ELECTRONICALLY CONTROLLED FUEL INJECTION SYSTEM FOR ROTARY INTERNAL COMBUSTION ENGINES

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ABSTRACT

An electronic system for electronically controlling a fuel injection valve to properly inject fuel into a rotary internal combustion engine during deceleration. The system injects fuel into the engine once per crank shaft revolution during normal engine operation, and once per two crank shaft revolutions during deceleration.

3 Claims, 1 Drawing Figure
ELECTRONICALLY CONTROLLED FUEL INJECTION SYSTEM FOR ROTARY INTERNAL COMBUSTION ENGINES

The present invention generally relates to a fuel supply system for an internal combustion engine and, more particularly, to an electronically controlled fuel injection system for a rotary internal combustion engine of an automotive vehicle which is capable of electronically controlling a fuel injection valve to properly supply fuel into the engine during deceleration.

It is well known that in an automotive vehicle equipped with an existing rotary internal combustion engine, the engine output power or torque fluctuates considerably during deceleration, causing undesirable vibration of the vehicle body which is called "car-shake." The cause of the undesirable car-shake is twofold. First, during deceleration, the air-fuel mixture fed into the combustion chamber of the engine is so lean that normal ignition thereof is not possible in the combustion chamber, resulting in undesirable misfiring. Second, during deceleration, burned gas is not completely discharged from the combustion chamber so that residual gas interferes with the subsequent ignition operation, resulting also in undesirable misfiring. Such undesirable misfiring as mentioned above generally occurs once per two revolutions of a rotor of a rotary combustion engine and, moreover, the frequency of the misfiring corresponds with the resonant frequency of various members of the vehicle body, so that the car-shake effect occurs in the vehicle.

In order to solve the above-mentioned problem, it has been previously proposed to eliminate car-shake in an automotive vehicle during deceleration by reducing the ignition frequency from once per revolution of the crank shaft to once per 2 revolutions of the crank shaft. In other words, there occurs alternately ignition and non-ignition in the combustion chamber every two revolutions of the crank shaft so that the frequency of the non-ignition does not correspond with a resonant frequency of a member of the vehicle body during deceleration. In this prior art method, however, fuel continues to be fed into the engine even during non-ignition in the combustion chamber so that unburned gas is emitted from the combustion chamber into the atmosphere. This means that there arises a serious problem of air pollution especially in urban areas. Moreover, not only is this not economical in fuel consumption, but unburned gas would destroy or damage any reasonably sized exhaust gas purifier such as a thermal reactor or a catalytic converter which would be overheated by excessive exothermic reaction of the unburned gas.

Thus, the prior art method mentioned above is inadequate and a serious problem remains to be solved, so that there is a pressing need for an improved electronically controlled fuel injection system for a rotary internal combustion engine.

The present invention alleviates the disadvantages of the prior art by preventing fuel from being fed into the engine during misfiring in the combustion chamber during deceleration so as to prevent unburned gas from being emitted from the engine and to eliminate undesirable car-shake. In other words, the present invention provides an improved electronically controlled fuel injection system for a rotary internal combustion engine in which the frequency of fuel injection during deceleration is reduced from once per revolution of the engine crank shaft to once per 2 revolutions thereof. This effect is accomplished by generating two alternating fuel injection triggering pulse signals, each with a frequency of one-half the crank shaft rotational frequency, using both pulse signals to trigger fuel injection during normal engine operation, and inhibiting or cutting-off one of the pulse signals during deceleration. The cut-off means employed operates in response to an electric signal representing an engine deceleration operation. The electronic computing means is responsive to electric signals representing engine deceleration operation including engine speed and throttle opening, or responsive to an electric signal representing an engine deceleration operation including intake manifold vacuum to produce the engine deceleration operation signal.

It is accordingly a principal object of the present invention to provide an improved electronically controlled fuel injection system for a rotary internal combustion engine overcoming the disadvantages of the prior art.

Another object of the present invention is to provide an improved electronically controlled fuel injection system for a rotary internal combustion engine which is capable of electronically controlling a fuel injection valve to properly inject fuel into the engine during deceleration.

Still another object of the present invention is to provide an improved electronically controlled fuel injection system for a rotary internal combustion engine which is capable of preventing unburned gas from being emitted from the engine to eliminate or minimize air pollution caused by the presence of unburned gas.

Still another object of the present invention is to provide an improved electronically controlled fuel injection system for a rotary internal combustion engine which is capable of prolonging the expected life span of an exhaust gas purifier incorporated in an automotive vehicle.

A further object of the present invention is to provide an improved electronically controlled fuel injection system for a rotary internal combustion engine which is capable of maximizing fuel economy during deceleration.

Still a further object of the present invention is to provide an improved electronically controlled fuel injection system for a rotary internal combustion engine which is capable of improving the driveability of an automotive vehicle.

Still a further object of the present invention is to provide an improved electronically controlled fuel injection system for a rotary internal combustion engine which is highly reliable in operation and can easily be installed in various rotary internal combustion engines.

These and other objects and advantages of the present invention will become more apparent from the following detailed description taken in conjunction with the accompanying drawing in which the single FIGURE is a schematic diagram of a preferred embodiment of an electronically controlled fuel injection system according to the present invention and a rotary internal combustion engine controlled thereby.

Referring now to the drawing, there is shown an embodiment of an electronically controlled fuel injection
system of the present invention and a rotary internal combustion engine, for example, of an epitrochoidal "Wankel" type which is controlled by the system, the rotary internal combustion engine being generally indicated by a reference numeral 1. A reference numeral 2 designates a fuel supply system; 3, a triggering pulse signal generator responsive to the angular position of the engine crank shaft which produces triggering pulse signals \( S_1 \) and \( S'_1 \) each representing fuel injection commencement time; 4, first electronic computing means responsive to electric signals representing engine deceleration operation including an engine speed analog signal \( n \) and throttle opening analog signal \( \theta \) or including an intake manifold vacuum analog signal \( p \) to produce an electric engine deceleration operation signal \( S_2 \); 5, cut-off means for cutting off one of the triggering pulse signals \( S_1 \) or \( S'_1 \) in response to the engine deceleration operation signal \( S_2 \); 6, second electronic computing means responsive to at least one of electric signals representing prevailing values of the engine speed analog signal \( n \), throttle opening analog signal \( \theta \), an engine temperature analog signal \( \tau \) and the intake manifold vacuum analog signal \( p \) to produce an electric output pulse signal \( S_3 \) having a pulse width representing the proper duration of fuel injection under the prevailing engine operating conditions; and 7, electronic control means responsive to the output pulse signal \( S_3 \) from the second electronic computing means 6 and the triggering pulse signals \( S_1 \) and \( S'_1 \) to produce an electric command pulse signal \( S_4 \).

As is well known in the art, the rotary internal combustion engine 1 generally comprises a rotor housing 11, a rotor 12 rotatable in the housing 11 and an engine crank shaft 13 carrying thereon the rotor 12. The rotor housing 11 is provided with an ignition means such as a spark plug 14 for igniting air-fuel mixture fed thereinto. The rotor housing 11 is further provided with an intake manifold 15 having an intake port 15' opening into a combustion chamber 16 and an exhaust pipe 17. The intake manifold 15 is also provided with a fuel injection control valve 18 and an actuating means 19 for opening the fuel injection valve 18.

The fuel supply system 2 comprises a fuel tank 21, a fuel pump 22, and a regulator valve 23 serving to keep the pressure of fuel fed into a fuel line 24 at a predetermined value. Fuel under pressure is fed to the fuel injection control valve 18 mounted on the intake manifold 15 of the engine 1 through the fuel line 24.

The triggering pulse signal generator 3 comprises an engine driven breaker (no numeral) including a cam 31 coupled with the engine crank shaft 13 and first and second triggering contacts 32 and 33 respectively. The triggering contact 32 is composed of a stationary contact 32a and a movable contact 32b, while the triggering contact 33 is composed of a stationary contact 33a and a movable contact 33b. Both of the stationary contacts 32a and 33a are connected through a resistor \( R \) to a positive terminal of an electric power supply such as a battery \( B \). On the other hand, both of the movable contacts 32b and 33b are connected to the cut-off means 5. The cam 31 is driven by the engine crank shaft 13 and rotates about a cam shaft 31', the rotational speed of which is reduced to half that of the engine crank shaft 13 through a reduction gear means (not shown). The cam 31 functions to alternately open and close the triggering contacts 32 and 33 at respective intervals of 180° of rotation of the cam shaft 31', so that the triggering pulse signal generator 3 produces the alternating triggering pulse signals \( S_1 \) and \( S'_1 \) during rotation of the engine crank shaft 13. The alternating triggering pulse signals \( S_1 \) and \( S'_1 \) are fed into the cut-off means 5 through output terminals (no numerals) of the triggering pulse signal generator 3.

The first electronic computing means 4 comprises an electronic computing circuit 41 which is responsive to electric signals representing engine deceleration operation including engine speed analog signal \( n \) and throttle opening analog signal \( \theta \), or including intake manifold vacuum analog signal \( p \) to produce an electric engine deceleration operation signal \( S_2 \) which is also fed into the cut-off means 5. The electronic computing circuit 41 may be of any known configuration as long as it performs the function mentioned above. For example, it may be of the type which is disclosed in the U.S. Pat. No. 3,240,191 entitled "Fuel injection systems for internal combustion engines," and the U.S. Pat. No. 3,335,708 entitled "Discriminator devices".

The cut-off means 5 comprises an electromagnetic relay having a pair of relay contacts 51 and 52, a relay armature 53, and a relay coil 54. The relay contact 51 is connected to the movable contact 33b of the triggering contact 33 through the respective output terminal, while the relay contact 52 is connected to the movable contact 32b through the respective output terminal and to the electronic control means 7. The relay armature 53 functions to disconnect the relay contacts 51 and 52 when the relay coil 54 is energized in response to the engine deceleration operation signal \( S_2 \) from the first electronic computing means 4.

The second electronic computing means 6 comprises an electronic computing circuit 61 which is responsive to at least one of electric signals representing prevailing engine operating conditions including the engine speed analog signal \( n \) from an engine speed sensor 62, the electric throttle opening analog signal \( \theta \) from a throttle opening sensor 63, the electric intake manifold vacuum analog signal \( p \) from an intake manifold vacuum sensor 64, and the electric engine temperature analog signal \( \tau \) from an engine temperature sensor 65 to produce the electric output pulse signal \( S_3 \) having a pulse width representing the proper duration of fuel injection under all continuously variable engine operating conditions. The electronic computing circuit 61 may be of any known configuration as long as it performs the function mentioned above. For example, it may be of the type which is disclosed in the U.S. Pat. No. 3,240,191 entitled "Fuel injection systems for internal combustion engines," and the U.S. Pat. No. 3,335,708 entitled "Discriminator devices" as already mentioned respectively.

The electronic control means 7 comprises an AND circuit 71, an input of which is connected to the output of the electronic computing circuit 61 to receive the electric output pulse signal \( S_3 \) therefrom, and an amplifier 72 connected to the output of the AND circuit 71. Another input of the AND circuit 71 is connected to the movable contact 32b of the triggering pulse signal generator 3 through the cut-off means 5 and to the relay contact 52 thereof to receive the alternating triggering pulse signals \( S_1 \) and \( S'_1 \) therefrom. Thus, when the electronic control means 7 receives the electric output pulse signal \( S_3 \) from the electronic computing circuit 61 and one of the alternating triggering pulse signals \( S_1 \) or \( S'_1 \), it produces the electric command pulse signal \( S_4 \) which is fed into the actuating means 19.
for the fuel injection control valve 18, so that the fuel injection control valve 18 injects a proper amount of fuel into the intake manifold 15 under the prevailing engine operating conditions.

During normal operation of the rotary internal combustion engine 1 as shown in the drawing, the first electronic computing means 4 does not produce the electric engine deceleration operation signal S₁, so that the relay coil 54 is de-energized, and the relay contacts 51 and 52 are closed through the relay armature 53. Since both of the triggering contacts 32 and 33 operate during rotation of the engine crank shaft 13, the triggering pulse generator 3 produces the alternating triggering pulse signal S₁ and S₁', representing the fuel injection commencement time at intervals of 180° of rotation of the cam shaft 31, and since the relay contacts 51 and 52 are closed, both alternating triggering pulse signals S₁ and S₁' are fed into the AND circuit 71 of the electronic control means 7. In other words, the AND circuit 71 receives one of the alternating triggering pulse signals S₁ and S₁' per revolution of the engine crank shaft 13, because the rotational speed of the cam shaft 31' is reduced to half that of the engine crank shaft 13 by the reduction gear means as mentioned above. Also, the computing circuit 61 of the second electronic computing means 6 receives prevailing values of the engine speed analog signal n, throttle opening analog signal θ, intake manifold vacuum analog signal p and engine temperature analog signal t, and produces the electric output pulse signal S₆ having a pulse width representing the proper duration of fuel injection under those engine operating conditions. The electric output pulse signal S₆ from the computing circuit 61 is fed into the AND circuit 71 which then produces a pulse signal (no designation) which is fed into the amplifier 72 which then produces the electric command pulse signal S₆ to be fed into the actuating means 19, so that the fuel injection valve 18 injects the proper amount of fuel once per revolution of the engine crank shaft 13 at timings controlled by the alternating triggering pulse signals S₁ and S₁'.

When, on the other hand, the engine is operated during deceleration, the first electronic computing means 4, in response to the electronic signals representing the engine deceleration operation including the engine speed analog signal n and the throttle opening analog signal θ or including the intake manifold vacuum analog signal p, produces the electric engine deceleration operation signal S₆ which energizes the relay coil 54 of the cut-off means 5 to open the relay contacts 51 and 52. Thus, only the triggering pulse signal S₁ is allowed to pass through the cut-off means 5 into the electric control means 7, and the AND circuit 71 receives the alternating triggering pulse signal S₁ once per 2 revolutions of the engine crank shaft 13 because of the provision of the reduction gear means. On the other hand, the electronic computing circuit 61 of the second electronic computing means 6 receives the electric signals n, θ, p and t representing the prevailing engine operating conditions and produces the electric output pulse signal S₆ having a pulse width representing the proper duration of fuel injection under those engine operating conditions. The electric pulse signal S₆ from the electronic computing circuit 61 is fed into the AND circuit 71 which then produces the electric command pulse signal S₆ which is fed into the actuating means 19, so that the fuel injection control valve 18 opens to inject the proper amount of fuel once per 2 revolutions of the engine crank shaft 13 at timings controlled by the electric triggering pulse signal S₁ during deceleration.

It is to be noted that the fuel injection duration is controlled by the second electronic computing means 6, and that the fuel injection commencement time is controlled by the triggering pulse generator 3.

The herein presented detailed description of a preferred embodiment of the present invention are for the purpose of explaining the principles thereof only, and is not to be considered as limiting or restricting the present invention, since many modifications may be made by exercise of skill in the art without departing from the scope of the present invention.

What is claimed is:

1. In combination, a rotary internal combustion engine and an electronically controlled fuel injection system for said rotary internal combustion engine comprising:

a fuel injection control valve for controlling fuel injection into said engine;
actuating means for opening said fuel injection control valve when said actuating means is energized;
a triggering pulse signal generator operatively connected to a crank shaft of said engine and responsive to the angular position of said crank shaft to produce two alternating triggering pulse signals each representing fuel injection commencement time;
first electronic computing means responsive to at least one of said electronic signals representing prevailing values of engine deceleration operation including engine speed, throttle opening and intake manifold vacuum to produce an electric engine deceleration operation signal;
electronic control means;
cut-off means for cutting off one of said alternating triggering pulse signals in response to said engine deceleration operation signal, said cut-off means comprising an electromagnetic relay including a pair of relay contacts which are opened by the movement of a relay armature when a relay coil is energized by said engine deceleration operation signal for said first electronic computing means, said relay contacts being closed by said relay armature when said engine deceleration operation signal is absent, said cut-off means being connected between output terminals of said triggering pulse signal generator and said electronic control means and being operative to prevent transmission therethrough of one of said alternating triggering pulse signals when said relay coil is energized;
second electronic computing means responsive to at least one of said electronic signals representing prevailing values of engine speed, throttle opening, engine temperature and intake manifold vacuum to produce an electric output pulse signal having a pulse width representing the proper duration of fuel injection under prevailing engine operating conditions; and
said electronic control means being responsive to said output pulse signal from said second electronic computing means and said alternating triggering pulse signals to produce an electric command pulse signal which is fed into said actuating means ener-
gizing said actuating means to open said fuel injection control valve.

2. The combination as claimed in claim 1, wherein said triggering pulse signal generator comprises a cam which is coupled with said engine crank shaft to be driven at half the rotational speed of said engine crank shaft and first and second triggering contacts which are alternately actuated by said cam during rotation thereof, said first and second triggering contacts having stationary contacts connected to an electric power supply and movable contacts connected to the respective output terminals of said triggering pulse signal generator.

3. The combination as claimed in claim 2, wherein said electronic control means comprises an AND circuit responsive to said output pulse signal from said second electronic computing means and said alternating triggering pulse signals to produce a pulse signal, and an amplifier responsive to said pulse signal from said AND circuit to produce said electric command pulse signal. * * * *