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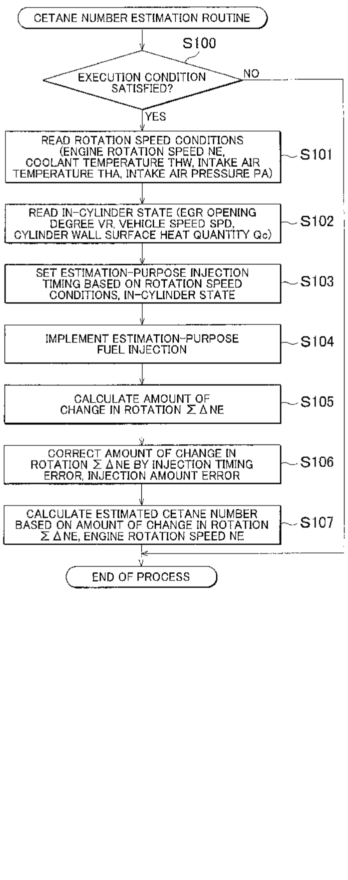
[Continued on next page]

(54) **Title**: ENGINE FUEL PROPERTY ESTIMATION APPARATUS

FIG. 4



(57) Abstract: An engine fuel property estimation apparatus according to the invention estimates the ignition quality (cetane number) of fuel based on torque produced after fuel injection. By variably setting the timing of the fuel injection for estimating the cetane number (cetane number estimation-purpose injection timing) according to the EGR opening degree VR, the vehicle speed SPD and the cylinder wall surface heat quantity Qc (SI 03), the influence that change in the ignition delay that is caused by a factor other than the ignition property of the fuel has the results of estimation of the cetane number is restrained.

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ENGINE FUEL PROPERTY ESTIMATION APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to an engine fuel property estimation apparatus that estimates the ignition quality of fuel on the basis of the engine torque produced by combustion of the fuel injected.

2. Description of Related Art

[0002] A diesel engine burns injected fuel by igniting it through compression. Diesel engines use light oil as fuel. Commercially available light oils are different in their components, and vary in fuel properties such as the ignition quality. The ignition quality of fuel greatly affects the situation of occurrence of misfire, the engine output, etc. Therefore, in order to improve the output performance, the fuel economy performance and the emission performance of a diesel engine, it is necessary to check the ignition quality of the fuel that is currently used and to adjust the manners of execution of engine controls regarding the timing and amount of fuel injection, etc. according to a result of the checking of the ignition quality of the fuel.

[0003] The ignition quality of light oil as a fuel of diesel engines is evaluated by the cetane number. The cetane number of a specimen light oil is expressed by the volume percentage of the amount of cetane in a mixture of cetane and α-methyl naphthalene which exhibits the same ignition quality as the specimen light oil.

[0004] Japanese Patent Application Publication No. 2010-024870 (JP 2010-024870 A) discloses an apparatus that performs a single injection of fuel when the engine rotation speed is decreasing in a state of no load and no fuel injection and that estimates the cetane number of the currently used fuel on the basis of the magnitude of the engine torque produced by the combustion of the injected fuel and the injection timing of the single injection.

[0005] The principle of the foregoing estimation of the cetane number of fuel is as follows. If the in-cylinder pressure or the in-cylinder temperature declines before fuel completely burns, a part of the injected fuel does not burn out but is left unburned. As the cetane number of fuel is lower, the ignition delay time is longer and the start of combustion of the fuel is later. Therefore, as the cetane number of fuel is lower, the time from the start of combustion of fuel to a decline of the in-cylinder pressure or the in-cylinder temperature is shorter. Hence, as the cetane number of fuel is lower, the amount of fuel that does not burn out but is left unburned is larger and the amount of fuel that reaches combustion is less, so that the engine torque produced by the combustion of fuel is smaller. Therefore, by checking the magnitude of engine torque produced by the combustion of injected fuel, it is possible to estimate the cetane number of the fuel, that is, the degree of the ignition quality of the fuel.

[0006] In addition to the ignition quality of fuel, the in-cylinder gas temperature at the time of combustion also affects the delay time of ignition of the fuel. The in-cylinder gas temperature changes depending on the situation of operation of the engine. Therefore, even when the amount of fuel injected and the cetane number of injected fuel are fixed, the magnitude of the engine torque produced may vary depending on the situation of operation of the engine that precedes the estimation of the cetane number of fuel. Such variations can possibly deteriorate the accuracy of estimation of the ignition quality of fuel based on the magnitude of engine torque produced by combustion of injected fuel.

SUMMARY OF THE INVENTION

[0007] The invention provides an engine fuel property estimation apparatus capable of estimating the ignition quality of fuel with improved accuracy.

[0008] A first aspect of the invention is an engine fuel property estimation apparatus that estimates ignition quality of fuel based on magnitude of engine torque produced by combustion of the fuel injected. Timing of fuel injection for estimating the ignition quality of the fuel is varied according to exhaust gas recirculation amount. In this aspect, the exhaust gas recirculation amount is a first amount, the timing of the fuel injection for estimating the ignition quality of the fuel may be set to be later than when the exhaust gas recirculation amount is a second amount that is smaller than the first amount.

[0009] The time of the delay of ignition of fuel in a cylinder is shorter as the gas temperature in the cylinder is higher. In an engine in which exhaust gas is recirculated into intake air, the higher the exhaust gas recirculation amount is, the higher the temperature of the intake after the intake has been mixed with recirculated high-temperature exhaust gas is and, therefore, the higher the in-cylinder gas temperature is.

[0010] In conjunction with this respect, in the first aspect, since the timing of the fuel injection for estimating the ignition quality of fuel is varied according to the exhaust gas recirculation amount, it becomes possible to adjust the timing of the fuel injection for estimation of the ignition quality so as to reduce the influence that the change in the ignition delay time, which depends on the exhaust gas recirculation amount, has on the results of the estimation of the ignition quality. Concretely, it is possible to reduce the change in engine torque caused by the exhaust gas recirculation and therefore reduce the deterioration of the accuracy of estimation of the ignition quality by retarding the timing of the fuel injection for the estimation further as the exhaust gas recirculation amount is larger. Therefore, according to the foregoing construction, the ignition quality of fuel can be estimated with improved accuracy.

[0011] A second aspect of the invention is an engine fuel property estimation apparatus that estimates ignition quality of fuel based on magnitude of engine torque produced by combustion of the fuel injected. Timing of fuel injection for estimating the ignition quality of the fuel is varied according to vehicle speed. In this aspect, when the vehicle speed is a first speed, the timing of the fuel injection for estimating the ignition quality of the fuel may be set to be later than when the vehicle speed is a second speed that is lower than the first speed.

[0012] The time of the delay of ignition of fuel changes depending on the quantity of heat of the cylinder wall surface as well. Concretely, as the quantity of heat of the cylinder wall surface is larger, the ignition delay is shorter because heat from the cylinder wall heats the in-cylinder gas so that the temperature of the in-cylinder gas increases. If the engine is operated under high load prior to estimation of the ignition quality, the quantity of heat of the cylinder wall surface is large at the time of the estimation. Then, if the vehicle speed at the time of estimation of the ignition quality is high, it can be estimated that the engine is highly likely to have previously been operated under high load.

[0013] In conjunction with that respect, in the second aspect, since the timing of the fuel injection for estimating the ignition quality of fuel is varied according to the vehicle speed, it becomes possible to adjust the timing of the fuel injection for estimation of the ignition quality so as to reduce the influence that the change in the ignition delay time, which depends on the quantity of heat of the cylinder wall surface, has on the results of the estimation of the ignition quality. Concretely, it is possible to reduce the change in engine torque caused by differences in the quantity of heat of the cylinder wall surface and therefore reduce the deterioration of the accuracy of estimation of the ignition quality by retarding the timing of the fuel injection for the estimation further as the vehicle speed is higher and therefore the engine load prior to the estimation of the ignition quality is estimated to have been higher. Therefore, according to the foregoing aspect, the ignition quality of fuel can be estimated with improved accuracy.

[0014] A third aspect of the invention is an engine fuel property estimation apparatus that estimates ignition quality of fuel based on magnitude of engine torque produced by combustion of the fuel injected. Timing of fuel injection for estimating the ignition quality of the fuel is varied according to heat quantity of a cylinder wall surface. In this aspect, when the quantity of heat of the cylinder wall surface is a first quantity, the timing of fuel injection for estimating the ignition quality of the fuel may be set to be later than when the quantity of heat of the cylinder wall surface is a second quantity that is smaller than the first quantity.

[0015] As stated above, the delay time of ignition of fuel changes depending on the quantity of heat of the cylinder wall surface as well. Therefore, in the third aspect, since the timing of the fuel injection for estimating the ignition quality is varied according to the quantity of heat of the cylinder wall surface, it becomes possible to adjust the timing of the fuel injection for estimation of the ignition quality so as to reduce the influence that the change in the ignition delay time, which depends on the quantity of heat of the cylinder wall surface, has on the results of the estimation of the ignition quality. Concretely, it is possible to reduce the change in engine torque caused by differences in the quantity of heat of the cylinder wall surface and therefore reduce the deterioration of the accuracy of estimation of the ignition quality by retarding the timing of the fuel injection for the estimation further as the quantity of heat of the cylinder wall surface is larger. Therefore, according to the third aspect, the ignition quality of fuel can be estimated with improved accuracy. In this aspect, the quantity of heat of the cylinder wall surface may be estimated from state of load of the engine occurring before the estimation of the ignition quality is performed.

[0016] A fourth aspect of the invention is an engine fuel property estimation apparatus that estimates ignition quality of fuel based on magnitude of engine torque produced by combustion of the fuel injected. Timing of fuel injection for estimating the ignition quality of the fuel is varied according to intake air pressure. In this aspect, when the intake air pressure is a first pressure, the timing of fuel injection for estimating the ignition quality of the fuel may be set to be earlier than when the intake air pressure is a second pressure that is higher than the first pressure.

[0017] The delay time of ignition of fuel changes depending on a maximum value of the pressure in a cylinder (peak in-cylinder pressure) of the engine during the compression stroke of the cylinder as well. Concretely, the lower the peak in-cylinder pressure, the longer the delay of ignition of fuel. For example, as the intake air pressure is lower, the peak in-cylinder pressure is lower and therefore the ignition delay is longer. Therefore, by allowing the ignition quality estimation-purpose injection timing to be varied according to the intake air pressure and advancing the ignition quality estimation-purpose injection timing further the lower the intake air pressure, it is possible to restrain the influence that the change in the ignition delay time, which depends on the peak in-cylinder pressure, has on the results of the estimation of the ignition quality and therefore estimate the ignition quality of fuel with improved accuracy.

[0018] A fifth aspect of the invention is an engine fuel property estimation apparatus that estimates ignition quality of fuel based on magnitude of engine torque produced by combustion of the fuel injected. Timing of fuel injection for estimating the ignition quality of the fuel is varied according to intake air temperature. In this aspect, when the intake air temperature is a first temperature, the timing of fuel injection for estimating the ignition quality of the fuel may be set to be earlier than when the intake air temperature is a second temperature that is higher than the first temperature.

[0019] The delay time of ignition of fuel changes depending on a maximum value of the temperature of the gas in a cylinder (peak in-cylinder temperature) of the engine during the compression stroke of the cylinder as well. Concretely, the lower the peak in-cylinder temperature, the longer the delay of ignition of fuel. For example, as the temperature of the gas taken into a cylinder (in-cylinder intake gas temperature) is lower, the peak in-cylinder temperature is lower and, therefore, the ignition delay is longer. Then, the in-cylinder intake gas temperature is lower as the intake air temperature is lower. Therefore, by allowing the ignition quality estimation-purpose injection timing to be varied according to the intake air temperature and advancing the ignition quality estimation-purpose injection timing further the lower the intake air temperature, it is possible to restrain the influence that the change in the ignition delay time, which depends on the in-cylinder intake gas temperature, has on the results of the estimation of the ignition quality and therefore estimate the ignition quality of fuel with improved accuracy.

[0020] A sixth aspect of the invention is an engine fuel property estimation apparatus that estimates ignition quality of fuel based on magnitude of engine torque produced by combustion of the fuel injected. Timing of fuel injection for estimating the ignition quality of the fuel is varied according to engine coolant temperature. In this aspect, when the coolant temperature is a first temperature, the timing of fuel injection for estimating the ignition quality of the fuel may be set to be earlier than when the coolant temperature is a second temperature that is higher than the first temperature.

[0021] As stated above, the delay time of ignition of fuel changes depending on the quantity of heat of the cylinder wall surface as well. The temperature of the cylinder wall surface can be estimated from the coolant temperature. If the temperature of the cylinder wall surface is lower, the cylinder wall surface heat quantity is smaller. Therefore, by allowing the ignition quality estimation-purpose injection timing to be varied according to the engine coolant temperature and advancing the ignition quality estimation-purpose injection timing further the lower the intake air temperature, it is possible to restrain the influence that the change in the ignition delay time, which depends on the cylinder wall surface heat quantity, has on the results of the estimation of the ignition quality and therefore estimate the ignition quality of fuel with improved accuracy.

[0022] Furthermore, in the foregoing aspects, estimation of the ignition quality may be performed during fuel cut of the engine. The estimation of the ignition quality of fuel as described above can be suitably performed by performing the estimation during the fuel cut of the engine during which it is easy to check the engine torque.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a general diagram schematically showing an overall construction of an engine control apparatus in accordance with an embodiment of the invention;

FIG. 2 is a sectional view showing a structure of a side portion of an injector provided in a diesel engine to which the embodiment is applied;

FIG. 3 is a graph showing an example of a time waveform of a fuel injection rate;

FIG. 4 is a flowchart of a cetane number estimation routine that is employed in the embodiment;

FIG. 5 is a time chart showing transition of the engine rotation speed and transition of the rotation speed difference before and after execution of the fuel injection for detection of the cetane number;

FIG. 6A is a diagram showing transition of the in-cylinder pressure;

FIG. 6B is a diagram showing an example of a manner of combustion;

FIG. 6C is a diagram showing an example of a manner of combustion when the ignition delay is short; and

FIG. 6D is a diagram showing an example of a manner of combustion when the fuel injection timing is delayed according to reduction of the ignition delay.

DETAILED DESCRIPTION OF EMBODIMENTS

[0024] Hereinafter, an embodiment in which an engine fuel property estimation apparatus in accordance with the invention is embodied will be described in detail with reference to FIGS. 1 to 6. The estimation apparatus of this embodiment is applied to a diesel engine that is to be mounted in a vehicle.

[0025] As shown in FIG. 1, a fuel tank 10 of a diesel engine to which the estimation apparatus of this embodiment is applied is provided with a fuel gauge 11 that measures the amount of fuel remaining in the fuel tank 10. Furthermore, a fuel supply passageway 12 through which fuel to be supplied to the engine passes is connected to the fuel tank 10. An intermediate portion of the fuel supply passageway 12 is provided with a high-pressure fuel pump 13 that pumps up fuel from the fuel tank 10, pressurizes it and discharges pressurized fuel. A downstream end of the fuel supply passageway 12 is connected to a common rail 14 that holds pressurized fuel.

[0026] Injectors 16 for the cylinders of the diesel engine are connected to the common rail 14. Each injector 16 is provided with a fuel pressure sensor 17 that detects fuel pressure in the injector 16. Furthermore, the injectors 16 are connected to a return passageway 18 for returning surplus amounts of fuel to the fuel tank 10.

[0027] This diesel engine is equipped with an EGR (exhaust gas recirculation) system. The EGR system recirculates a part of the exhaust gas into intake air and thus reduces the oxygen concentration in the gas taken into the cylinders, so that the combustion temperature lowers and therefore production of NOx is restrained. The amount of exhaust gas recirculated by the EGR system is adjusted by an EGR valve 26 that is disposed in an EGR passageway that connects an exhaust passageway and an intake passageway of the diesel engine.

[0028] The thus-constructed diesel engine is controlled by an electronic control unit 19. The electronic control unit 19 includes a microcomputer that performs various computation processes related to the engine control. Furthermore, the electronic control unit 19 is provided with an input circuit that accepts input of signals from various sensors that detect situations of operation of the diesel engine. The fuel gauge 11 and the fuel pressure sensors 17 are connected to the input circuit. The other sensors connected to the input circuit include an intake pressure sensor 20, a rotation speed sensor 21, a coolant temperature sensor 22 and an intake temperature sensor 25 that detect the intake pressure, the rotation speed, the coolant temperature and the intake air temperature, respectively, of the diesel engine as well as a vehicle speed sensor 24 that detects the vehicle speed, an accelerator pedal sensor 23 that detects the amount of depression of an accelerator pedal, etc.

[0029] Furthermore, the electronic control unit 19 is provided with drive circuits for actuators that drive various portions of the diesel engine. These drive circuits include circuits that drive the injectors 16 of the cylinders, and a circuit that drives the EGR valve 26. The electronic control unit 19 performs an EGR control based on adjustment of the degree of opening of the EGR valve 26 as a part of the engine control. Then, at the time of the EGR control, the electronic control unit 19 finds the amount of recirculated exhaust gas contained in the gas within the cylinders (EGR amount) from the opening degree of the EGR valve 26 (EGR opening degree), the engine rotation speed, etc.

[0030] With reference to FIG. 2, further details of the construction of each of the injectors 16 provided for the individual cylinders of the diesel engine will be described. This diesel engine employs electrically-driven type injectors as the injectors 16.

[0031] As shown in FIG. 2, each injector 16 has a housing 30 that has a hollow cylindrical shape. Within the housing 30 there is disposed a needle valve 31 for reciprocating movements in the up-down directions in FIG. 2. Furthermore, a spring 32 that always urges the needle valve 31 downward in FIG. 2 is disposed within a portion of the housing 30 which is upward relative to the needle valve 31 in FIG. 2.

[0032] Furthermore, within the housing 30 there are formed two fuel chambers that are separated from each other by the needle valve 31, more specifically, a nozzle chamber 33 located relatively downward in FIG. 2 with respect to the needle valve 31 and a pressure chamber 34 located relatively upward in FIG. 2 with respect to the needle valve 31.

[0033] The nozzle chamber 33 is provided with injection holes 35 that provide communication between the inside of the the nozzle chamber 33 and the outside of the housing 30. The nozzle chamber 33 is connected with an introduction passageway 36 that is formed within the housing 30. The introduction passageway 36 is connected to the common rail 14 (FIG. 1) so that fuel is supplied into the nozzle chamber 33 through the introduction passageway 36.

[0034] On another hand, the pressure chamber 34 is connected to the nozzle chamber 33 through a communication passageway 37, and to the aforementioned return passageway 18 through a discharge passageway 38. Furthermore, within the pressure chamber 34 there is provided a valve body 40 that is driven by a pressure-electric actuator 39 that is formed by laminating pressure-electric elements, for example, piezoelectric elements. Thus, a construction is provided such that the pressure chamber 34 is selectively caused to communicate with one of the communication passageway 37 and the discharge passageway 38 by driving the valve body 40.

[0035] A fuel pressure sensor 17 as described above is provided integrally with an upper portion of the injector 16 in FIG. 2. The fuel pressure sensor 17 is constructed so as to detect the pressure of fuel within the introduction passageway 36.

[0036] Each of the thus-constructed injectors 16 operates as follows. The pressure-electric actuator 39, when not energized with drive voltage, assumes a contracted state in which the entire length of the pressure-electric actuator 39 is reduced, so as to position the valve body 40 at such a position that the pressure chamber 34 communicates with the communication passageway 37 and is shut off from the discharge passageway 38. At this time, the nozzle chamber 33 and the pressure chamber 34 communicate with each other, so that the pressures in the two chambers are substantially equal. Therefore, at this time, the needle valve 31 has been disposed downward in FIG. 2 by the spring force of the spring 32 so that the injection holes 35 are closed. Hence, at this time, fuel is not injected from the injector 16.

[0037] On another hand, when the pressure-electric actuator 39 is energized with drive voltage, the entire length thereof increases so as to position the valve body 40 at such a position that the pressure chamber 34 is shut off from the communication passageway 37 and communicates with the discharge passageway 38. At this time, fuel is discharged from the pressure chamber 34 and the pressure in the pressure chamber 34 declines, so that the pressure in the nozzle chamber 33 is greater than the pressure in the pressure chamber 34. Due to the pressure difference, at this time, the needle valve 31 is displaced upward in FIG. 2, that is, so as to move away from the position at which the needle valve 31 closes the injection holes 35. Therefore, at this time, the injector 16 injects fuel.

[0038] In the embodiment constructed as described above, the electronic control unit 19 performs a fuel injection control of the diesel engine. Concretely, the electronic control unit 19 calculates a target value of the fuel injection amount (target fuel injection amount) from the engine rotation speed, the amount of depression of the accelerator pedal and an estimated value of the cetane number (control cetane number) of the fuel in use. Furthermore, the electronic control unit 19 calculates target values of the fuel injection timing and of the fuel injection duration from the target fuel injection amount and the engine rotation speed. Then, according to these calculated target values, the electronic control unit 19 applies the drive voltage to the pressure-electric actuator 39 of each injector 16 so as to control the fuel injection.

[0039] Furthermore, in this embodiment, in conjunction with the above-described fuel injection control, the electronic control unit 19 implements a control of forming a time waveform of the fuel injection rate of each injector 16 (the amount of fuel injected per unit time) on the basis of the fuel pressure detected by the fuel pressure sensors 17 provided for the individual injectors 16. This control is performed in the following manner.

[0040] After the needle valve 31 of an injector 16 starts to lift from the injection holes 35 according to the drive voltage applied to the pressure-electric actuator 39, the fuel pressure in the nozzle chamber 33 decreases with the increasing lift of the needle valve 31. Then, the application of the drive voltage stops and the lift of the needle valve 31 decreases. With the decreasing lift of the valve, the fuel pressure in the nozzle chamber 33 gradually rises. Therefore, from the fuel pressure detected by the fuel pressure sensor 17 of the injector 16, it is possible to specifically determine the timing at which the needle valve 31 starts to lift (valve opening-drive start timing Tos), the timing at which the fuel injection rate becomes maximum (maximum injection rate attainment timing Toe), the timing at which the fuel injection rate starts to decrease (fuel injection rate decrease start timing Tcs) and the timing at which the lift of the needle valve 31 ends (minimum lift attainment timing Tce). Then, from these determined timings, a time waveform of the fuel injection rate as shown in FIG. 3 can be found. From that waveform, it is possible to check the actual situation of fuel injection, that is, the actual fuel injection amount, the actual fuel injection timing, etc., with very high accuracy. In this embodiment, the electronic control unit 19 finds the rate of change of the fuel pressure (the time derivative of the fuel pressure) within each injector 16, and finds the aforementioned timings on the basis of the value of the rate of change.

[0041] In this embodiment, the electronic control unit 19 estimates the cetane number of the fuel that is presently used, which is an index value of the ignition quality of the fuel. The estimation of the cetane number is performed through processing a cetane number estimation routine shown in FIG. 4. This routine is repeatedly executed at every predetermined control cycle time by the electronic control unit 19 during operation of the diesel engine.

[0042] When the processing of this routine starts, it is determined in step S100 whether a condition for execution of torque determination cetane number calculation has been satisfied. This execution condition is that all the conditions (i) to (iii) stated below are satisfied. (i) The deceleration-time fuel cut of the diesel engine to be implemented according to discontinuation of the accelerator operation (i.e., of the depression of the accelerator pedal) is being executed. (ii) The total amount of fuel injection following the previous refueling (refilling of the tank) is greater than or equal to a predetermined value α. The predetermined value α is set to a value that is greater than a total amount of fuel that can be charged into the fuel channels extending from the fuel tank 10 to the injectors 16. That is, satisfaction of the condition (ii) means that after the previous refueling, the fuel in the aforementioned fuel channels has been replaced by the new fuel supplied from the fuel tank 10. (iii) After the previous refueling, the estimated value of the cetane number of the fuel has not been determined.

[0043] If the aforementioned execution condition is not satisfied (NO), the present processing of the routine immediately ends. If the execution condition is satisfied (YES), the process proceeds to step S101. Then, when the process has proceeded to step S101, conditions regarding the rotation speed of the diesel engine are read in step S101, that is, the engine rotation speed NE, the coolant temperature THW, the intake air temperature THA and the intake air pressure PA are read in. Subsequently, in step S102, the in-cylinder state of the diesel engine is read in; specifically, the EGR opening degree VR, the vehicle speed SPD and the cylinder wall surface heat quantity Qc, are read in. The cylinder wall surface heat quantity Qc read in at this time has been found through estimation from the state of engine load preceding the time.

[0044] Then, in step S103, the timing of fuel injection for estimating the cetane number of fuel (cetane number estimation-purpose injection timing) is set on the basis of the read condition regarding rotation speed and the read in-cylinder state. Concretely, the cetane number estimation-purpose injection timing is set to be earlier as the engine rotation speed NE is higher, or as the coolant temperature THW is lower, or as the intake air pressure PA is lower. Furthermore, the cetane number estimation-purpose injection timing is set to be earlier as the EGR opening degree VR is smaller, or as the vehicle speed SPD is lower, or as the cylinder wall surface heat quantity Qc is smaller.

[0045] Subsequently, in step S104, a single injection of a predetermined amount of fuel is implemented as a cetane number estimation-purpose fuel injection at the fuel injection timing that is set as described above. Then, in step S105, the magnitude of engine torque produced by combustion of the injected fuel (produced torque) is found.

[0046] The calculation of the produced torque in step S105 is performed in the following manner. That is, the electronic control unit 19 acquires the engine rotation speed at every predetermined cycle time, and finds a difference between the acquired engine rotation speed and the engine rotation speed acquired the previous cycle time before (rotation speed difference ΔNE).

[0047] An upper section of FIG. 5 shows transition of the engine rotation speed before and after execution of the fuel injection for detection of the cetane number, and a lower section of FIG. 5 shows transition of the rotation speed difference ΔNE at that time. As the engine torque is produced due to execution of the fuel injection for detection of the cetane number of the fuel, the engine rotation speed increases or the rate of decrease in the engine rotation speed decreases, so that the rotation speed difference ΔNE increases. The time integrated value of the increase in the rotation speed difference ΔNE (which corresponds to the area of a hatched portion in FIG. 5) is larger as the produced torque is larger. Therefore, in this embodiment, the time integrated value of the increase in the rotation speed difference ΔNE is calculated as an amount of change in rotation ΣΔNE, and the value of the amount is used as an index value of the produced torque.

[0048] Subsequently, in step S106, the actual fuel injection timing and the actual amount of fuel injection are found from the time waveform of the rate of fuel injection in the fuel injection performed in step S104, and errors of the actual values of the fuel injection timing and of the amount of fuel injection from their command values (the injection timing error and the injection amount error) are calculated. Then, on the basis of the injection timing error and the injection amount error, the amount of change in rotation ΣΔNE is corrected. This correction is performed to reduce the influence that the injection timing error and the injection amount error have on the result of estimation of the cetane number of the fuel by performing correction of an amount that corresponds to the amount of change in a produced torque that is caused by the injection timing error and the injection amount error. Concretely, as the injection timing error to the advanced side (the side to which the injection timing becomes further advanced) is larger, the produced torque is larger, so that the amount of change in rotation ΣΔNE is more greatly reduced for correction. Furthermore, as the injection amount error to the side of increased amount is larger, the produced torque is larger, so that the amount of change in rotation ΣΔNE is more greatly reduced for correction.

[0049] Subsequently, in step S107, an estimated cetane number of the fuel is calculated on the basis of the post-correction amount of change in rotation ΣΔNE and the engine rotation speed occurring at the time of execution of the fuel injection. The microcomputer of the electronic control unit 19 pre-stores empirically predetermined relations of the cetane number of fuel with the amount of change in rotation ΣΔNE and the engine rotation speed. The calculation in step S204 is performed on the basis of the pre-stored relations. After the estimated cetane number is calculated, the present processing of the routine ends.

[0050] Next, operation of the engine fuel property estimation apparatus of the embodiment having the foregoing construction will be described. In this embodiment, the cetane number of fuel is estimated on the basis of the torque produced after fuel injection. The principle of this estimation is as follows.

[0051] As shown in FIG. 6A, after the piston of a cylinder reaches the compression top dead center (TDC), the pressure in the cylinder decreases as the piston descends. Furthermore, as the pressure decreases, the temperature within the cylinder also decreases. Then, the state in the cylinder eventually reaches a combustion limit beyond which combustion cannot be established.

[0052] A certain delay (lag) time exists from injection of fuel to ignition thereof as shown in FIG. 6B. The delay time from injection of fuel to ignition thereof is shorter as the ignition quality of fuel is higher, that is, as the cetane number of fuel is higher.

[0053] As shown in FIG. 6C, if the ignition delay becomes shorter, the time from the ignition until the combustion limit is reached, that is, the combustion duration, becomes longer, so that the amount of fuel that does not burn out but is left unburned becomes smaller. Therefore, if the ignition delay is shorter, the amount of fuel that burns is larger and, therefore, the engine torque produced by combustion of fuel is larger. Therefore, the ignition quality (cetane number) of fuel can be estimated from the magnitude of the engine torque produced after fuel injection.

[0054] In the embodiment, the cetane number estimation-purpose injection timing is set on the basis of the conditions regarding the rotation speed of the diesel engine (the engine rotation speed NE, the coolant temperature THW, the intake air temperature THA and the intake air pressure PA) and the in-cylinder states (the EGR opening degree VR, the vehicle speed SPD and the cylinder wall surface heat quantity Qc). This setting of the fuel injection timing is performed for the following reason.

[0055] If the engine rotation speed NE is higher while the ignition timing remains the same, the combustion time from ignition until the combustion limit is reached is shorter and, therefore, the produced torque is smaller. Therefore, in the embodiment, by appropriately advancing the timing of fuel injection further as the engine rotation speed NE is higher, the time from injection until the combustion limit is reached is made constant regardless of the engine rotation speed NE.

[0056] The delay of ignition of fuel changes depending on factors other than the ignition quality (cetane number) of fuel as well. For example, a maximum value of the temperature of the gas in a cylinder (peak value of the in-cylinder gas temperature, peak in-cylinder temperature) of the engine during the compression stroke of the cylinder and a maximum value of the pressure in the cylinder (peak value of the in-cylinder pressure, peak in-cylinder pressure) during the compression stroke also affect the time of the delay of ignition of fuel. Concretely, the delay of ignition of fuel is longer as the peak in-cylinder temperature and/or the peak in-cylinder pressure is lower.

[0057] If the time of the delay of ignition of fuel changes due to a factor other than the ignition quality of fuel, the timing of ignition changes and therefore the combustion time and the produced torque change even though the ignition quality of fuel remains the same. As a result, the accuracy of the estimation of the ignition quality of fuel based on the production torque deteriorates.

[0058] Even in such a case, if the fuel injection timing is changed by an amount that corresponds to the change in the delay of ignition of fuel which is caused by the factor that is other than the ignition quality of fuel, the timing of ignition remains the same and the production torque remains unchanged despite the change in the ignition quality of fuel which is caused by the factor that is other than the ignition quality of fuel provided that the ignition quality of fuel remains the same.

[0059] For example, let it assumed that the shortening of the ignition delay as shown in FIG. 6C occurs due to a factor that is other than the ignition quality of fuel. In that case, too, if the fuel ignition timing is retarded by the amount of the shortening of the ignition delay as shown in FIG. 6D, the same ignition timing as shown in FIG. 6B can be obtained. Therefore, no change occurs in the combustion time and therefore in the produced torque. Thus, if the fuel injection timing is adjusted according to the change in the time of the ignition delay which is caused by a factor other than the ignition quality of fuel, the change in the produced torque due to the change in the ignition delay that is caused by the factor other than the ignition quality of fuel can be restrained, and the accuracy of estimation of the cetane number of fuel can be heightened.

[0060] Therefore, in the embodiment, the accuracy of estimation of the cetane number of fuel is heightened by finding the change in the ignition delay which is caused by a factor other than the ignition quality of fuel from the coolant temperature THW, the intake air temperature THA, the intake air pressure PA, the EGR opening degree VR, the vehicle speed SPD and the cylinder wall surface heat quantity Qc, and then variably setting the cetane number estimation-purpose injection timing according to the amount of the change in the ignition delay.

[0061] For example, with respect to the intake air pressure PA, the cetane number estimation-purpose injection timing is variably set in an embodiment described below. As the intake air pressure PA is lower, the peak in-cylinder pressure is lower and the ignition delay is longer. Therefore, in this embodiment, as the intake air pressure PA is lower, the cetane number estimation-purpose injection timing is advanced further.

[0062] On another hand, as the temperature of the gas taken into a cylinder (in-cylinder intake gas temperature) is lower, the peak in-cylinder temperature is lower and the ignition delay is longer. The in-cylinder intake gas temperature is lower as the intake air temperature THA is lower. Therefore, in the embodiment, the cetane number estimation-purpose injection timing is advanced further as the intake air temperature THA is lower.

[0063] In the engine that employs the EGR system, the in-cylinder intake gas temperature changes depending on the EGR amount as well. That is, as the amount of high-temperature exhaust gas mixed with intake air is larger, the in-cylinder intake gas temperature is higher and, therefore, the ignition delay is shorter. Therefore, in this embodiment, as the EGR opening degree VR is larger and therefore the EGR amount is larger, the estimation-purpose injection timing is further retarded.

[0064] Furthermore, the peak in-cylinder temperature changes depending on the quantity of heat of the cylinder wall surface as well. That is, if the quantity of heat of the cylinder wall surface is large, an increased amount of heat is transferred to the gas in the cylinder, and the temperature of the in-cylinder gas heightens. Therefore, in order to keep the ignition timing constant regardless of the quantity of heat of the cylinder wall surface, it is necessary to retard the cetane number estimation-purpose injection timing further as the cylinder wall surface heat quantity is larger. Therefore, in the embodiment, the cetane number estimation-purpose injection timing is retarded further, the larger the cylinder wall surface heat quantity Qc estimated from the state of load of the engine.

[0065] Furthermore, when the vehicle speed SPD is high, the engine is highly likely to have previously been operated under high load. Then, during a high-load operation of the engine during which a large amount of fuel is injected, the quantity of heat that the cylinder wall surface receives is large. Therefore, when the vehicle speed is high, the quantity of heat of the cylinder wall surface is estimated to be large. Therefore, in this embodiment, as the vehicle speed SPD is higher, the cetane number estimation-purpose injection timing is further retarded.

[0066] Furthermore, the temperature of the cylinder wall surface can be estimated from the coolant temperature THW. Then, if the temperature of the cylinder wall surface is relatively low, the cylinder wall surface heat quantity is relatively small. Therefore, in this embodiment, as the coolant temperature THW is lower, the cetane number estimation-purpose injection timing is further advanced.

[0067] According to the engine fuel property estimation apparatus of the above-described embodiment, the following effects can be achieved. (1) In the embodiment, the cetane number estimation-purpose injection timing is varied according to the EGR amount (the EGR opening degree VR). Therefore, it is possible to restrain the influence that the change in the ignition delay time, which depends on the EGR amount, has on the results of estimation of the ignition quality of fuel and to estimate the ignition quality of fuel with improved accuracy.

[0068] (2) In the embodiment, the cetane number estimation-purpose injection timing is varied according to the vehicle speed SPD. From the vehicle speed SPD, the cylinder wall surface heat quantity can be estimated. Therefore, it is possible to restrain the influence that the change in the ignition delay time, which depends on the cylinder wall surface heat quantity, has on the results of estimation of the ignition quality of fuel and to estimate the ignition quality of fuel with improved accuracy.

[0069] (3) In the embodiment, the cetane number estimation-purpose injection timing is varied according to the cylinder wall surface heat quantity Qc that is estimated from the state of load of the engine occurring prior to the estimation of the cetane number. Therefore, it is possible to restrain the influence that the change in the ignition delay time, which depends on the quantity of heat of the cylinder wall surface, has on the results of estimation of the ignition quality of fuel and to estimate the ignition quality of fuel with improved accuracy.

[0070] (4) In the embodiment, the cetane number estimation-purpose injection timing is varied according to coolant temperature THW. From the coolant temperature THW, it is possible to estimate the temperature of the cylinder wall surface and therefore the quantity of heat of the cylinder wall surface. Therefore, it is possible to restrain the influence that the change in the ignition delay time, which depends on the cylinder wall surface heat quantity, has on the results of estimation of the ignition quality of fuel and to estimate the ignition quality of fuel with improved accuracy.

[0071] (5) In the embodiment, the cetane number estimation-purpose injection timing is varied according to the intake air temperature THA. Therefore, it is possible to restrain the influence that the change in the ignition delay time, which depends on the in-cylinder intake gas temperature, has on the results of estimation of the ignition quality of fuel and to estimate the ignition quality of fuel with improved accuracy.

[0072] (6) In the embodiment, the cetane number estimation-purpose injection timing is varied according to the intake air pressure PA. Therefore, it is possible to restrain the influence that the change in the ignition delay time, which depends on the peak in-cylinder pressure, has on the results of estimation of the ignition quality of fuel and to estimate the ignition quality of fuel with improved accuracy.

[0073] (7) In the embodiment, the cetane number estimation-purpose injection timing is varied according to the engine rotation speed NE. Therefore, it is possible to restrain the influence that the change in the ignition delay time, which depends on the engine rotation speed NE, has on the results of estimation of the ignition quality of fuel and to estimate the ignition quality of fuel with improved accuracy.

[0074] (8) In the embodiment, errors between the command values of the fuel injection timing and the amount of fuel injection and the actual values thereof (an injection timing error and an injection amount error) are found from changes in the fuel pressure in the injectors 16 detected by the fuel pressure sensors 17 that are provided for the injectors 16. Then, using the errors, the amount of change in rotation ΣΔNE, which is an index value of the produced torque of the engine, is corrected and therefore the result of estimation of the cetane number of fuel is corrected. Therefore, it is possible to suitably restrain the deterioration of the accuracy of estimation of the ignition quality of fuel which is caused by the errors in the amount of fuel injection and the fuel injection timing.

[0075] The foregoing embodiment can also be carried out with the following modifications. In the embodiment, errors between the command values of the fuel injection timing and the amount of fuel injection and the actual values thereof (the injection timing error and the injection amount error) are found from changes in the fuel pressure in the injectors 16 detected by the fuel pressure sensors 17. Then, using the errors, the amount of change in rotation ΣΔNE, which is an index value of the produced torque of the engine, is corrected. Instead of the amount of change in rotation ΣΔNE, an estimated cetane number can also be corrected directly by the injection timing error and the injection amount error. In such a case, too, it is possible to suitably restrain the deterioration of the accuracy of estimation of the ignition quality of fuel which is caused by the errors in the amount of fuel injection and the fuel injection timing.

[0076] Although the foregoing embodiment uses the amount of change in rotation ΣΔNE as an index value of the produced torque of the engine, the produced torque may also be found from other parameters, such as the amount of increase in the in-cylinder pressure associated with combustion.

[0077] Although in the embodiment, the cetane number of fuel is estimated during fuel cut of the diesel engine, estimation of the cetane number may also be performed in a situation other than the fuel cut provided that the situation allows accurate estimation of the torque produced after fuel injection.

[0078] In the case where the engine rotation speed NE at the time of estimation of the cetane number is substantially constant, estimation of the cetane number can be accurately performed without a need to variably set the estimation-purpose injection timing according to the engine rotation speed NE.

[0079] In the case where the coolant temperature THW at the time of estimation of the cetane number of fuel is substantially constant or the case where the influence of the coolant temperature THW on the ignition delay time is sufficiently ignorably small, estimation of the cetane number can be accurately performed without a need to variably set the cetane number estimation-purpose injection timing according to the coolant temperature THW.

[0080] In the case where the intake air temperature THA at the time of estimation of the cetane number of fuel is substantially constant or the case where the influence of the intake air temperature THA on the ignition delay time is sufficiently ignorably small, estimation of the cetane number can be accurately performed without a need to variably set the cetane number estimation-purpose injection timing according to the intake air temperature THA.

[0081] In the case where the intake air pressure PA at the time of estimation of the cetane number of fuel is substantially constant or the case where the influence of the intake air pressure PA on the ignition delay time is sufficiently ignorably small, estimation of the cetane number can be accurately performed without a need to variably set the cetane number estimation-purpose injection timing according to the intake air pressure PA.

[0082] In the foregoing embodiment, the cetane number estimation-purpose injection timing is variably set according to the EGR amount (the EGR opening degree VR), the vehicle speed SPD and the cylinder wall surface heat quantity Qc. In the case where the influence of any one or two of the three parameters on the ignition delay can be ignored, it is permissible to omit the variable setting of the cetane number estimation-purpose injection timing based on the parameter or parameters whose influence can be ignored. Concretely, the following constructions (I) to (VI) are conceivable. (I) A construction in which the variable setting of the cetane number estimation-purpose injection timing based on the EGR amount (the EGR opening degree VR) is omitted and the estimation-purpose injection timing is varied according to the vehicle speed SPD and the cylinder wall surface heat quantity Qc. (II) A construction in which the variable setting of the cetane number estimation-purpose injection timing based on the vehicle speed SPD is omitted and the estimation-purpose injection timing is varied according to the EGR amount (the EGR opening degree VR) and the cylinder wall surface heat quantity Qc. (III) A construction in which the variable setting of the cetane number estimation-purpose injection timing based on the cylinder wall surface heat quantity Qc is omitted and the estimation-purpose injection timing is varied according to the EGR amount (the EGR opening degree VR) and the vehicle speed SPD. (IV) A construction in which the variable setting of the cetane number estimation-purpose injection timing based on the EGR amount (the EGR opening degree VR) and the vehicle speed SPD is omitted and the estimation-purpose injection timing is varied according to the cylinder wall surface heat quantity Qc. (V) A construction in which the variable setting of the cetane number estimation-purpose injection timing based on the EGR amount (the EGR opening degree VR) and the cylinder wall surface heat quantity Qc is omitted and the estimation-purpose injection timing is varied according to the vehicle speed SPD. (VI) A construction in which the variable setting of the cetane number estimation-purpose injection timing based on the vehicle speed SPD and the cylinder wall surface heat quantity Qc is omitted and the estimation-purpose injection timing is varied according to the EGR amount (the EGR opening degree VR).

[0083] In the diesel engine to which the foregoing embodiment is applied, the amount of fuel actually injected is found from changes in the fuel pressure within the injectors 16 detected by the fuel pressure sensors 17, and the found actual amount of injected fuel is fed back to the drive control of the injectors. The estimation of the cetane number of fuel (the ignition quality of fuel) in the foregoing embodiment can also be similarly applied to diesel engines that do not perform such feedback.

[0084] The estimation logic in the foregoing embodiment can also be applied to estimation of an index value of the ignition quality of fuel other than the cetane number, in the same manner or a manner comparable to the manner employed in the foregoing embodiment. For example, using as a dividing-line value a lower limit value of the cetane number above which no problem is caused by misfire, fuels are divided into high-cetane-number fuels whose cetane numbers are higher than the lower limit value and low-cetane-number fuels whose cetane numbers are lower than the lower limit value. In such a construction, substantially the same estimation logic as in the foregoing embodiment can be used in order to estimate which one of the two types of fuel the fuel presently in use is.

CLAIMS

1. An engine fuel property estimation apparatus that estimates ignition quality of fuel based on magnitude of engine torque produced by combustion of the fuel injected, characterized in that

timing of fuel injection for estimating the ignition quality of the fuel is varied according to exhaust gas recirculation amount.

2. The engine fuel property estimation apparatus according to claim 1, wherein

when the exhaust gas recirculation amount is a first amount, the timing of the fuel injection for estimating the ignition quality of the fuel is set to be later than when the exhaust gas recirculation amount is a second amount that is smaller than the first amount.

3. An engine fuel property estimation apparatus that estimates ignition quality of fuel based on magnitude of engine torque produced by combustion of the fuel injected, characterized in that

timing of fuel injection for estimating the ignition quality of the fuel is varied according to vehicle speed.

4. The engine fuel property estimation apparatus according to claim 3, wherein

when the vehicle speed is a first speed, the timing of the fuel injection for estimating the ignition quality of the fuel is set to be later than when the vehicle speed is a second speed that is lower than the first speed.

5. An engine fuel property estimation apparatus that estimates ignition quality of fuel based on magnitude of engine torque produced by combustion of the fuel injected, characterized in that

timing of fuel injection for estimating the ignition quality of the fuel is varied according to quantity of heat of a cylinder wall surface.

6. The engine fuel property estimation apparatus according to claim 5, wherein

when the quantity of heat of the cylinder wall surface is a first quantity, the timing of fuel injection for estimating the ignition quality of the fuel is set to be later than when the quantity of heat of the cylinder wall surface is a second quantity that is smaller than the first quantity.

7. The engine fuel property estimation apparatus according to claim 5 or 6, wherein

the quantity of heat of the cylinder wall surface is estimated from state of load of the engine prior to estimation of the ignition quality.

8. An engine fuel property estimation apparatus that estimates ignition quality of fuel based on magnitude of engine torque produced by combustion of the fuel injected, characterized in that

timing of fuel injection for estimating the ignition quality of the fuel is varied according to intake air pressure.

9. The engine fuel property estimation apparatus according to claim 8, wherein

when the intake air pressure is a first pressure, the timing of fuel injection for estimating the ignition quality of the fuel is set to be earlier than when the intake air pressure is a second pressure that is higher than the first pressure.

10. An engine fuel property estimation apparatus that estimates ignition quality of fuel based on magnitude of engine torque produced by combustion of the fuel injected, characterized in that

timing of fuel injection for estimating the ignition quality of the fuel is varied according to intake air temperature.

11. The engine fuel property estimation apparatus according to claim 8, wherein

when the intake air temperature is a first temperature, the timing of fuel injection for estimating the ignition quality of the fuel is set to be earlier than when the intake air temperature is a second temperature that is higher than the first temperature.

12. An engine fuel property estimation apparatus that estimates ignition quality of fuel based on magnitude of engine torque produced by combustion of the fuel injected, characterized in that

timing of fuel injection for estimating the ignition quality of the fuel is varied according to engine coolant temperature.

13. The engine fuel property estimation apparatus according to claim 12, wherein

when the coolant temperature is a first temperature, the timing of fuel injection for estimating the ignition quality of the fuel is set to be earlier than when the coolant temperature is a second temperature that is higher than the first temperature.

14. The engine fuel property estimation apparatus according to any one of claims 1 to 13, wherein

estimation of the ignition quality is performed during fuel cut of the engine.

FIG. 1

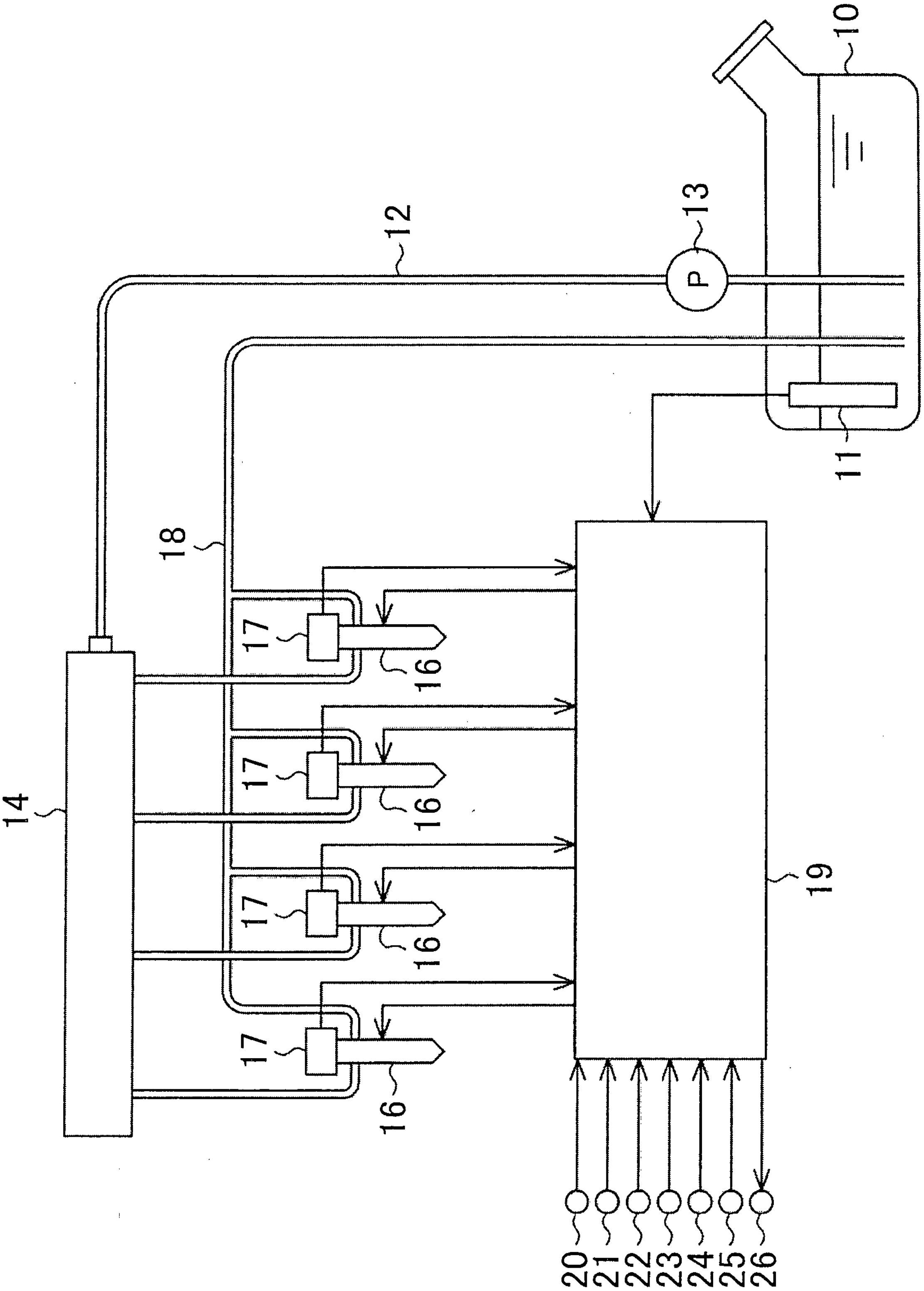
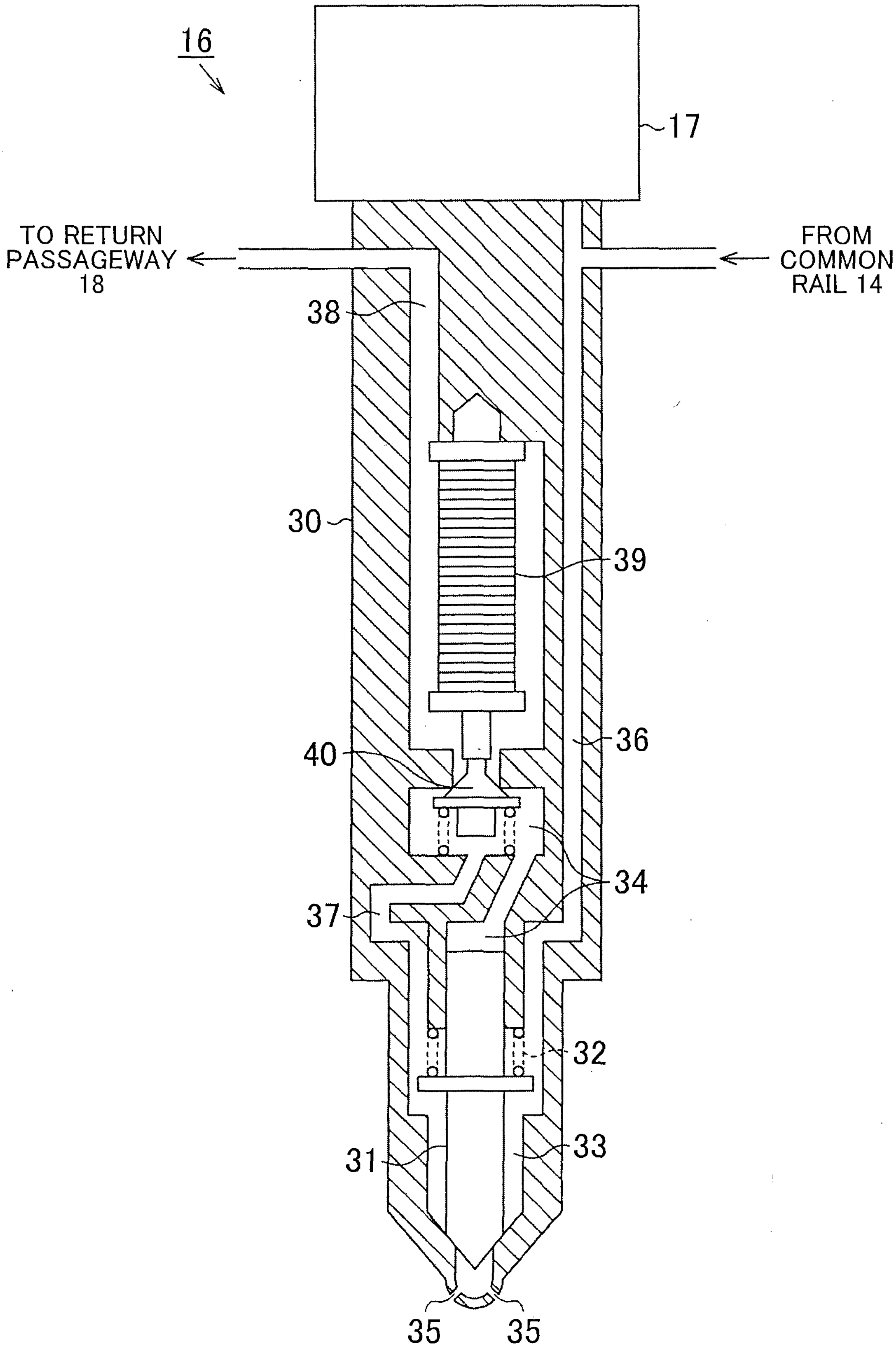


FIG.2


16
17
TO RETURN PASSAGEWAY 18
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33
35
35

F I G . 3

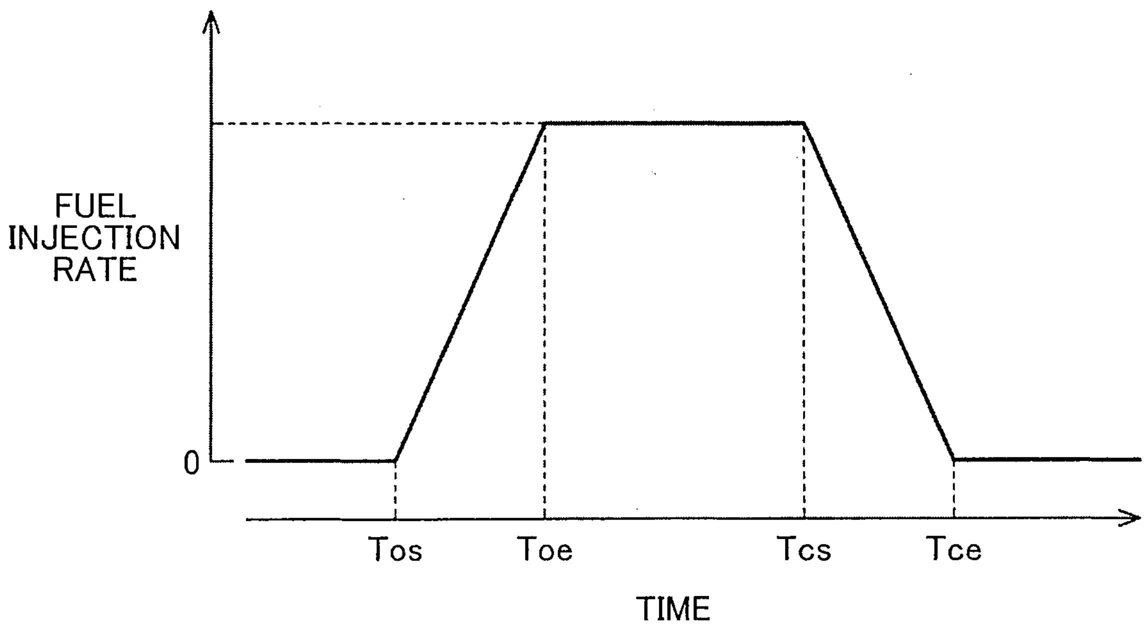
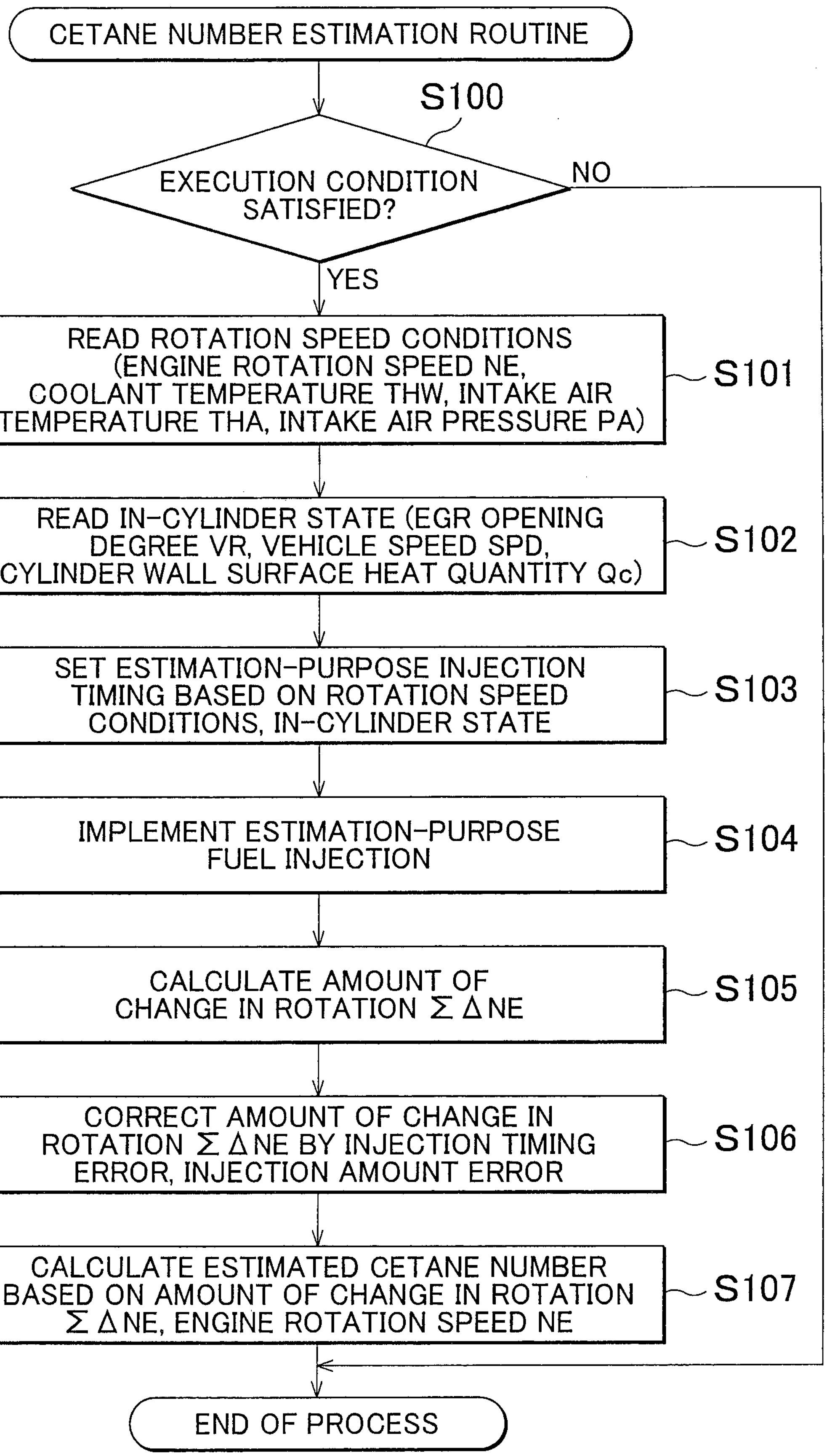
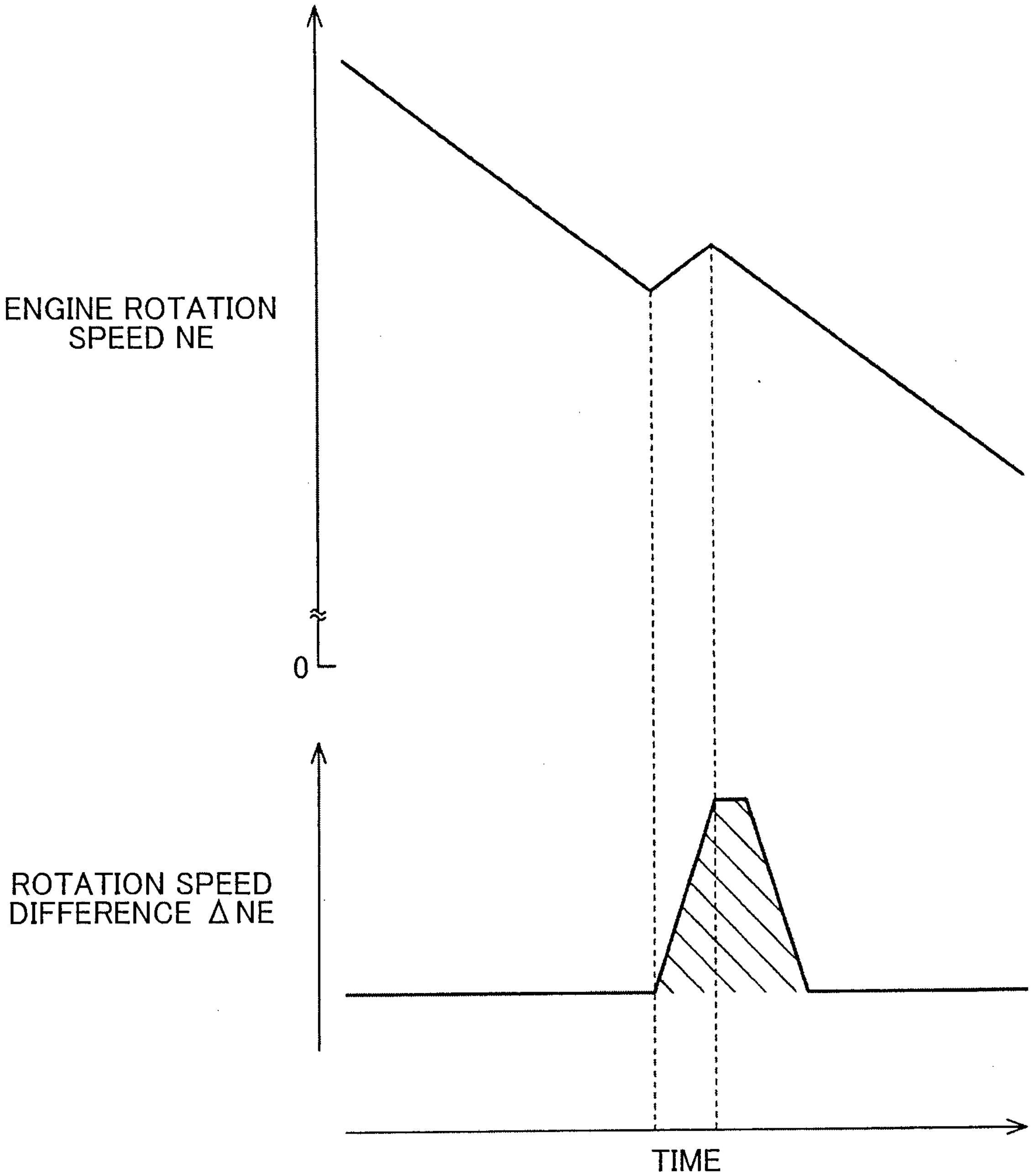


FIG. 4


CETANE NUMBER ESTIMATION ROUTINE
S100
EXECUTION CONDITION SATISFIED?
NO
YES
READ ROTATION SPEED CONDITIONS (ENGINE ROTATION SPEED NE, COOLANT TEMPERATURE THW, INTAKE AIR TEMPERATURE THA, INTAKE AIR PRESSURE PA)
S101
READ IN-CYLINDER STATE (EGR OPENING DEGREE VR, VEHICLE SPEED SPD, CYLINDER WALL SURFACE HEAT QUANTITY Qc)
S102
SET ESTIMATION-PURPOSE INJECTION TIMING BASED ON ROTATION SPEED CONDITIONS, IN-CYLINDER STATE
S103
IMPLEMENT ESTIMATION-PURPOSE FUEL INJECTION
S104
CALCULATE AMOUNT OF CHANGE IN ROTATION ΣΔNE
S105
CORRECT AMOUNT OF CHANGE IN ROTATION ΣΔNE BY INJECTION TIMING ERROR, INJECTION AMOUNT ERROR
S106
CALCULATE ESTIMATED CETANE NUMBER BASED ON AMOUNT OF CHANGE IN ROTATION ΣΔNE, ENGINE ROTATION SPEED NE
S107
END OF PROCESS

F I G . 5


ENGINE ROTATION SPEED NE
0
ROTATION SPEED DIFFERENCE ΔNE
TIME

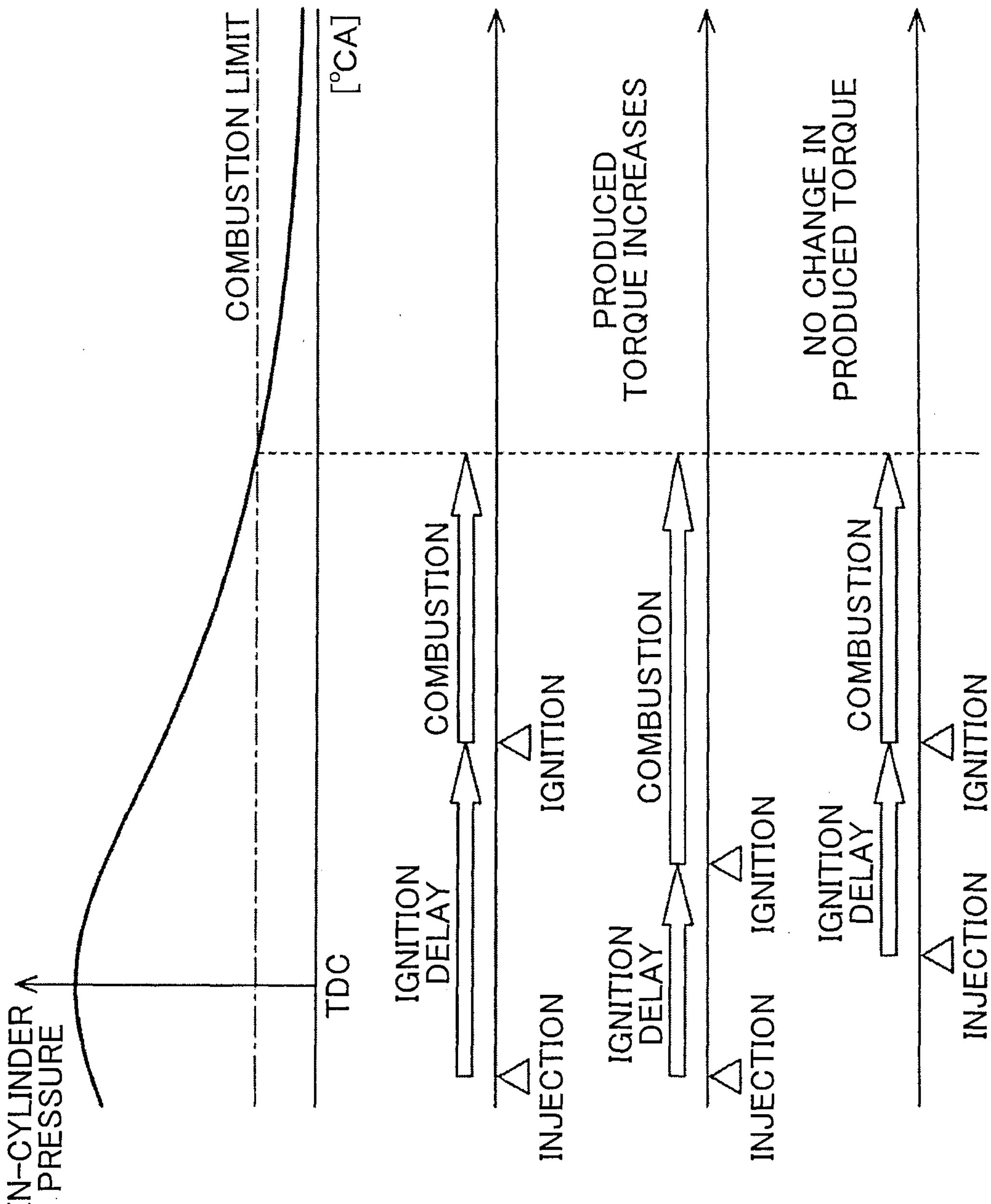


FIG. 6A

FIG. 6B

FIG. 6C

FIG. 6D

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/000357

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02D41/14 F02D41/34
ADD. F02D41/00 F02D19/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/088008 A1 (TANAKA KENSUKE [JP] ET AL) 8 April 2010 (2010-04-08) abstract; claim 1; figure 2 paragraph [0006] - paragraph [0022] paragraph [0044] - paragraph [0055] paragraph [0064] - paragraph [0069] -----	1-14
A	US 2009/198456 A1 (TSUTSUMI KOJI [JP] ET AL) 6 August 2009 (2009-08-06) paragraph [0040] paragraph [0054] - paragraph [0057] paragraph [0080] -----	1-14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 August 2013	26/08/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Van der Staay, Frank

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2013/000357

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010088008 A1	08-04-2010	JP 4596064 B2	08-12-2010
		JP 2010084746 A	15-04-2010
		US 2010088008 A1	08-04-2010
US 2009198456 A1	06-08-2009	JP 4600484 B2	15-12-2010
		JP 2009180174 A	13-08-2009
		US 2009198456 A1	06-08-2009