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(54) **STOP CONTROL APPARATUS FOR ENGINE, ENGINE SYSTEM, AND VEHICLE**

(57) A stop control apparatus for an engine includes a determination unit which determines whether or not an automatic stop condition is satisfied and a control unit which stops the engine when the automatic stop condition is satisfied. The control unit executes oxygen concentration adjustment control which controls a throttle valve and an EGR valve such that an oxygen concentration in an intake passage on a downstream side of a connection portion with an EGR passage has a predetermined target value Dx in a period until the engine is completely stopped after fuel cut is executed. The oxygen concentration adjustment control includes first control which sets the throttle valve to a valve-open state such that the oxygen concentration is elevated and a second control which closes the throttle valve at a time point when the oxygen concentration is elevated to the target value.

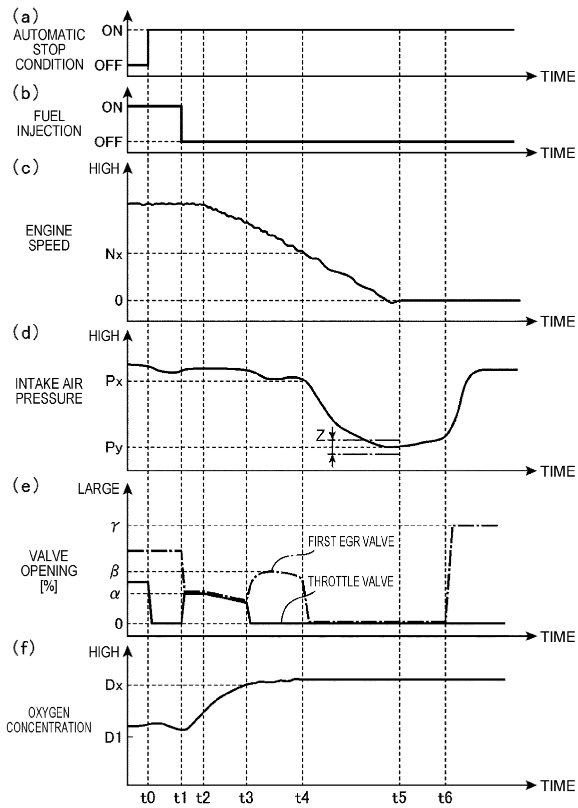

FIG. 5

Description

[Technical Field]

[0001] The present invention relates to a stop control apparatus which stops an engine in a case where a predetermined automatic stop condition is satisfied, the stop control apparatus being applied to an engine which includes a cylinder, an output shaft rotating by receiving energy of combustion in the cylinder, an intake passage through which intake air introduced into the cylinder flows, an exhaust passage through which exhaust gas exhausted from the cylinder flows, and an EGR passage which connects the intake passage and the exhaust passage together.

[Background Art]

[0002] As one example of the above stop control apparatus, a stop control apparatus in the following Patent Literature 1 has been known. This stop control apparatus for an engine, which is disclosed in Patent Literature 1, includes a throttle valve provided to an intake passage, an EGR valve (EGR control valve) provided to an EGR passage, and a control unit which controls the throttle valve and the EGR valve. When an automatic stop of an engine is requested, the control unit stops fuel injection to a cylinder while opening the EGR valve and closes the throttle valve and the EGR valve at a time point when the engine is stopped by the injection stop (fuel cut). By such control, in Patent Literature 1, EGR gas (exhaust gas) is introduced into the intake passage through the EGR passage before the engine stops, and the EGR gas is confined in the intake passage after the engine is stopped.

[Citation List]

[Patent Literature]

[0003] [Patent Literature 1] Japanese Patent Laid-Open No. 2004-100497

[Summary]

[Problems to be Solved]

[0004] In a stop control apparatus for an engine, which is disclosed in above Patent Literature 1, at a restart when the stopped engine is started, intake air containing EGR gas is introduced into a cylinder, and an effect of reducing a NOx generation amount by combustion in the restart is thereby expected. However, depending on a driving state at time immediately before fuel cut is performed, it can be assumed that the engine stops in a state where excessively much EGR gas is confined in an intake passage. In such a case, ignitability of fuel might not be capable of being secured due to a too low ratio of fresh air which is introduced into the cylinder at the restart.

[0005] The present invention has been made in consideration of the above circumstance, and an object thereof is to provide a stop control apparatus for an engine which is capable of reducing a generation amount of NOx while securing ignitability at a restart.

[Means for Solving the Problems]

[0006] To solve the above problems, the present invention is a stop control apparatus as defined in claim 1. The stop control apparatus is to be applied to an engine which includes a cylinder, an output shaft rotating by receiving energy of combustion in the cylinder, an intake passage through which intake air introduced into the cylinder flows, an exhaust passage through which exhaust gas exhausted from the cylinder flows, and an EGR passage which connects the intake passage and the exhaust passage together. The stop control apparatus includes: an injector which supplies fuel to the cylinder; an EGR valve which is provided to the EGR passage in an openable and closable manner; a throttle valve which is provided in an openable and closable manner to an intake passage on an upstream side of (or upstream of) a connection portion between the EGR passage and the intake passage; a determination unit which determines whether or not an automatic stop condition for automatically stopping the engine is satisfied; and a control unit which controls each of units of the engine, the units including the injector, the throttle valve, and the EGR valve. In a case where the determination unit confirms that the automatic stop condition is satisfied, the control unit may execute fuel cut for stopping supply of fuel by the injector and executes oxygen concentration adjustment control which controls the throttle valve and the EGR valve such that an oxygen concentration in an intake passage on a downstream side of (or downstream of) the connection portion has or becomes a predetermined target value in a period until rotation of the output shaft stops after the fuel cut is executed, and the oxygen concentration adjustment control includes first control which sets the throttle valve to a valve-open state such that the oxygen concentration is elevated and a second control which closes the throttle valve at a time point when the oxygen concentration is elevated to the target value.

[0007] In other words, in a case where the determination unit confirms that the automatic stop condition is satisfied, control unit may stop supply of fuel by the injector, control the throttle valve to be a valve-open state such that an oxygen concentration in an intake passage downstream of the connection portion becomes a predetermined target value in a period until rotation of the output shaft stops after the fuel supply is stopped, and close the throttle valve when the oxygen concentration is elevated to the target value.

[0008] According to the present invention, because the throttle valve is set to the valve-open state after the fuel cut (first control), fresh air which abundantly contains oxygen flows into the intake passage on the downstream side of the throttle valve, and the oxygen concentration in the intake passage on the downstream side of the connection portion with the EGR passage (which will hereinafter also be referred to as final intake oxygen concentration) is thereby elevated. Further, because the throttle valve is closed at a time point when the final intake oxygen concentration is elevated to the target value (second control), introduction of fresh air through the throttle valve is stopped, and as a result the final intake oxygen concentration can substantially be maintained at the target value. This means that the final intake oxygen concentration at a restart of the engine can be adjusted to a value which is higher than the concentration at time when the automatic stop condition is satisfied and is lower than the oxygen concentration contained in the atmosphere.

[0009] Here, before the automatic stop condition is satisfied, return of exhaust gas through the EGR passage (EGR operation) is performed, and the final intake oxygen concentration is thereby significantly lower than the oxygen concentration in the atmosphere. Thus, in a case where the first control is hypothetically not performed which temporarily sets the throttle valve to the valve-open state, the engine is restarted while the final intake oxygen concentration is kept significantly low, and ignitability of fuel at a restart might be impaired. On the other hand, in the present invention, because the throttle valve is set to the valve-open state after the fuel cut, ignitability at a restart can be secured by elevating the final intake oxygen concentration.

[0010] However, when the final intake oxygen concentration is unreasonably elevated, combustion in the cylinder is performed in a state where very little EGR gas as inactive gas is present, as a result a combustion temperature is elevated, and a NOx amount produced by the combustion might increase. On the other hand, in the present invention, because the throttle valve is closed at a time point when the final intake oxygen concentration is elevated to a proper concentration (target concentration) (second control), the final intake oxygen concentration can be maintained at a concentration lower than the oxygen concentration in the atmosphere (in other words, a state can be maintained where EGR gas is contained in the intake air), a NOx generation amount by combustion can effectively be reduced.

[0011] The first control may be control which sets not only the throttle valve but also the EGR valve to the valve-open state.

[0012] In other words, the control unit may control the throttle valve and the EGR valve to open.

[0013] With this configuration, an inflow amount of fresh air can be decreased compared to a case where the EGR valve is not opened, and rapid elevation of the final intake oxygen concentration can be avoided. Accordingly, the time point when the final intake oxygen concentration reaches the target value can precisely be specified, and precision of concentration adjustment can be enhanced.

[0014] In the above configuration, the first control may further include control which decreases an opening of the throttle valve in accordance with lowering of an engine speed as a rotation speed of the output shaft.

[0015] In other words, the control unit may decrease an opening of the throttle valve as an engine speed or a rotation speed of the output shaft decreases.

[0016] With this configuration, fluctuation in an elevation rate of the final intake oxygen concentration can be inhibited while stability of the intake air pressure is intended. That is, when the engine speed lowers after the fuel cut, a reciprocating speed of a piston lowers, a drawing force in an intake stroke is decreased, and an intake air amount drawn into the cylinder is decreased. Thus, when the opening of the opened throttle valve is hypothetically kept fixed, the possibility becomes high that much fresh air, which is not balanced with the gas amount discharged from the cylinder, is introduced into the cylinder, and elevation of the intake air pressure and fluctuation in the elevation rate of the final intake oxygen concentration might be caused. On the other hand, in the above configuration, because the opening of the throttle valve is gradually decreased such that the gradual decrease conforms with the engine speed lowering after the fuel cut, a proper amount of fresh air, which can be balanced with the gas amount discharged from the cylinder, can be introduced, and fluctuation in the elevation rate of the final intake oxygen concentration can be inhibited while stability of the intake air pressure is intended.

[0017] In the above configuration, the first control may further include control which decreases an opening of the EGR valve in accordance with lowering of the engine speed.

[0018] In other words, the control unit may decrease an opening of the EGR valve as the engine speed or the rotation speed of the output shaft decreases.

[0019] As described above, in a case where the opening of the EGR valve is gradually decreased together with the throttle valve, fluctuation in the elevation rate of the final intake oxygen concentration can sufficiently be inhibited, and the time point when the final intake oxygen concentration reaches the target value can precisely be specified.

[0020] The control unit may close the EGR valve later than the time point when the oxygen concentration is elevated to the target value and at a timing earlier than a stop of rotation of the output shaft.

[0021] As described above, in a case where the EGR valve is closed later than closing of the throttle valve, the intake air pressure can be prevented from becoming an excessive negative pressure between closing of the EGR valve and a complete stop of the engine, and an advantage where a shock which can occur when the engine is completely stopped is lessen and so forth are provided. The term "degree" of the opening of the throttle valve and/or the EGR valve as used in the present application may refer to a ratio of the opening cross section of the valve in a specific state with respect to the opening cross section of said valve in a fully open state.

[Advantageous Effects]

[0022] As described above, a stop control apparatus for an engine of the present invention can reduce a generation amount of NOx while securing ignitability at a restart.

[Brief Description of Drawings]

[0023]

FIG. 1 is an outline system diagram of a preferable embodiment of an engine to which a stop control apparatus according to the present invention is applied.
FIG. 2 is a function block diagram illustrating a control system of the engine.
FIG. 3 is a flowchart illustrating a former period portion of automatic stop control to automatically stop the engine.
FIG. 4 is a flowchart illustrating a latter period portion of the automatic stop control.
FIG. 5 is a time chart illustrating one example of a time change of each state quantity in a case where the automatic stop control is executed.
FIG. 6 is a time chart illustrating one example of the time change of each of the state quantities in a case where the automatic stop control is executed in a different condition from FIG. 5.

[Embodiments for Carrying Out the Invention]

<General Configuration of Engine>

[0024] FIG. 1 is an outline system diagram of an embodiment of an engine to which a stop control apparatus according to the present invention is applied. All of the features as shown in the figures may not necessarily be essential. The engine illustrated in FIG. 1 may be a four-cycle diesel engine which is installed in a vehicle as a power source for traveling. The engine particularly includes an engine body 1 which is driven by being supplied with fuel containing diesel fuel, an intake passage 30 through which intake air introduced into the engine body 1 flows, an exhaust passage 40 through which exhaust gas exhausted from the engine body 1 flows, a supercharger 50 which is driven by exhaust gas passing through the exhaust passage 40, and a high-pressure EGR apparatus 60 and a low-pressure EGR apparatus 70 which return a portion of exhaust gas flowing through the exhaust passage 40 to the intake passage 30.

[0025] The engine body 1 may be of an in-line multi-cylinder type which has plural cylinders 2 aligned in the direction orthogonal to the page of FIG. 1 (only one of those is illustrated in FIG. 1). The engine body 1 particularly includes a cylinder block 3 in whose internal portion the plural cylinders 2 are formed, a cylinder head 4 which is mounted on an upper surface of the cylinder block 3 so as to block respective upper end openings of the cylinders 2, and plural pistons 5 which are respectively housed in the cylinders 2 to be capable of reciprocative sliding. Note that in the present embodiment, a direction from the cylinder block 3 toward the cylinder head 4 is dealt with as up, and its opposite direction is dealt with as down; however, this is for convenience of description and is not intended to limit an installation position of the engine.

[0026] Above the pistons 5 of the cylinders 2, respective combustion chambers 6 are formed. Each combustion chamber 6 is particularly a space which is demarcated by a lower surface of the cylinder head 4, a side peripheral surface (cylinder liner) of the cylinder 2, and a crown surface 5a of the piston 5. The combustion chamber 6 is supplied with fuel by injection from an injector 15 described later. Air-fuel mixture of air and the supplied fuel is combusted in the combustion chamber 6, and the piston 5 pushed down by an expansion force of the combustion performs reciprocating motion in an up-down direction.

[0027] In a lower portion of the cylinder block 3 (below the piston 5), a crankshaft 7 as an output shaft of the engine body 1 is provided. The crankshaft 7 is coupled with the piston 5 of each of the cylinders 2 via a connecting rod 8 and rotates around a central axis in accordance with reciprocating motion (up-down motion) of the piston 5.

[0028] A crank angle sensor SN1 and a water temperature sensor SN2 may be mounted on the cylinder block 3. The crank angle sensor SN1 detects a crank angle as a rotation angle of the crankshaft 7 and an engine speed as a rotation speed of the crankshaft 7. The water temperature sensor SN2 detects the temperature of cooling water which flows through internal portions of the cylinder block 3 and the cylinder head 4, in other words, an engine water temperature.

[0029] In the cylinder head 4, an intake port 9 and an exhaust port 10 which communicate with the combustion chamber 6 are formed for each of the cylinders 2. Further, in the cylinder head 4, each of the cylinders 2 is equipped with a combination of an intake valve 11, an exhaust valve 12, and an injector 15. The intake valve 11 is a valve which opens and closes an opening of the intake port 9 on the combustion chamber 6 side. The exhaust valve 12 is a valve which opens and closes an opening of the exhaust port 10 on the combustion chamber 6 side. The injector 15 is an injection valve which injects fuel (particularly, diesel fuel) into the combustion chamber 6 and is mounted on the cylinder head 4 so as to inject fuel from a center of a ceiling surface of the combustion chamber 6 toward the crown surface 5a of the piston 5, for example.

[0030] To the cylinder head 4, a valve mechanism 13 which drives the intake valves 11 to open and/or close and a valve mechanism 14 which drives the exhaust valves 12 to open and/or close are attached. A combination of those valve mechanisms 13 and 14 particularly includes one pair of camshafts which are linked with the crankshaft 7, for example, and drives the intake valve 11 and the exhaust valve 12 of each of the cylinders 2 in response to rotation of the crankshaft 7.

[0031] The intake passage 30 may be a tubular member which forms a flow passage of intake air introduced into the combustion chamber 6 of each of the cylinders 2. The intake passage 30 particularly has, in its downstream side portion close to the engine body 1, an intake manifold 30a which is branched while corresponding to the plural cylinders 2 (including plural branch pipes aligned in the direction orthogonal to the page of FIG. 1). This intake manifold 30a is connected with the cylinder head 4 so as to communicate with the intake port 9 of each of the cylinders 2. Note that portions other than the intake manifold 30a in the intake passage 30 are made single-tube-like members which form a shared passage communicating with the intake manifold 30a.

[0032] In the intake passage 30, in order from its upstream side, an air cleaner 31, a throttle valve 32, an intercooler 33, and a surge tank 34 may be disposed. The air cleaner 31 is a filter which removes foreign substances in the intake air. The throttle valve 32 is an electric butterfly valve which is capable of adjusting a flow amount of the intake air flowing through the intake passage 30. The intercooler 33 is a heat exchanger which cools the intake air compressed by the supercharger 50 (specifically, a compressor 51 described later). The surge tank 34 is a tank which provides a space for equivalently distributing intake air to each of the cylinders 2 and is connected with an upstream end of the intake manifold 30a.

[0033] In the intake passage 30, an airflow sensor SN3 and an intake air pressure sensor SN4 may be disposed. The airflow sensor SN3 is disposed in a portion on a downstream side of the air cleaner 31 in the intake passage 30 and detects a flow amount of the intake air which passes through the portion, in other words, an intake air flow amount. The intake air pressure sensor SN4 is disposed in the surge tank 34 and detects a pressure of the intake air passing through the surge tank 34, in other words, an intake air pressure.

[0034] The exhaust passage 40 may be a tubular member which forms a flow passage of exhaust gas exhausted from the combustion chamber 6 of each of the cylinders 2. The exhaust passage 40 particularly has, in its upstream side portion close to the engine body 1, an exhaust manifold 40a which is branched while corresponding to the plural cylinders 2 (including plural branch pipes aligned in the direction orthogonal to the page of FIG. 1). This exhaust manifold 40a is connected with the cylinder head 4 so as to communicate with the exhaust port 10 of each of the cylinders 2. Note that portions other than the exhaust manifold 40a in the exhaust passage 40 are made single-tube-like members which form a shared passage communicating with the exhaust manifold 40a.

[0035] The exhaust passage 40 may be provided with a catalyst apparatus 41 which purifies exhaust gas. In the catalyst apparatus 41, an oxidation catalyst 42 which oxidizes CO and HC in exhaust gas and detoxifies the exhaust gas and a DPF (diesel particulate filter) 43 for capturing particulate substances contained in exhaust gas are built.

[0036] An exhaust O_2 sensor SN5 may be mounted on the exhaust passage 40. The exhaust O_2 sensor SN5 is provided between a portion between a turbine 52 and the catalyst apparatus 41 in the exhaust passage 40 and detects a concentration of oxygen contained in the exhaust gas passing through the portion, in other words, an exhaust oxygen concentration.

[0037] The supercharger 50 includes the compressor 51 disposed in the intake passage 30, the turbine 52 disposed in the exhaust passage 40, and a turbine shaft 53 which couples the compressor 51 and the turbine 52 together.

[0038] The turbine 52 is an impeller which rotates by receiving energy of the exhaust gas flowing through the exhaust passage 40. The turbine 52 may be disposed in the exhaust passage 40 between a downstream end (exhaust collecting portion) of the exhaust manifold 40a and the catalyst apparatus 41. Rotation of the turbine 52 is transmitted to the compressor 51 via the turbine shaft 53.

[0039] The compressor 51 is an impeller which rotates in response to the rotation of the turbine 52 and thereby sends intake air while compressing that (boosts intake air). The compressor 51 may be disposed in the intake passage 30 between the air cleaner 31 and the throttle valve 32.

[0040] The high-pressure EGR apparatus 60 is a returning apparatus for returning a portion of exhaust gas, which has not yet flowed into the turbine 52 and is at a comparatively high pressure, as EGR gas to the intake passage 30. The high-pressure EGR apparatus 60 particularly includes a first EGR passage 61 which connects the exhaust passage 40 and the intake passage 30 together, a first EGR valve 62 which is provided to the first EGR passage 61, and a first EGR cooler 63. The first EGR valve 62 may be an electric valve which is capable of adjusting a flow amount of the EGR gas flowing through the first EGR passage 61. The first EGR cooler 63 is a heat exchanger which cools the EGR gas flowing through the first EGR passage 61. Note that the first EGR passage 61 and the first EGR valve 62 respectively correspond to "EGR passage" and "EGR valve" in the present invention.

[0041] A part where an end portion of the first EGR passage 61 on an upstream side (the exhaust passage 40 side) is connected with the exhaust passage 40 is set as a first EGR entrance portion 61a, and a part where an end portion of the first EGR passage 61 on the downstream side (the intake passage 30 side) is connected with the intake passage 30 is set as a first EGR exit portion 61b. In this case, the first EGR entrance portion 61a may be positioned between the turbine 52 and the downstream end (exhaust collecting portion) of the exhaust manifold 40a in the exhaust passage 40. Further, the first EGR exit portion 61b may be positioned between the throttle valve 32 and the surge tank 34 in the intake passage 30. In other words, the first EGR passage 61 connects the exhaust passage 40 on the upstream side of the turbine 52 and the intake passage 30 on the downstream side of the throttle valve 32 with each other. Note that the first EGR exit portion 61b corresponds to "a connection portion between an EGR passage and an intake passage" in the present invention.

[0042] The low-pressure EGR apparatus 70 is a returning apparatus for returning a portion of exhaust gas, which has already flowed into the turbine 52 and is at a comparatively low pressure, as EGR gas to the intake passage 30. The low-pressure EGR apparatus 70 particularly includes a second EGR passage 71 which connects the exhaust passage 40 and the intake passage 30 together, a second EGR valve 72 which is provided to the second EGR passage 71, and a second EGR cooler 73. The second EGR valve 72 may be an electric valve which is capable of adjusting a flow amount of the EGR gas flowing through the second EGR passage 71. The second EGR cooler 73 is a heat exchanger which cools the EGR gas flowing through the second EGR passage 71.

[0043] A part where an end portion of the second EGR passage 71 on the upstream side (the exhaust passage 40 side) is connected with the exhaust passage 40 is set as a second EGR entrance portion 71a, and a part where an end portion of the second EGR passage 71 on the downstream side (the intake passage 30 side) is connected with the intake passage 30 is set as a second EGR exit portion 71b. In this case, the second EGR entrance portion 71a may be positioned on the downstream side of the turbine 52 and the catalyst apparatus 41 in the exhaust passage 40. Further, the second EGR exit portion 71b may be positioned between the air cleaner 31 and the throttle valve 32 (more specifically, between the air cleaner 31 and the compressor 51) in the intake passage 30. In other words, the second EGR passage 71 connects the exhaust passage 40 on the downstream side of the turbine 52 and the intake passage 30 on the upstream side of the throttle valve 32 with each other.

<Control System>

[0044] FIG. 2 is a function block diagram illustrating a control system of the engine. An electronic control unit or ECU 100 illustrated in FIG. 2 is an apparatus for integrally controlling the engine and is configured with a microcomputer which includes a processor (CPU) performing various kinds of arithmetic processing, memories such as a ROM and a RAM, and various kinds of input-output buses.

[0045] Detection information by each of the sensors of the engine is input to the ECU 100. For example, the ECU 100 is electrically connected with the above-described crank angle sensor SN1, water temperature sensor SN2, airflow sensor SN3, intake air pressure sensor SN4, and exhaust O_2 sensor SN5. To the ECU 100, information detected by the sensors SN1 to S5, in other words, information such as the crank angle, the engine speed, the engine water temperature, the intake air flow amount, the intake air pressure, and the exhaust oxygen concentration is sequentially input.

[0046] Further, detection information by one or various kinds of sensors included in a vehicle is input to the ECU 100. In the present embodiment, the vehicle may be provided with a vehicle speed sensor SN6, an accelerator sensor SN7, and a brake sensor SN8. The vehicle speed sensor SN6 is a sensor which detects a vehicle speed as a traveling speed of the vehicle, the accelerator sensor SN7 is a sensor which detects an accelerator opening as an opening of an accelerator pedal included in the vehicle, and the brake sensor SN8 is a sensor which detects whether or not an operation of a brake pedal included in the vehicle (brake operation) is made. To the ECU 100, detection information (information about the vehicle speed, the accelerator opening, and the brake operation) by the sensors SN6 to SN8 is sequentially input.

[0047] The ECU 100 controls each unit of the engine while executing various determinations, computation, and so forth based on information input from each of the above sensors SN1 to SN8. For example, the ECU 100 is electrically connected with the injectors 15, the throttle valve 32, the first EGR valve 62, and the second EGR valve 72 and outputs control signals to those devices based on results of the computation and so forth.

[0048] As elements for realizing the above-described control, the ECU 100 functionally has a determination unit 101, an automatic stop control unit 102, and a restart control unit 103. Note that the automatic stop control unit 102 corresponds to "control unit" in the present invention.

[0049] The automatic stop control unit 102 may be a control module which automatically stops the working engine when a specific condition is satisfied. The restart control unit 103 may be a control module which restarts the engine stopped by the automatic stop control unit 102. The determination unit 101 may be a control module which performs various determinations and computation necessary for executing control by the automatic stop control unit 102 and the restart control unit 103.

<Automatic Stop Control>

[0050] Next, a description will be made about details of automatic stop control which automatically stops the working engine. FIG. 3 and FIG. 4 are flowcharts illustrating specific procedures of the automatic stop control. When the control in those flowcharts starts, the determination unit 101 of the ECU 100 determines whether or not an automatic stop condition defined in advance is satisfied (step S1). The automatic stop condition is a condition for permitting an automatic stop of the engine, and various conditions can be set in accordance with types or the like of vehicles.

[0051] For example, in a vehicle whose power source for traveling is substantially only an engine (so-called engine vehicle), in a case where all of plural conditions including (i) the vehicle substantially stops, (ii) the accelerator pedal is in an OFF state, and (iii) the brake pedal is in an ON state are complete, the automatic stop condition can be satisfied. In this case, the determination unit 101 respectively determines whether or not the vehicle speed is substantially zero, whether or not the accelerator opening is substantially zero, and whether or not a depression operation of the brake pedal is performed based on information input from the vehicle speed sensor SN6, the accelerator sensor SN7, and the brake sensor SN8. Then, in a case where all of those determinations turn out to be YES (in other words, all of the above (i) to (iii) conditions are satisfied), it is determined that the automatic stop condition is satisfied.

[0052] Meanwhile, in a vehicle which also uses a motor as a power source for traveling, that is, in a hybrid vehicle which is capable of electric-vehicle traveling only by a motor, there may be a case where a driving force of the engine becomes unnecessary even during traveling of the vehicle, and when such a situation occurs, the automatic stop condition can be satisfied. In this case, the determination unit 101 calculates a target torque of drive sources including the engine and the motor from the vehicle speed detected by the vehicle speed sensor SN6, the accelerator opening detected by the accelerator sensor SN7, and so forth and determines whether or not an engine output is necessary (a positive output torque which contributes to traveling) based on various kinds of conditions including the calculated target torque. Then, in a case where it is determined that the engine output is not necessary, it is determined that the automatic stop condition is satisfied.

[0053] As for the automatic stop condition in each of the above patterns, a load on the engine is not high immediately before the automatic stop condition is satisfied. In this state, the engine is driven in a state where at least either one of the first EGR valve 62 and the second EGR valve 72 is open. That is, as the presupposition of satisfaction of the automatic stop condition, the engine is executing EGR for returning exhaust gas from the exhaust passage 40 to the intake passage 30, and further the EGR rate (the ratio of EGR gas contained in intake air) is comparatively high. Thus, when the automatic stop condition is satisfied, the oxygen concentration in the intake passage 30 is significantly lowered with respect to the oxygen concentration in the atmosphere in at least the vicinity of the engine body 1 (specifically, a portion on the downstream side of the first EGR exit portion 61b), and its value is lower than a target value Dx of the oxygen concentration which is used in step S9 described later.

[0054] In a case where the determination in above step S1 is YES and it is confirmed that the automatic stop condition is satisfied, the automatic stop control unit 102 of the ECU 100 may close the throttle valve 32 (step S2). That is, the automatic stop control unit 102 drives the throttle valve 32 to close such that the opening of the throttle valve 32 lowers to an almost fully closed (0%) state. Note that the openings of the first EGR valve 62 and the second EGR valve 72 can be different in accordance with a driving condition at time before the automatic stop condition is satisfied; however, it is assumed that at least the first EGR valve 62 is in a valve-open state (states other than a fully closed state) when the automatic stop condition is satisfied and particularly maintains this state in the step S2 also. In other words, in the step S2, while the valve-open state of the first EGR valve 62 is maintained, control for closing the throttle valve 32 may be executed.

[0055] Next, the automatic stop control unit 102 executes fuel cut for stopping fuel injection from the injector 15 of each of the cylinders 2 (step S3). After this fuel cut is executed, combustion is stopped in each of the cylinders 2, and the engine speed thereby gradually lowers.

[0056] Next, the determination unit 101 may determine whether or not a permission condition for oxygen concentration adjustment control is satisfied (step S4). The oxygen concentration adjustment control particularly denotes control that adjusts the oxygen concentration in the intake air, which is present in the intake passage 30 on the downstream side of (or downstream of) the first EGR exit portion 61b as a connection portion between the first EGR passage 61 and the intake passage 30 (mainly the surge tank 34 and the intake manifold 30a), to a predetermined target value, here, indicates control in steps S5 to S10 described later.

[0057] Further, the permission condition for the oxygen concentration adjustment control is a condition which influences feasibility of such adjustment of the oxygen concentration to the target value. Note that in the following, the oxygen concentration to be adjusted, in other words, the oxygen concentration in the intake air which is present in the intake passage 30 on the downstream side of the first EGR exit portion 61b (in other words, the oxygen concentration in the intake air which results from return of EGR gas from the first EGR passage 61) will also be referred to as "final intake oxygen concentration".

[0058] Specifically, in above step S4, whether or not the permission condition for the oxygen concentration adjustment control is satisfied is determined based on the engine water temperature and the atmospheric pressure. For example, the determination unit 101 may determine that the above permission condition is satisfied in a case where both of a first condition that the engine water temperature detected by the water temperature sensor SN2 is a predetermined threshold value or more and a second condition that the atmospheric pressure estimated from a detected value by the intake air pressure sensor SN4 is a predetermined threshold value or more are satisfied. That is, the determination unit 101 permits execution of the oxygen concentration adjustment control in step S5 and subsequent steps which will be described later.

[0059] On the other hand, in a case where either one of the above first and second conditions is not satisfied, in other words, in a condition where the engine water temperature is low or the atmospheric pressure is low, it is possible that ignitability necessary for a restart cannot be secured, and priority has to be given to ignitability of fuel over adjustment of the oxygen concentration. Accordingly, in such a case, the determination unit 101 may determine that the above permission condition is not satisfied in above step S4 and prohibits the oxygen concentration adjustment control. In this case, the automatic stop control unit 102 executes control for stopping the engine while largely elevating the oxygen concentration (step S22). Although details are not described, in this step S22, control is executed such as increasing the opening of the throttle valve 32 to a comparatively high value at a certain timing after the fuel cut such that the above-described final intake oxygen concentration is elevated to a value at which ignitability is sufficiently secured.

[0060] In a case where the determination in above step S4 is YES and it is confirmed that the oxygen concentration adjustment control is permitted, the automatic stop control unit 102 controls the throttle valve 32 and the first EGR valve 62 such that the openings of the valves 32 and the first EGR valve 62 particularly become respective intermediate openings which are defined in advance (step S5). An intermediate opening denotes an opening which is neither fully closed (0%) nor fully open (100%) and denotes an opening which substantially narrows a channel while permitting the flow of gas. The control in step S5 changes the state of the throttle valve 32 from a fully closed state to the valve-open state. Such opening of the throttle valve 32 causes an effect of elevating the oxygen concentration in intake air.

[0061] Particularly, in above step S5, the openings of the throttle valve 32 and the first EGR valve 62 are set to generally the same values. For example, the openings of the throttle valve 32 and the first EGR valve 62 are respectively set to approximately 30%. Note that the opening of the second EGR valve 72 can be set to an appropriate value and can be set to a specific intermediate opening which is defined differently from the throttle valve 32 and the first EGR valve 62, for example.

[0062] Next, the determination unit 101 may determine whether or not the present oxygen concentration condition corresponds to an assumed concentration condition which is in advance defined (step S6). Particularly, the determination unit 101 determines that the oxygen concentration condition corresponds to the assumed concentration condition in a case where both of the following conditions (x) and (y) are satisfied.

(x) An estimated value of the final intake oxygen concentration is a first threshold value D1 defined in advance or more.

(y) A detected value of the exhaust oxygen concentration is a second threshold value D2 defined in advance or more.

[0063] As for the above condition (x), the estimated value of the final intake oxygen concentration may be an estimated value of the oxygen concentration in the intake air which is present in a specific part (for example, the surge tank 34) in the intake passage 30 on the downstream side of the first EGR exit portion 61b and is estimated by computation from conditions which include the exhaust oxygen concentration detected by the exhaust O_2 sensor SN5 and a driving history of the engine (such as opening data of the first and second EGR valves 62 and 72 in the most recent specific period, for example), for example.

[0064] As for the above condition (y), the detected value of the exhaust oxygen concentration may be an exhaust oxygen concentration detected by the exhaust O_2 sensor SN5.

[0065] Further, the first threshold value D1 used for the above condition (x) may be set to a smaller value than a target value Dx of the oxygen concentration used in step S9 described later (D1 < Dx), and the second threshold value D2 used for the above condition (y) may be set to a much smaller value than the above first threshold value D1 (D2 < D1).

[0066] In a case where the determination in above step S6 is YES and it is confirmed that the present oxygen concentration condition corresponds to the assumed concentration condition, in other words, in a case where it is confirmed that both of the estimated value of the final intake oxygen concentration and the detected value of the exhaust oxygen concentration are the threshold values (D1 and D2) or more, the automatic stop control unit 102 control the throttle valve 32 and the first EGR valve 62 such that the respective openings of the valves 32 and 62 change in response to the engine speed (step S7) .

[0067] Particularly, the automatic stop control unit 102 controls the throttle valve 32 and the first EGR valve 62 such that the respective openings of the valves 32 and 62 gradually decrease in accordance with a gradual decrease in the engine speed after the fuel cut.

[0068] When the respective ratios of opening lowering amounts of the valves 32 and 62 to a lowering amount of the engine speed are set as opening change rates, the opening change rates are in advance defined so as to be appropriate values which do not cause a sudden change in the final intake oxygen concentration and can stabilize the intake air pressure.

[0069] Note that in the present embodiment, the respective openings of the throttle valve 32 and the first EGR valve 62 are controlled so as to lower at the same opening change rates. In other words, in the step S7, the respective openings of the throttle valve 32 and the first EGR valve 62 are gradually decreased while being maintained at generally the same values.

[0070] On the other hand, in a case where the determination in above step S6 is NO and it is confirmed that the present oxygen concentration condition does not correspond to the assumed concentration condition, in other words, in a case where it is confirmed that at least either one of the estimated value of the final intake oxygen concentration and the detected value of the exhaust oxygen concentration is less than the threshold value (D1 or D2), the automatic stop control unit 102 may control the throttle valve 32 and the first EGR valve 62 such that the opening of the throttle valve 32 becomes larger than the opening of the first EGR valve 62 (step S8) .

[0071] In this step S8, the opening of the throttle valve 32 is set to a value which is larger than the opening of the throttle valve 32 in a case where the present oxygen concentration condition hypothetically corresponds to the assumed concentration condition (in other words, the opening set in above step S7) and which is larger than the opening of the first EGR valve 62.

[0072] For example, when it is assumed that both of the openings of the throttle valve 32 and the first EGR valve 62 at a start point of above step S7 are approximately 30%, in this step S8, it is possible to increase the opening of the throttle valve 32 to approximately 50% and to set the opening of the first EGR valve 62 to 30% or a value slightly below this. That is, in the control in step S8 which is executed under a condition where the oxygen concentration is lower than an assumed concentration, compared to the control in above step S7 which is executed not under such a condition, the opening of the throttle valve 32 is increased. On the other hand, the opening of the first EGR valve 62 is not increased but is maintained at generally the same opening (the same or a slightly lower opening).

[0073] After the control in either one of above steps S7 and S8 is started, the determination unit 101 determines whether or not the estimated value of the final intake oxygen concentration is elevated to the target value Dx defined in advance or more (step S9). The target value Dx of the final intake oxygen concentration which is used here is set to a value larger than the above-described first threshold value D1 but is set to a value smaller than the oxygen concentration in the atmosphere, in other words, the intake oxygen concentration in a case where the whole intake air is occupied by fresh air.

[0074] In a case where the determination in above step S9 is YES and it is confirmed that the final intake oxygen concentration has the target value Dx or more, the automatic stop control unit 102 closes the throttle valve 32 (step S10). That is, the automatic stop control unit 102 drives the throttle valve 32 to close such that the opening of the throttle valve 32 lowers to an almost fully closed state.

[0075] Next, the automatic stop control unit 102 may adjust the opening of the first EGR valve 62 such that the intake air pressure does not fall below a predetermined reference pressure Px (see FIG. 5(d)) (step S11). The reference pressure Px used here is a reference value of a pressure in the surge tank 34, which is detected by the intake air pressure sensor SN4, in other words, the intake air pressure and is set to a value corresponding to a weak negative pressure which falls slightly below the atmospheric pressure. Because the reference pressure Px is such a value (weak negative pressure), when the step S11 is started, the opening of the first EGR valve 62 is increased compared to the opening at time immediately before the start. That is, because introduction of fresh intake air is basically stopped by closing of the throttle valve 32 in above step S10, in order to sustain the intake air pressure at the weak negative pressure in this state, it is necessary to promote return of EGR gas through the first EGR passage 61 by increasing the opening of the first EGR valve 62. Accordingly, in the step S11, the automatic stop control unit 102 drives the first EGR valve 62 in an opening direction and thereby performs adjustment such that the intake air pressure does not fall below the reference pressure Px (is sustained at the weak negative pressure). Specifically, the automatic stop control unit 102 decides a basic opening of the first EGR valve 62 based on the engine speed while referring to a map or the like, corrects the decided basic opening by using a detected pressure by the intake air pressure sensor SN4, and thereby calculates a target opening of the first EGR valve 62. In step S11, the opening of the first EGR valve 62 is controlled in accordance with the target opening calculated in such a manner, and adjustment is thereby performed such that the intake air pressure in the surge tank 34 does not fall below the reference pressure Px (is adjusted to the weak negative pressure).

[0076] Next, the determination unit 101 may determine whether or not the engine speed lowers to less than a reference speed Nx which is in advance defined (step S12). The reference speed Nx is set to a value which is smaller than the engine speed in the fuel cut in above step S3 and at which a future change in the intake air pressure to a negative pressure can be adjusted to a proper level. Specifically, the reference speed Nx is set to such a value that a minimum value Py (see FIG. 5(d)) of the intake air pressure which largely changes to a negative pressure after step S13 described later falls within a target range Z which is in advance defined. Note that the target range Z can be set so as to include 50 kPa, for example, and the reference speed Nx can be set to approximately 700 to 800 rpm, for example.

[0077] In a case where the determination in above step S12 is YES and it is confirmed that the engine speed becomes less than the reference speed Nx, the automatic stop control unit 102 closes the first EGR valve 62 (step S13). That is, the automatic stop control unit 102 drives the first EGR valve 62 to close such that the opening of the first EGR valve 62 lowers to an almost fully closed state. Here, the throttle valve 32 has already been in the fully closed state via the control in above step S10. Thus, after the step S13, both of the throttle valve 32 and the first EGR valve 62 are set to the fully closed state, and the change in the intake air pressure to a negative pressure thereby progresses.

[0078] Next, the determination unit 101 may determines whether or not the engine is completely stopped (step S14). That is, the determination unit 101 determines whether or not the engine speed detected by the crank angle sensor SN1 substantially lowers to zero and determines that the engine is completely stopped at a time point when the engine speed substantially lowers to zero (in other words, a time point when rotation of the crankshaft 7 is stopped).

[0079] In a case where the determination in above step S14 is YES and it is confirmed that the engine is completely stopped, the automatic stop control unit 102 maintains the throttle valve 32 in the fully closed state and opens the first EGR valve 62 to the intermediate opening or an opening close to a fully open state (step S15). This is preparation control to be ready for a restart of the engine and is performed for the purpose such as avoiding an excessively large cranking resistance at a restart of the engine.

[0080] As it is understood from the above-described flow of the control in step S9 and subsequent steps, in the engine of the present embodiment, a phenomenon where the final intake oxygen concentration is elevated to the target value Dx or more and a phenomenon where the engine speed lowers to less than the reference speed Nx usually occur in this order. However, for example, in a case where the engine speed at time when the automatic stop condition (S1) is satisfied is considerably lower than an assumed speed, a case where the intake oxygen concentration at time when the automatic stop condition is satisfied is considerably lower than an assumed concentration, or the like, it is possible that the latter phenomenon occurs earlier than the former phenomenon. Next, a description will be made about contents of control to be performed in such a peculiar case.

[0081] In order to check whether or not the above peculiar case has occurred, in a case where the determination in above step S9 is NO (a case where the final intake oxygen concentration is less than the target value Dx), the determination unit 101 further determines whether or not the engine speed lowers to less than the reference speed Nx (step S17).

[0082] In a case where the determination in above step S17 is YES and it is confirmed that the engine speed lowers to less than the reference speed Nx, in other words, in a case where it is confirmed that the peculiar case has occurred where the engine speed lowers to less than the reference speed Nx before the final intake oxygen concentration has the target value Dx or more, the automatic stop control unit 102 closes both of the throttle valve 32 and the first EGR valve 62 (step S18). That is, the automatic stop control unit 102 drives the throttle valve 32 and the first EGR valve 62 to close such that the respective openings of the throttle valve 32 and the first EGR valve 62 lower to almost fully closed states.

[0083] Next, the determination unit 101 may determine whether or not the engine is completely stopped, in other words, whether or not the engine speed substantially lowers to zero (step S19).

[0084] In a case where the determination in above step S19 is YES and it is confirmed that the engine is completely stopped, the automatic stop control unit 102 may open the throttle valve 32 to a predetermined intermediate opening (step S20). This is preparation control to be ready for a restart of the engine and is performed for the purpose such as avoiding insufficient ignitability at a restart of the engine. That is, in the above peculiar case, because the throttle valve 32 is closed before the final intake oxygen concentration is elevated to the target value Dx, when the engine is restarted while this state is maintained, the possibility that necessary ignitability is not secured is high. Accordingly, the throttle valve 32 is in advance opened in the step S20, and ignitability at a restart is thereby secured.

<Action example of Each Unit by Automatic Stop Control>

[0085] FIG. 5 is a time chart illustrating one example of a time change of each state quantity in a case where the automatic stop control illustrated in FIG. 3 and FIG. 4 is executed. A chart (a) illustrates a time change in a flag which indicates whether or not the automatic stop condition is satisfied, a chart (b) illustrates a time change in a flag which indicates whether or not fuel injection from the injectors 15 is necessary, a chart (c) illustrates a time change in the engine speed, a chart (d) illustrates a time change in the intake air pressure in the surge tank 34, a chart (e) illustrates time changes in the respective openings of the throttle valve 32 and the first EGR valve 62, and a chart (f) illustrates a time change in the intake oxygen concentration in the surge tank 34 (in other words, the final intake oxygen concentration).

[0086] In FIG. 5, the time point when the automatic stop condition (step S1 in FIG. 3) is satisfied is set as t0. In response to satisfaction of the automatic stop condition at this time point t0, the opening of the throttle valve 32 is first decreased to 0% (fully closed) (chart (e)). This corresponds to control in step S2 in FIG. 3.

[0087] At a time point t1 later than the time point t0 when the automatic stop condition is satisfied, the fuel cut for stopping fuel injection is executed (chart (b)). This corresponds to control in step S3 in FIG. 3. In addition, immediately after this fuel cut, the opening of the throttle valve 32 is increased from 0% to α%, and the opening of the first EGR valve 62 is the same set to α% (chart (e)). This corresponds to the control in step S5 in FIG. 3. An opening of α%is set to a predetermined intermediate opening which is neither 0% nor 100% (for example, approximately 30%). In such a manner, the throttle valve 32 is opened to the intermediate opening, the final intake oxygen concentration gradually increases after the time point t1 (chart (f)). Further, because not only the throttle valve 32 but also the first EGR valve 62 is opened, the final intake oxygen concentration is not very rapidly elevated but is elevated at a comparatively stable elevation rate. Note that in the example in FIG. 5, before the time point t0 when the automatic stop condition is satisfied, the opening of the first EGR valve 62 is set to a larger value than α%. Thus, in response to the fuel cut, the opening of the first EGR valve 62 is decreased from a larger opening than α% to α%.

[0088] At a time point t2 later than the time point t1 when the fuel cut is executed, the engine speed actually starts lowering (chart (c)). In response to this, after the time point t2, the respective openings of the throttle valve 32 and the first EGR valve 62 are gradually decreased (chart (e)). This corresponds to the control in step S7 in FIG. 3. Here, the fact that the control in step S7 is executed means that both of the determinations in steps S4 and S6 prior to that are YES. In other words, the time chart in FIG. 5 illustrates an action example of a case where the permission condition for the oxygen concentration adjustment control is satisfied and the oxygen concentration condition corresponds to the assumed concentration condition. In this case, because the final intake oxygen concentration is the threshold value D1 or more, the final intake oxygen concentration does not have to be very rapidly elevated. Accordingly, in FIG. 5, in order to restrict the elevation rate of the final intake oxygen concentration to a proper elevation rate, after the time point t2, the above control is executed which gradually decreases the respective openings of the throttle valve 32 and the first EGR valve 62 in response to the engine speed.

[0089] At a time point t3 later than the time point t2 when the engine speed starts lowering, the final intake oxygen concentration is elevated to the target value Dx (chart (f)). In response to this, the opening of the throttle valve 32 is decreased to 0%, and the opening of the first EGR valve 62 is increased toy β% (> α%) (chart (e)). This corresponds to control in steps S10 and S11 in FIG. 4. The throttle valve 32 is set to the fully closed state, elevation of the final intake oxygen concentration is thereby substantially stopped, and its value is maintained at the vicinity of the target value Dx (chart (f)). Further, the opening of the first EGR valve 62 is increased, adjustment is thereby performed such that the intake air pressure does not largely lower, and its value is maintained at a value which does not fall below the reference pressure Px (chart (d)).

[0090] At a time point t4 later than the time point t3 when the target value Dx is achieved, the engine speed lowers to the reference speed Nx (chart (c)). In response to this, the opening of the first EGR valve 62 is decreased to 0% (chart (e)). This corresponds to control in step S13 in FIG. 4. Because the control sets both of the first EGR valve 62 and the throttle valve 32 to the fully closed state, after the time point t4, the intake air pressure rapidly lowers, and a comparatively strong negative pressure is generated in the surge tank 34 and the intake manifold 30a (chart (d)). Generation of such a negative pressure increases pumping loss in the engine and thus makes a lowering speed of the engine speed fast compared to a case where the throttle valve 32 or the first EGR valve 62 is hypothetically opened.

[0091] After a certain time from the time point t4 (here, immediately before the engine is completely stopped), the intake air pressure lowers to the minimum value Py and does not lower any more. The chart (d) illustrates an example where this minimum value Py of the intake air pressure properly falls within the target range Z. This means that closing of the first EGR valve 62 which is triggered by lowering to the reference speed Nx is executed at such a proper timing that the minimum value Py of the intake air pressure falls within the target range Z.

[0092] At a time point t5 later than the time point t4 when the engine speed lowers to the reference speed Nx, the engine speed lowers to zero, and the engine reaches a complete stop. Then, at a subsequent time point t6, the first EGR valve 62 is increased from 0% to γ%. This corresponds to control in step S15 in FIG. 4. In the example in FIG. 5, an opening of γ% is set to a high opening which is larger than both of the above-described α% and β% (for example, an opening close to the fully open state).

[0093] Note that in the action example in FIG. 5 which is described above, control which sets both of the throttle valve 32 and the first EGR valve 62 to the valve-open state between the time point t1 to the time point t3 corresponds to "first control" in the present invention. Further, control which closes the throttle valve 32 at the time point t3 corresponds to "second control" in the present invention.

[0094] Next, a description will be made, by using FIG. 6, about an action example in a case where the determination in step S6 in FIG. 3 is NO, in other words, in a case where the oxygen concentration condition does not correspond to the assumed concentration condition. It is assumed that time points t0 to t6 in a time chart in this FIG. 6 have the same meanings as the time points t0 to t6 in the above-described time chart in FIG. 5. However, in the example in FIG. 6, the final intake oxygen concentration at the time point t1 when the fuel cut is executed is lower than that in FIG. 5 and falls below the first threshold value D1. Accordingly, in the example in FIG. 6, the determination in above step S6 is NO, and the control in step S8 is executed which comparatively largely opens the throttle valve 32. Because of that, the opening of the throttle valve 32 between the time point t1 and the time point t3 in FIG. 6 is larger than that in FIG. 5. Specifically, in FIG. 6, the opening of the throttle valve 32 is increased from 0% to α1% after the time point t1, and this increased opening α1 is set larger than an opening α2% of the first EGR valve 62 which is set immediately after the time point t1.

[0095] The above-described opening of the throttle valve 32 after the time point t1 elevates the final intake oxygen concentration at a comparatively large elevation rate. Accordingly, at the time point t3 later than the time point t1, the final intake oxygen concentration is elevated to the target value Dx, and in response to this, the throttle valve 32 is set to the fully closed state. Meanwhile, the first EGR valve 62 is temporarily driven in the opening direction at the time point t3 and is set to the fully closed state at the subsequent time point t4.

<Work and Effect>

[0096] As described above, in the present embodiment, the fuel cut (step S3 in FIG. 3) for stopping fuel injection from the injectors 15 is executed when the automatic stop condition for the engine is satisfied, and the throttle valve 32 and so forth are controlled such that the final intake oxygen concentration, which is the oxygen concentration in the intake air present in the intake passage 30 on the downstream side of the first EGR exit portion 61b, has the target value Dx between the fuel cut and a complete stop of the engine. Specifically, control which sets the throttle valve 32 to the valve-open state immediately after the fuel cut (step S4 and so forth in FIG. 3) and control which closes the throttle valve 32 at a time point when the final intake oxygen concentration is elevated to the target value Dx (step S10 in FIG. 4) are executed. Such a configuration provides an advantage where a generation amount of NOx can be reduced while ignitability is secured at a restart when the automatically stopped engine is started.

[0097] That is, in the present embodiment, because the throttle valve 32 is set to the valve-open state after the fuel cut, fresh air which abundantly contains oxygen flows into the intake passage 30 on the downstream side of the throttle valve 32, and the final intake oxygen concentration is thereby elevated. Further, because the throttle valve 32 is closed (set to the fully closed state) at the time point when the final intake oxygen concentration is elevated to the target value Dx, introduction of fresh air through the throttle valve 32 is stopped, and as a result the final intake oxygen concentration can substantially be maintained at the target value Dx. This means that the final intake oxygen concentration at a restart of the engine can be adjusted to a value which is higher than the concentration at time when the automatic stop condition is satisfied and is lower than the oxygen concentration contained in the atmosphere.

[0098] Here, before the automatic stop condition is satisfied, return of exhaust gas through the EGR passages 61 and 71 (EGR operation) is performed, and the final intake oxygen concentration is thereby significantly lower than the oxygen concentration in the atmosphere. Thus, in a case where the above control is hypothetically not performed which temporarily sets the throttle valve 32 to the valve-open state, the engine is restarted while the final intake oxygen concentration is kept significantly low, and ignitability of fuel at a restart might be impaired. On the other hand, in the present embodiment, because the throttle valve 32 is set to the valve-open state after the fuel cut, ignitability at a restart can be secured by elevating the final intake oxygen concentration.

[0099] However, when the final intake oxygen concentration is unreasonably elevated, combustion in each of the cylinders 2 is performed in a state where very little EGR gas as inactive gas is present, as a result a combustion temperature is elevated, and a NOx amount produced by the combustion might increase. On the other hand, in the present embodiment, because the throttle valve 32 is closed at the time point when the final intake oxygen concentration is elevated to a proper concentration (target concentration Dx), the final intake oxygen concentration can be maintained at a concentration lower than the oxygen concentration in the atmosphere (in other words, a state can be maintained where EGR gas is contained in the intake air), a NOx generation amount by combustion can effectively be reduced.

[0100] Further, in the present embodiment, in control which sets the throttle valve 32 to the valve-open state immediately after the fuel cut, the first EGR valve 62 is also set to the valve-open state (step S4 in FIG. 3). Thus, an inflow amount of fresh air can be decreased compared to a case where the first EGR valve 62 is not set to the valve-open state but is closed, and rapid elevation of the final intake oxygen concentration can be avoided. Accordingly, because the final intake oxygen concentration is easily estimated, the time point when the final intake oxygen concentration reaches the target value Dx can precisely be specified, and precision of concentration adjustment can be enhanced.

[0101] Further, in the present embodiment, because the respective openings of the throttle valve 32 and the first EGR valve 62 which are set to the valve-open state after the fuel cut are gradually decreased in response to the engine speed at time after the fuel cut (step S7 in FIG. 3), fluctuation in the elevation rate of the final intake oxygen concentration can be inhibited while stability of the intake air pressure is intended. That is, when the engine speed lowers after the fuel cut, a reciprocating speed of the piston 5 lowers, a drawing force in an intake stroke is decreased, and the intake air amount drawn into each of the cylinders 2 is decreased. Thus, when the opening of the opened throttle valve 32 is hypothetically kept fixed, the possibility becomes high that much fresh air, which is not balanced with the gas amount discharged from each of the cylinders 2, is introduced into each of the cylinders 2, and elevation of the intake air pressure and fluctuation in the elevation rate of the final intake oxygen concentration might be caused. On the other hand, in the present embodiment, because the opening of the throttle valve 32 is gradually decreased such that the gradual decrease conforms with the engine speed lowering after the fuel cut, a proper amount of fresh air, which can be balanced with the gas amount discharged from each of the cylinders 2, can be introduced, and fluctuation in the elevation rate of the final intake oxygen concentration can be inhibited while stability of the intake air pressure is intended. In addition, because the opening of the first EGR valve 62 is gradually decreased together with the throttle valve 32, fluctuation in the elevation rate of the final intake oxygen concentration can sufficiently be inhibited, and the time point when the final intake oxygen concentration reaches the target value Dx can precisely be specified.

[0102] Further, in the present embodiment, when the final intake oxygen concentration reaches the target value Dx, while the throttle valve 32 is closed as described above, the opening of the first EGR valve 62 is controlled in an increasing direction (step S11 in FIG. 4). Subsequently, the first EGR valve 62 is maintained in the valve-open state for a certain time and is closed at the time point when the engine speed becomes less than the reference speed Nx (step S13 in FIG. 4). As described above, in a case where the first EGR valve 62 is closed later than closing of the throttle valve 32, the intake air pressure can be prevented from becoming an excessive negative pressure between closing of the first EGR valve 62 and a complete stop of the engine. For example, the minimum value Py of the intake air pressure which is indicated in the chart (d) in FIG. 5 can be prevented from becoming excessively small, and a probability can be enhanced that the minimum value Py falls within the target range Z. In a case where the minimum value Py of the intake air pressure hypothetically falls below the target range Z, in other words, in a case where the intake air pressure lowers to an excessively strong negative pressure, a lowering speed of the engine speed becomes excessively fast. As a result, a shock which occurs when the engine is completely stopped (a shock transmitted to a vehicle body due to reaction of a sudden stop) is likely to increase, and an occupant might feel discomfort. On the other hand, in the present embodiment, a closing timing of the first EGR valve 62 is set relatively later (later than a closing timing of the throttle valve 32), a lowering amount of the intake air pressure can be caused to fall within a proper range, and a shock in an engine stop can be lessened.

[0103] Further, depending on engines, stop position control may be performed in which a stop position of the piston 5 of each of the cylinders 2 is adjusted to a convenient position for a restart. In such an engine, in a case where control is employed which relatively delays closing of the first EGR valve 62 as in the present embodiment, the lowering speed of the engine speed can be adjusted to a proper range. Thus, precision of the above-described stop position control of the piston 5 can be prevented from lowering, and restart characteristics of the engine can be improved.

<Modifications>

[0104] In the above embodiment, the final intake oxygen concentration, which is the oxygen concentration in the intake air present in the intake passage 30 on the downstream side of the first EGR exit portion 61b (the oxygen concentration in the intake air to which EGR gas has already be returned from the first EGR passage 61), is estimated by computation, and the throttle valve 32 is closed at the time point when the estimated final intake oxygen concentration is elevated to the target value Dx; however, the final intake oxygen concentration may directly be detected by a sensor. For example, a sensor which is capable of detecting the oxygen concentration may be mounted on the surge tank 34, and the final intake oxygen concentration may be detected by the sensor.

[0105] In the above embodiment, in addition to the high-pressure EGR apparatus 60 that includes the first EGR passage 61 which connects the exhaust passage 40 on the upstream side of the turbine 52 and the intake passage 30 on the downstream side of the throttle valve 32 with each other, the low-pressure EGR apparatus 70 that includes the second EGR passage 71 which connects the exhaust passage 40 on the downstream side of the turbine 52 and the intake passage 30 on the upstream side of the throttle valve 32 with each other is provided to the engine; however, the low-pressure EGR apparatus 70 is not essential and may be omitted.

[0106] In the above embodiment, a description is made about an example where the present invention is applied to a diesel engine which combusts fuel containing diesel oil by compression ignition; however, an engine to which the present invention is applicable may be an engine capable of an EGR operation which returns exhaust gas from an exhaust passage to an intake passage, and the present invention may be applied to engines other than diesel engines. For example, it is possible to apply the present invention to a gasoline engine which is capable of combusting fuel containing gasoline by spark ignition and includes an EGR apparatus.

[Reference Signs List]

[0107]

1	engine body
2	cylinder
7	crankshaft (output shaft)
15	injector
30	intake passage
32	throttle valve
40	exhaust passage
61	first EGR passage (EGR passage)
61b	first EGR exit portion (connection portion between EGR passage and intake passage)
62	first EGR valve (EGR valve)
101	determination unit
102	automatic stop control unit (control unit)

Claims

1. A stop control apparatus to be applied to an engine which includes a cylinder (2), an output shaft (7) configured to rotate by receiving energy of combustion in the cylinder (2), an intake passage (30) through which intake air introduced into the cylinder (2) flows, an exhaust passage (40) through which exhaust gas exhausted from the cylinder (2) flows, and an EGR

passage (61) which connects the intake passage (30) and the exhaust passage (40) together, the stop control apparatus comprising:

an injector (15) configured to supply fuel to the cylinder (2);
an EGR valve (62) which is provided to the EGR passage (61) in an openable and/or closable manner;
a throttle valve (32) which is provided in an openable and/or closable manner to the intake passage (30) on an upstream side of a connection portion (61b) between the EGR passage (61) and the intake passage (30);
a determination unit (101) configured to determine whether or not an automatic stop condition for automatically stopping the engine is satisfied; and
a control unit (102) configured to control the injector (15), the throttle valve (32), and the EGR valve (62), wherein
in a case where the determination unit (101) confirms that the automatic stop condition is satisfied, the control unit (102) is configured to execute fuel cut to stop supply of fuel by the injector (15) and execute oxygen concentration adjustment control which controls the throttle valve (32) and the EGR valve (62) such that an oxygen concentration in the intake passage (30) on a downstream side of the connection portion (61b) becomes a predetermined target value (Dx) in a period until rotation of the output shaft (7) stops after the fuel cut is executed, and
the oxygen concentration adjustment control includes first control which sets the throttle valve (32) to a valve-open state such that the oxygen concentration is elevated and a second control which closes the throttle valve (32) at a time point (t3) when the oxygen concentration is elevated to the target value (Dx).

2. The stop control apparatus according to claim 1, wherein
the first control is control which sets not only the throttle valve (32) but also the EGR valve (62) to the valve-open state.

3. The stop control apparatus according to claim 2, wherein
the first control includes control which decreases an opening of the throttle valve (32) in accordance with lowering of an engine speed as a rotation speed of the output shaft (7).

4. The stop control apparatus according to claim 3, wherein
the first control includes control which decreases an opening of the EGR valve (62) in accordance with lowering of the engine speed.

5. The stop control apparatus according to any one of the preceding claims, wherein
the control unit (102) is configured to close the EGR valve (62) later than the time point when the oxygen concentration is elevated to the target value (Dx) and at a timing earlier than a stop of rotation of the output shaft (7).

6. The stop control apparatus according to any one of the preceding claims, wherein

in a case where the determination unit (101) confirms that the automatic stop condition is satisfied, the control unit (102) is configured
to stop supply of fuel by the injector (15),
to control the throttle valve (32) and the EGR valve (62) to be the valve-open state so as to elevate the oxygen concentration, and
to close the throttle valve (32) when the oxygen concentration is elevated to the target value (Dx).

7. The stop control apparatus according to claim 6, wherein
the control unit (102) is configured to open the throttle valve (32) in a same degree as the EGR valve (62) .

8. The stop control apparatus according to claim 6, wherein
the control unit (102) is configured to open the throttle valve (32) in a degree more than the EGR valve (62) .

9. The stop control apparatus according to any one of the preceding claims, wherein
the control unit (102) is configured to decrease an opening of the throttle valve (32) as an engine speed decreases.

10. The stop control apparatus according to claim 9, wherein
the control unit (102) is configured to decrease an opening of the EGR valve (62) as the engine speed decreases.

11. The stop control apparatus according to claim 10, wherein
the control unit (102) is configured to increase the opening of the EGR valve (62) when the engine stops.

12. An engine system comprising:

an engine including a cylinder (2), an output shaft (7) configured to rotate receiving energy of combustion in the cylinder (2), an intake passage (30) through which intake air introduced

into the cylinder (2) flows, an exhaust passage (40) through which exhaust gas exhausted from the cylinder (2) flows, and an EGR passage (61) which connects the intake passage (30) and the exhaust passage (40) together; and
the stop control apparatus according to any one of the preceding claims.

13. The engine system according to claim 12, wherein the engine is a diesel engine.

14. A vehicle comprising the engine system according to claim 12 or 13.

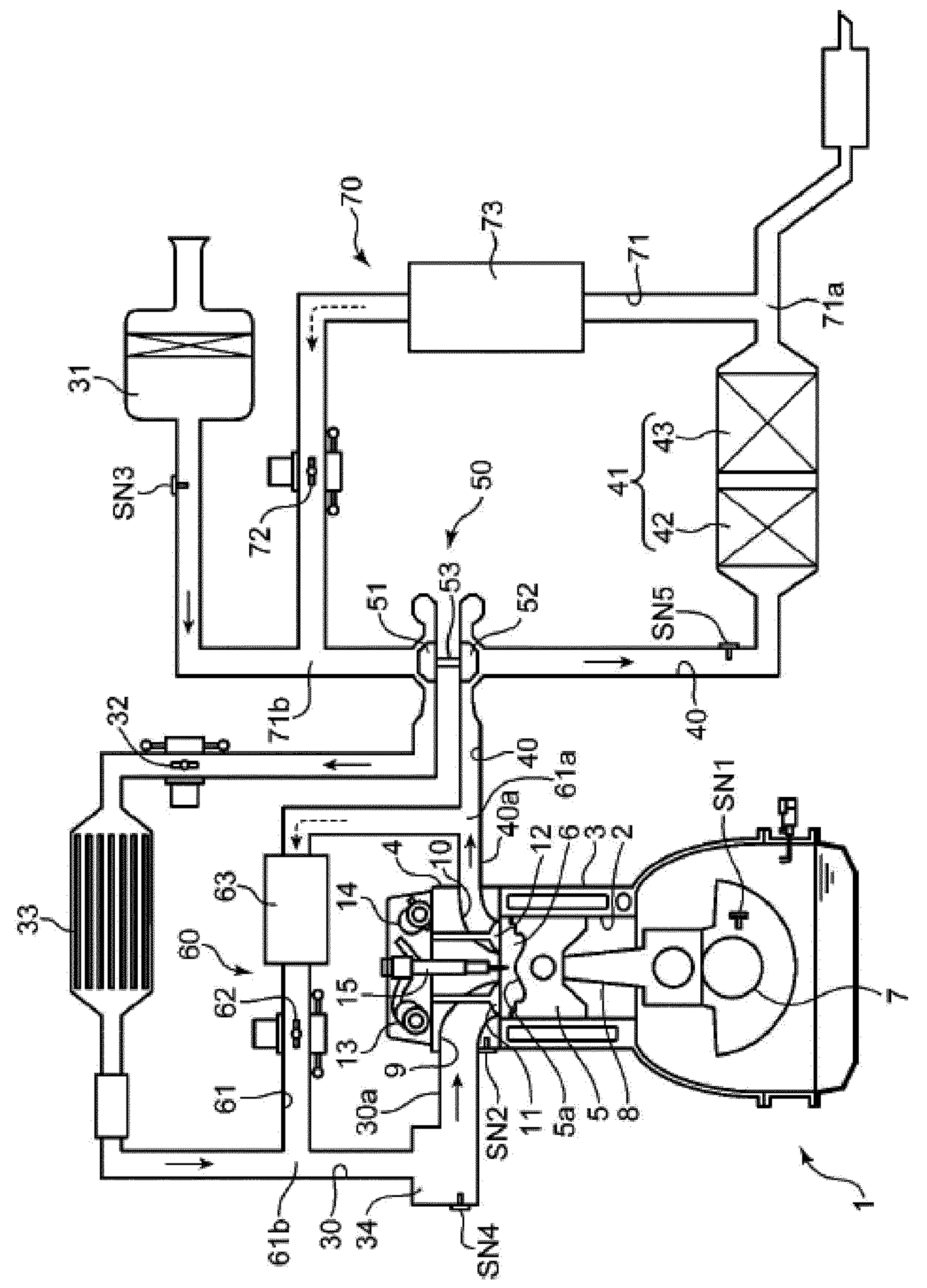
1
2
3
4
5
5a
6
7
8
9
10
11
12
13
14
15
30
30a
31
32
33
34
40
40a
41
42
43
50
51
52
53
60
61
61a
61b
62
63
70
71
71a
71b
72
73
SN1
SN2
SN3
SN4
SN5

FIG. 1

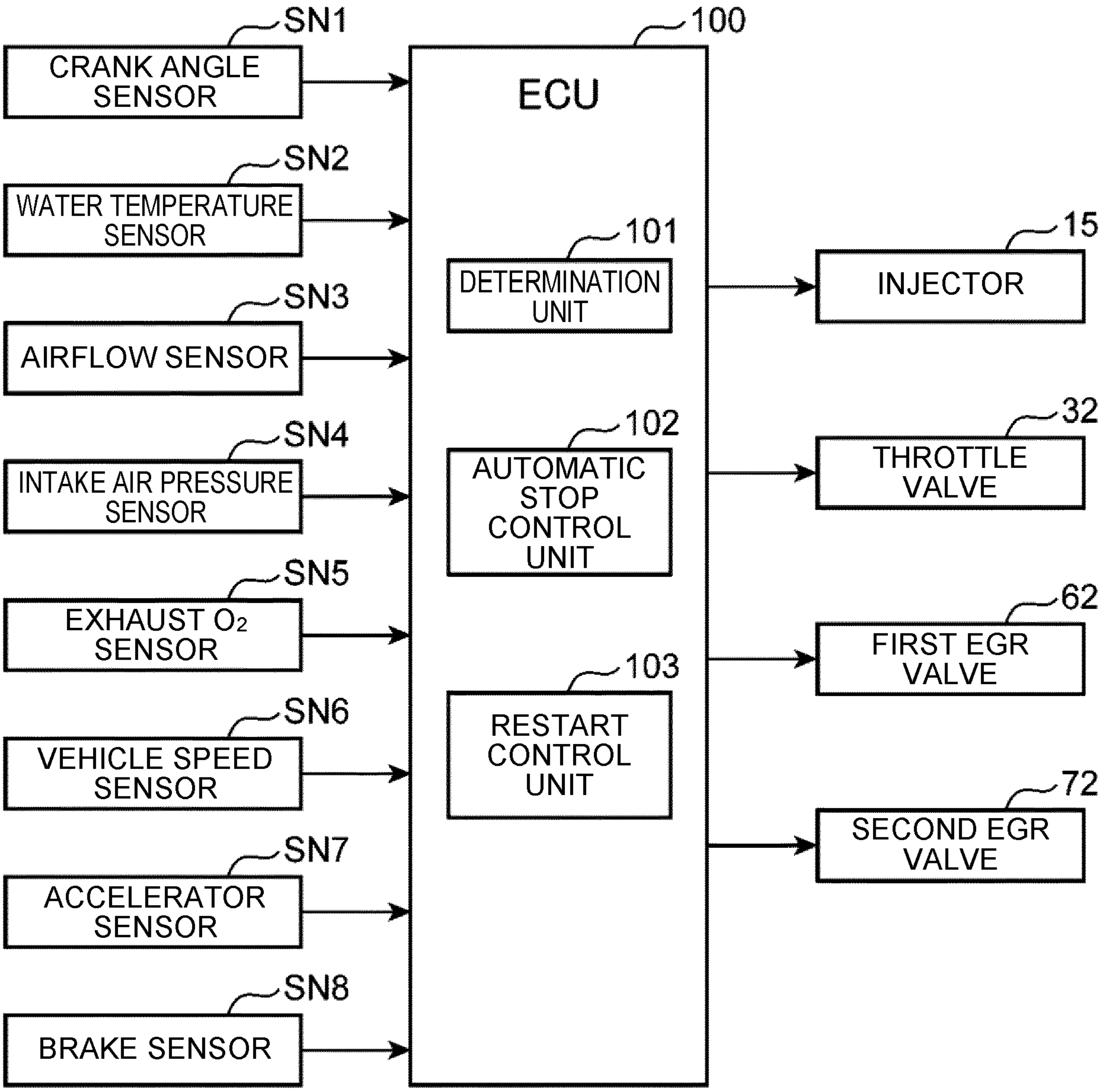
SN1
CRANK ANGLE SENSOR
SN2
WATER TEMPERATURE SENSOR
SN3
AIRFLOW SENSOR
SN4
INTAKE AIR PRESSURE SENSOR
SN5
EXHAUST O2 SENSOR
SN6
VEHICLE SPEED SENSOR
SN7
ACCELERATOR SENSOR
SN8
BRAKE SENSOR
100
ECU
101
DETERMINATION UNIT
102
AUTOMATIC STOP CONTROL UNIT
103
RESTART CONTROL UNIT
15
INJECTOR
32
THROTTLE VALVE
62
FIRST EGR VALVE
72
SECOND EGR VALVE

FIG. 2

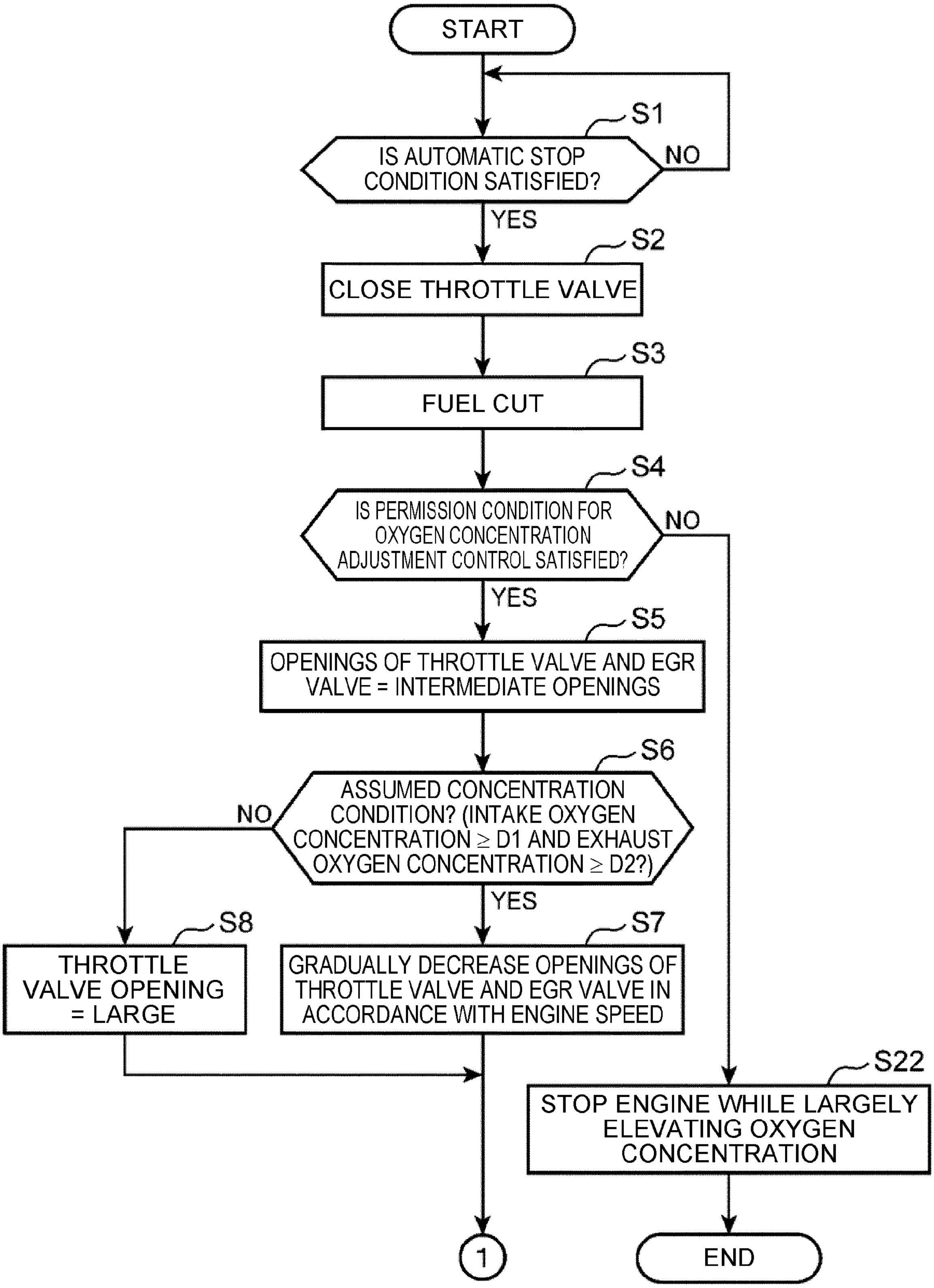
START
S1
IS AUTOMATIC STOP CONDITION SATISFIED?
NO
YES
S2
CLOSE THROTTLE VALVE
S3
FUEL CUT
S4
IS PERMISSION CONDITION FOR OXYGEN CONCENTRATION ADJUSTMENT CONTROL SATISFIED?
NO
YES
S5
OPENINGS OF THROTTLE VALVE AND EGR VALVE = INTERMEDIATE OPENINGS
S6
ASSUMED CONCENTRATION CONDITION? (INTAKE OXYGEN CONCENTRATION ≥ D1 AND EXHAUST OXYGEN CONCENTRATION ≥ D2?)
NO
YES
S8
THROTTLE VALVE OPENING = LARGE
S7
GRADUALLY DECREASE OPENINGS OF THROTTLE VALVE AND EGR VALVE IN ACCORDANCE WITH ENGINE SPEED
S22
STOP ENGINE WHILE LARGELY ELEVATING OXYGEN CONCENTRATION
1
END

FIG. 3

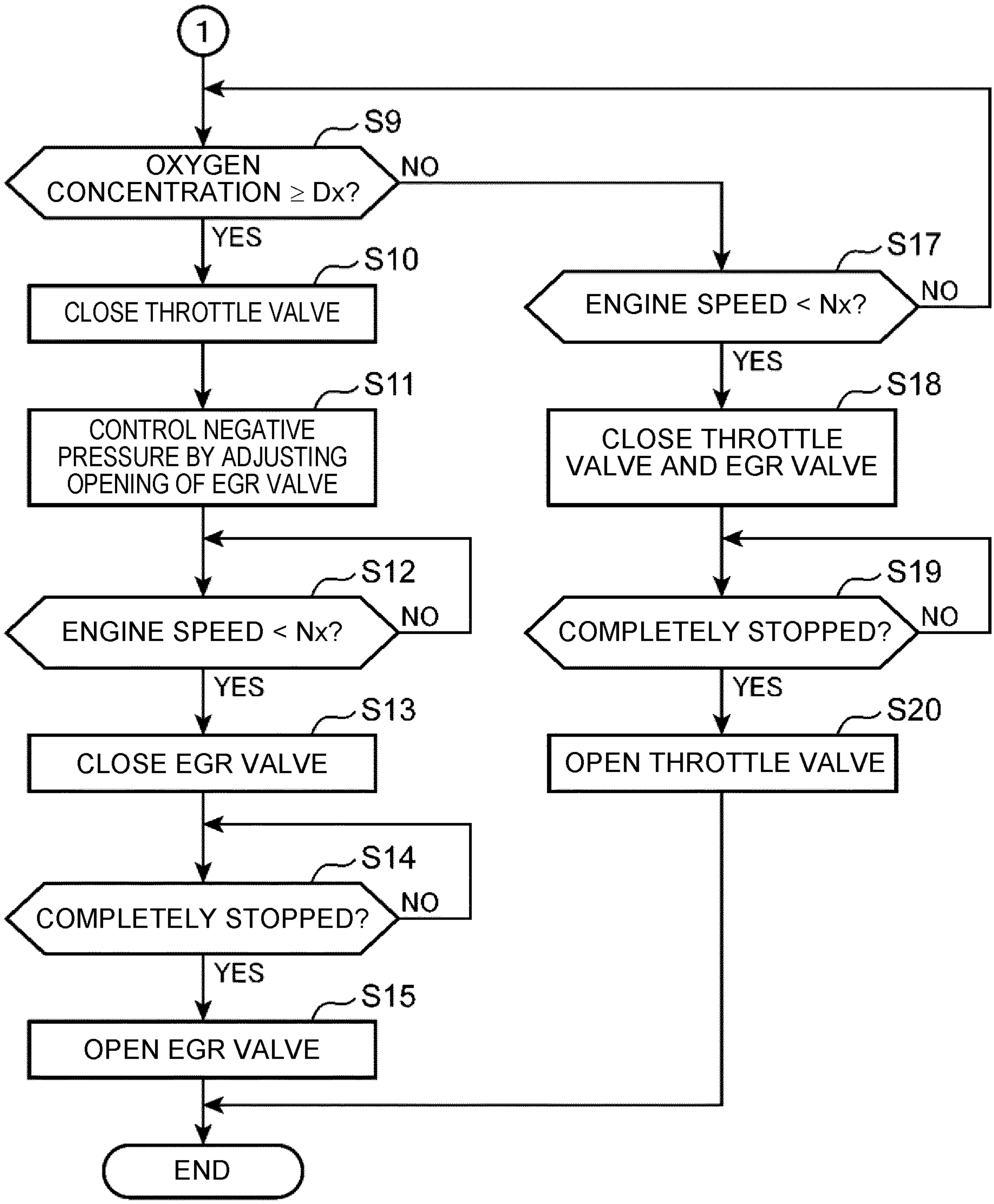
1
S9
OXYGEN CONCENTRATION ≥ Dx?
NO
YES
S10
CLOSE THROTTLE VALVE
S11
CONTROL NEGATIVE PRESSURE BY ADJUSTING OPENING OF EGR VALVE
S12
ENGINE SPEED < Nx?
NO
YES
S13
CLOSE EGR VALVE
S14
COMPLETELY STOPPED?
NO
YES
S15
OPEN EGR VALVE
END
S17
ENGINE SPEED < Nx?
NO
YES
S18
CLOSE THROTTLE VALVE AND EGR VALVE
S19
COMPLETELY STOPPED?
NO
YES
S20
OPEN THROTTLE VALVE

FIG. 4

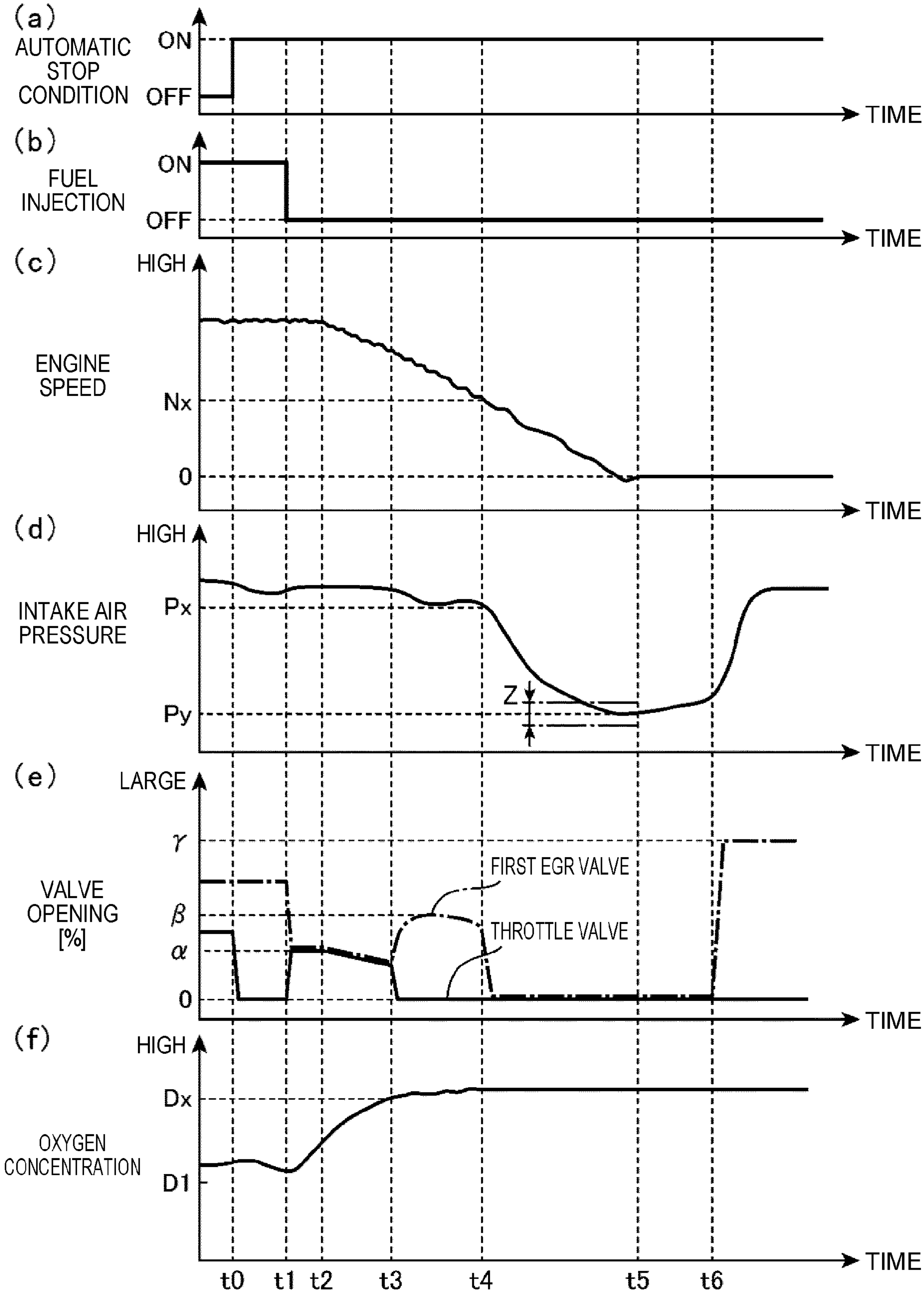
(a)
AUTOMATIC STOP CONDITION
ON
OFF
TIME
(b)
FUEL INJECTION
ON
OFF
TIME
(c)
HIGH
ENGINE SPEED
Nx
0
TIME
(d)
HIGH
INTAKE AIR PRESSURE
Px
Z
Py
TIME
(e)
LARGE
VALVE OPENING [%]
γ
FIRST EGR VALVE
β
THROTTLE VALVE
α
0
TIME
(f)
HIGH
Dx
OXYGEN CONCENTRATION
D1
TIME
t0
t1
t2
t3
t4
t5
t6

FIG. 5

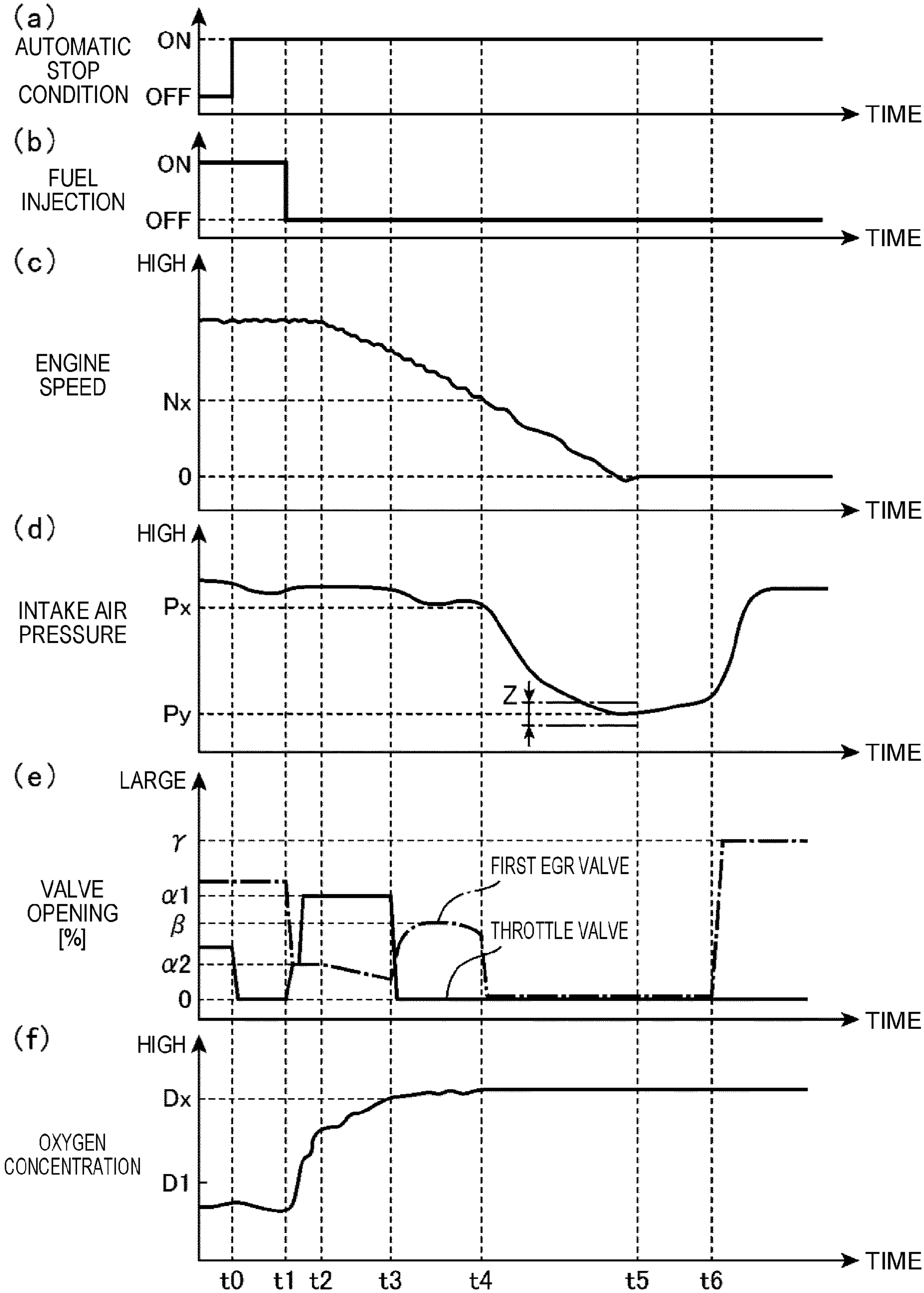
(a)
AUTOMATIC STOP CONDITION
ON
OFF
TIME
(b)
FUEL INJECTION
ON
OFF
TIME
(c)
ENGINE SPEED
HIGH
Nx
0
TIME
(d)
INTAKE AIR PRESSURE
HIGH
Px
Z
Py
TIME
(e)
VALVE OPENING [%]
LARGE
γ
α1
β
α2
0
FIRST EGR VALVE
THROTTLE VALVE
TIME
(f)
OXYGEN CONCENTRATION
HIGH
Dx
D1
TIME
t0
t1
t2
t3
t4
t5
t6

FIG. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 22 16 1227

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A	* claims 1-11; figures 1,7 * -----	3,4,6-8	
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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
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L : document cited for other reasons

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EPO FORM 1503 03.82 (P04C01)

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