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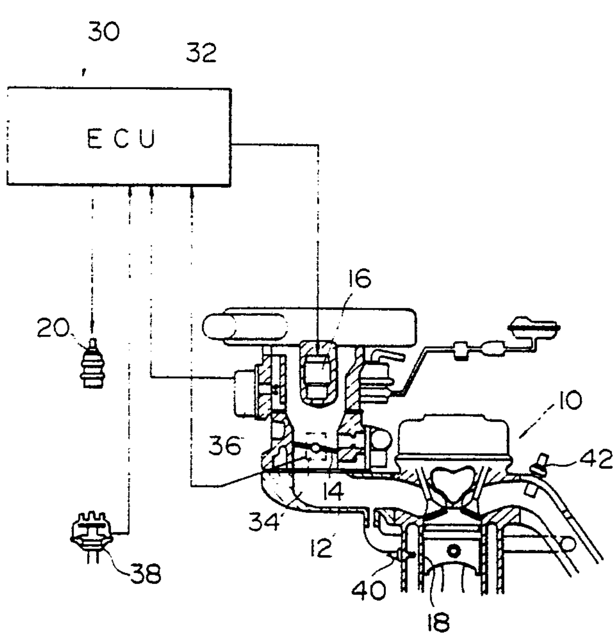
(54) **Engine control system.**

(57) An engine controlling system has an electrical control unit (32) operative during an engine deceleration to deenergize an electrically actuated fuel injector (16) to interrupt fuel supply to the engine when a throttle valve (14) is in closed idle position and the engine speed is above a first predetermined r.p.m. level. When it is detected by the control unit (32) that the throttle valve (14) is still in the idle position and the engine speed has been lowered to a second predetermined r.p.m. level lower than the first predetermined level, the control unit operates to resume the fuel supply at a rate increased compared with engine intake air flow rate and engine speed both detected at this time, and, simultaneously, retard the ignition timing whereby the engine speed smoothly and gradually varies after the resumption of fuel supply.

FIG. 1



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ENGINE CONTROL SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to a system for controlling an internal combustion engine of the type that has an intake manifold, a throttle valve disposed in the intake valve for movement between an idle position and a fully open position, an electrically actuated fuel injector disposed upstream of the throttle valve and operative to inject a fuel into an air flow through the intake manifold so that the injected fuel is mixed with the air in the intake manifold to form an air-fuel mixture to be sucked into engine cylinders, and an ignition system including spark plugs for igniting charges of the mixture in respective engine cylinders.

An engine control system has been known in the art which system includes an electrical control unit electrically connected to a fuel injection system and an ignition system, a throttle position sensor electrically connected to the control unit and operative to detect positions of a throttle valve in an intake manifold of the engine and including an idle switch for detecting the throttle valve in its idle position, an air flow meter electrically connected to the control unit and operative to detect a rate of air flow through the intake manifold into the engine, and an engine speed sensor electrically connected to the control unit and operative to detect the engine speed. The control unit is operative normally to determine the rate of fuel supply to the engine based on an engine intake air flow rate detected by the air flow sensor and an engine speed detected by the engine speed sensor to electrically energize the fuel injection system so that the fuel is supplied into the engine at a rate determined by the control unit. The control unit is operative during an engine deceleration to deenergize the fuel injection system to interrupt the fuel supply to the engine when the throttle valve has been moved from an open position to the idle position (see "ON" position of idle switch in Fig. 4) and the engine speed is above a first predetermined r.p.m. level N_1 (Fig. 4). When a condition is reached that the throttle valve is still in the idle position represented by "ON" in Fig. 4 and the engine speed has been lowered to a second predetermined r.p.m. level N_2 (Fig. 4) lower than the first predetermined r.p.m. level N_1, the control unit is operative to again energize the fuel injection system to supply the fuel into the engine to recover the fuel-combustion operation of the engine.

The engine control system discussed in the preceding paragraph is effective to improve the emission control and minimize the fuel consumption in the case where the engine is of the type that is provided with a plurality of injectors disposed adjacent to and just upstream of intake valves of respective engine cylinders. However, in an internal combustion engine of the type that is provided with a fuel injection system having a single or a pair of injectors mounted to inject the fuel into an intake manifold upstream of a throttle valve, the engine controlling system which operates in a manner discussed in the preceding paragraph causes a problem that, when the engine speed has been lowered during an engine deceleration from the first predetermined r.p.m. level N_1 to the second predetermined r.p.m. level N_2 and the throttler valve is still in its closed idle position represented by the "ON" position of the idle switch (Fig. 4) and the control unit again energizes the fuel injector or injectors to resume the fuel supply into the intake manifold, the engine is not capable of immediately recovering its fuel combustion operation. This is because the fuel injector or injectors are far remote from the intake valves of respective engine cylinders and, accordingly, there occurs a time lag from the moment when the injector or injectors are again energized to inject the fuel into the intake manifold to the moment when the engine cylinders are supplied with air-fuel mixture charges. After the fuel supply through there injector or injectors has been interrupted by the control unit, the intake manifold does not contain any amount of fuel and only air is sucked through the intake manifold into respective cylinders. Thus, even if the ignition plugs are energized to produce sparks, no combustion takes place in the combustion chambers. When the injector or injectors are again energize to resume its fuel injection operation, jets of fuel injected immediately after the resumption of the injection operation are adhered to the inner peripheral walls of the intake manifold, with a result that the engine cylinders are not charged with air-fuel mixture until after a certain period of time passes. For the reason, the engine speed is further lowered below the r.p.m. level N_2 even after the fuel injector resumes its injection operation as will be seen from Fig. 4. Meanwhile, the fuel adhered to the inner peripheral surfaces of the intake manifold is gradually evaporated and mixed with air flowing through the intake manifold to form an air-fuel mixture sucked into the engine cylinders in which spark plugs are cyclically energized to produce sparks. When the air-fuel mixture produced in the intake manifold and sucked into the engine cylinders become sufficiently rich enough to be spark-ignited, the engine resumes its combustion operation to produce torque. Up to this moment, however, because the engine speed has been lowered beyond the second predetermined r.p.m. level N_2, the resumption of the combustion operation of the engine raises the engine speed, as will be seen in Fig. 4, and disadvantageously imparts a strong shock to the vehicle and occupants therein.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an engine controlling system of the type specified in the above and which is improved to eliminate the problems discussed in the preceding paragraph.

The engine controlling system according to the present invention is designed to be used with an internal combustion engine of the type specified in the first paragraph of this specification and has a control unit which includes a judgement means operative, after the fuel supply through a fuel injector or injectors has been interrupted during an engine deceleration, to judge as to (a) whether the throttle valve is still in the idle position and (b) whether the ending speed has been lowered to a second predetermined r.p.m. level lower than the first predetermined r.p.m. level. When the answers to the questions (a) and (b) are both YES, the control unit is operative to again energize the fuel injector or injectors to resume the fuel supply into the intake manifold at a rate increased relative to an engine intake air flow rate and an engine speed both detected at this time and, at the same time, retard the ignition timing. The increase in the resumed fuel supply rate and the retardation of the ignition timing are gradually cancelled in a predetermined time period.

The increase in the resumed fuel supply rate is effective to advantageously minimize the time period from the moment when the fuel supply through the injector or injectors is resumed to the moment when the engine resumes its combustion operation. The retardation of the ignition timing advantageously decreases the torque generated by the resumed combustion operation of the engine to thereby eliminate or at least minimize the shock imparted to the vehicle and to occupants therein when the engine resumes the combustion operation.

The above and other objects, features and advantages of the present invention will be made more apparent by the following description with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a fragmentary schematic illustration of an internal combustion engine equipped with an embodiment of an engine controlling system according to the present invention;

Fig. 2 shows a chart of the characterized part of the operation of an electrical control unit of the engine controlling system;

Fig. 3 graphically illustrates the operation characteristics of the engine controlling system according to the present invention; and

Fig. 4 graphically shows the operation characteristics of the prior art engine controlling system.

BRIEF DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to Fig. 1, an internal combustion engine 10 has an intake manifold 12 with a throttle valve 14 mounted therein for movement between an idle position and a fully closed position. A single electrically actuated fuel injector 16 is mounted on the engine to inject a fuel into the intake manifold 12 upstream of the throttle valve 14, so that the injected fuel is mixed with air in the intake manifold to form an air-fuel mixture to be sucked into engine cylinders one of which is shows as at 18. A conventional ignition system includes an ignition coil 20 and spark plugs (not shown) for igniting charges of the air-fuel mixture fed into respective engine cylinders 18.

A controlling system generally designated by 30 includes an electrical control unit 32 electrically connected to the fuel injector 16. A conventional throttle position sensor 34 is mounted to detect positions of the throttle valve 14. The throttle position sensor 34 is electrically connected to the control unit 32 so that the throttle position sensor emits to the control unit an electrical signal representing a position of the throttle valve detected. The throttle position sensor includes a conventional idle switch which is not shown in the drawings but is so arranged as to be closed or switched on when the throttle valve is in its closed position to thereby emit a throttle-closed signal to the control unit 32. The controlling system 30 further includes a conventional air flow meter 36 electrically connected to the control unit 32 and mounted to detect a rate of the air flow through the intake manifold into the engine cylinders 18. An electrical signal representing the detected rate of air flow is emitted by the air flow meter 36 to the control unit 32. An engine speed sensor in the form of a crank angle sensor

38 is electrically connected to the control unit 32 and detects the engine speed and emits to the control unit 32 an electrical signal representing the detected speed of the engine.

The engine controlling system may be provided with any further conventional sensors for detecting other engine operating parameters, such as temperature sensor 40 for detecting the temperature of the engine cooling water, an 02 sensor 42. These further sensors are well known, in the art and, thus, are not described herein for the purpose of simplification of the description.

The engine speed sensor in the form of the crack angle sensor 38 produces electrical pulses which are fed into the control unit 32 so that the control unit counts the pulses to calculate the engine speed N (r.p.m.). The control unit 32 is also operative to calculate the rate of air flow QA through the intake manifold into the engine on the basis of the electrical signal from the air flow meter 36. On the basis of the calculated engine speed N and the air flow rate QA, the control unit 32 is normally operative to determine the amount of the fuel to be injected by the fuel injector per engine rotation as follows:

$Tp = k \times QA/N$

where Tp represents the width of an electrical pulse to be imparted to the fuel injector at each injection time and k is constant.

The fuel injector 16 is of conventional structure and operative to inject the fuel for a time period determined by the width Tp of each electrical pulse received from the control unit 32. Thus, the amount of fuel supply through the injector 16 to the engine per each engine rotation, i.e., rate of fuel supply Tpi, is dependent on the pulse width Tp.

Referring to Fig. 3, it is now assumed that the engine is in a deceleration operation and the engine speed N is decelerated as shown by a curve A. During this deceleration operation, if the throttle valve is moved from an open position to its closed idle position (idle switch is turned "ON") and the engine speed N is above a first predetermined r.p.m. level N_1 (for example, 1700 r.p.m.), the control unit operates to deenergize the fuel injector 16 to interrupt the fuel supply to the engine, as will be ssen from a curve B in Fig. 3. However, the ignition system is still in operation to cyclically energize spark plugs even after the fuel supply is interrupted. The energization of the spark plugs, however, does not cause any combustion in any of the engine cylinders 18 because no fuel is contained in the air sucked into the engine cylinders after the fuel supply has been interrupted. Accordingly, the engine speed is further lowered.

The arrangement and operation of the engine controlling system described above are similar to those of the prior art. However, the engine controlling system 30 according to the present invention is distinguished over the prior art in the following points:

When the engine speed N is lowered to a second predetermined r.p.m. level N_2 (for example, 1500 r.p.m.) lower than the first predetermined r.p.m. level and the throttle valve is still in the closed idle position to keep the idle switch in the "ON" state, the control unit operates to again electrically energize the fuel injector to resume the fuel supply into the intake manifold at an increased rate.

More specifically, the control unit 32 of the engine controlling system 30 according to the present invention does not simply resume the fuel supply through the injector 16 but imparts to the injector electrical pulses of widened widths in an early or beginning stage of the resumed fuel supplying operation so that, in this stage of operation, the fuel is supplied through the injector 16 into the intake manifold 12 at a rate Tpi which is increased compared with the rate of engine intake air flow and the engine speed both detected at this moment, as will be seen from the curve B in Fig. 3. Simultaneously, the control unit 32 also operates to retard the ignition timing of the ignition system 20 in the early stage of the resumed fuel supplying operation, as will be seen from the curve C in Fig. 3. It will be also noted from the curves B and C in Fig. 3 that the increase in the resumed fuel supply rate Tpi and the retardation of the ignition timing are both gradually cancelled in a predetermined time period t_1 so that, after the lapse of this predetermined period of time t_1, the rate Tpi of the resumed fuel supply and the ignition timing are both recovered.

The chart shown in Fig. 2 illustrates the characterized part of the operation of the electrical control unit 32, i.e., the judgement operation thereof after the fuel supply has been interrupted during the engine deceleration. In this condition of the engine operation, the control unit 32 judges in a step 101 as to whether the throttle valve 14 is still in the closed idle position. This judgement is conducted on the basis of a signal from the idle switch. If the idle switch is in "ON" state, it is judged that the throttle position is in the closed idle position. In this case, the operation proceeds to a next step 102 at which the control unit 32 judges as to whether the engine speed has been lowered to the second predetermined r.p.m. level (for example, 1500 r.p.m.). When the engine speed becomes to be equal to the second predetermined r.p.m. level, the operation proceeds to a further step 103 in which the control unit 32 operates to imparts electrical pulses of increased widths so that the injector 16 is again electrically energized to inject the fuel at a rate which is increased compared with the engine intake air flow rate and engine r.p.m. both detected at this time. Simultaneously, the control unit 32 also operates in a further step 104 to retard the ignition timing. It will be appreciated that the resumed fuel supply at the increased rate greatly shortens or minimizes the time period from the moment when the fuel supply into the intake manifold 12 is resumed to the moment when the air-fuel mixture sucked into the engine cylinders after the resumption of the fuel supply becomes to be rich enough to be spark-ignited. It will be also appreciated that the retarded ignition timing is effective to decrease the magnitude of torque produced by the combustion of fuel charges fed into the engine cylinders by the resumed fuel supply. Accordingly, the engine speed smoothly varies after the fuel charge is resumed, as will be clearly seen from the curve A in Fig. 3. This is in sharp contrast with the prior art shown by the solid line in Fig. 4. It will, therefore, be appreciated that the engine controlling system according to the present invention advantageously eliminates or at least minimize such a shock as was experienced with the conventional engine controlling system.

The increase in the resumed fuel supply rate and the retardation of the ignition timing are both gradually cancelled in a predetermined time period from the resumption of the fuel supply. After the increase in the fuel supply rate and the retardation of the ignition timing have both been cancelled, the fuel supply rate is controlled on the basis of QA/N and the ignition timing is controlled in accordance with a map predetermined on the basis of QA/N.

Again referring to Fig. 2, in the case where any one of the answers to the questions at the judging steps 101 and 102 is NO, the operation of the controlling unit 32 proceeds in the conventional manner which bypasses the steps 103 and 104, namely, the control unit 32 simply resumes the fuel supply (i.e., not at an increased rate). This part of the engine control, however, is not a part of the invention.

Claims

1. A system for controlling an internal combustion engine having an intake manifold (12), a throttle valve (14) disposed in said intake manifold (12) for movement between an idle position and a fully open position, an electrically actuated fuel injector (16) disposed upstream of said throttle valve (14) and operative to inject fuel into an air flow through said intake manifold (12) so that the injected fuel is mixed with the air in said intake manifold (12) to form an air-fuel mixture to be sucked into engine cylinders (18), and an ignition system including spark plugs for igniting charges of the mixture in respective engine cylinders (18), said controlling system including an electrical control unit (32) electrically connected to said fuel injector (16) and said ignition system, a throttle position sensor (34) electrically connected to said control unit (32) and operative to detect positions of said throttle valve (14), said throttle position sensor (34) including an idle switch for detecting said throttle valve when in said idle position, an air flow meter (36) electrically connected to said control unit (32) and operative to detect a rate of the air flow through said intake manifold (12) into said engine, and an engine speed sensor electrically connected to said control unit and operative to detect the engine speed, said control unit (32) being operative normally to determine the rate of fuel supply through said fuel injector (16) based on an engine intake air flow rate detected by said air flow sensor (36) and an engine speed detected by said engine speed sensor to electrically energize said fuel injector (16) so that said injector (16) injects the fuel at a rate determined by said control unit (32), said control unit (32) being operative during an engine deceleration to deenergize said fuel injector (16) to interrupt the fuel supply to the engine when said throttle valve (14) has been moved from an open position to said idle position and the engine speed is above a first predetermined r.p.m. level, wherein:
said control unit (32) includes a judgement means (101) operative to judge as to (a) whether said throttle valve (14) is still in said idle position and (b) whether the engine speed has been lowered to a second predetermined r.p.m. level lower than said first predetermined r.p.m. level, said control unit (32) being operative to again energize said fuel injector (16) to resume the fuel supply into the intake manifold (12) at a rate increased relative to engine intake air flow rate and engine speed both detected at this time and, at the same time, retard the ignition timing when the answers to the questions (a) and (b) are both YES, the increase in the resumed fuel supply rate and the retardation of the ignition timing being both gradually cancelled in a predetermined time period from the resumption of the fuel supply.

FIG. 1

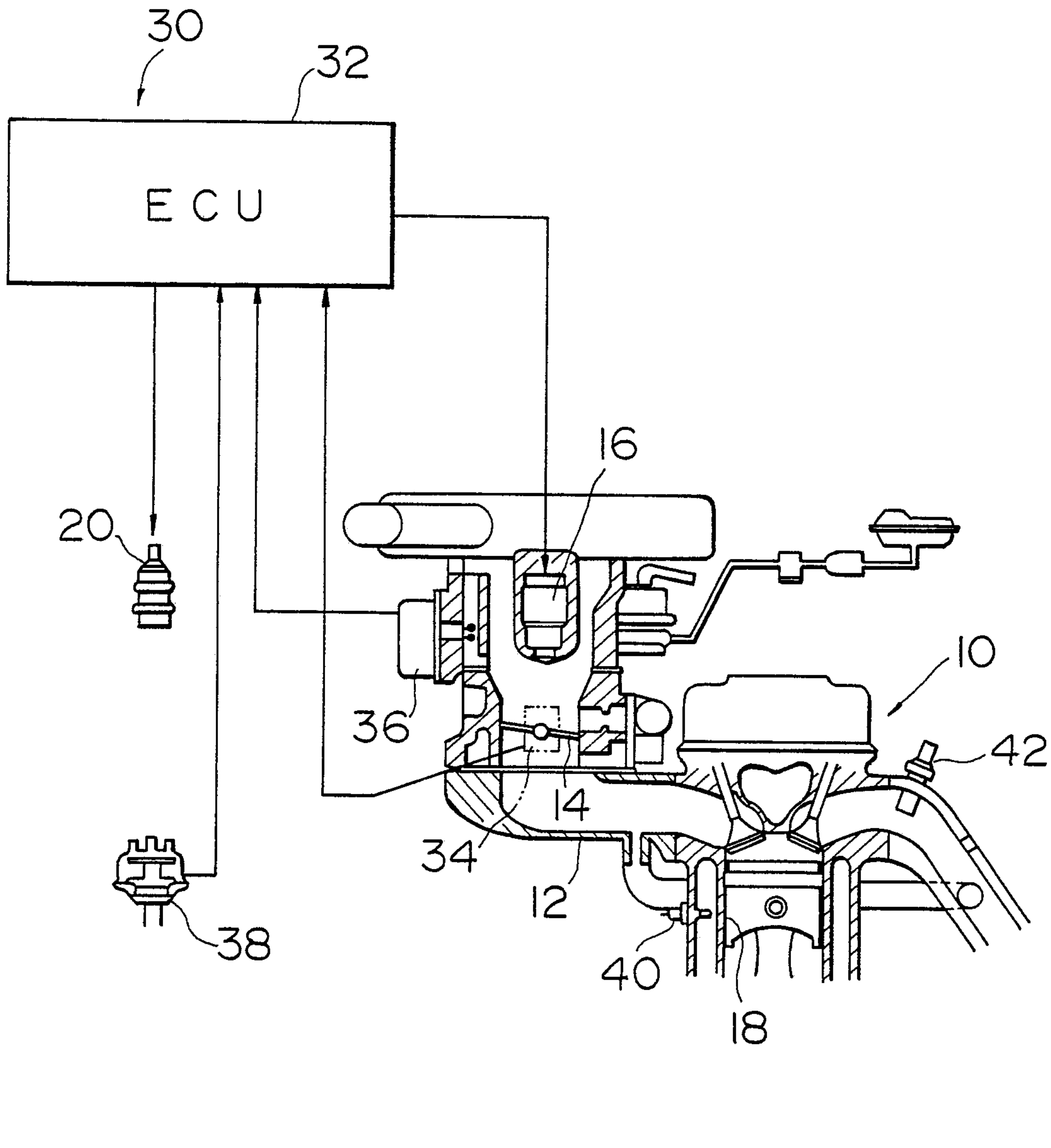

FIG. 2

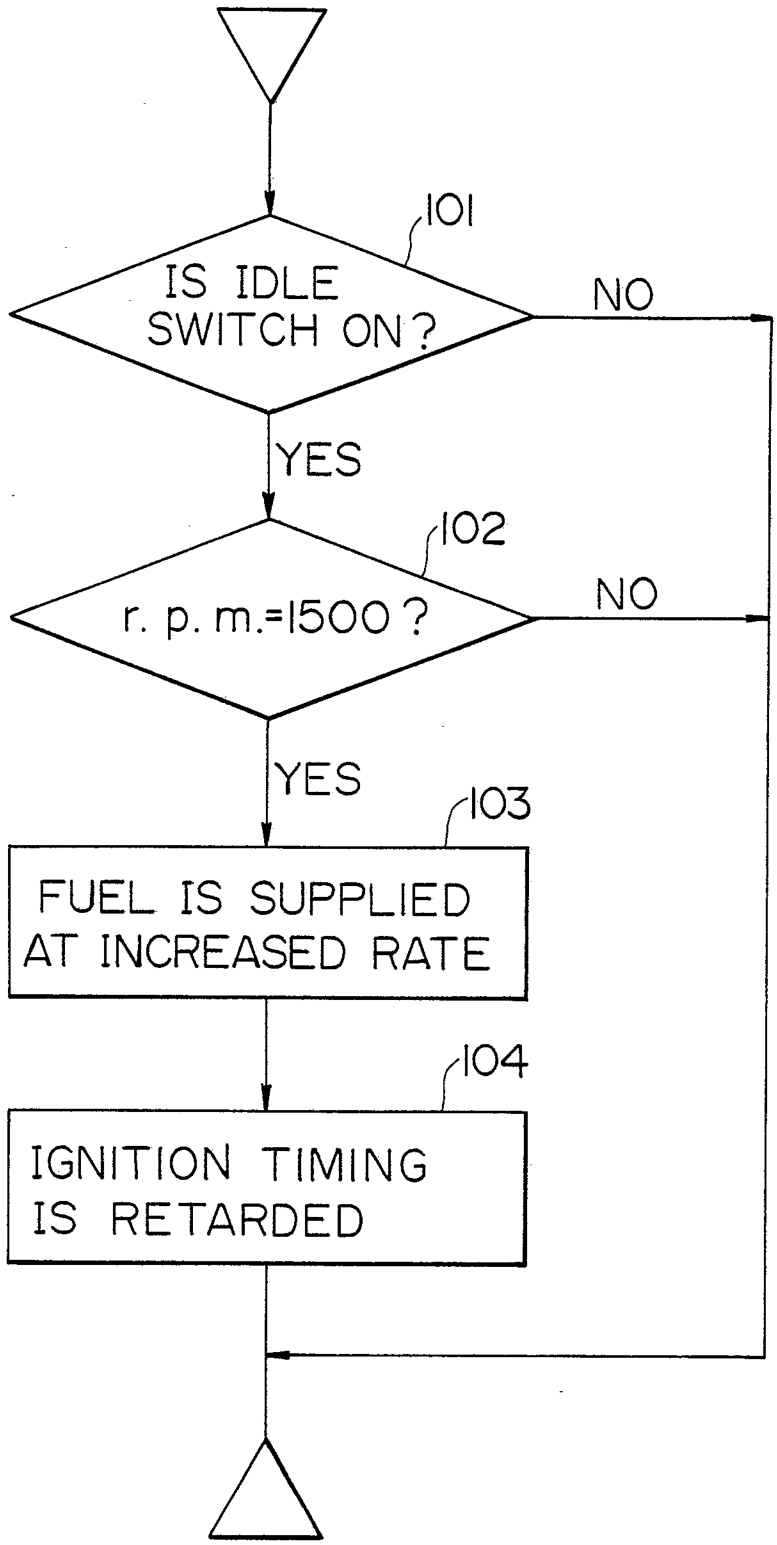
101
IS IDLE SWITCH ON?
NO
YES
102
r. p. m.=1500?
NO
YES
103
FUEL IS SUPPLIED AT INCREASED RATE
104
IGNITION TIMING IS RETARDED

FIG. 3

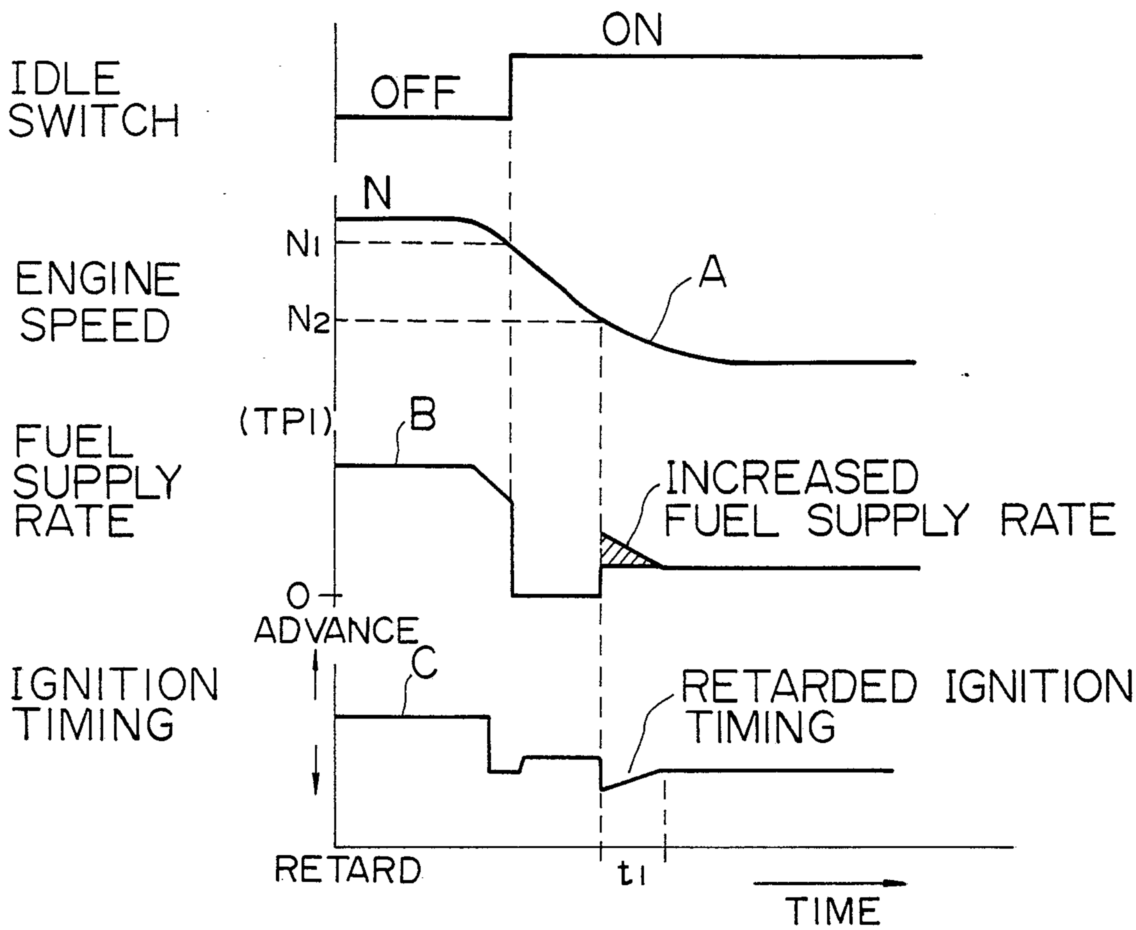
IDLE SWITCH
OFF
ON
ENGINE SPEED
N
N1
N2
A
FUEL SUPPLY RATE
(TP1)
B
INCREASED FUEL SUPPLY RATE
0
ADVANCE
IGNITION TIMING
C
RETARDED IGNITION TIMING
RETARD
t1
TIME

FIG. 4 PRIOR ART