June 17, 1969 K. ECKERT 3,450,353

ELECTROMAGNETICALLY ACTUATED FUEL INJECTION VALVE
FOR INTERNAL COMBUSTION ENGINES

Filed Sept. 26, 1967 Sheet 1 of 3

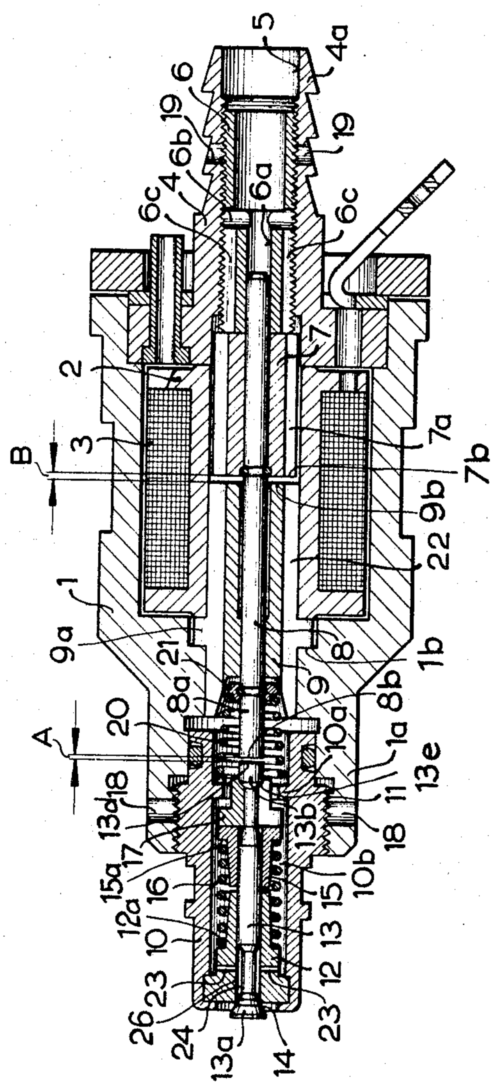

FIG.1

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FIG. 2

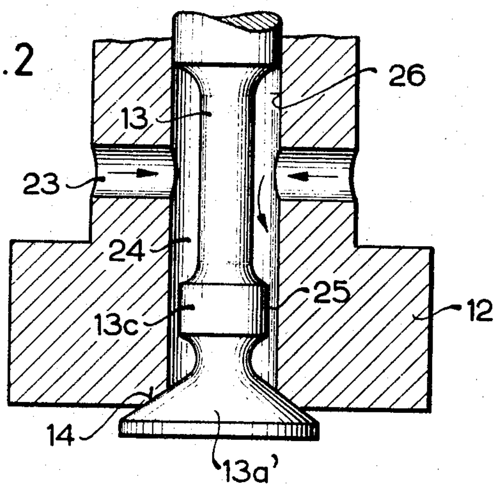

FIG. 3

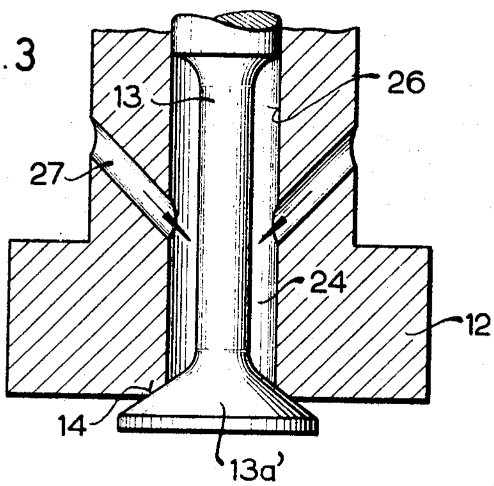

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FIG. 4

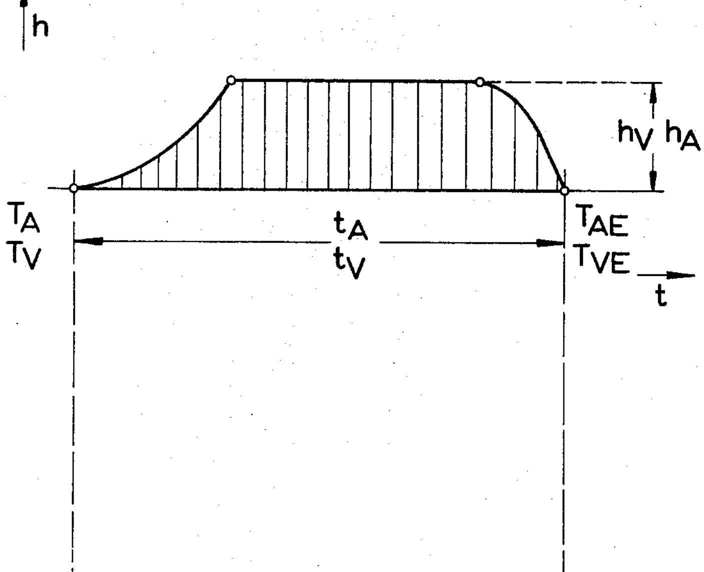
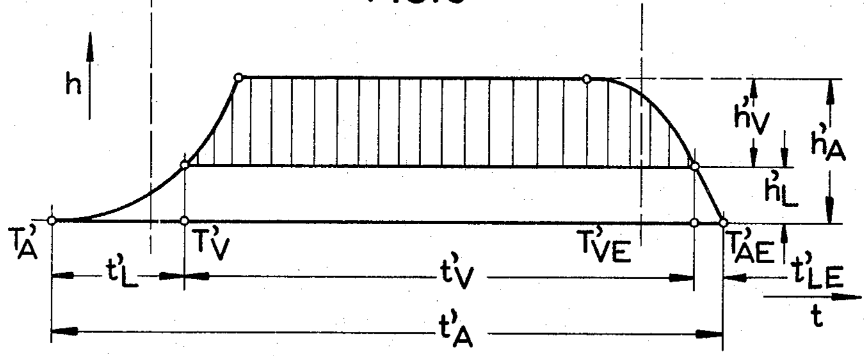


FIG. 5



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ELECTROMAGNETICALLY ACTUATED FUEL INJECTION VALVE FOR INTERNAL COMBUSTION ENGINES

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U.S. Cl. 239—585 10 Claims

ABSTRACT OF THE DISCLOSURE

An electromagnetically operated fuel injection valve having a valve needle intermittently unseated by a reciprocating armature displaced by the magnetic field generated by an intermittently energized solenoid and returned into its original position by a return spring, said armature and said valve needle are formed as two separate, unconnected members.

Background of the invention

Fuel injection valves having an electromagnetically displaceable valve needle to open a nozzle or discharge outlet are well known in the art. In these known valves the armature associated with the electromagnet is fixedly secured to the valve needle and consequently the two move as a unit. As a result, the stroke of the valve needle is equal to that of the armature and the moment of opening the nozzle (that is, unseating of the valve needle) coincides with the start of displacement of the armature attracted by the magnet. Further, the nozzle remains open until the armature returns into its position of rest. Such a structure is described, e.g., in German patent to Knapp et al., No. 1,156,602.

In fuel injection valves of the aforenoted type, due to the unitary structure of the armature and valve needle, the solenoid has to displace a relatively large mass from its position of rest. Further, initial movement of the armature from its position of rest is resisted by a relatively large counterforce exerted by a return spring of the unitary valve needle and armature. Consequently, an initial creeping motion of the armature and the valve needle will occur. Since the duration and course of this creeping motion is not uniform, varying delays between the start of the injection and the solenoid-energizing signals from the control or regulating system may appear in the same valve under different operating conditions or in different valves under identical operating conditions. In view of the fact that the "open" period of the valve lasts only a small fraction of a second, the aforenoted circumstances cause difficulties in obtaining a desired uniformity of the injected fuel quantity over the total time of engine operation or a uniformity of the injected quantities in simultaneously operating different valves.

In addition, due to the relatively large mass of the unitary armature and valve needle structure, stray defects often appear in the final phase of the return stroke of the armature due to its rebound from the position of rest. This circumstance further undesirably affects the uniformity of the "open" period and thus the uniformity of the injected fuel quantities.

Summary and advantages of the invention

It is an object of the invention to provide an electromagnetically actuated improved fuel injection valve

wherein the aforenoted deficiencies of the prior art devices are overcome and as a result a great uniformity of the injected fuel quantities is achieved.

Briefly stated, according to the invention there is provided an electromagnetically actuated fuel injection valve in which the armature associated with the electromagnet and the valve needle are formed as separate, unconnected members and are separately movably held in such a manner that the armature upon energization of the electromagnet performs an advance stroke before causing motion of the valve needle. Thus, the magnetic coil has to impart an initial accelerating force only to the armature to displace the same from its position of rest against the relatively small force of a return spring associated with the armature alone. The valve needle has its own return spring which in no way counteracts the force of the magnetic field while the armature performs its advance stroke. The already accelerated armature, at the end of its advance stroke, impinges upon the valve needle in an impact-like manner causing the valve needle to move very rapidly into its "open" position. As a result, the nozzle is correspondingly opened in an impact-like, rather than in a gradual manner.

The aforenoted structural separation of the armature and the valve needle according to the invention has numerous advantages over the devices of the prior art. Thus,

(a) the separate, unconnected structure and separate positioning of the armature and the valve needle result in a better guidance of reduced friction whereby a more uniform distribution of the magnetic flux in the armature may be achieved which is essential for a positive and secure initial displacement thereof in response to the generated magnetic field;

(b) due to the impact-like engagement between the accelerated armature and the valve needle, the latter moves very rapidly into its "open" position. Consequently, an initial creeping motion of the valve needle as experienced in the prior art devices is eliminated;

(c) the valve closing time, initiated as the solenoid is de-energized, is shortened with respect to the prior art devices since a stronger return spring for the valve needle may be used. This is made possible by the fact that the said return spring, regardless of its strength, has no effect on the armature at rest and during its advance stroke; consequently, this spring can cause no delay in the beginning of the fuel injection;

(d) during the final phase of the return stroke a possible rebound of the armature from its position of rest cannot be transferred to the valve needle, thus an undesired post-injection experienced in prior art structures is effectively avoided;

(e) as it will be shown graphically, the period of one full cycle of armature movement (that is, the time of absence of the armature from its position of rest) is larger for the novel valve than for devices known heretofore while the injected fuel quantities are substantially the same during one cycle in both instances. Consequently, with unchanged tolerances of the lengths of said periods, the percentage of error is automatically reduced increasing thereby the uniformity of the injected fuel quantities;

(f) the structurally separate armature and valve needle also make possible to separately assemble and test, on the one hand, the nozzle body containing the valve needle and ,on the other hand, the valve housing containing the electromagnetic system and the armature.

The invention will be better understood and further objects and advantages will become more apparent from the ensuing detailed specification of a preferred but merely exemplary embodiment taken in conjunction with the drawings.

Brief description of the drawings

FIG. 1 is an axial sectional view of the injection valve according to the invention;

FIG. 2 is an enlarged view of one modified part of the injection valve;

FIG. 3 is a view similar to FIG. 2 showing another modification of the same part;

FIG. 4 is a stroke v. time curve of a known valve needle with integral armature; and

FIG. 5 is a stroke v. time curve of a valve needle with separately constructed and arranged armature according to the invention.

Structural description of the preferred embodiment

Turning now to FIG. 1, there is shown a fuel injection valve comprising a hollow valve housing **1** having an axial cylindrical bore of stepped sections therethrough. Within the housing **1** there is disposed a spool **2** on which there is wound a solenoid **3**. The bore section of the valve housing **1** accommodating spool **2** is closed at its upper or fuel input end by means of an insert **4** having an outwardly projecting externally terraced nipple **4a** which extends coaxially with the valve housing and which is adapted to receive the end of a fuel conduit (not shown). The insert **4** is provided with an axial bore **5** for the admission of fuel. The bore **5** is internally threaded to receive an abutment sleeve **6**, the lower end face of which forms an abutment for an armature **7** slidably disposed in the bore of the housing **1** and projecting into the axial bore of the magnet spool **2**. The armature **7** is axially downwardly extended by an armature pin **8** rigidly affixed to the armature **7**. Pin **8**, beyond the upper end of armature **7**, projects into the bore **6a** of the abutment sleeve **6** and, beyond the lower end of armature **7**, extends through the axial bore of a magnetic core **9**. The core **9** is fixedly held in the valve housing **1** by the lower end of spool **2** clamping a collar **9a** of core **9** against a radially inwardly projecting shoulder **1b** of housing **1**. The armature pin **8** which is shown in its position of rest, projects, beyond core **9**, into the bore section of the valve housing portion **1a** forming the output (injection) end of the valve housing **1**.

The lower terminus of the axial bore in housing portion **1a** is provided with an internal thread to receive a hollow valve body **10** having at its upper enlarged portion a complemental external thread **11**. The valve body **10** houses a nozzle body **12** in which there is disposed a valve needle **13**. In the front or discharge end of the nozzle body **12** there is formed a valve seat **14** which cooperates with the conical head **13a** of the valve needle **13**. The valve needle **13**, at a location spaced from head **13a**, is surrounded by a spring seat sleeve **15** having a radially offstanding upper shoulder **15a** which is engaged by one end of a valve spring **16**. The other end of spring **16** rests against a radially extending lower shoulder **12a** of the nozzle body **12**. The shoulder **15a** of spring seat sleeve **15** abuts against an axially apertured and sectional stop member **17** which at its other end conforms to a shoulder **13e** of the end section **13b** of the valve needle **13**. In the position of rest shown in FIG. 1, the terminal face **13d** of the valve needle **13** is at a predetermined distance A from the terminal face **8b** of the end section **8a** of the armature pin **8**. The clearance A may be adjusted by rotating to a lesser or greater extent the valve body **10** in the housing section **1a**. The terminal section **1a** of the valve housing **1** has a plurality of radial bores **18** which extend through the wall of the housing and end in the area of the internal thread receiving the complemental thread **11** of the valve body **10**. After the clearance A which determines the magnitude of the advance stroke of armature **7** and its pin **8** has been set by the appropriate angular adjusting or tightening of the nozzle body **10** in the valve housing **1**, the bores **18** are filled with sealing putty or any other suitable adhesive for preventing an accidental rotary displacement of the valve body **10** with respect to the housing section **1a** and thus causing an accidental change of clearance A. It is thus seen that the advance stroke of armature **7** may be externally set.

The total stroke or displacement of armature **7** is determined by the clearance B between the lower end face **7b** of armature **7** and the upper end face **9b** of core **9**. The clearance B which is greater than the clearance A may be finely adjusted by turning the abutment sleeve **6** within the insert **4**. Nipple **4a**, similarly to the end portion **1a** of the housing **1** is provided in the area of its internal thread with a plurality of radially extending bore holes **19** which, after the setting of the abutment sleeve **6**, are filled with sealing putty or other suitable adhesive for the purpose of locking the abutment sleeve **6** in its predetermined angular position with respect to the insert **4**.

The armature **7** is urged into its position of rest and into engagement with abutment sleeve **6** by means of an armature return spring **20** which is compressed between a spring seat ring **21** rigidly affixed to the armature pin **8** and an inwardly extending shoulder **10a** of the valve body **10**.

The fuel is introduced in the electromagnetically actuated injection valve through bore **5** of nipple **4a** and passes through transverse bores **6b** and axial grooves **6c** to armature **7** which is also provided with longitudinal or axial grooves **7a** serving as fuel channels. From the grooves **7a** the fuel flows through axial grooves **22** of the magnet core **9** into the inner space **10b** of the valve body **10**. From the inner space **10b** of the valve body **10** the fuel flows through transverse bores **23** provided in the nozzle body **12** into an annular chamber **24** defined by the valve needle **13** and the adjacent internal cylindrical wall **26** of constant diameter. The annular chamber **24** terminates in the outwardly flared valve seat **14**.

Turning now to FIG. 2, the fuel flowing to the nozzle opening (defined by valve seat **14**) and discharged therethrough when the valve needle **13** is unseated, is metered by means of a throttle clearance **25** formed by an enlargement **13c** of the valve needle **13** (disposed immediately above the head **13a'**) and the internal cylindrical wall **26** in the valve body **12**.

FIG. 3 shows a modified means for metering the admission of fuel to the nozzle. In this embodiment there are provided calibrated slanted bores **27** (replacing the transversal bores **23** of FIGS. 1 and 2) which merge into the annular chamber **24** of the nozzle body **12**. The calibrated bores **27** may merge tangentially into wall **26** to cause a helical swirling motion of the fuel resulting in a more uniform stream of the injected fuel when the nozzle is open (i.e. the valve head **13a'** is unseated).

Operational description of the preferred embodiment

When solenoid **3** is energized, the generated magnetic field will cause the armature **7** and pin **8** to move as a unit towards the output (injection) end of the valve housing **1** reducing both clearances A and B. As seen, the armature **7** and the pin **8** are first accelerated against the force of the return spring **20** only. The end face **8b** of pin **8**, after reducing clearance A to zero, abuts against the terminal face **13d** of the valve needle **13** and displaces the latter together with stop member **17** (urged by shoulder **13c**) and spring seat sleeve **15** (urged by stop member **17**) in an impact-like manner against the force of spring **16** causing the head **13a** of valve needle **13** to be unseated from valve seat **14** of the nozzle body **12**. It is seen that the advance stroke of the armature **7** and pin **8** prior to abutment against valve needle **13** is A; the total stroke of the armature **7** and pin **8** is B; while the stroke of the valve needle **13** is B–A. After the solenoid **3** has been deenergized, the armature **7** and pin **8**, both urged by armature return spring **20**, are shifted back into their position of rest shown in FIG. 1. The valve needle **13**, on the other hand, is retracted into its position of rest and the head **13a** reseated in seat **14** by means of the valve return spring **16** acting on the shoulder **13c** of the valve needle through spring seat sleeve **15** and stop member **17**. One cycle of operation is now completed and the valve is ready to perform its subsequent cycle initiated by the subsequent energization of solenoid **3**.

Operational effects of the novel injection valve will become apparent from a comparison of the graphs shown in FIGS. 4 and 5. In both FIGS. 4 and 5 one full cycle of armature and valve needle movement is shown. The movement of the armature is composed by a working stroke caused by the generated magnetic field and a return stroke caused by a return spring after the magnetic field has disappeared. The movement of the valve needle is composed by an opening stroke caused by the armature performing its working stroke and a return or closing stroke caused by a return spring while the armature performs its return stroke. In the graphs, the abscissae indicate duration or period of movements while the ordinates represent the distance of displacements.

FIG. 4 shows the course of stroke of a valve needle and armature in a heretofore known arrangement wherein the armature and the valve needle are fixedly secured to one another. Accordingly, the period t_A of one full cycle of armature movement equals exactly the "open" period t_V of the valve, and the valve stroke h_V equals the armature stroke h_A.

On the other hand, as depicted in FIG. 5, the course is quite different for the armature and the valve needle constructed and arranged according to the invention. As seen, the period t'_A of one full cycle of armature movement is larger than the "open" period t'_V of the valve because the armature first performs an advance stroke h'_L during a period t'_L and actuates the valve in the opening direction only at moment T'_V. After the solenoid has been de-energized, the valve will close under the influence of the return spring at moment T'_{VE} at the end of the "open" period t'_V. The armature, however, assumes its position of rest only at moment T'_{AE} at the end of period t'_{LE} during which the armature performs the final portion h'_L of its return stroke h'_A while the valve is already closed.

FIG. 5 demonstrates that, on the one hand, the armature stroke h'_A is by the advance stroke h'_L longer than the valve stroke h'_V and, on the other hand, the period t'_A of one full cycle of armature movement is by $t'_L+t'_{LE}$ longer than the "open" period t'_V of the valve needle.

A comparison between FIGS. 4 and 5 shows that under equal conditions of injected fuel quantity (represented by the shaded areas in FIGS. 4 and 5), pressure of injection, throttle area, and r.p.m. of the engine, the period t'_A of one full cycle of armature movement in the novel injection valve is longer than the period t_A of one full cycle of armature movement in valve devices known heretofore. Thus, assuming that the absolute value of the tolerances in the length of period t'_A being the same as for period t_A, the maximum percentage of permissible error in t'_A is reduced with respect to t_A. As a consequence, the percentage of error in the injected fuel quantities during one cycle of valve operation is smaller in the injection valves according to the invention than in the known devices although, as shown hereinabove, the injected fuel quantities are substantially the same in both cases.

What is claimed is:

1. In an electromagnetically actuated fuel injection valve of the type including a solenoid, the improvement comprising an armature having a position of rest and movable by a magnetic field generated by said solenoid upon energization thereof to perform a working stroke and a valve needle having a position of rest and movable

by said armature to perform an opening stroke, said valve needle and said armature, when in their respective positions of rest, being separated from one another by a clearance so that said armature, when said solenoid is energized, is adapted to perform an advance stroke before moving said valve needle out of its position of rest.

2. A fuel injection valve as defined in claim **1** including a valve return spring urging said valve needle into its position of rest and causing said valve needle to perform a return stroke when said solenoid is de-energized and an armature return spring urging said armature into its position of rest and causing said armature to perform a return stroke when said solenoid is de-energized.

3. A fuel injection valve as defined in claim **1** wherein said armature and said valve needle are of an elongated shape and are axially aligned and axially slidable, said armature is provided with a terminal face adapted to impinge upon an adjacent terminal face of said valve needle at the end of said advance stroke, said terminal faces, in said positions of rest, are separated by a clearance that corresponds to the length of said advance stroke.

4. A fuel injection valve as defined in claim **3** wherein said valve needle and said valve return spring are contained in a valve body, said valve housing and said valve body are provided with complemental threads and are threadably secured to one another, said clearance corresponding to said advance stroke is variable by a relative rotation between said valve body and said valve housing.

5. A fuel injection valve as defined in claim **4** wherein said valve housing includes transversal bores in the region of said threads, said transversal bores adapted to receive securing means to prevent relative rotation between said valve body and said valve housing after setting said clearance.

6. A fuel injection valve as defined in claim **3** including an axially adjustable abutement inserted into said valve housing and defining said position of rest for said armature.

7. A fuel injection valve as defined in claim **4** including a hollow nozzle body secured within said valve body and provided with an internal cylindrical wall surrounding said valve needle, said cylindrical wall having a diameter constant throughout its length and terminating at one end in a flared portion defining a valve seat, said valve needle, remote from said terminal face thereof, terminating in a valve head associated with said valve seat, said valve head and said valve seat defining a nozzle, said valve needle provided with a portion of reduced diameter immediately adjacent said head to define with said cylindrical wall an annular chamber and means for admitting fuel into said chamber.

8. A fuel injection valve as defined in claim **7** wherein said portion of reduced diameter includes a radial enlargement defining with said cylindrical wall a throttle clearance for metering said fuel passing therethrough.

9. A fuel injection valve as defined in claim **7** wherein said means admitting fuel into said chamber includes at least one calibrated bore provided in said nozzle body.

10. A fuel injection valve as defined in claim **9** wherein said bore merges tangentially into said cylindrical wall.

References Cited

UNITED STATES PATENTS

2,339,352	1/1944	Roy	251—141
3,004,720	10/1961	Knapp et al.	239—585

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U.S. Cl. X.R.

123—32; 239—453; 251—141, 138