United States Patent

Endo

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[54] FUEL INJECTION CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINE

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[30] **Foreign Application Priority Data**

Jan. 21, 1969 Japan.....44/4213

[52] **U.S. Cl.** .....**123/32 EA,** 123/179 A

[51] **Int. Cl.**.....**F02m 51/00**

[58] **Field of Search**.....123/32 E, 32 EA, 119 R, 139 E, 123/179 A

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[57] **ABSTRACT**

A fuel injection control system for internal combustion engines wherein an injection reference signal synchronized with the rotation of the engine and in advance of the valve opening times of the inlet valves is produced and the signal is then delayed such that a fuel injection duration modulator for driving the fuel injection solenoid valves is actuated by said delayed signal, while said delay time is controlled by means of signals corresponding to the temperature of the engine and the engine rpm, whereby the fuel injection starting time is changed according to variations in the engine temperature thereby achieving excellent starting characteristics and the optimum rate of fuel consumption.

1 Claim, 4 Drawing Figures

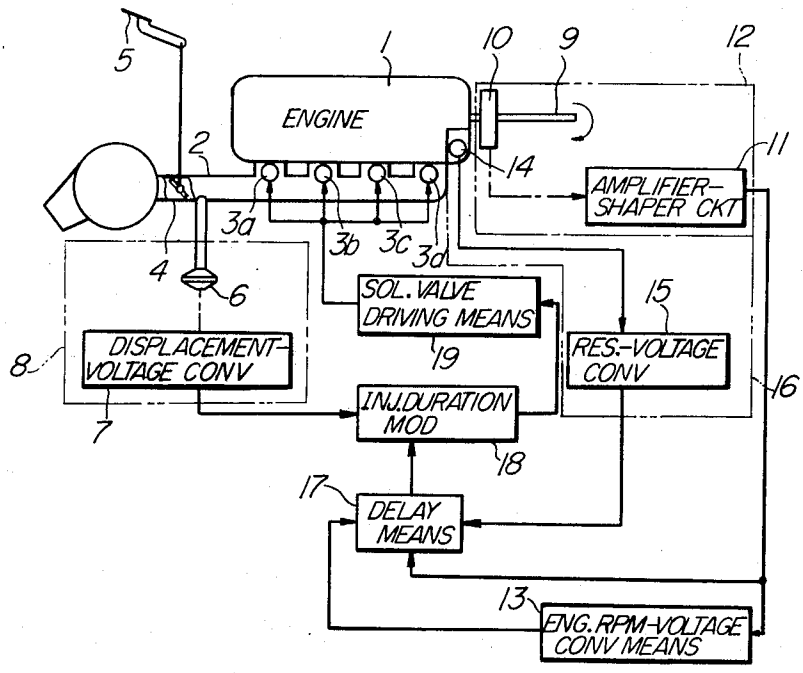


FIG. 1

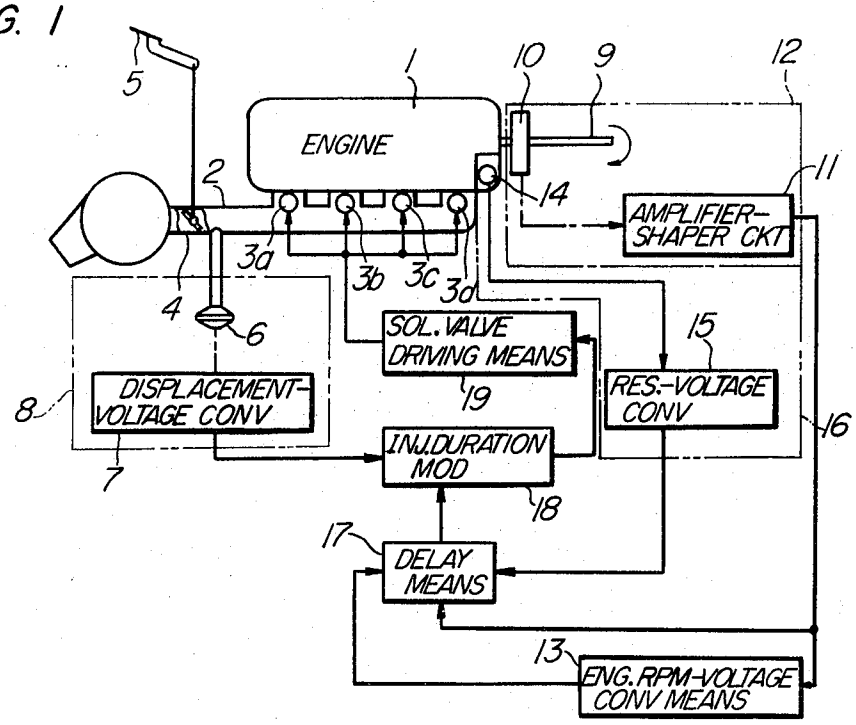


FIG. 2

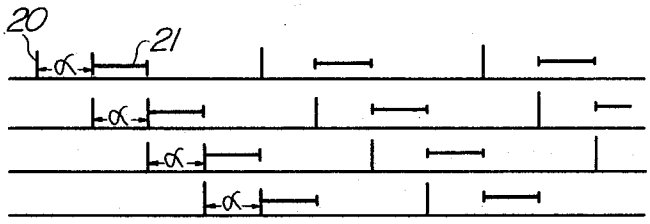


FIG. 3

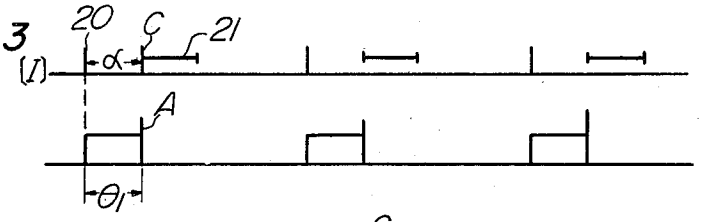
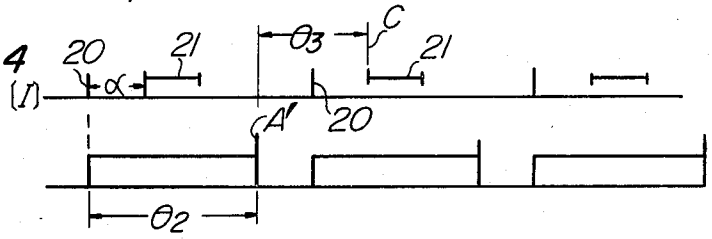


FIG. 4



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FUEL INJECTION CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to electrical fuel injection control systems for internal combustion engines, and more particularly to a control system for controlling the injection starting time of fuel injection solenoid valves.

2. DESCRIPTION OF THE PRIOR ART

The conventional electrical fuel injection systems have been so designed that fuel injection signals are provided by a switching means or the like which is mechanically coupled to a rotary member correlated with the rotation of the engine and the fuel is injected by means of said signals in synchronism with the valve open duration of inlet valves of the engine cylinders. Accordingly, the difference between the valve opening time and the injection starting time is prefixed by the crank angles.

On the other hand, the inventors have discovered through investigation, made by studying various aspects of the problem, that in order to attain satisfactory starting characteristics and the optimum rate of fuel consumption, it is essential to vary the injection starting time with respect to the valve opening time for different engine temperatures. In other words, the result of the experiments has shown that if the injection of the fuel is initiated in synchronism with the valve opening time of the inlet valves in starting the engine, the atomized fuel is directly drawn into the cylinders with no atomized fuel being adhered to the inner wall of the inlet pipes and in the vicinity of the inlet valves, thus attaining a satisfactory starting characteristic, and when the engine is running under normal operating conditions with a rise in the temperature thereof, the inlet valves are opened a little while after the start of fuel injection to allow the atomized fuel to stay for a short period of time in those portions of the inlet pipes near the respective inlet valves where, during this time, the fuel is completely vaporized by the heat around the inlet pipe walls and the inlet valves so that the fuel when delivered to the cylinders may be perfectly burnt to thereby attain an improved rate of fuel consumption.

However, since the difference between the inlet valve opening time and the injection timing is prefixed by the crank angles in the previously described conventional systems, they have some drawbacks, that is, unsatisfactory starting characteristic of the engine and a poor rate of fuel consumption under normal operating condition of the engine.

SUMMARY OF THE INVENTION

The object of the present invention is therefore to provide a fuel injection control system for internal combustion engines wherein an injection reference signal is produced which is synchronized with the rotation of the engine and in advance of the inlet valve opening time, the signal is then delayed in delay means and applied to an injection duration modulator means to provide a fuel injection pulse corresponding to the suction of the engine, whereby the delay time is decreased in inverse proportion to the engine rpm.

According to the present invention, the delay angle of the inlet valve opening time with respect to the fuel injection timing in terms of crank angles may be maintained at a predetermined value for variations in the engine rpm.

Further, according to the present invention, the aforesaid delay time is made longer relative to the engine temperature and therefore the delay angle of the inlet valve opening time with respect to the fuel injection timing in terms of crank angles may be increased in accordance with such engine temperature rises. This produces a remarkable effect in that if the temperature of the engine is low, such as when starting, the fuel may be injected in coincidence with the inlet valve opening time so that the atomized fuel is quickly drawn into the engine cylinder without adhering to the inner wall of the inlet pipe and to the inlet valve to thereby attain an improved starting characteristic of the engine.

Furthermore, there is another remarkable effect that, as an engine gets warmer, such as during normal running thereof, the fuel injection timing may be changed to inject the fuel earlier than the inlet valve opening time so that the atomized fuel is allowed to remain in the vicinity of the inlet valve for a short period of time during which it is completely vaporized by the heat around the inlet pipe wall and the inlet valve, and the fuel is then drawn into the engine cylinder, thereby attaining perfect combustion within the cylinder and achieving an improved rate of fuel consumption.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing an embodiment of the system according to the present invention;

FIG. **2** is a diagram showing the timing relationships between the fuel injection reference signals and the inlet valve open durations for different engine cylinders corresponding to the respective crank angles;

FIG. **3** is a diagram showing the timing relationship between the fuel injection reference signal, the inlet valve open duration and the fuel injection starting time for one of the cylinders when the engine temperature is low; and

FIG. **4** is a diagram showing the timing relationship between the fuel injection reference signal, the inlet valve open duration and the fuel injection starting time for one of the cylinders when the engine temperature is high.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, numeral **1** designates a four-cylinder fuel injection type internal combustion engine; **2** an inlet pipe communicating with the engine cylinders; **3***a*, **3***b*, **3***c* and **3***d*, fuel injection solenoid valves attached to the inlet pipe **2** in the vicinity of the inlet valves of the cylinders. Numeral **4** designates a throttle valve disposed upstream in the inlet pipe **2**; **5** an accelerator pedal to open and close the throttle valve **4**. Numeral **6** designates a suction detector which may be composed of a bellows mechanism to convert the engine suction pressure within the inlet pipe **2** into a mechanical displacement. Numeral **7** designates a displacement-voltage converter to convert the mechanical displacement into a DC voltage corresponding to the required performance of the engine and it may comprise, in combination, a differential transformer and a rectifier-smoothing circuit. And suction-voltage converter means **8** is formed by the suction detector **6** and the displacement-voltage converter **7**. Numeral **9** designates an output shaft of the engine **1**; **10** a pulse generator for generating pulses according to the rotation of the output shaft **9** earlier than the opening time of the inlet valves for the engine cylinders, the pulse generator comprising, for example, four poles of permanent magnets corresponding to the four cylinders which are mounted on the output shaft **9** and enclosed switches which are disposed in the vicinity of the poles. Numeral **11** designates an amplifier-shaper circuit which, if necessary, amplifies and shapes the output pulse from the pulse generator **10** to produce a fuel injection reference signal. And signal generator means **12** is composed of this amplifier-shaper circuit **11** and the pulse generator **10**. Numeral **13** designates engine rpm-voltage converter means for producing, from the output signal of the amplifier-shaper circuit **11**, a DC voltage which corresponds to the characteristic required for the engine **1** and is inversely proportional to the engine rpm, the converter means comprising in combination a monostable multivibrator and an integrating circuit, for example. Numeral **14** designates a heat sensitive element such as a thermistor forming a temperature detector which detects the temperature of the engine **1** as a variation in electrical resistance caused by the temperature change of the cooling water, the oil temperature, the temperature of the cylinder head, cylinder block, etc. Numeral **15** designates a resistance-voltage converter to convert a variation in resistance into voltage and this converter may be composed of a bridge circuit having the temperature detector **14** inserted in one arm thereof, thus forming temperature-voltage converter means

16 with the temperature detector 14. Numeral 17 designates delay means consisting, for example, of a monostable multivibrator which delays the injection reference signal from the amplifier-shaper circuit 11, and the delay time is reduced by the output from the engine rpm-voltage converter means 13 in inverse proportion to the engine rpm, that is, the angle of delay in terms of a crank angle is maintained at a predetermined value irrespective of the increase in the engine rpm, while the delay time is increased by the output from the resistance-voltage converter 15 in proportion to the engine temperature, that is, the delay angle in terms of a crank angle is increased in proportion to a rise in the engine temperature. Numeral 18 designates a fuel injection duration modulator which may be composed of a differential amplifier, and this modulator is actuated by the application of the injection reference signal delayed by the delay means 17 which triggers modulator 18 to provide a fuel injection pulse corresponding to the output of the displacement-voltage converter 7. Numeral 19 designates solenoid valve driving means comprising, for example, a transistor switching circuit which is actuated by the application of the fuel injection pulse from the injection duration modulator 18 to open the solenoid valve for a time corresponding to the pulse width. FIG. 2 relates to an instance where the engine 1 is a four-cycle four-cylinder engine and it illustrates, in terms of time, the positions of the injection reference signals 20 from the amplifier-shaper circuit 11 and the time duration during which the inlet valves are opened for the engine cylinders I, II, III and IV, showing that the injection reference signals 20 are provided earlier than the inlet valve opening time by a constant time α. Numeral 21 designates the duration of an inlet valve opening. FIG. 3 shows that, on the basis of the injection reference signal 20 for starting the cylinder I of the four cylinders, the solenoid valve 3*a* opens to start injection at a point A after the time delay θ_1 and point C indicates the time at which the inlet valve starts opening. FIG. 4 shows a similar relationship when the engine 1 is running under normal operating condition, that is, the injection of fuel is started at a point A' which is behind the injection reference signal 20 by a time θ_2, which means that the injection takes place a time θ_3 before the inlet valve opens at point C and the fuel is thus drawn into the cylinder with a time delay θ_3.

Now, with the arrangement described above, the operation of the system according to the present invention will be explained hereunder. When the engine 1 is at a standstill, the temperature of the engine 1 is low and thus the output voltage of the temperature-voltage converter means 16 is zero. Assuming that in this state the engine 1 is started by means of a starting motor, the operation will be explained with respect to the cylinder I in conjunction with FIG. 3. With the engine 1 now started, the engine rpm-voltage converter means 13 produces a voltage corresponding to the engine rpm and the fuel is injected the time θ_1 behind the injection reference signal 20. Since it is prearranged that θ_1 and α coincide with each other in such a case, the solenoid valve 3*a* opens to start the injection of fuel at point A which coincides with point C where the inlet valve opens, whereupon the atomized fuel is directly drawn into the cylinder. In this case, if the number of rotations, i.e., rotational speed, of the engine 1 is increased the repetition period of the injection reference signal 20 is reduced. However, since the delay time of the delay means 17 is also reduced by the output of the engine rpm-voltage converter means 13 in accordance with the engine rpm, the delay in terms of a crank angle is maintained at a predetermined value, irrespective of the engine rpm. Thereafter, as the engine 1 continues to run and its temperature rises, the output voltage of the temperature-voltage converter means 16 increases to cause the delay means 17 to act in a direction to increase the delay time, and the solenoid valve 3*a* is eventually actuated to start injecting at point A' (FIG. 4) which lags by the time θ_2 and the atomized fuel is delivered into the engine cylinder at a point behind point A' by the time θ_3. Thus, during the time θ_3, the fuel is heated by the heat around the inlet pipe wall and the inlet valve to accelerate the vaporization of the fuel so that the fuel drawn into the engine cylinder is perfectly burnt.

The same series of operation will take place with respect to the other cylinders, II, III and IV in a manner similar to the cylinder I.

While the above description of the embodiment has been made in conjunction with a four-cylinder engine, the present invention may be similarly worked with other multiple-cylinder engines and single-cylinder engines as well.

I claim:

1. A fuel injection control system for an internal combustion engine having at least one inlet valve and a fuel injection solenoid valve provided in the vicinity of said inlet valve which is operated at predetermined times, comprising:

signal generator means for producing a reference signal synchronized with the rotation of said engine and in advance of each of said inlet valve opening times,

engine rpm-voltage converter means connected in circuit with said signal generator means for producing from said reference signal a first voltage representing engine rpm,

temperature-voltage converter means for producing a second voltage representing engine temperature,

delay means connected in circuit with said signal generator means, said engine rpm-voltage converter means and said temperature-voltage converter means for generating a trigger signal by delaying each said reference signal in inverse proportion to said first voltage to maintain the timing of the trigger signals independent of engine rpm so as to cause the delayed reference signals to occur at a constant time prior to said inlet valve opening times and by further delaying said delayed reference signals in direct proportion to said second voltage to cause generation of said trigger signals at valve opening times only for cold starting of said engine,

engine operating parameter-voltage converter means for generating a voltage signal representing a predetermined engine operating parameter,

a fuel injection duration modulator connected in circuit with said engine operating parameter-voltage converter means and said delay means for producing an injection pulse having a duration corresponding to said voltage signal when said trigger signal is generated, and

solenoid valve driving means connected in circuit with said fuel injection duration modulator for actuating said solenoid valve by the application of said injection pulse.

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