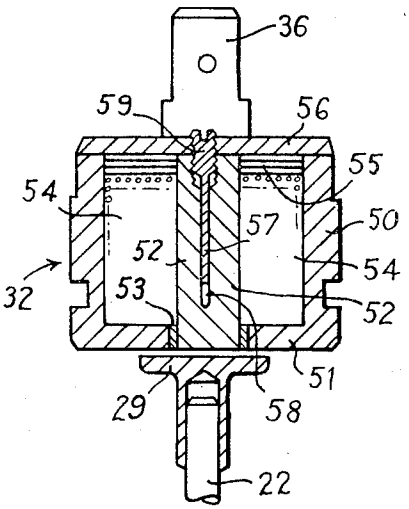
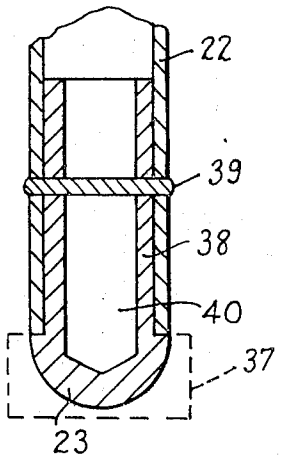


Fig.3



METHOD OF MAKING A FUEL INJECTOR

This is a division, of application Ser. No. 171,472, filed Aug. 13, 1971, now U.S. Pat. No. 3,773,265.

This invention relates to fuel injectors, and particularly, but not exclusively, to fuel injectors for supplying fuel to an internal combustion piston engine.

According to one aspect of the invention, in an electromagnetic fuel injector a winding, when fed with electrical operating current, produces a saturated magnetic field in at least part of a magnetic circuit, the magnetic field being arranged to produce a force to move a member controlling the flow of fuel from the injector.

Preferably means are provided for optionally adjusting the force produced on the member by the magnetic field.

Conveniently the position of a ferromagnetic saturatable body is adjustable in an aperture in that portion of the magnetic circuit which becomes saturated in operation, whereby to adjust the magnetic field obtained when the portion of the magnetic circuit is saturated.

Suitably the magnetic circuit includes a central core which becomes saturated, the core having an axial bore extending into the saturated portion, and a ferromagnetic rod axially adjustable along the bore.

According to another aspect of the invention, a fuel injector in which pressurised fuel is periodically admitted to or cut off from an injector orifice by a valve means includes a seating face against which a plunger is urged to seal the pressurised fuel from the orifice and from which seating face the plunger is withdrawn to admit the pressurised fuel to the orifice, and in which the portion of the plunger which contacts the seating face is of a plastics or rubber-like material.

The plunger is generally of metal and has a tip portion fastened thereto of plastics or rubber-like material for making sealing contact with the seating face.

Suitably the seating face is of hollow conical form. Preferably the said portion of the plunger which contacts the seating face is of part-spherical form.

Conveniently the metal portion of the plunger has an axial bore into which a stem on the plastics or rubber-like tip is fastened. Preferably the stem is a press fit into the bore.

Desirably the stem is additionally fastened in the bore by a diametral pin passing through the stem and the surrounding metal.

Advantageously the tip has a coaxial bore extending through the stem and to a point in the tip adjacent the portion which contacts the seating face.

Preferably the plastics material is an acetal copolymer.

According to a further aspect of the invention, a method of making a fuel injector of the kind having a plunger of which a metal portion has a bore into which is fastened a stem of a tip of plastics or rubber-like material, said tip being for sealing against a seating face of the fuel injector, includes inserting the stem into the bore, loading the tip towards the metal portion with a load at which the tip material just starts to plastic flow, and mechanically securing the stem to the metal portion while so loaded.

Suitably the method includes drilling a diametral bore through the stem and metal portion and inserting a fastening pin therein while the tip is still loaded.

Conveniently the method includes subsequently removing the load on the tip, rough shaping the portion of the tip for contacting the seating face, annealing the plunger at an annealing temperature for the plastics or rubber-like material, cooling the plunger and finish shaping the portion of the tip.

Preferably the method includes raising the assembled injector with the tip subject to its normal working load against the seating face, to a temperature at which the plastics or rubber-like material just starts to plastic flow.

The invention is described, by way of example only, with reference to the accompanying drawings in which:

FIG. **1** is a longitudinal section through a fuel injector,

FIG. **2** is a longitudinal section through a solenoid shown in part of FIG. **1**, and

FIG. **3** shows part of FIG. **1** to an enlarged scale.

In FIG. **1** a fuel injector has a tubular metal body **10** into the lower end of which is pressed a metal thimble **11.** A conical seating face **12** is formed inside the thimble **11** from which a central passage **13** leads to a thin metal disc **14,** held by peening into a depression in the end of the thimble **11.** A very fine hole of carefully selected diameter serves as a metering spray orifice through the centre of the disc **14.**

In use the fuel injector is located in an unshown injector housing positioned so that fuel issuing from the spray orifice discharges into an inlet duct of an internal combustion engine. The injector is located in two concentric bores in the injector housing and is sealed in the bores by two O-rings **15, 16.** The junction between the injector housing bores forms a step against which a flexible flange **17** seals. The space in the injector housing between the O-ring **15** and flexible flange **17** forms a fuel inlet chamber to the injector, and the space between the flexible flange **17** and the O-ring **16** forms a fuel outlet chamber. The flexible flange **17** forms an integral part of the nylon filter **18** having a circumferential band of fine integral filter panels above and below the flexible flange **17** so that fuel is filtered before entering the injector and again before leaving it.

The filtered fuel passes to the interior of the injector body **10** through radial drillings **19.** As described below, some fuel passes downwardly and out through the passage **13** and metering orifice in the disc **14.** Surplus fuel rises to a chamber **20** and thence passes downwardly through passages **21** and out through the filter **18,** as shown by the arrows.

Passage of fuel through the orifice in the disc **14** is controlled by an axially movable plunger having a tubular metal shaft **22** into the lower end of which is fastened a hemispherical ended tip **23** of an acetal copolymer, such as "Delrin" or other suitable plastics or rubber-like material. The metal shaft **22** is guided by guide blocks **24, 25** fastened in the injector body **10** and the thimble **11** respectively. A precompressed low rate helical spring **26** acts between the guide block **24** and a collar **27,** held to the shaft **22** by a spring clip **28,** to urge the tip **23** against the conical seating face **12** to cut off the supply of fuel to the passage **13.**

At the upper end of the shaft **22** is fastened a soft iron mushroom-shaped head **29** having a top face **30** which is accurately normal to the axis of the shaft **22.** This accuracy is achieved, without expensively accurate machining of the shaft **22** and head **29,** by providing a bore

31 in the head 29 which is a clearance fit on the shaft 22. The head 29 and shaft 22 are assembled in an accurate jig, with the face 30 normal to the shaft axis, and the gap between the shaft 22 and the bore 31 is filled by a bonding agent which fastens the components together. This may be achieved by induction brazing or by the use of an appropriate adhesive.

A solenoid unit 32 is held in a counterbore 33 against a shoulder 34 in the injector body 10, by a nut 35. The solenoid has electrical terminals 36, and when fed with electrical current, generates a magnetic field which attracts the head 29 and shaft 22 upwards to close a small accurately set gap between the face 30 of the head 29 and the lower opposing face of the solenoid 32. As long as the electrical current flows the shaft 22 will hold the plastics tip 23 a fixed distance off the conical seating face 12 so that fuel will flow through the orifice in the plate 14 at a constant rate, if the fuel pressure difference across the orifice is constant.

In order to achieve good sealing of the tip 23 to the seating face 12 and reliable operation, it has been found necessary to take special precautions in the design and assembly of the components. The design of the tip 23 is shown in greater detail in FIG. 3. It has been found advantageous to form the tip 23 with an oversize head 37 and a stem 38. A bore 40 extends downwards through the stem 38 and to a point in the head 37 adjacent the eventual position of the hemispherical end of the tip 23.

The plunger is assembled by inserting the stem 38 into the shaft 22 and loading the tip axially towards the shaft 22 with a load at which the tip material just starts to plastic flow. In one design of plunger we have found 25 lb. to be a suitable load. A diametral drilling is made through the shaft 22 and stem 38 and a pin 39 is pressed therethrough.

The axial load is then removed from the tip 23 and it is rough turned to its hemispherical shape. The plunger is next annealed, conveniently at around 60°C. After cooling the tip 23 is formed to its final hemispherical shape.

After the injector is completely assembled it is preferably raised to a temperature such as 130°C at which the material of the tip 23 just begins to plastic flow, to ensure good sealing of the tip 23 against the seating face 12.

If preferred suitable shapes other than hemispherical for the tip 23 and conical for the seating face 12 may be used. Furthermore other suitable ways may be used for fastening the tip 23 to the shaft 22.

FIG. 2 shows in more detail one solenoid unit 32 according to the present invention. The solenoid unit has a cylindrical body 50 and integral base 51, both of Swedish iron. A coaxial Swedish iron core 52 is held in a bore in the base 51 by a ring of braze 53. The ring of braze also serves as a magnetic gap causing the lines of magnetic force between the base 51 and core 52 to pass out of the solenoid unit 32 and through the mushroom-shaped head 29 which is thereby attracted upward until it contacts the lower face of the solenoid unit 32. The terminals 36 are connected to a wire winding 54. The upper part of the magnetic circuit is completed by Swedish iron lamina 55 which are a press fit on the core 52 and inside the body 50 to ensure magnetic continuity. The solenoid unit 32 is sealed by a plastics capping 56. A ferromagnetic rod 57 typically approximately 1/16 inch diameter is a sliding fit in an axial bore 58 extending most of the way down the core 52. The rod 57 has an enlarged threaded head 59 engaged in a threaded bore in the plastics capping 56, the upper part of the core 52 or in both, whereby a fine adjustment may be made of the axial position of the rod 57 inside the core 52.

In normal operation the fuel injector solenoid unit 32 is fed with a stream of electrical pulses, during each of which the fuel is to be injected into the engine. As the voltage of the leading edge of the pulse starts to rise the magnetic flux in the magnetic circuit starts to rise correspondingly producing a rising force on the head 29 of the plunger and corresponding acceleration thereof.

The acceleration and motion of the plunger depends inter alia on the difference between the simultaneous upwards magnetic force and downwards force due to the spring 26. The force pattern would therefore be expected to depend on the value of the voltage of the relatively flat top of the electrical pulse, and variations in this peak voltage will produce some variation in the time pattern of magnetic field and ensuing force and plunger motion. This sensitivity of fuel flow to variations in the pulse peak voltage can be reduced by arranging for at least a part of the magnetic circuit of the solenoid unit 32 and head 29 to become magnetically saturated at an electrical input voltage less than the pulse peak voltage. In this way the magnetic field, ensuing force and pattern of plunger movement will be significantly less sensitive to pulse peak voltage.

Since several fuel injectors are commonly fed with the same electrical pulses on a multi-cylinder engine it is necessary for the injectors to pass simultaneously equal quantities of fuel per pulse. We have found that a fine adjustment to the fuel flow versus pulse length characteristic of each injector can be made by altering the magnetic field in the magnetic circuit when saturation is reached. This is done by axial movement of the rod 57, the core 52 being saturated by normal pulses. Due to the bore 58, the core 52, will become saturated at a lower upwards force on the head 29 as the rod 57 is withdrawn.

I claim:

1. A method of making a fuel injector of the kind having a plunger including a metal portion which has a bore into which is fastened a stem of a tip of plastics or rubber-like material, said tip being for sealing against a seating face of the fuel injector, to close the fuel outlet from said injector, said method including the steps of inserting the stem into the bore, loading the tip towards the metal portion with a load at which the tip material just starts to plastic flow, and mechanically securing the stem to the metal pertion while so loaded.

2. A method as claimed in claim 1 which includes drilling a diametral bore through the stem and metal portion and inserting a fastening pin therein while the tip is still loaded.

3. A method as claimed in claim 2, which includes subsequently removing the load on the tip, rough shaping the portion of the tip for contacting the seating face, annealing the plunger at an annealing temperature for the plastics or rubber-like material, cooling the plunger and finish shaping the portion of the tip.

4. A method as claimed in claim 3, which includes raising the assembled injector with the tip subject to its normal working load against the seating face, to a temperature at which the plastics or rubber-like material just starts to plastic flow.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,820,213 Dated June 28, 1974

Inventor(s) PETER MICHAEL KENT

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

[30] Foreign Application Priority Data

August 19, 1970 Great Britain . . . 40012/70

Signed and sealed this 5th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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