ELECTRIC FUEL INJECTION CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINES

Abstract

In internal combustion engines, where the fuel injection valves are electromagnetically operated, at the time of engine acceleration the amount of fuel injected is increased by converting sudden changes in such parameters as the negative pressure in the engine intake manifold into corresponding changes of the mechanical type, such as by the displacement of a diaphragm, according to which mechanical changes an electric fuel injection control is operated. Thus, a delay time is involved, resulting in an insufficient response characteristic. In the specification, there is disclosed an electric fuel injection system for internal combustion engines, comprising: a means to generate electric signals corresponding to the speed of motion of the throttle of the engine or particularly when the speed of the throttle motion exceeds a predetermined value; and a means to increase the amount of fuel delivered for acceleration by so controlling fuel injection valves upon reception of the signal from the first means.

FOREIGN PATENTS OR APPLICATIONS
1,193,728 5/1965 Germany............... 123/32 EA

Primary Examiner—Laurence M. Goodridge
Attorney, Agent, or Firm—Cushman, Darby & Cushman

4 Claims, 3 Drawing Figures
3,842,811

ELECTRIC FUEL INJECTION CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINES

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of application Ser. No. 53,821 filed July 10, 1970 now U.S. Pat. No. 3,179,176.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to improvements in electric fuel injection control systems for internal combustion engines to provide for effectively increasing the amount of the delivered fuel at the time of acceleration without time delay.

2. Description of the Prior Art

In internal combustion engines having the usual electric fuel injection control system capable of increasing the fuel delivery at the time of acceleration of the engine, sudden changes of the pressure in the intake manifold of the engine as the result of the accelerating operation are first mechanically detected by such pressure-sensitive mechanisms as a diaphragm corresponding to a displacement the switching elements in an electrical circuit are controlled to extend the pulse width of the pulse signal fed to the injector valves so as to correspondingly prolong the open-position time of the injector valves, thereby increasing the fuel amount delivered at the time of acceleration.

Therefore, with the conventional system of this type a time delay is involved from the instant of actuating the accelerating means, for instance, upon depressing the accelerator pedal, until the increased fuel delivery actually occurs, during which delay time the pressure in the intake manifold first changes, the change in this pressure is then detected as a displacement of the mechanical means and thereafter the detection signal corresponding to the displacement drives the switching elements, so that the response time is very inferior. So long as the above response steps are involved, it is extremely difficult to improve the response time by any means available at present. Thus, the above conventional system is disadvantageously incapable of exactly following the demand of the engine for an increased fuel supply at the time of acceleration without delay, so that it cannot fully achieve the intended object.

In another aspect, the operating point, at which the function of increasing the fuel delivery is brought about by detecting the accelerating operation through the pressure-sensitive mechanism such as a diaphragm for accelerating the engine, substantially depends upon a point, at which the above pressure-sensitive mechanism such as the diaphragm detecting the sudden change in the engine intake manifold pressure as the result of the accelerating operation starts to undergo mechanical displacement to control the switching elements, and it is fixed as the displacement starting point is determined by structural factors in the design such as the dimensions and configuration of the pressure-sensitive mechanism, mechanical constants involved and design specifications. Therefore, if the afore-mentioned operating point to bring about the action of increasing the fuel delivery for the acceleration of the engine is to be changed, the design specification for the pressure-sensitive mechanism such as the diaphragm should be fundamentally changed, which is extremely disadvantageous, as well as providing no compatibility with engines having different ratings.

SUMMARY OF THE INVENTION

An object of the invention is to provide an electric fuel injection control system for use in internal combustion engines, where injector valves are controlled by an electric control system in accordance with an operating parameter for the engine, thereby being capable of increasing the amount of fuel delivered at the time of accelerating the engine without time delay.

Another object of the invention is to provide an electric fuel injection control system for use in internal combustion engines, which enables readily changing the operating point to bring about the action of increasing the fuel delivery for the acceleration of the engine and provides compatibility with engines of different ratings.

According to the invention, there is provided an electric fuel injection control system for internal combustion engines comprising a means to generate an electric signal derived from the action of the throttle or a movable part associated with the throttle valve of the engine when the speed of motion of the throttle in the direction of opening thereof exceeds a predetermined value, and a means to control injection valves to increase the amount of fuel delivery in response to the electric signal from the first means, whereby said control system is capable of meeting the requirements of the engine characteristics to increase the fuel delivery at the time of acceleration with good response, readily changing the operating point to bring about the action of increasing the fuel delivery for the acceleration of the engine as well as affording compatibility with engines of different ratings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic block diagram of an embodiment of the electric fuel injection control system according to the invention.

FIG. 2 is a circuit diagram of the embodiment of FIG. 1.

FIG. 3 shows the operating characteristics of the embodiment of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention will now be described in conjunction with preferred embodiments thereof with reference to the accompanying drawings.

Referring to FIG. 1, which shows an embodiment of the invention, there are shown four fuel injection valves 1 to 4, which are electromagnetically operated and provided in respective first to forth cylinders (I) to (IV), shown). Numerals 105 designates a pressure detector to detect the pressure in the intake manifold, which is one of the operating parameters of the engine, as a corresponding DC voltage. The output voltage from the pressure detector 105 is amplified by an amplifier 106. Numerals 107 designates a fuel injection timing detector to generate signal pulses in synchronism with the timing of the opening of the intake valves of the respective cylinders (I) to (IV) or the fuel injection timing of the fuel injection valves 1 to 4. The pulses may be generated as a function of the rotation angle of the cam shaft, for ex-
ample. The outputs from the amplifier 106 and from the fuel injection timing detector 107 are fed to a pulse width modifier 108, which generates fuel injection pulses synchronous with the output pulse signal from the fuel injection timing detector 107 and having a pulse width corresponding to the output voltage from the amplifier 106, that is, the pressure in the intake manifold. A fuel injection valve driving circuit 109 receives the fuel injection pulse signal from the pulse width modulator 108 and energizes a corresponding one of the fuel injection valves 1 to 4 to hold it in the open position for a time interval equal to the pulse width, which is proportional to the amount of fuel to be injected. Shown within a broken-line rectangular section 110 is an acceleration fuel-increase signal generator to generate an electric signal for increasing the fuel supply for accelerating the engine, which comprises a permanent magnet 111 linked to the throttle of the engine or to a movable member associated to the throttle, a coil 112 disposed within the magnetic field established by the permanent magnet 111, a diode 113, a capacitor 114 and a variable resistor 115. A voltage induced in the coil 112 by the movement of the predetermined magnet 111 which accompanies the rotation of the throttle in the opening direction charges the capacitor 114 through the diode 113.

It will be appreciated that the voltage induced in the coil 112 is at a level proportional to the speed of motion of the throttle or the movable part associated with the throttle. The capacitor 114 is discharged through the variable resistor 115 for a time interval determined by the time constant of the circuit consisting of the resistor 115 and the capacitor 114. The voltage on the output terminal 116 of the acceleration fuel-increase signal generator 110, that is, the terminal voltage across the capacitor 114, is fed in superposition upon the voltage of the output from the pressure detector 105 to the amplifier 106.

Now referring to FIG. 2, which is a circuit diagram of the abovementioned embodiment, the pressure detector 105 comprises an engine vacuum sensor 1051, a diode 1052, a resistor 1053 and a capacitor 1054. The engine vacuum sensor 1051 includes a diaphragm, which is movable responsive to variation of the pressure in an engine intake manifold (not shown), a moving core which is connected to a movable member fixed to the diaphragm, and a differential transformer having a winding means 1055 which is electrically connected to an oscillator 1056 and adaptable to produce a signal voltage depending upon the position of the movable member relative to the winding means 1055.

The amplifier 106 includes an operational amplifier 1061 whose input is connected to the outputs of the pressure detector 105 and the acceleration fuel increase signal generator 110. The injection timing detector 107 includes four identical circuits 107a, 107b, 107c and 107d, each having a breaker 1071 which opens and closes in synchronism with rotation of the engine, a capacitor 1072 and a transistor 1073. The pulse width modulator 108 comprises four identical circuits 108a, 108b, 108c and 108d connected to the circuits 107a, 107b, 107c and 107d, respectively, and each having a saw tooth wave generator 1081 and a comparator 1082. The fuel injection driving circuit 109 comprises also four identical circuits 109a, 109b, 109c and 109d connected to the circuits 108a, 108b, 108c and 108d, respectively, and each having a pair of transistors 1091 and 1092. Thus the injection timing detector 107, the pulse width modulator 108 and the fuel injection driving circuit 109 comprises four identical sets of series circuits respectively connected to the fuel injection valves 1 to 4. It is noted that the number of the sets of series circuits corresponds to the number of engine cylinders.

The operation of this embodiment will now be described in detail with reference to the graphs of FIG. 3, in which the abscissa is commonly taken for time t, and which shows at (A) the voltage induced in the coil 112, at (B) the terminal voltage across the capacitor 114 and at (C) the fuel injection pulses for impression on the individual fuel injection valves 1, 3, 4 and 2 provided respectively in the first, third, fourth and second cylinders as indicated respectively from the top downwards at (I), (III), (IV) and (II).

In the normal engine operation with the throttle held at a predetermined normal position, the permanent magnet 111 assumes a predetermined position and does not move, causing no voltage to be induced in the coil 112, so that the fuel injection valve driver circuit 109, receiving successive fuel injection pulses generally indicated at P, generated by the pulse width modulator 108, which pulses have a pulse width (as generally indicated at T at (C) in FIG. 3) conforming only to the output voltage from the pressure detector 105 and which are synchronized with the output pulse signal from the fuel injection timing detector 107, drives the respective fuel injection valves 1 to 4 in accordance with the corresponding pulses P and holds these valves open for a period equal to the pulse width T, during which the fuel is injected, for the normal operation of the engine conforming to the requirements of the engine characteristics under normal driving conditions. The order of driving (fuel injection) of the fuel injection valves depends upon the distribution function of the fuel injection valve driver circuit 109, and is consistent with the order of firing the cylinders, for instance in the order of first cylinder (I), third cylinder (III), fourth cylinder (IV) and second cylinder (II).

When the permanent magnet 111 moves in accompaniment to the accidental movement of the throttle or the movable member associated thereto due to such causes as vibration of the engine during the normal engine operation without any action taken for accelerating the engine, voltage is induced in the coil 112 as indicated at V in FIG. 3, and such induced voltage is at levels lower than the level of the reference voltage V determined by the forward voltage drop across the diode 113, so that the capacitor is not charged.

When acceleration is applied to the engine, for instance by depressing the accelerator pedal, to move the throttle toward the full position, the permanent magnet 111 moves, inducing a voltage in the coil 112 with a maximum level exceeding the reference voltage V, as indicated at V at (A) in FIG. 3, thus charging the capacitor 114 through the diode 113, as shown at (B) in FIG. 3. After the operation of opening the throttle valve is stopped, voltage is no longer induced in the coil 112, and the charge accumulated on the capacitor 114 is discharged through the resistor 115 within a time determined by the time constant for the circuit of the parts 114 and 115. As the terminal voltage across the capacitor 114 is fed in superposition upon the output signal from the pressure detector 105 to the amplifier 106, the output voltage from the amplifier 106 has a
component accounting for the terminal voltage across the capacitor 114 charging in accordance with a charging-and-discharging characteristic as indicated at $V_a$ at (B) in FIG. 3 in addition to the component accounting for the output voltage from the negative pressure detector 105. Accordingly, the pulse width of the fuel injection pulses $P_1$ to $P_n$ produced by the pulse width modulator 108 during the discharging of the capacitor 114 vary, as indicated at $T_1$ to $T_n$ at (C) in FIG. 3, in correspondence to the level of the voltage produced after amplification of the terminal voltage across the capacitor 114 by the amplifier 106. Thus, the amount of the fuel injected is increased in proportion to the pulse width $T_1$ to $T_n$ thus smoothly accelerate the engine.

After the capacitor 114 is discharged through the resistor 115, the pulse width $T_2$ of the fuel injection pulse signal from the pulse width amplifier 108 is again determined solely by the voltage output from the detector 105.

When quicker or more forceful accelerating action is applied to the engine, a higher voltage exceeding the reference voltage $V_{ref}$ as indicated at $V_r$ at (A) in FIG. 3, is induced in the coil 112, and a corresponding higher terminal voltage, as indicated at $V$ at (B) in FIG. 3, is built up across the capacitor 114. Accordingly, the pulse widths of the fuel injection pulses $P_1'$ to $P_n'$ occurring during a time interval from instant $t_0$ at which the charging of the capacitor 114 starts, until instant $t_0$ at which the discharging of the capacitor 114 ends, are further increased, as indicated at $T_1'$ to $T_n'$ at (C) in FIG. 3, in correspondence to the level of the terminal voltage across the capacitor 114 in accordance with the charging-and-discharging characteristic of the capacitor 114. In addition to the increase in the pulse width, the number of times the injection of an increased amount of fuel is made, is increased. In case the throttle valve is suddenly closed for rapidly decelerating the engine, a negative voltage induced in the coil 112, so that the capacitor 114 is not charged, thus generating no signal for increasing the fuel delivery.

The number of times the injection of an increased amount of fuel is made may be preset to meet the requirements of the engine characteristics by making variable at least one of the capacitance of the capacitor 114 and the resistance of the resistor 115 or by selecting suitable values of these quantities. The voltage level to be established for avoiding malfunctioning of the system due to such causes as vibration of the engine or the operating point to start increasing the fuel delivery for accelerating the engine, that is, the reference voltage $V_{ref}$ in the above embodiment, is determined by the forward voltage drop across the single diode 113. It may as well be preset by a plurality of diodes connected in series, a constant-voltage diode having a certain breakdown voltage, a transistor and so forth. Also, in this embodiment only the pressure in the intake manifold, which is one of the operating parameters of the engine, is used for determining the pulse width of the fuel injection pulse signal. Other operating parameters such as the engine temperature, atmospheric temperature and pressure may as well be used to modulate the pulse width of the fuel injection pulse signal.

As is described, with this embodiment including the acceleration fuel-increase signal generator to generate an electric output signal at a level corresponding to the speed of motion of the throttle or the movable member associated thereto of the engine when such speed exceeds a predetermined value and a means to extend the time, during which the fuel injection valve is open, in accordance with the level of the output signal from the acceleration fuel-increase signal generator, it is possible to increase the fuel delivered with excellent response characteristics.

Also, by the incorporation of a means to gradually decrease the level of the output signal from the acceleration fuel-increase signal generator with time according to the above embodiment, the amount of the fuel to be increased and the period and the number of times the injection of the increased fuel may be so determined as to meet the requirements of the engine characteristics, thus providing for further smoother acceleration of the engine.

This embodiment can also feature the excellent effects that the operating point to start increasing the fuel delivery may be readily changed to meet compatibility with engines of different ratings is provided, and that the malfunctioning due to such causes as vibration of the engine is prevented.

The means to obtain an electric output signal corresponding to the speed of motion of the throttle or the movable member associated thereto of the engine is not limited to the combination of permanent magnet 111 and coil 112 as in the preceding first and second embodiments, but other means such as a semiconductor element and a magnetostriiction element may also be used. As the movable member associated with the throttle may serve an accelerator ring, the accelerator pedal and so forth. Further, though the preceding embodiments are concerned to the four-cylinder engine, the invention may of course be applied to the single cylinder engine and other multi-cylinder engines.

We claim:

1. An electrical fuel injection control system for an internal combustion engine having electromagnetic means for operating fuel injection valves of the engine and operative to inject fuel in response to injection pulses each having a pulse width varying as a function of parameters indicative of the condition of said engine comprising:

   a permanent magnet signal generator having a permanent magnet linked to the throttle of the engine and an armature coil electromagnetically coupled with said permanent magnet for producing an output voltage responsive to the movement of said permanent magnet;

   first circuit means connected between said armature coil and second circuit means for rectifying said output voltage of said armature coil and supplying a current depending on said rectified output voltage to said second circuit means when said output voltage, exceeds a predetermined level;

   said second circuit means having a capacitor adaptable to store electricity by said current supplied thereto and a resistor adaptable to discharge said stored electricity for producing a voltage variable signal with discharging of said stored electricity;

   pressure signal generating means responsive to the pressure of engine intake manifold of said engine for generating a voltage signal indicative of said pressure;
third circuit means connected to said second circuit means and said pressure signal generating means and including an operational amplifier to add the signal derived from said second circuit means to the signal derived from said pressure signal generating means to produce a signal which varies as a function of the superposition of said voltage variable signal produced by said second circuit means and said voltage signal of said pressure signal generating means;

fourth circuit means connected to said third circuit means for producing a fuel injection pulse signal whose pulse width is determined by said signal produced by said third circuit means;

fifth circuit means connected to said fourth circuit means and said electromagnetic means for driving said electromagnetic means for an interval corresponding to the pulse width of said fuel injection pulse signal.

2. An electrical fuel injection control system for an internal combustion engine comprising:
a signal generator having a member movable in response to the operation of the throttle and means responsive to the movement of said member for producing a first signal voltage indicative of the moving speed of the throttle;

first circuit means having a rectifier connected to said signal generator, a capacitor connected to said rectifier to store electricity supplied thereto through said rectifier by said first signal voltage of said signal generator, and a variable resistor connected in parallel with said capacitor for discharging said stored electricity, said rectifier having a predetermined forward breakdown voltage whereby said first signal voltage is applied to said capacitor only when said signal first voltage exceeds said forward breakdown voltage;

means for detecting the condition of the engine for producing a second signal voltage indicative of at least one predetermined parameter of the condition of said engine;

means connected to said capacitor of said signal generator and said detecting means and including an amplifier having an operational amplifier for adding the signal derived from said signal generator to the signal derived from said detecting means;

means connected to said operational amplifier for generating a fuel injection signal whose pulse width is controlled as a function of the addition by said operational amplifier; and

means connected to said fuel injection pulse signal generating means and having electromagnetic valves for injecting fuel into cylinders of the engine in a predetermined sequence for an interval corresponding to said controlled pulse width of said fuel injection pulse signal.

3. An electrical fuel injection control system according to claim 1, wherein said fourth circuit means comprises a saw tooth wave generator.

4. An electrical fuel injection control system according to claim 2, wherein said fuel injection signal generating means comprises a saw tooth wave generator.

* * * * *
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,842,811 Dated October 22, 1974
Inventor(s) Shinoda et al

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

Page 1, line [63], delete "Aug." and insert --July--.

Signed and sealed this 4th day of March 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks