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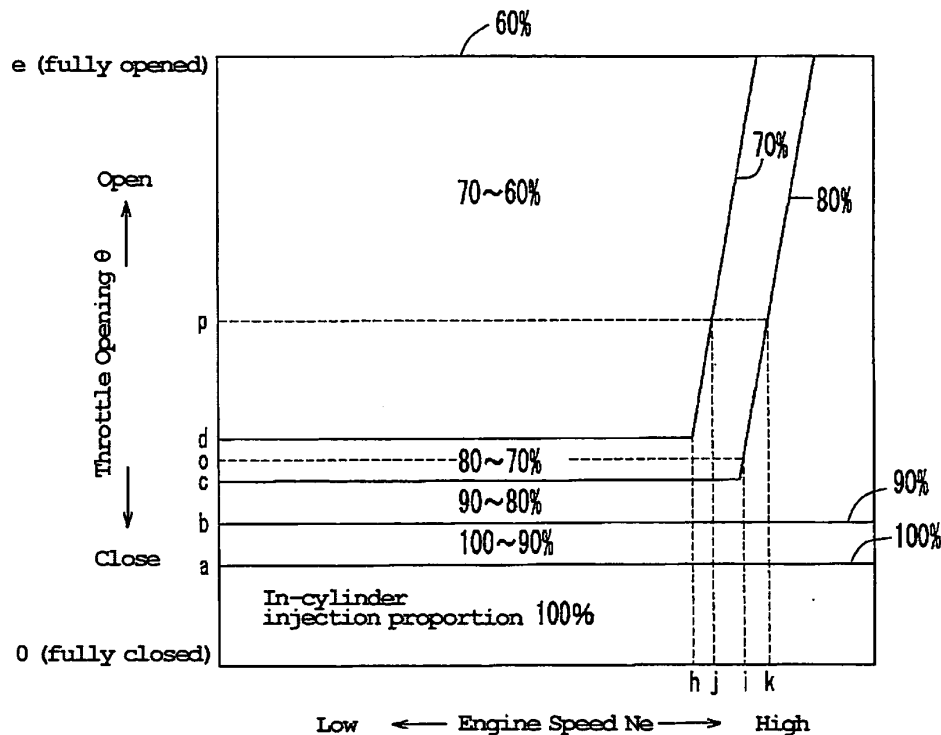
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(54) **Fuel injection control device, engine and straddle type vehicle**

(57) A fuel injection control device provides improvements in engine output, fuel efficiency and throttle response while reducing smoke emissions. If a throttle opening exceeds a prescribed value (a) and an engine load is in a prescribed high load range, an in-pipe injection

by an in-pipe injector is used together in addition to an in-cylinder injection by an in-cylinder injector. In a low load range, in which an engine load is smaller than in the high load range, only the in-cylinder injection by the in-cylinder injector is used.

**FIG. 8****EP 1 975 397 A1**

Description

BACKGROUND

[0001] The present invention relates to a fuel injection control device for an engine for a straddle type vehicle including an in-cylinder injector for directly injecting fuel into a cylinder and an in-pipe injector for injecting fuel into an intake pipe, and relates to an engine and a straddle type vehicle including the fuel injection control device.

[0002] An engine including an in-cylinder injector for directly injecting fuel into a cylinder has been suggested for an engine for a four-wheeled automobile (see, for example, JP-A-Hei 11-351041 and JP-A-2000-8916). In the engine, an engine output, fuel efficiency, and so forth can be improved comparing with an engine including an in-pipe injector.

[0003] In the case that an engine including the above in-cylinder injector is applied to a motorcycle or the like, similarly to a case of a four-wheeled automobile, improvements in an engine output, fuel efficiency, throttle response and so forth can be expected. Especially, in a motorcycle, a prompt throttle response is required in many cases, and thus it is preferable to employ a fuel injection by the in-cylinder injector for an entire operation range.

[0004] However, in the case that an engine including the in-cylinder injector is applied to a motorcycle, there is a problem that smoke is generated in a high load range of the engine. The inventors had a careful research on the causes of generation of smoke, and as a result figured out the facts explained in the following.

[0005] That is, a period from a fuel injection to an ignition is shorter in the in-cylinder injection that fuel is directly injected into the cylinder by the in-cylinder injector comparing with the case that fuel is injected into the intake pipe by the in-pipe injector. Further, since, in a motorcycle, an engine speed in a normal use is higher comparing with a four-wheeled automobile, the period tends to be further shorter. Therefore, in the case that the engine including the in-cylinder injector is applied to a motorcycle, a time required for carburetion and mixing of fuel cannot be sufficiently obtained since a fuel injection period is long in a high load range of the engine. As a result, smoke is generated.

[0006] Therefore, the inventors further had a research on the technique for reducing the smoke mentioned above. First, the inventors attempted to reduce smoke by leaning air-fuel mixture (reducing a fuel ratio in an air-fuel mixture). However, in a high load range of the engine, the engine needs to operate at a dense air-fuel ratio (richer) than the theoretical air-fuel ratio to assure an engine output and prevent a seizure in the engine. Therefore, the inventors could not adopt the method that an air-fuel mixture is weakened.

[0007] The present invention seeks to achieve improvements in an engine output, fuel efficiency, and throttle response, and to reduce smoke.

SUMMARY

[0008] An aspect of the present invention provides a fuel injection control device for an engine for a straddle type vehicle, which engine includes a cylinder, an intake pipe communicatively connected to the cylinder, an in-cylinder injector for injecting fuel into the cylinder, an in-pipe injector for injecting fuel into the intake pipe. The fuel injection control device is operable to cause fuel injection by both the in-cylinder injector and the in-pipe injector together when an engine load is in a preset prescribed high load range.

[0009] Thus a reduction in the generation of smoke can be realized with a use of the in-pipe injection by the in-pipe injector in addition to the in-cylinder injection by the in-cylinder injector in a high load range of the engine.

[0010] With such a fuel injection control device, fuel injection can be made by the in-pipe injector together with and in addition to the in-cylinder injector in a high load range of the engine. Fuel injected by the in-pipe injector is combusted having a sufficient time for carburetion and mixing comparing with the fuel injected by the in-cylinder injector, and thus smoke is less likely to be generated. Therefore, both the in-cylinder injector and the in-pipe injector are used together, and thereby improvements in an engine output, fuel efficiency, and throttle response by the in-cylinder injection, and also a reduction of smoke can be realized.

[0011] An embodiment of the present invention can enable improvements in an engine output, fuel efficiency, and throttle response to be achieved, and a reduction of smoke can be realized at the same time.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Embodiments of the present invention will be described hereinafter, by way of example only, with reference to drawings.

FIG. 1 is a side view of a motorcycle.

FIG. 2 is a structural drawing of a driveline of the motorcycle shown in FIG. 1.

FIG. 3 is a view schematically showing a peripheral construction of a cylinder in an engine, and constructions of a fuel system and a control system of the engine.

FIG. 4 is a block diagram showing a sensor group.

FIG. 5 is a flowchart showing a fuel injection control process.

FIG. 6 is a flowchart showing a required injection amount computation process.

FIG. 7 is a flowchart showing an assignment computation process.

FIG. 8 is a graph indicating characteristics of an assignment map.

FIG. 9 is a graph indicating characteristics of an assignment map according to a second embodiment.

DETAILED DESCRIPTION

[0013] FIG. 1 illustrates an embodiment of a vehicle in the form of a motorcycle 10. The motorcycle 10 includes a vehicle body frame 11 constructing a skeletal structure, and a seat 16, on which a rider (driver) sits. A rider to sit on the seat 16 rides on the vehicle straddling the vehicle body frame 11. In the present invention, a form of the vehicle is not limited to the vehicle shown in FIG. 1 (a so-called motorcycle type), but can be a so-called moped type vehicle. A maximum speed, a displacement, a size and so forth of the vehicle are not limited either. Further, the vehicle is not limited to a motorcycle, but can be another straddle type vehicle such as a four-wheeled buggy.

[0014] In the descriptions hereinafter, the fore to aft, and the right and left directions are the directions in the view of a rider sitting on the seat 16. The vehicle body frame 11 includes a steering head pipe 12, a mainframe 13 extending rearward obliquely downward from the steering head pipe 12, and right and left seat rails 14 extending rearward obliquely upward from midway parts of the main frame 13.

[0015] A front wheel 19 is supported by the steering head pipe 12 via a front fork 18. A fuel tank 20 and the seat 16 are supported on the seat rails 14. The seat 16 extends from the rear of the fuel tank 20 toward rear ends of the seat rails 14.

[0016] A pair of right and left rear arm brackets 24 is provided at rear ends of the mainframe 13.

[0017] The rear arm brackets 24 protrude downward from the rear ends of the mainframe 13. A pivot shaft 38 is provided on the rear arm brackets 24. A front end of a rear arm 25 is swingably supported by the pivot shaft 38. A rear wheel 26 is supported at a rear end of the rear arm 25.

[0018] An engine unit 28 for driving the rear wheel 26 is supported by the vehicle body frame 11. The mainframe 13 supports a crankcase 35 hanging down therefrom. In addition, in this embodiment, the engine unit 28 includes an engine 29 (see FIG. 3), which is a gasoline engine. However, the engine is not limited to this case, the engine unit 28 can include an engine, in which a gasoline engine and a motor (e. g. , an electric motor) engine are combined.

[0019] The motorcycle 10 includes a front cowl 33 and right and left leg shields 34. The leg shields 34 are cover members for covering the legs of a rider from the front side.

[0020] Although not shown in FIG. 1, a brake pedal is provided in a lower part on the right side of the motorcycle 10. The mentioned brake pedal is for braking the rear wheel 26. The front wheel 19 is braked by operating a brake lever 103 (see FIG. 2) provided in a vicinity of a right grip 41R (see FIG. 2) of handlebars 41. A clutch lever 104 is provided in a vicinity of a left grip 41L of the handlebars 41. A clutch 54 (see FIG. 2) is connected or disconnected by operation of the clutch lever 104. Fur-

ther, a gear change pedal 105 is provided in a lower part on the left side of the motorcycle 10. A gear change is made in a transmission 80 (see FIG. 2) by operation of the gear change pedal 105.

[0021] FIG. 2 is a structural drawing of a driveline of the motorcycle 10 shown in FIG. 1. The right grip 41R of the handlebars 41 (see FIG. 1 also) constructs an accelerator grip. The accelerator grip wears an accelerator input sensor 42. The accelerator input sensor 42 detects an operation amount (accelerator operation amount) of the right grip 41R by a rider. An indicator 45 for indicating a present gear position is provided on a center part of the handlebars 41. In this embodiment, a shift position can be increased or decreased between the neutral position and the sixth position, which is the highest gear position, by operating the gear change pedal 105 (see FIG. 1).

[0022] A throttle valve 46 is put on a throttle 47 constructing an intake passage. A throttle driving actuator 49 is provided on a right end of a valve stem 48 of the throttle valves 46. Also, a throttle opening sensor 50 is provided on a left end of the valve stem 48. An electric control throttle device 51 is constructed with the right grip 41R as the accelerator grip, the throttles 47, the throttle driving actuator 49, and the throttle opening sensor 50. This embodiment is not limited to the motorcycle including the electric control throttle device 51, but the motorcycle 10 can include a wire type throttle, in which the throttle valve 46 is operated by a wire.

[0023] An engine speed sensor 53 for detecting an engine speed (revolutions of a crankshaft 52) is provided on the right side of a right end of the crankshaft 52 of the engine 29 (see FIG. 3). The crankshaft 52 is connected to a main shaft 55 via a wet type multiple plate clutch 54. The clutch 54 includes a clutch housing 54a and a clutch boss 54b. A plurality of friction plates 54c is mounted on the clutch housing 54a. Also, a plurality of clutch plates 54d is mounted on the clutch boss 54b. Each of the clutch plates 54d is disposed between the adjoining friction plates 54c, 54c. Distances between the friction plates 54c and the clutch plates 54d change due to operation of the clutch lever 104, and thereby the clutch 54 is connected or disconnected. Multi-position transmission gears 57 are put on the main shaft 55, and a main shaft revolution sensor 56 is provided thereon also. Each of the transmission gears 57 put on the main shaft 55 engages with a transmission gear 59 put on a drive shaft 58. The drive shaft 58 is disposed in parallel to the main shaft 55. In FIG. 2, for convenience of description, the transmission gears 57 and the transmission gears 59 are separately shown.

[0024] Among those transmission gears 57 and the transmission gears 59 except for the selected gears, either one set of gears or both the sets of gears are put on the main shaft 55 and/or the drive shaft 58 in an idling state. Therefore, transmission of driving force from the main shaft 55 to the drive shaft 58 is made via only a selected pair of the transmission gears. A state that a

pair of the transmission gears 57 and 59 are engaged together in a state that driving force is transmitted from the main shaft 55 to the drive shaft 58 is a gear-connection state.

[0025] An action such that a gear change is made by selecting the transmission gear 57 and the transmission gear 59 is made by a shift cam 79. A plurality (three in FIG. 2) of cam grooves 60 is formed on the shift cam 79. A shift fork 61 is put on each of the cam grooves 60. The shift forks 61 respectively engage with the prescribed transmission gears 57 and 59 of the main shaft 55 and the drive shaft 59. The shift cam 79 rotates, and thereby the shift forks 61 move in the axis direction along the cam grooves 60. Linking with the movements of the shift forks 61, the prescribed transmission gears 57 and 59 splined to the main shaft 55 and the drive shaft 58 move in the axial directions. The transmission gears 57 and 59 moved in the axial directions engage with other transmission gears 57 and 59 put on the main shaft 55 and the drive shaft 58 in idling states, and thereby a gear change is made. The transmission 80 is constructed with those transmission gears 57 and 59, and the shift cam 79.

[0026] A vehicle speed sensor 69 is provided on the drive shaft 58. Further, a gear position sensor 70 for detecting a gear position (rotating amount of the shift cam) is provided on the shift cam 79.

[0027] FIG. 3 is a view schematically showing a peripheral construction of a cylinder 81 in the engine 29 and constructions of a fuel system and a control system of the engine 29. A piston 82 is reciprocally movably housed in the cylinder 81 of the engine 29. A combustion chamber 83 is formed with an upper surface of the piston 82 and an inner wall surface of the cylinder 81.

[0028] An intake pipe 85 and an exhaust pipe 86 are connected to the cylinder 81. The intake pipe 85 is communicatively connected to the combustion chamber 83 via an intake port 87. An intake valve 88 for modifying a communicative connection state between the intake pipe 85 and the combustion chamber 83 by opening or closing is disposed in the intake port 87. An in-pipe injector 89 for supplying fuel into the intake pipe 85 is provided in the intake pipe 85. In addition, the in-pipe injector 89 can also supply fuel into the intake port 87. Further, an in-cylinder injector 189 for supplying fuel into the cylinder 81 is provided in the cylinder 81. In this embodiment, both two kinds of the injectors, which are the in-pipe injector 89 and the in-cylinder injector 189, are used together.

[0029] An intake pipe pressure sensor 90 for detecting a pressure in the intake pipe 85 (intake pipe pressure) is provided at a downstream part (a part close to the cylinder 81) of the throttle valve 46 (see FIG. 2 also) in the intake pipe 85. In addition, the intake pipe pressure sensor 90 can also be provided in the intake port 87 for detecting a pressure in the intake port 87.

[0030] The exhaust pipe 86 is communicatively connected to the combustion chamber 83 via an exhaust port 97. An exhaust valve 98 for modifying a communi-

cative connection state between the exhaust pipe 86 and the combustion chamber 83 by opening or closing is disposed in the exhaust port 97. An ignition plug 99 for igniting a fuel-air mixture formed with fuel and air is disposed in an upper part of the combustion chamber 83.

[0031] The engine 29 includes a fuel system 120 for supplying fuel to the in-pipe injector 89 and the in-cylinder injector 189. The fuel system 120 includes a fuel tank 121, a low-pressure pump 122, a high-pressure pump 123, a high-pressure fuel pipeline 124, and a low-pressure fuel pipeline 125.

[0032] The low-pressure pump 122 is connected to the fuel tank 121. The low-pressure pump 122 draws fuel in the fuel tank 121, and force-feeds the drawn fuel to the in-pipe injector 89 via the low-pressure fuel pipeline 125.

[0033] The high-pressure pump 123 is connected to the low-pressure pump 122 mentioned above. The high-pressure pump 123 further pressurizes the fuel force-fed by the low-pressure pump 122. The high-pressure fuel pressurized by the high-pressure pump 123 is supplied to the in-cylinder injector 189 via the high-pressure fuel pipeline 124.

[0034] Fuel injection by the in-pipe injector 89 and the in-cylinder injector 189 is controlled by an ECU (Engine Control Unit) 100 individually connected to the in-pipe injector 89 and the in-cylinder injector 189. The ECU 100 is connected to the ignition plug 99, and controls ignition by the ignition plug 99. Further, the ECU 100 is connected to the throttle driving actuator 49 (see FIG. 2, also) and controls operation of the throttle driving actuator 49.

[0035] The intake pipe pressure sensor 90 mentioned above is connected to the ECU 100 as an input system. Also, a sensor group 130 is connected to the ECU 100 as another input system. As shown in FIG. 4, the sensor group 130 is constructed with the accelerator input sensor 42, the throttle opening sensor 50, the engine speed sensor 53, the main shaft revolution sensor 56, the vehicle speed sensor 69, the gear position sensor 70 (see FIG. 2 also), a water temperature sensor 71, an atmospheric pressure sensor 72, and an intake air temperature sensor 73. The water temperature sensor 71 detects a water temperature of coolant of the engine 29. The atmospheric pressure sensor 72 detects an atmospheric pressure. Further, the intake air temperature sensor 73 detects a temperature of air flowing into the intake pipe 85. A detection result of each of those sensors 42, 50, 53, 56, 69, 70, 71, 72, and 73 is input to the ECU 100.

[0036] As shown in FIG. 3, the ECU includes a CPU 101, a RAM 102, a ROM 106, input and output busses, which are not shown, and so forth. The CPU 101 deploys required program and data among programs and data stored in the ROM 106 in the RAM 102 and operates each kind of process.

[0037] An engine control program is stored in the ROM 106. The engine control program is a program for controlling operation of each device such as the throttle driving actuator 49, the in-pipe injector 89, the in-cylinder injector 189, and the ignition plug 99 (see FIG. 3), and is

a program for controlling operation of the whole engine 29.

[0038] Next, a fuel injection control process made by the ECU 100 based on the engine control program described above will be described with reference to FIG. 5. This process is generally a process that a fuel injection amount of each of the in-pipe injector 89 and the in-cylinder injector 189 is computed, and thereafter fuel injection periods (injection pulse widths) of the in-pipe injector 89 and the in-cylinder injector 189 are computed based on each computed fuel injection amount. The fuel injection control process is a process made synchronized with a prescribed computation cycle of a fuel injection amount.

[0039] Now, characteristics of fuel injection by the in-pipe injector 89 and the in-cylinder injector 189 will be described. As described above, with fuel injection by the in-cylinder injector 189 (in-cylinder injection), improvements in an engine output, fuel efficiency, throttle response, and so forth can be realized. However, in the in-cylinder injection, the period from fuel injection to ignition is short since fuel is directly injected into the cylinder 81 (see FIG. 3). In addition, since the motorcycle 10 has a higher engine speed in normal operation comparing with a four-wheeled motor vehicle, the period tends to be further shorter. Therefore, in the case of applying the in-cylinder injection to the motorcycle 10, a time required for carburetion of fuel and mixing of fuel and air cannot be sufficiently obtained in a high load range, in which a fuel injection period is long (an injection pulse width is long). As a result, smoke tends to be generated in the case that an in-cylinder injection is made only by the in-cylinder injector 189 in a high load range.

[0040] On the other hand, in the fuel injection by the in-pipe injector 89 (in-pipe injection), since fuel is injected into the intake pipe 85 disposed upstream of the cylinder 81 (at a part close to the fuel tank 121), a time for carburetion of fuel and mixing of fuel and air can be sufficiently obtained. Accordingly, in the case that the in-pipe injection is made by the in-pipe injector 89, smoke is less likely to be generated in a high load range.

[0041] Therefore, the above characteristics of the in-cylinder injection and the in-pipe injection are utilized in this embodiment. While only the in-cylinder injection is made in a low load range, in which smoke is less likely to be generated, both the in-cylinder injection and the in-pipe injection are used together in a high load range, in which smoke tends to be generated.

[0042] When the fuel injection control process shown in FIG. 5 is started, the ECU 100 first executes a required injection amount computation process in step S100. In this process, the ECU 100 computes a whole amount of fuel injected into the cylinder 81 (required injection amount). The required injection amount computation process will be described in detail with reference to a figure (FIG. 6) in the following.

[0043] After the process of step S100 is executed, an assignment computation process is executed in step S300. In this process, the ECU 100 splits a required in-

jection amount computed in the process of step S100 into a fuel injection amount of the in-pipe injector 89 (in-pipe injection amount) and a fuel injection amount of the in-cylinder injector 189 (in-cylinder injection amount). Thereafter, the ECU 100 calculates a fuel injection period (injection pulse width) for each of the injectors 89 and 189 from assigned in-pipe injection amount and in-cylinder injection amount.

[0044] FIG. 6 is a flowchart showing the flow of the required injection amount computation process accessed and executed in step S100 of the fuel injection control process shown in FIG. 5. After this process is started, first, an engine speed, an intake pipe pressure, a throttle opening, an atmospheric pressure, an intake air temperature, and a water temperature are input in steps S110 through S160, respectively. In this process, the ECU 100 inputs each of output results of the engine speed sensor 53 (see FIG. 4), the intake pressure sensor 90 (see FIG. 3), the throttle opening sensor 50, the atmospheric pressure sensor 72, the intake air temperature sensor 73, and the water temperature sensor 71 (see FIG. 4).

[0045] After the process of step S160 is executed, a first air amount map is searched in step S170. The first air amount map is a map used in obtaining an inflow air amount into the intake pipe 85 from an engine speed and an intake pipe pressure. Such a map providing a relationship between engine speed, intake pipe pressure and inflow air amount is generally called a speed density type map.

[0046] In step S170, the ECU 100 searches the first air amount map, and obtains an inflow air amount corresponding to the engine speed input in the process of step S110 and the intake pipe pressure input in the process of step S120.

[0047] After the process of step S170 is executed, a second air amount map is searched in step S180. The second air amount map is a map used in obtaining an inflow air amount into the intake pipe 85 from an engine speed and a throttle opening. Such a map providing a relationship between engine speed, throttle opening and inflow air amount is generally called a throttle speed type map.

[0048] In step S180, the ECU 100 searches the second air amount map, and obtains an inflow air amount corresponding to the engine speed input in the process of step S110 and the throttle opening input in the process of step S130.

[0049] The inflow air amounts obtained in steps S170 and S180 are provisional values. Those two provisional values are weighted in a process in step S190 described below. An inflow air amount obtained by the weighting is used in a calculation for a required fuel amount.

[0050] After the process of step S180 is executed, a provisional value of inflow air amount obtained in each of steps S170 and S180 is weighted in step S190, and thereby a final value of inflow air amount is calculated. The weighting corresponds to a throttle opening. Specif-

ically, as a throttle opening becomes larger, a proportion of a provisional value obtained in the process of step S170 is made smaller, and a proportion of a provisional value obtained in the process of step S180 is made larger. Conversely, as a throttle opening becomes smaller, a proportion of a provisional value obtained in the process of step S170 is made larger, and a proportion of a provisional value obtained in the process of step S180 is made smaller.

[0051] After the process of step S190 is executed, a correction corresponding to an atmospheric pressure is made in step S200 in FIG. 9. In this process, the ECU 100 makes a prescribed correction process corresponding to the atmospheric pressure value input in the process of step S140 to an inflow air amount calculated in the process of step S190 (a final value).

[0052] After the process of step S200 is executed, a correction corresponding to an intake air temperature is made in step S210. In this process, the ECU 100 makes a prescribed correction corresponding to the intake air temperature input in the process of step S150 to the inflow air amount after the correction for the atmospheric pressure is made in the process of step S200.

[0053] After the process of step S210 is executed, an air-fuel ratio map is searched in step S220. The air-fuel map is a map used in obtaining a target air-fuel ratio from an engine speed and a throttle opening. In step S220, the ECU 100 searches the air-fuel ratio map, and obtains a target air-fuel ratio corresponding to the engine speed input in the process of step S110 and the throttle opening input in the process of step S130.

[0054] After the process of step S220 is executed, a required injection amount is calculated in step S230. In this process, the ECU 100 calculates a required injection amount based on the target air-fuel ratio obtained in the process of step S220 and the inflow air amount calculated in the process of step S210 (an inflow air amount after correction processes). After the process of step S230 is executed, the required injection amount computation process is finished.

[0055] FIG. 7 is a flowchart showing the flow of the assignment computation process accessed and executed in step S300 of the fuel injection control process shown in FIG. 5. After this process is started, first, an assignment map is searched in step S310. This assignment map is a map used in obtaining each of a proportion of the in-cylinder injection amount (in-cylinder injection proportion) and a proportion of the in-pipe injection amount (in-pipe injection proportion) to the required injection amount computed in the process of step S100 from an engine speed and a throttle opening. In the process of step S310, the ECU 100 searches the assignment map, and obtains an in-cylinder injection proportion corresponding to the engine speed input in the process of step S110 and the throttle opening input in the process of step S130. When an in-cylinder injection proportion is obtained, an in-pipe injection proportion is naturally determined.

[0056] FIG. 8 is a graph indicating characteristics of

the assignment map. The assignment map provides the relationship between throttle opening θ (vertical axis), engine speed N_e (horizontal axis), and in-cylinder injection proportion. As shown in FIG. 8, an in-cylinder injection proportion is 100% independent of an engine speed N_e in the range that a throttle opening θ is between 0 (fully closed) and (a). Therefore, in this case, the whole amount of a required injection amount is injected by the in-cylinder injector 189, but no fuel injection is made by the in-pipe injector 89.

[0057] In the range that a throttle opening θ is between (a) and (e) (fully opened), an in-cylinder injection proportion becomes smaller as a throttle opening θ becomes larger. For example, in the range that an engine speed N_e is between 0 and (h) and in the range that a throttle opening θ is between (a) and (b) ($>$ (a)), an in-cylinder injection proportion decreases in the range between 100% and 90% depending on an increase of a throttle opening θ . Also, in the range that a throttle opening θ is between (b) and (c) ($>$ (b)), (c) and (d) ($>$ (c)), or (d) and (e) (fully opened), an in-cylinder injection proportion decreases between 90% and 80%, 80% and 70%, or 70% and 60%, respectively, depending on an increase of a throttle opening θ .

[0058] Here, if a throttle opening θ is large, a load on the engine 29 becomes large, resulting in a condition that smoke is apt to be generated if the in-cylinder injection is used alone. Therefore, in this embodiment, if a throttle opening θ is in a high load range exceeding the prescribed value (a) both the in-cylinder injection and the in-pipe injection are used together.

[0059] A load on the engine 29 becomes larger generally in proportion to a throttle opening θ . Thus, as a throttle opening θ becomes larger, smoke is more apt to be generated due to the in-cylinder injection. Therefore, in this embodiment, as a throttle opening θ becomes larger exceeding the prescribed value (a), an in-cylinder injection proportion becomes smaller. In addition, as an in-cylinder injection proportion becomes smaller, an in-pipe injection proportion naturally becomes larger.

[0060] Also, as shown in FIG. 8, in the range that a throttle opening θ exceeds (b), an in-cylinder injection proportion becomes larger if an engine speed N_e exceeds a prescribed value. For example, in the case that a throttle opening θ is (o) between (c) and (d), and an engine speed N_e is equal to or less than a prescribed value (i), an in-cylinder injection proportion is in the range between 80% and 70%. However, if an engine speed N_e exceeds the prescribed value (i), an in-cylinder injection proportion is in the range between 90% and 80%. Further, for example, in the case that a throttle opening θ is (p) between (d) and (e), if an engine speed N_e is equal to or less than a prescribed value (j), an in-cylinder injection proportion is in the range between 70% and 60%. However, in the range that an engine speed N_e is between (j) and (k) ($>$ (j)), an in-cylinder injection proportion is in the range between 80% and 70%. If an engine speed N_e exceeds (k), an in-cylinder injection proportion is in the

range between 90% and 80%.

[0061] Here, if an engine speed N_e becomes high, a temperature of the in-cylinder injector 189 rises accompanying a rise of a temperature of the cylinder 81. On the other hand, fuel injected by the in-cylinder injector 189 absorbs heat from the in-cylinder injector 189 while passing through the in-cylinder injector 189, and thereby causes an effect of reducing a temperature of the in-cylinder injector 189. In this embodiment, as described above, an in-cylinder injection proportion becomes larger as an engine speed N_e becomes higher, and thereby an effect of cooling the in-cylinder injector 189 is enhanced. As a result, an excessive rise of a temperature of the in-cylinder injector 189 can be prevented.

[0062] Also, as shown in FIG. 8, if a throttle opening θ is the largest (fully opened), a minimum value of the in-cylinder injection proportion is 60%. That is, in this embodiment, an in-cylinder injection proportion does not become less than 60% in the entire operation range of the engine 29. If an in-cylinder injection proportion becomes less than 60%, improvements in an engine output, fuel efficiency, and throttle response may not be sufficiently realized. However, in this embodiment, since an in-cylinder injection proportion is equal to or more than 60% in the entire operation range of the engine 29, improvements in an engine output, fuel efficiency, and throttle response can be sufficiently realized.

[0063] After the process of step S310 is executed, each of fuel injection amounts by the in-cylinder injection and the in-pipe injection is calculated in step S320. In this process, the ECU 100 calculates each of the injection amounts based on the in-cylinder injection proportion and the in-pipe injection proportion obtained in the process of step S310. For example, in the case that a required injection amount is V , a determination in the process of step S310 is that an in-cylinder injection proportion is 60%, and an in-pipe injection proportion is 40%, a fuel injection amount by the in-cylinder injection and a fuel injection amount by the in-pipe injection are $0.6V$ and $0.4V$, respectively.

[0064] After the process of step S320 is executed, conversion into injection period is made in step S330. In this process, the ECU 100 runs prescribed computations on each of fuel injection amounts by the in-cylinder injection and by the in-pipe injection, which is calculated in step S320, and thereby fuel injection periods (injection pulse widths) of the in-cylinder injector 189 and the in-pipe injector 89 are calculated.

[0065] After the process of step S330 is executed, each of corrections corresponding to a water temperature and an ineffective period is made in step S340. In this process, the ECU 100 makes a prescribed correction process corresponding to the water temperature input in the process of step S160 on the injection period of each of the in-cylinder injector 189 and the in-pipe injector 89, which is calculated in step S330. Also, the ECU 100 makes a prescribed correction process in consideration of an ineffective period (a delay until fuel injection starts

after an operation signal is provided to each of the injectors) on each injection period after a correction corresponding to the water temperature is made in the process of step S340. After the process of step S340 is executed, the assignment computation process is finished.

[0066] As described in the foregoing, in the example of a motorcycle 10 according to this embodiment, if a throttle opening θ exceeds the prescribed value (a) and a load on the engine 29 is in the prescribed high load range, the in-pipe injection by the in-pipe injector 89 is used together in addition to the in-cylinder injection by the in-cylinder injector 189. As described above, if a throttle opening θ is large, a load on the engine 29 is in a high load range, and the in-cylinder injection is used alone, smoke is apt to be generated. On the other hand, smoke is less likely to be generated with the in-pipe injection if a load on the engine 29 is in a high load range. Therefore, when both the in-cylinder injection and the in-pipe injection are used together, improvements in an engine output, fuel efficiency, and throttle response because of the in-cylinder injection can be achieved, and smoke can be reduced at the same time.

[0067] Also, in the example of a motorcycle 10 according to the embodiment, if a throttle opening θ is smaller than the prescribed value (a), and a load on the engine 29 is in a low load range, in which an engine load is lower than a high load range, only the in-cylinder injection is made, but the in-pipe injection is not made. That is, a whole amount of a required injection amount is injected by the in-cylinder injector 189. In a low load range, a fuel injection period is short, and thus smoke is less likely to be generated if the in-cylinder injection is made. Therefore, as in this embodiment, when only the in-cylinder injection is made in a low load range, an engine output, fuel efficiency, and throttle response can be improved.

[0068] Also, in the example of a motorcycle 10 according to the embodiment, as a throttle opening θ becomes larger exceeding the prescribed value (a), an in-cylinder injection proportion becomes smaller. As described above, as a throttle opening θ is larger and a load on the engine 29 is larger, smoke is more apt to be generated due to the in-cylinder injection. Therefore, as in this embodiment, when an in-cylinder injection proportion becomes smaller as a throttle opening θ becomes larger, smoke can be certainly reduced.

[0069] Further, in the example of a motorcycle 10 according to the embodiment, an in-cylinder injection proportion does not become less than 60%. Therefore, improvements in an engine output, fuel efficiency, and throttle response can be sufficiently achieved.

[0070] In the example of a motorcycle 10 according to the embodiment, an in-cylinder injection proportion in the case that an engine speed N_e exceeds the prescribed value (i) or (j) is larger than an in-cylinder injection proportion in the case that an engine speed N_e is equal to or less than the prescribed value (i) or (j). An in-cylinder injection proportion in the case that an engine speed N_e exceeds a prescribed value (k) is larger than an in-cylinder

der injection proportion in the case that an engine speed N_e is equal to or less than the prescribed value (k). As described above, if an engine speed N_e becomes high, a temperature of the in-cylinder injector 189 rises. On the other hand, fuel injected by the in-cylinder injector 189 has an effect of lowering a temperature of the in-cylinder injector 189. Therefore, as in this embodiment, when an in-cylinder injection proportion becomes larger in the case that an engine speed N_e is high, the cooling effect on the in-cylinder injector 189 can be enhanced. As a result, an excessive rise of a temperature of the in-cylinder injector 189 can be prevented.

[0071] In the first embodiment, a magnitude of a load on the engine 29 is determined with a magnitude of a throttle opening θ . In this case, characteristic that a load on the engine 29 becomes larger as a throttle opening θ becomes larger is utilized for the determination. However, a magnitude of a load on the engine 29 can be determined with a pressure p in the intake pipe 85 (intake pipe pressure). That is, a load on the engine 29 becomes larger as an intake pipe pressure p becomes higher. In a second embodiment described hereinafter, a load on the engine 29 is determined based on the intake pipe pressure p , and thereby an in-cylinder injection proportion and an in-pipe injection proportion are determined.

[0072] FIG. 9 is a graph indicating characteristics of an assignment map according to the second embodiment. The assignment map is referred to in the process of step S310 in the flowchart shown in FIG. 7. In the second embodiment, since elements of a construction of the motorcycle and processes except for the assignment map shown in FIG. 9 and a process of step S310 (see FIG. 7), in which the assignment map is used, are similar to the motorcycle 10 according to the first embodiment, descriptions thereof will not be made.

[0073] In the assignment map shown in FIG. 9, difference from the assignment map shown in FIG. 8 is that the vertical axis is not throttle opening θ , but intake pipe pressure p . Thus, the assignment map of FIG. 9 is a map, which provides the relationship between intake pipe pressure p (vertical axis), engine speed (horizontal axis), and in-cylinder injection proportion. In the process of step S310 (see FIG. 7) according to the second embodiment, the ECU 100 searches the assignment map, and obtains an in-cylinder injection proportion corresponding to the intake pipe pressure p input in the process of step S120 and the engine speed N_e input in the process of step S110.

[0074] As shown in FIG. 9, in the range that an intake pipe pressure p is between 0 and (a'), an in-cylinder injection proportion is 100% independent of an engine speed N_e . Therefore, in this case, a whole amount of a required injection amount is injected by the in-cylinder injector 189, but a fuel injection by the in-pipe injector 89 is not made.

[0075] In the range that an intake pipe pressure p is between (a') and (e') (largest), an in-cylinder injection proportion becomes smaller as an intake pipe pressure

p becomes larger. For example, in the range that an engine speed N_e is between 0 and (h') and in the range that an intake pipe pressure p is between (a') and (b') ($> (a')$), an in-cylinder injection proportion decreases in the range between 100% and 90% depending on an increase of an intake pipe pressure p . Also, in the range that an intake pipe pressure p is between (b') and (c') ($> (b')$), (c') and (d') ($> (c')$), or (d') and (e') (largest), an in-cylinder injection proportion decreases in the range between 90% and 80%, 80% and 70%, or 70% and 60%, respectively, depending on an increase of an intake pipe pressure p .

[0076] As described above, if an intake pipe pressure p is large, a load on the engine 29 is also large, and smoke is apt to be generated if the in-cylinder injection is used alone. Thus, in this embodiment, if an intake pipe pressure p is in a high load range exceeding the prescribed value (a'), both the in-cylinder injection and the in-pipe injection are used together. Therefore, in the motorcycle according to the second embodiment, similarly to the first embodiment, improvements in an engine output, fuel efficiency, and throttle response can be achieved, and smoke can be reduced at the same time.

[0077] In this embodiment, if an intake pipe pressure p is smaller than the prescribed value (a'), and a load of the engine 29 is in a low load range, the in-cylinder injection is made alone, but the in-pipe injection is not made. That is, a whole amount of a required injection amount is injected by the in-cylinder injector 189. Therefore, in the motorcycle according to the second embodiment, similarly to the first embodiment, an engine output, fuel efficiency, and throttle response can be improved.

[0078] A load on the engine 29 becomes larger generally in proportion to an intake pipe pressure p . Thus, as an intake pipe pressure p becomes higher, smoke is more apt to be generated due to the in-cylinder injection. Therefore, in this embodiment, an in-cylinder injection proportion becomes smaller as an intake pipe pressure p becomes higher exceeding the prescribed value (a'). In the motorcycle according to the second embodiment, similarly to the first embodiment, smoke can be certainly reduced.

[0079] An in-cylinder injection proportion does not become less than 60% in an example of a motorcycle according to the second embodiment. Therefore, similarly to the first embodiment, improvements in an engine output, fuel efficiency, and throttle response can be sufficiently achieved.

[0080] In the example of a motorcycle according to the second embodiment, an in-cylinder injection proportion becomes large if an engine speed N_e is high. Therefore, similarly to the first embodiment, an effect of cooling the in-cylinder injector 189 can be enhanced. As a result, an excessive rise of a temperature of the in-cylinder injector 189 can be prevented.

[0081] Accordingly, there has been described a fuel injection control device that provides improvements in engine output, fuel efficiency and throttle response, while reducing smoke emissions. If a throttle opening exceeds

a prescribed value (a) and an engine load is in a prescribed high load range, an in-pipe injection by an in-pipe injector is used together in addition to an in-cylinder injection by an in-cylinder injector. In a low load range, in which an engine load is smaller than in the high load range, only the in-cylinder injection by the in-cylinder injector is used.

DESCRIPTION OF REFERENCE NUMERALS AND SYMBOLS

[0082]

10: motorcycle (straddle type vehicle)
 11: vehicle body frame
 16: seat
 28: engine unit
 29: engine
 41: handlebars
 41R: right grip
 42: accelerator input sensor
 46: throttle valve
 47: throttle
 49: throttle driving actuator
 50 : throttle opening sensor (throttle opening detection device)
 53: engine speed sensor (engine speed detection device)
 71: water temperature sensor
 72: atmospheric pressure sensor
 73: intake air temperature sensor
 81: cylinder
 85: intake pipe
 90: intake pipe pressure sensor (intake pipe pressure detection device)
 100: ECU (fuel injection control device)
 101: CPU
 102: RAM
 106: ROM

(a): a threshold value of a throttle opening, which is a reference for a case that an in-cylinder injection and an in-pipe injection are used together.

(a'): a threshold value of an intake pipe pressure, which is a reference for a case that an in-cylinder injection and an in-pipe injection are used together.

p: intake pipe pressure

Ne: engine speed

θ: throttle opening

(i), (j), (k): an example of a prescribed value of an engine speed, which is a reference for a case that an in-cylinder injection proportion becomes large.

Claims

1. A fuel injection control device for an engine for a straddle type vehicle, the engine including a cylinder,

an intake pipe communicatively connected to the cylinder, an in-cylinder injector for injecting fuel into the cylinder and, an in-pipe injector for injecting fuel into the intake pipe, the fuel injection control device being operable to cause fuel injection by both the in-cylinder injector and the in-pipe injector when an engine load is in a preset prescribed high load range.

2. The fuel injection control device according to claim 1, operable to cause fuel injection by the in-cylinder injector in a low load range, in which a load on the engine is lower than the high load range.

3. The fuel injection control device according to claim 1 or claim 2, operable to cause fuel injection by both the in-cylinder injector and the in-pipe injector in the case that a throttle opening, which is an opening of a throttle valve disposed in the intake pipe, exceeds a prescribed threshold value.

4. The fuel injection control device according to claim 3, operable to cause fuel injection by the in-cylinder injector in the case that the throttle opening is equal to or smaller than the prescribed threshold value.

5. The fuel injection control device according to claim 3, operable to cause an in-cylinder injection proportion, which is a proportion of a fuel amount injected by the in-cylinder injector to a required injection amount into the cylinder, to be reduced as the throttle opening becomes larger.

6. The fuel injection control device according to any preceding claim, operable to cause fuel injection by both the in-cylinder injector and the in-pipe injector in the case that an intake pipe pressure, which is a pressure inside the intake pipe, exceeds a prescribed threshold value.

7. The fuel injection control device according to claim 6, operable to cause fuel injection only by the in-cylinder injector in the case that the intake pipe pressure is equal to or lower than the prescribed threshold value.

8. The fuel injection control device according to claim 6, operable to cause an in-cylinder injection proportion, which is a proportion of a fuel amount injected by the in-cylinder injector to a required injection amount into the cylinder, to be reduced as the intake pipe pressure becomes larger.

9. The fuel injection control device according to claim 5 or 8, operable to cause the in-cylinder injection proportion does not become less than 60%.

10. The fuel injection control device according to claim 5 or 8, operable to cause the in-cylinder injection

proportion in the case that an engine speed exceeds a prescribed value to be larger than the in-cylinder injection proportion in the case that an engine speed is equal to or less than the prescribed value.

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- 11.** An engine including the fuel injection control device according to any preceding claim, the engine including the cylinder, the intake pipe communicatively connected to the cylinder, the in-cylinder injector for injecting fuel into the cylinder and the in-pipe injector for injecting fuel into the intake pipe. 10
- 12.** A straddle type vehicle including the engine of claim 11. 15
- 13.** The straddle type vehicle according to claim 12, which is a motorcycle.
- 14.** A method of controlling fuel injection for an engine for a straddle type vehicle, the engine including a cylinder, an intake pipe communicatively connected to the cylinder, an in-cylinder injector for injecting fuel into the cylinder and, an in-pipe injector for injecting fuel into the intake pipe, the method comprising causing fuel injection by both the in-cylinder injector and the in-pipe injector when an engine load is in a preset prescribed high load range. 20 25

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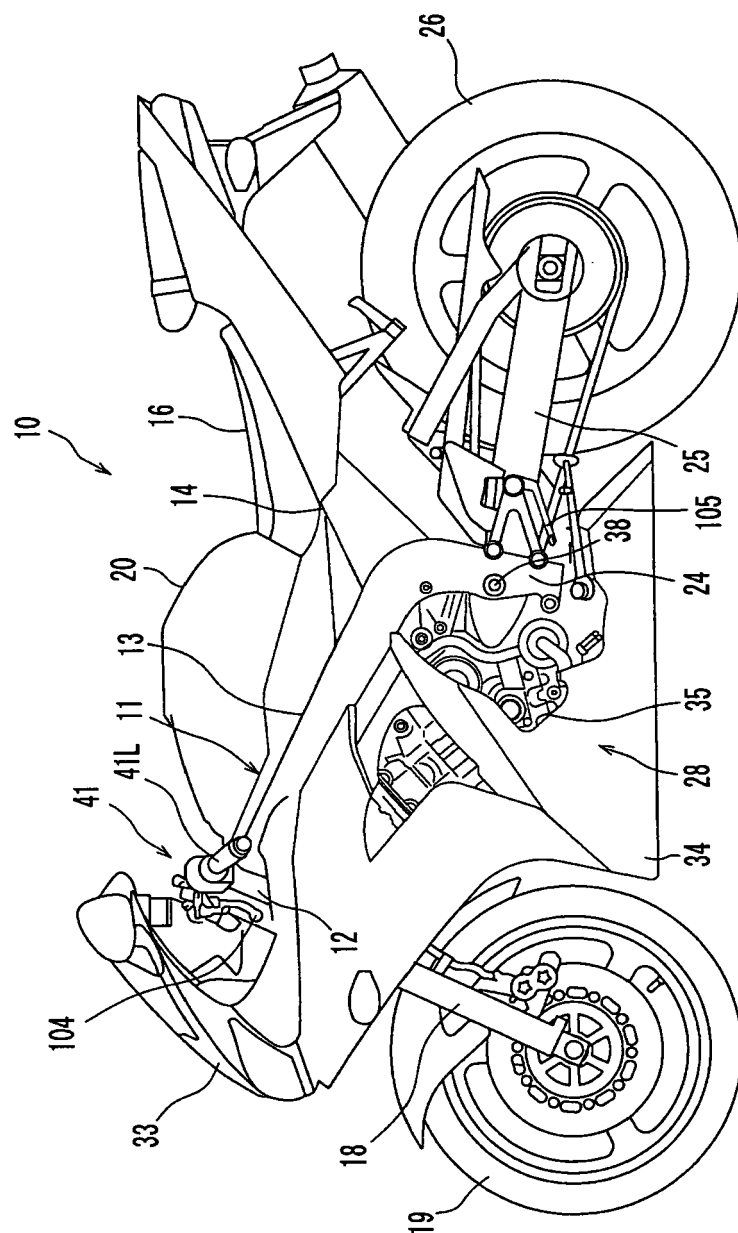


FIG. 1

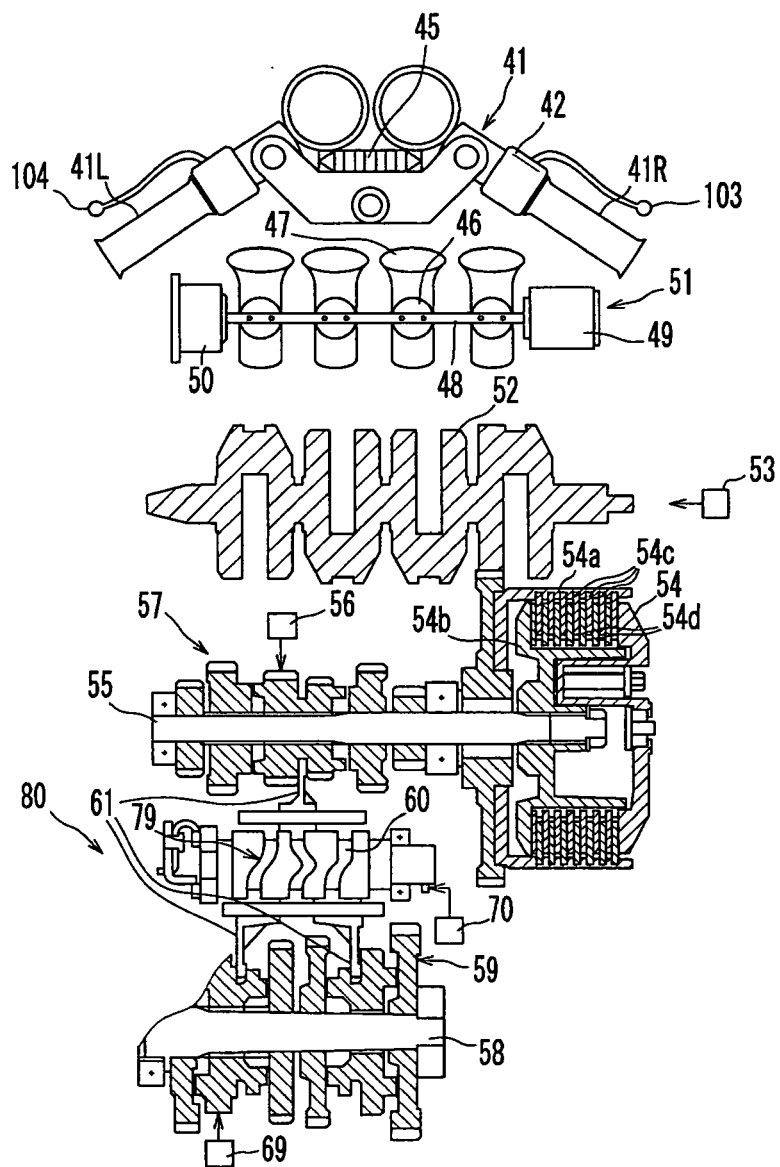


FIG. 2

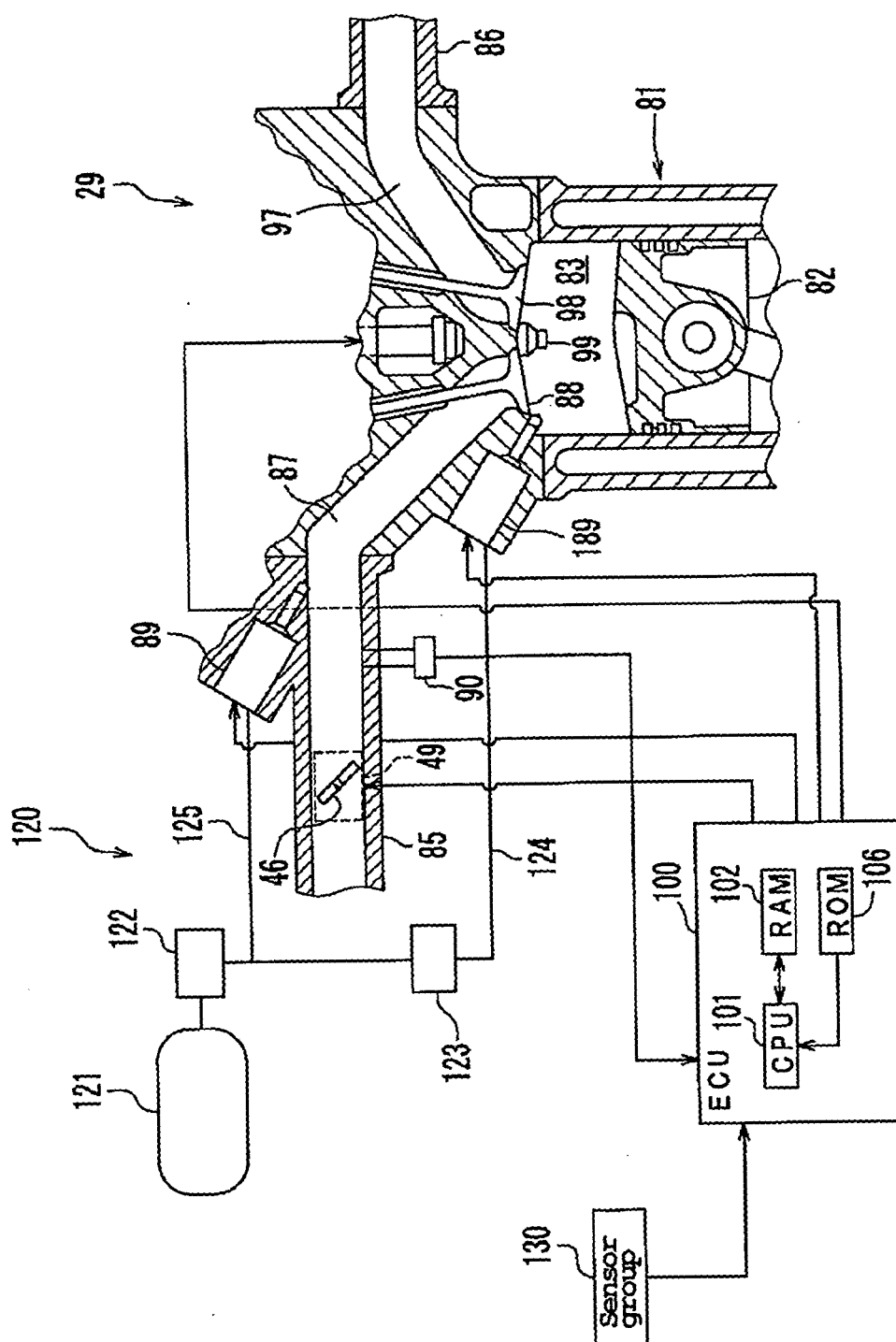


FIG. 3

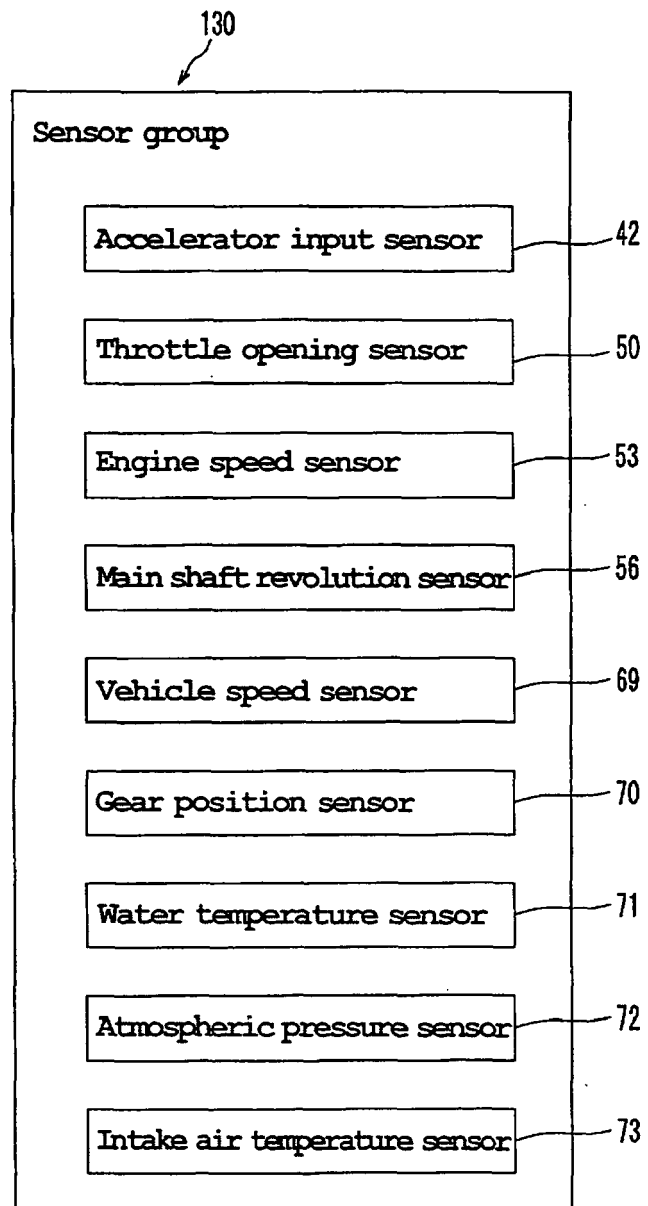


FIG. 4

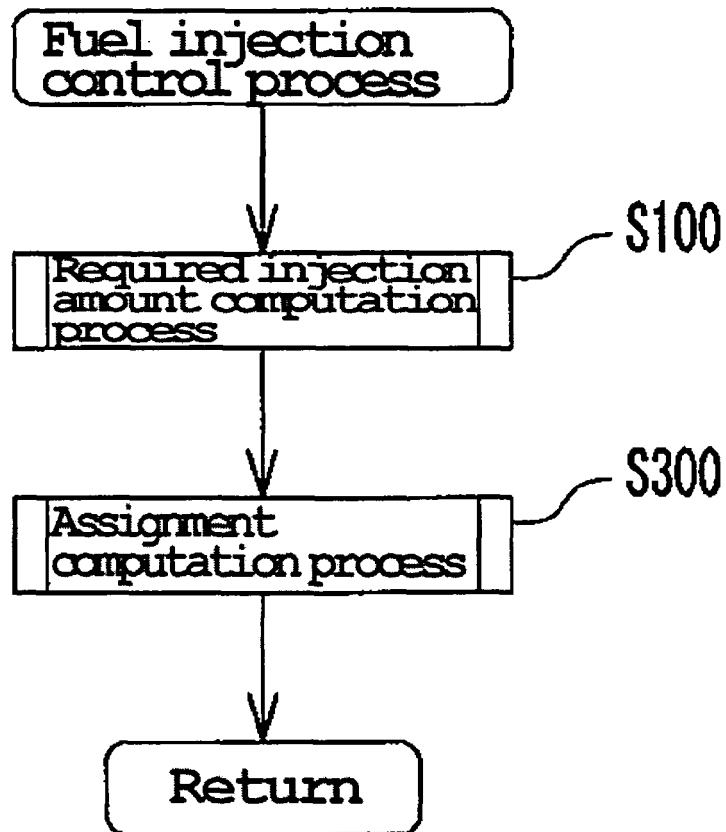


FIG. 5

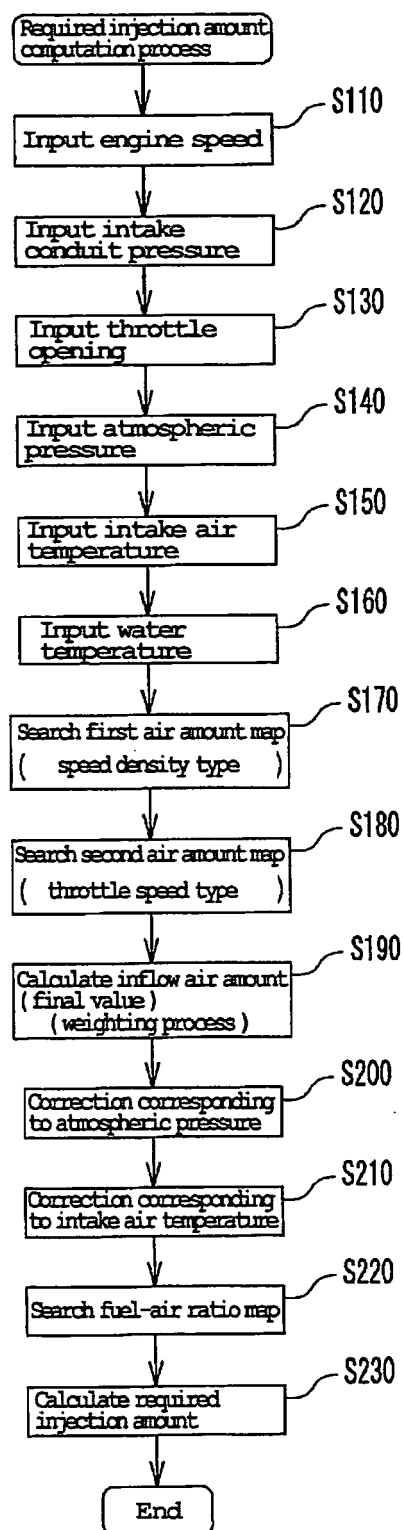


FIG. 6

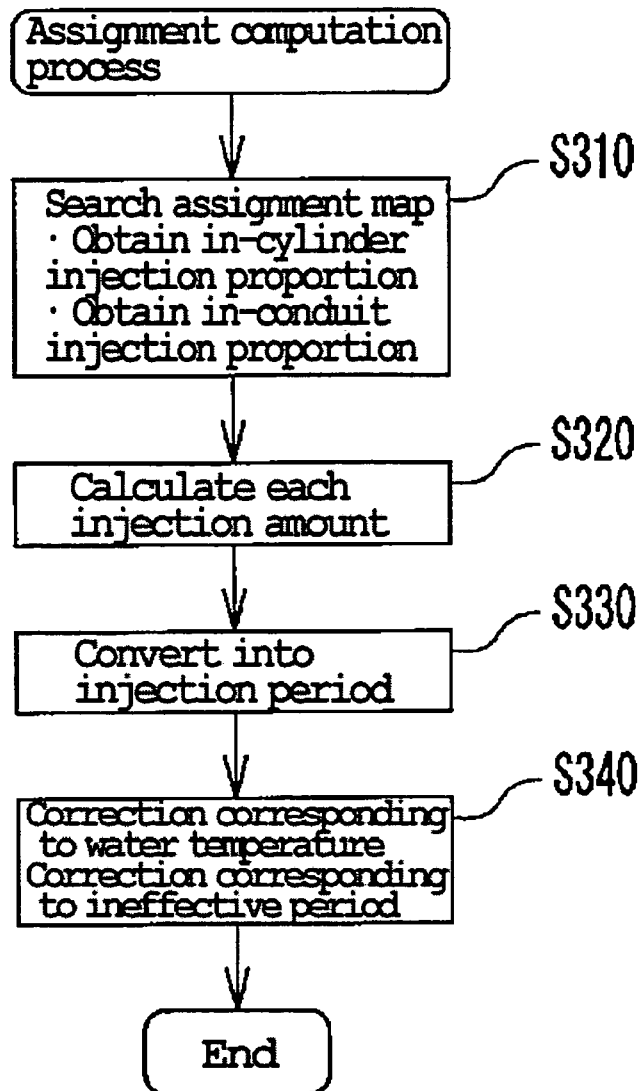


FIG. 7

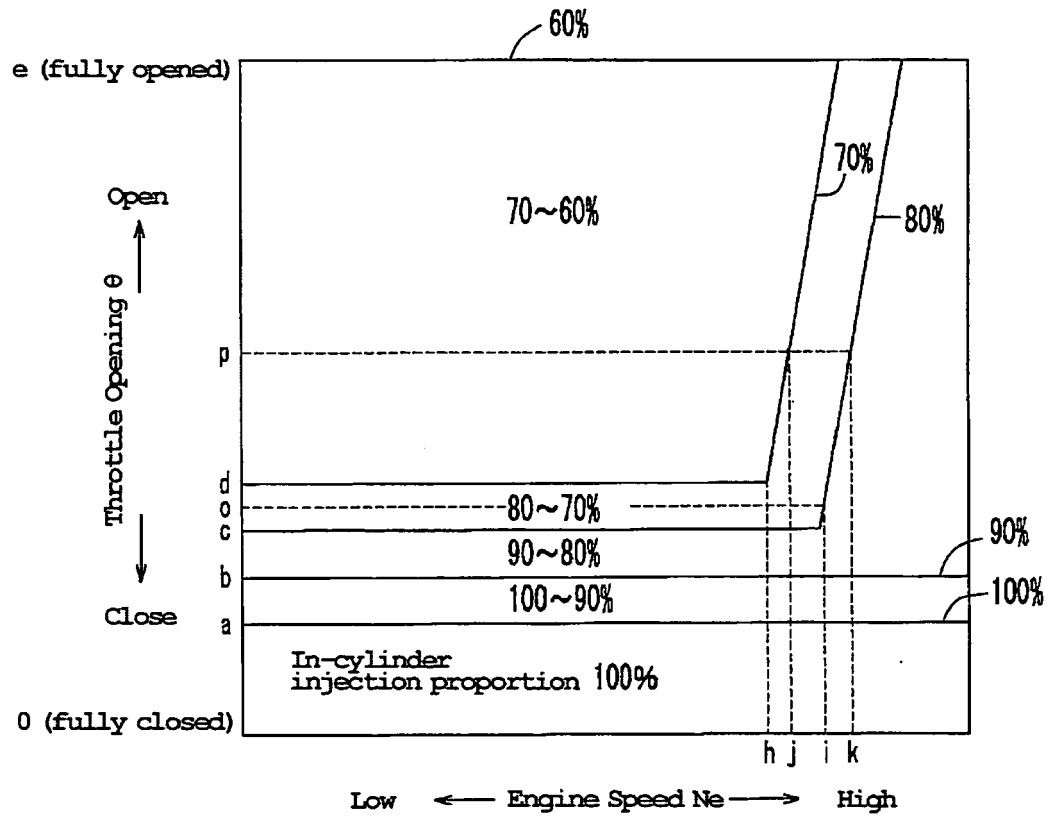


FIG. 8

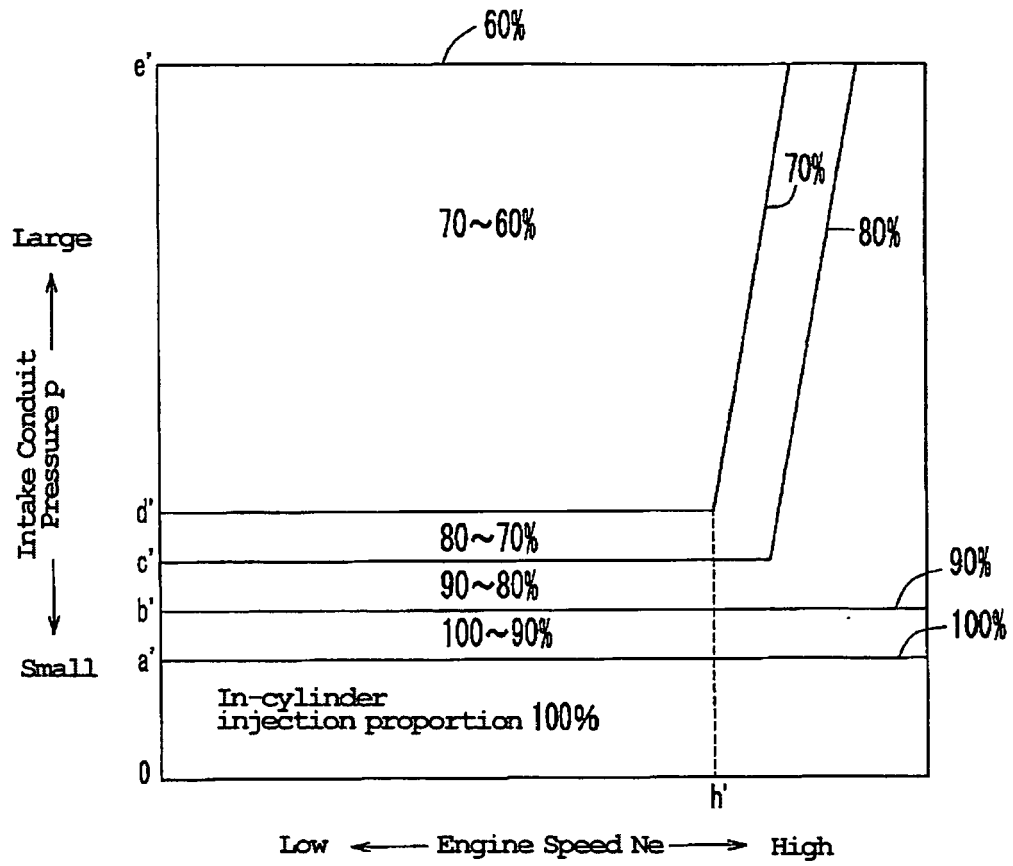


FIG. 9



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
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Place of search Munich		Date of completion of the search 13 August 2008	Examiner Jackson, Stephen
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