PATENT SPECIFICATION

1 447 791

(21) Application No. 48106/73 (22) Filed 16 Oct. 1973
(31) Convention Application No. 2 250 756 (32) Filed 17 Oct. 1972 in
(33) Germany (DT)
(44) Complete Specification published 2 Sept. 1976
(51) INT. CL.[2] F02M 51/00
F02D 5/02
F02P 5/08
(52) Index at acceptance
G3N 251 286 287 BH
F1B 2B12 2B13E 2B13F 2B13G 2B13M 2B15 2B16E
2B16G 2B1 2B4 2B7A 2D4B1

(19) THE PATENT OFFICE LONDON

(54) IMPROVEMENTS IN AND RELATING TO INTERNAL COMBUSTION ENGINES HAVING ELECTRICALLY CONTROLLED PETROL INJECTION

(71) We, ROBERT BOSCH GMBH, a German Company, of Postfach 50, 7 Stuttgart 1, Germany,

do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

The invention relates to internal combustion engines having electrically controlled petrol injection.

The invention is concerned with engines having injection systems of the type having at least one injection valve which is opened in synchronism with the rotation of the crankshaft and, by means of an electrical control system, is maintained open for a period dependent upon the pressure of the intake air downstream of the throttle valve or upon the flow of the intake air of the internal combustion engine, and having also a device for acting upon the internal combustion engine during overrun.

Petrol injection systems for motor-vehicle internal combustion engines are already known in which for overrun operation, when, in spite of the throttle valve being closed, for example during downhill travel or braking, the internal combustion engine operates at a speed substantially greater than the idling speed, a circuit breaking device is provided which, in this operating state, either prevents the triggering of electrical opening pulses and thereby blocks the control system or does not transmit the opening pulses provided by the control system to a power stage connected in series with the solenoid valve or valves. The circuit remains broken until the engine speed falls below a minimum speed providing a sufficient safety margin above the idling speed. Since injection does not take place during overrun, noxious gases cannot be emitted. However, the fact that, should the off period be prolonged, both the combustion chamber and also the exhaust system of the internal combustion engine may cool down substantially, has proved a disadvantage. The result is that, on the next acceleration operation, not only a substantial power drop may occur, but also a substantial increase in the noxious hydrocarbon content of the exhaust gas can be expected.

A differential pressure regulator has therefore already been proposed which responds to the substantial pressure drop in the inlet manifold on the sudden closure of the throttle valve and which by-passes a small, slowly reducing amount of air past the closed throttle valve sufficient to maintain sufficiently high-energy combustion in the individual cylinders of the internal combustion engine during overrun.

An electromagnetically actuated device is also known having a longitudinally movable shut-off device which, in the normal position, projects into a by-pass duct by-passing the throttle valve and opens this duct to admit auxiliary air when a switch actuable by means of the throttle valve is closed when the throttle valve is in the idling position, and simultaneously an engine-speed dependent switch is closed which switches to its open position on a fall in speed of the internal combustion engine, when the speed falls below a minimum value which is, however, substantially greater than the idling speed. The auxiliary air thus provided during overrun ensures sufficiently high energy of combustion. Associated with this, however, is a substantial impairment of the braking action of the internal combustion engine when operating on overrun.

In accordance with the present invention there is provided an internal combustion engine having an electrically controlled, petrol injection system comprising at least one injection valve which is arranged to be

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opened in synchronism with the rotation of the crankshaft and, by means of an electrical control system, to be maintained open for a period dependent upon the pressure of the intake air downstream of a throttle valve of the engine or upon the flow of the intake air of the internal combustion engine, a device for acting upon the internal combustion engine during overrun which device comprises a control valve for auxiliary air arranged in a circuit bypassing the engine throttle valve, and a spark timing device which is actuable together with the control valve and which is arranged to retard the ignition from its basic setting by 10° to 20° so that it occurs between 15° to 25° A.T.D.C.

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:—

Fig. 1 shows a general arrangement of an internal combustion engine having an inlet manifold injection system;

Figs. 2 to 7 are block circuit diagrams of electrical control systems for an electromagnetically actuable auxiliary air valve and an electromagnetically actuable spark timing device; and

Figs. 8 to 10 show various embodiments in which the partial vacuum produced in the inlet manifold of the internal combustion engine is used as a servo force to actuate an auxiliary air valve and a spark-timing adjusting element.

The four-cylinder four-stroke internal combustion engine 10 shown in Fig. 1 is provided with a conventional high-tension ignition system including four sparking plugs 11, each of which is associated with a respective cylinder of the internal combustion engine. In the immediate vicinity of the inlet valves (not illustrated) of the internal combustion engine an electromagnetically actuable injection valve 13 is mounted on each of the branch connections of the inlet manifold 12 leading to the individual cylinders. Fuel is fed to each injection valve via a respective fuel line 14 from a distributor 15. The fuel in the distributor and in the fuel lines 14 is drawn from a fuel storage tank 18 by means of a pump 16 driven by an electric motor and is delivered to a pressure regulator 17 provided upstream of the distributor 15 for the purpose of maintaining the pressure of the fuel for delivery to the injection valves at a substantially constant value of approximately 2 atmospheres.

Each of the injection valves 13 includes a solenoid winding (not shown), one end of which is connected to earth, while the other end of each of the windings is connected by means of connecting leads 19 to a respective one of four resistors 20. The resistors 20 are jointly connected to the collector of a power transistor 21, which is supplied with square-wave control pulses 23 at each revolution of the crankshaft 24 from an electronic control system (described further below) by way of a transistor amplifier 22, the control system supplying a current which opens the injection valves 13 for the duration of these pulses. The fuel injection quantity supplied to the inlet manifold and thence to the cylinders at each injection operation is proportional to the opening duration and must be adjusted according to the relevant operating state of the internal combustion engine.

The control system 25, whose function it is to do this, is outlined in broken lines in Fig. 1 and essentially comprises a monostable switching circuit consisting of a first switching transistor T1 of the PNP type and a second transistor T2 of the same type. The emitters of both transistors are connected by way of a positive supply line 26 to the positive pole of a motor vehicle battery (not shown) having a rated voltage of 12.6 volts, and serving as the operating current source. The collector of the first transistor T1 is connected by means of a load resistor 27, and the collector of the second transistor T2 is connected by means of a load resistor 28, to a common negative supply line 29, which is connected to earth and to the negative pole of the vehicle battery. When the switching circuit 25 is in the static state, transistor T1 is maintained conductive by way of the resistor 30 which connects its base to the negative supply line 29; transistor T2 is then blocked. The unstable switching state of the switching circuit determining the opening duration of the solenoid valves 13 is intiated when a cam 31, rotating at half the crankshaft speed, pushes a switch contact arm 32 associated with the cam 31 in opposition to the force of a restoring spring against its opposite contact connected to the positive supply line 26 and thereby connects a control capacitor 33, which by that time has been charged by way of a resistor 35 to the positive supply line 26, through its negatively charged electrode to the positive supply line. Transistor T1 is thereby blocked; transistor T2, and with it also the power transistor 21, become conductive and the solenoid valves 13 are opened. The solenoid valves close again when transistors T1 and T2 in the monostable switching circuit revert to their initial state.

This instant is dependent upon the inductance of a primary winding 37 included in the collector circuit of transistor T2 and forming, together with a secondary winding 38 and an adjustable iron core 39, a transformer. The iron core 39 is connected by

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means of a linkage 40 to the diaphragm of a pressure element 41, which is connected to the inlet manifold 12 immediately downstream, in the suction direction, of the throttle valve 48, which is actuable by means of an accelerator pedal 36. The lower the absolute pressure in the inlet manifold, the further the pressure element pulls the iron core out from between the primary and secondary windings, thereby reducing the inductance.

One end of the secondary winding 38 is connected by way of a diode 45 to the base of transistor T1, and its other end to the junction of two resistors 43, 44 connected between the positive supply line 26 and the negative supply line 29. As soon as the switch contact arm 32 engages its opposite contact and blocks transistor T1 by way of a diode 42, transistor T2 is able to supply a current through the primary winding 37, this current increasing at a rate inversely proportional to the inductance and inducing in the secondary winding 38 a voltage which maintains transistor T2 conductive independently of the subsequent position of the switch contact arm 32, until the current in the primary winding 37 reaches approximately its saturation value. The induced voltage blocking transistor T1 by way of diode 45 reduces as the saturation value is approached and ultimately drops to such an extent that the negative base bias voltage set by means of resistors 43, 44 predominates at transistor T1 and permits transistor T1 to revert to its initial conductive state. As soon as this occurs, the power transistor 21 is blocked and the injection operation ends.

In this injection system, in order to be able to use the pressure converter, comprising the pressure element 41 and the variable-inductance transformer, to determine the injection quantity even when, during overrun, the internal combustion engine initially described is propelled, for example, during downhill running or braking, by the mass of the vehicle at a speed which, in spite of the throttle valve being closed, is substantially greater than the idling speed, an auxiliary air valve referenced 50 in Fig. 1 is provided in a by-pass line which by-passes the throttle valve 48 and which includes two by-pass sections 57 and 58. Furthermore, a spark timing device 51 is provided, essentially comprising a mounting plate 54, rotatable about the camshaft 53 of the internal combustion engine, for a contact breaker 55 cooperating with a four-throw contact breaker cam 56 on the camshaft 53.

A common control system 60 (Figs. 2 to 7) is provided for actuating the auxiliary air valve 50 and the spark timing device 51. An electromagnet 61, connected to the auxiliary air valve 50, and a second electromagnet 62 adapted to actuate the spark timing device 51, are connected to the output of this control system. In order to detect the overrun state, units of information each represented by a small box in Figs. 2 to 7 can be fed to the control system 60, for example, as shown in Fig. 2, by means of an engine speed transducer 63 and a throttle valve transducer 64, in which case the engine speed transducer may be in the form of a switch which, on a fall in the speed of the internal combustion engine, changes its switching state when the speed falls below a predetermined minimum speed, which is greater, however, than the idling speed, for example 1000 rpm. The transducer 64 may also be constructed as a switch, which can be connected to the throttle valve shaft and which changes its switching state when the throttle valve reverts to its idling position in which it substantially closes the inlet manifold 12 and the auxiliary air necessary to maintain combustion in the cylinders of the internal combustion engine is supplied by the auxiliary air valve 50 which then switches to its open position.

As shown in Fig. 3, instead of an engine speed switch 63 or in addition to an engine speed transducer, a gear position transducer 65 may be provided, which supplies a signal, dependent upon the gear engaged in a gearbox (not shown) connected to the internal combustion engine, to the control system 60, and which cooperates with a clutch position transducer 66, which provides a control signal when a clutch (also not shown), arranged between the internal combustion engine 10 and the gearbox, is operated.

If the internal combustion engine is connected to an automatic gearbox, as shown in Fig. 4, a transducer 67 can be provided, which is caused by the relevant switching stage to deliver a control signal to the control system 60.

With reference to the block circuit diagram shown in Fig. 5, the internal combustion engine 10 incorporates in its inlet manifold a pivotable diaphragm plate acting as an air intake flow meter and connected to a switch 68 which changes its switching state at a presettable pivot angle γ. In order to detect the overrun state, i.e. when the vehicle is driving the engine, it is also possible, as illustrated in Fig. 6, to provide, in addition to the throttle valve switch 64 connected to the throttle valve, a vehicle speed transducer 69 which changes its switching state when the speed v of the vehicle driven by the internal combustion engine 10 falls below a predetermined value.

When the exhaust gases of the internal

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combustion engine are passed through a thermal and/or catalytic reactor, which is not shown in the drawings, it is often desired to heat such a reactor quickly during the warming-up phase of the internal combustion engine and thereby cause it to operate. In such a case, when the internal combustion engine is cold, retardation of the spark can be effected not only during overrun but also during slow idling. For this purpose, as shown in Fig. 7, besides the two transducers shown in Fig. 2, namely, the engine speed transducer 63 dependent upon the speed n of the internal combustion engine, and the throttle valve switch 64, an engine temperature sensor 70 may be provided which, instead of the engine speed switch 63, causes the control system 60 to retard the spark timing by means of the spark timing device 51 and at the same time to open the auxiliary air valve 50. In addition to the three transducers 63, 64, 70 mentioned, a fourth transducer 71 may be used to transmit other information to the control system 60. Such information may, for example, relate to the temperature of a thermal and/or chemical reactor arranged in the exhaust system of the internal combustion engine.

In the arrangement according to Fig. 8, the auxiliary air valve 50 and the spark timing device 51 are not actuated by means of an electromagnet 61 or 62, but the servo power is provided by the negative pressure created in the inlet manifold 12 of the internal combustion engine when the throttle valve 48 is closed or nearly closed. To control this servo power, a servo valve 75, connected to, the control system 60, is provided, which is actuated by means of an electromagnet (not illustrated in detail) and which, when this magnet is energised, connects a pressure element 76, connected to the auxiliary air valve 50, and a spark timing adjusting element 77, connected to the spark timing device 51, to the inlet manifold 12 downstream of the throttle valve, 48 in the air intake direction.

The pneumatically operated auxiliary air valve may, as illustrated very diagrammatically in Fig. 9, comprise two valve chambers 81 and 82 in a housing 80, the valve chambers 81 and 82 being separated from each other by a diaphragm 83. The first valve chamber 81 accommodates a compression spring 84 abutting the diaphragm 83 and can be connected by means of a connecting pipe 85 to an input 86 of the servo valve 75. The connecting line 58, included in the by-pass circuit, through which air extracted upstream of the throttle valve 48 can enter the circuit, is connected to the second valve chamber 82. A pipe 87, used instead of the air outlet pipe referenced 57 in Fig. 1, is inserted inside the second valve chamber 82 far enough to enable the auxiliary air to be cut off by means of a valve plate 88 provided at the centre of the diaphragm 83 when the first valve chamber 81, the servo valve 71 being in its normal position, is connected to atmosphere via the output line 89 of the latter and the compression spring 84 consequently holds the valve plate 88 in abutment with the air outlet pipe 87. When the servo valve 75 is switched on by the control system 60 and then connects the first valve chamber 81 to the inlet manifold via the pipe line 85, the negative pressure takes effect and lifts the diaphragm 83 so far from the air outlet pipe 87 that auxiliary air is able to pass from the line 58 via the air outlet pipe 87 to a point downstream of the closed throttle valve 48.

In the spark timing device as shown in Fig. 10, in order to rotate the mounting plate 54, shown in Fig. 1, for the contact breaker 55, the spark timing adjusting element 77 is arranged in tandem with a second negative pressure element 91, providing a basic setting which is connectible to the inlet manifold by means of a control line 92 via an idling bore, which is not shown in detail. The spark timing adjusting element 77 is connected, as shown in Fig. 8, via a suction pipe 94, together with the pipe 85 from the pressure element 76 to the connection 86 of the servo valve 75. When the servo valve 75 is switched on by the control system 60, the negative pressure in the spark timing adjusting element 77 moves an actuating rod 95, connected to the mounting plate 54, in the direction of the arrow and thereby rotates the mounting plate 52 so far that the firing instant is moved 15° to 20° in the spark retard direction from its basic setting, namely, approximately 5° A.T.D.C. The ignition processes are then triggered at a crankshaft angle of 20° to 25° A.T.D.C. This causes the braking action of the internal combustion engine to be fully maintained on overrun, although, owing to the auxiliary air supplied while the throttle valve 48 is closed and to the resultant extra amount of fuel injected, the combustion processes in the cylinders of the internal combustion engine are maintained.

WHAT WE CLAIM IS:—

1. An internal combustion engine having an electrically controlled, petrol injection system comprising at least one injection valve which is arranged to be opened in synchronism with the rotation of the crankshaft and, by means of an electrical control system to be maintained open for a period dependent upon the pressure of the intake air downstream of a throttle

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valve of the engine or upon the flow of the intake air of the internal combustion engine, a device for acting upon the internal combustion engine during overrun, which device comprises a control valve for auxiliary air arranged in a circuit by-passing the engine throttle valve, and a spark timing device which is actuable together with the control valve and which is arranged to retard the ignition from its basic setting by 10° to 20° so that it occurs between 15° to 25° A.T.D.C.

2. An internal combustion engine as claimed in claim 1 in which the spark timing device is arranged to retard the ignition from its basic setting by 15° to 20°.

3. An internal combustion engine as claimed in claim 1 or 2, in which an engine speed transducer and a throttle valve transducer are provided for the device in order to identify overrun operation.

4. An internal combustion engine as claimed in claim 3, in which the engine speed transducer includes a switch which is adjusted so that, on a fall in the speed of the internal combustion engine, the switching state of the switch changes when the speed falls below a predetermined minimum value greater than the idling speed.

5. An internal combustion engine as claimed in claim 3, in which the throttle valve transducer comprises a switch which is actuable by means of a shaft of the throttle valve and which changes its switching state when the throttle valve returns to its closed position.

6. An internal combustion engine as claimed in claim 3, in which, instead of an engine speed transducer or in addition to an engine speed transducer, a gear position transducer is provided, which provides a signal dependent upon the gear engaged in a gearbox.

7. An internal combustion engine as claimed in claim 6, in which a clutch position transducer is provided which delivers a control signal to the device when the clutch is operated.

8. An internal combustion engine as claimed in any of claims 1 to 7, having in its inlet manifold a diaphragm plate, pivotable against a restoring force and acting as an air intake flow meter, a switch, whose switching state changes at a predetermined pivot angle of the diaphragm plate, being connected to the shaft of the diaphragm plate to deliver a control signal to the device.

9. An internal combustion engine as claimed in any of claims 1 to 8, in which a vehicle speed transducer is provided to detect the overrun state whose switching state changes when the speed of a vehicle driven by the internal combustion engine falls below a predetermined value.

10. An internal combustion engine as claimed in any of claims 1 to 9, in which the exhaust system of the engine includes a thermal and/or catalytic reactor and in which a temperature sensor, provided in the exhaust system of the internal combustion engine, operates in parallel with the engine speed transducer and at low exhaust gas temperatures retards the spark timing device and opens the auxiliary air valve during slow idling.

11. An internal combustion engine as claimed in any of claims 1 to 10, in which an electromagnet is provided for actuating the spark timing control, or the auxiliary air valve or both.

12. An internal combustion engine as claimed in any of claims 1 to 10, in which an electromagnetically actuable servo valve is connected to the inlet manifold of the internal combustion engine downstream of the throttle valve in the air intake direction, the servo valve connecting, in its open position, at least one vacuum controlled element to the partial vacuum in the inlet manifold.

13. An internal combustion engine as claimed in claim 12, in which the pressure element is the auxiliary air control valve which has two valve chambers in its housing and a diaphragm separating the two valve chambers, the diaphragm being acted upon by the pressure of a spring accommodated in one of said valve chambers connectible by the servo valve to the inlet manifold and urging a valve plate, arranged at the centre of the diaphragm, against the end face of an auxiliary air outlet pipe communicating with the other of said valve chambers to which an auxiliary air inlet pipe is connected.

14. An internal combustion engine as claimed in claim 13 in which said outlet pipe is located centrally of the other of said valve chambers.

15. An internal combustion engine as claimed in claim 12, 13 or 14, in which a second vacuum controlled element, whose control line is connected to the inlet manifold by way of an idling bore, is arranged in tandem with the first vacuum controlled element, which is connectible by way of the servo valve to the inlet manifold.

16. An internal combustion engine as claimed in claim 15 in which an actuating rod, which acts eccentrically on a mounting plate rotatable about the axis of the contact breaker cam for the ignition contact breaker, is connected to said first vacuum controlled element.

17. An internal combustion engine substantially as illustrated in Fig. 1 having an overrun device constructed and adapted to operate substantially as hereinbefore particularly described with reference to and

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