(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 045 452 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
**25.10.2017 Bulletin 2017/43**

(21) Application number: **07790595.8**

(22) Date of filing: **11.07.2007**

(51) Int Cl.:
***F01P 7/16*** *(2006.01)* ***F01P 7/04*** *(2006.01)*

(86) International application number:
**PCT/JP2007/063791**

(87) International publication number:
**WO 2008/007686 (17.01.2008 Gazette 2008/03)**

# (54) COOLING CONTROLLER OF INTERNAL COMBUSTION ENGINE

KÜHLUNGSSTEUERUNG FÜR VERBRENNUNGSMOTOR

COMMANDE DE REFROIDISSEMENT DE MOTEUR À COMBUSTION INTERNE

(84) Designated Contracting States:
**DE FR GB IT**

(30) Priority: **11.07.2006 JP 2006190205**

(43) Date of publication of application:
**08.04.2009 Bulletin 2009/15**

(73) Proprietor: **TOYOTA JIDOSHA KABUSHIKI KAISHA**
**Toyota-shi, Aichi-ken, 471-8571 (JP)**

(72) Inventor: **TAKAHASHI, Shigenori**
**Kariya-shi, Aichi 448-8661 (JP)**

(74) Representative: **D Young & Co LLP**
**120 Holborn**
**London EC1N 2DY (GB)**

(56) References cited:
**JP-A- 63 215 811**
**JP-A- 2000 265 879**
**JP-A- 2001 032 714**
**JP-A- 2001 173 488**
**JP-A- 2001 173 488**
**JP-A- 2001 173 488**
**JP-A- 2001 182 580**
**JP-A- 2003 083 127**
**US-B2- 6 986 331**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 2 045 452 B1

## Description

### TECHNICAL FIELD

**[0001]** The present invention relates to a cooling control apparatus of an internal combustion engine.

### BACKGROUND ART

**[0002]** Internal combustion engines mounted on vehicles such as automobiles are desired to complete startup within a short period of time. To respond to such a demand, a typical internal combustion engine first burns fuel in a cylinder in which the first compression stroke after the initiation of starting of the engine takes place or in a cylinder in which the second compression stroke after the initiation of starting of the engine takes place, so that the initial explosion after the initiation of starting of the engine takes place during the compression stroke.

**[0003]** In the internal combustion engine, due to the pressure in the combustion chambers of the cylinders, the cylinders are respectively stopped at initial stages of an intake stroke, a compression stroke, an expansion stroke, and an exhaust stroke. Therefore, at the completion of stopping of the engine, the cylinder in which the first compression stroke takes place after subsequent the initiation of starting of the engine is the cylinder that is stopped at the initial stage of the compression stroke, and the cylinder in which the second compression stroke takes place after subsequent the initiation of starting of the engine is the cylinder that is stopped at the initial stage of the intake stroke.

**[0004]** Since the cylinder in which the first compression stroke after starting of the engine takes place and the cylinder in which the second compression stroke after the initiation of starting of the engine takes place are respectively in the initial stage of the compression stroke and the initial stage of the intake stroke while the engine is stopped, gas that has remained in the combustion chambers while the engine has been stopped is compressed after the initiation of starting of the engine. If the engine is started without taking enough time for cooling after stopping of the engine is completed, the first compression stroke and the second compression stroke take place in a state where the temperature of gas in the combustion chambers are increased by the heat of the engine. Thus, during those compression strokes, the temperature of gas in the combustion chambers is high. This might cause self-ignition (pre-ignition) of the fuel in the combustion chambers. In particular, in the internal combustion engine that automatically stops and restarts combustion operation in accordance with, for example, the travelling state of a vehicle to improve the fuel efficiency, the engine is often restarted without taking enough time for cooling after stopping of the engine. Thus, there is more possibility for the above-mentioned pre-ignition to occur.

**[0005]** In any cylinder in which the third or later compression stroke after the initiation of starting of the engine takes place, cool air that is drawn into the combustion chamber from an intake passage is compressed during the compression stroke. Thus, during the compression stroke, the temperature of gas in the combustion chamber does not become excessively high, and the possibility for the pre-ignition to occur is low.

**[0006]** Also, it has been found that at the first compression stroke and the second compression stroke after the initiation of starting of the engine, the pressure in the combustion chambers are higher than that during the compression stroke when the engine is in the normal combustion operation. This is also the cause of pre-ignition. Hereinafter, reasons for the pressure in the combustion chambers to become high during the first compression stroke and the second compression stroke after the initiation of starting of the engine will be explained.

**[0007]** During normal combustion operation of the internal combustion engine before being stopped, that is, when the engine is idling, while the piston moves in a direction to expand the combustion chamber in the intake stroke and the intake valve is openad, the pressure in the combustion chamber takes a lower value (negative pressure) than the atmospheric pressure, and air is drawn in from the intake passage to the combustion chamber. After that, the intake valve is closed while the piston moves in the direction to expand the combustion chamber, and the piston shifts to the compression stroke. Thus, during the intake stroke and the initial stage of the compression stroke, the pressure in the combustion chamber takes a lower value (negative pressure) than the atmospheric pressure. Therefore, in the cylinder that is stopped at the initial stage of the compression stroke and the cylinder that is stopped at the initial stage of the intake stroke at the completion of stopping of the engine, the pressure in the combustion chamber takes a lower value than the atmospheric pressure.

**[0008]** However, after a certain period of time (for example, 1 or 2 seconds) has passed after stopping of the engine is completed, gas enters the combustion chambers from around valves and around the piston rings of the engine, and the pressure in the combustion chambers increases from the negative pressure to the atmospheric pressure. When starting of the engine is initiated in this state, and gas in the combustion chambers is started to be compressed in the cylinder that is at the initial stage of the compression stroke and in the cylinder that is at the initial stage of the intake stroke, since, at that time, the pressure in the combustion chambers has been increased to the atmospheric pressure, the pressure in the combustion chambers after starting compression is higher than that when the engine is in the normal combustion operation.

**[0009]** As described above, in the engine in which the initial explosion takes place at the first compression stroke or the second compression stroke after starting of the engine is initiated, pre-ignition might occur if the engine is started without taking enough time for cooling after

stopping of the engine is completed.

**[0010]** Patent Document 1 discloses a cooling apparatus that is driven by a driving source different from the internal combustion engine and cools the engine with coolant. If the coolant temperature that takes a value corresponding to the engine temperature is higher than a predetermined value at the completion of stopping of the engine, the cooling apparatus is driven until the coolant temperature becomes less than the predetermined value while the engine is stopped. In this case, since the engine temperature is reduced while the engine is stopped by setting the predetermined value to a low value, pre-ignition is suppressed at the subsequent initiation of starting of the engine. However, to reliably suppress the pre-ignition, the predetermined value needs to be set appropriately.

**[0011]** That is, in the cylinder in which the initial explosion takes place after the subsequent initiation of starting of the engine, the closer to the bottom dead center the piston position in the cylinder when stopping of the engine is completed, the higher the temperature of gas and the pressure in the combustion chamber during the compression stroke in which the initial explosion takes place become. Thus, pre-ignition easily occurs. This is because, as the piston position in the cylinder at the completion of stopping of the engine becomes closer to the bottom dead center, the amount of gas that is heated in the combustion chamber while the engine is stopped is increased, and the negative pressure in the combustion chamber at the completion of stopping of the engine increased. This increases the amount of increase of the pressure in the combustion chamber to the atmospheric pressure that takes place until starting of the engine is initiated. Therefore, on the assumption that the piston position in the cylinder at the completion of stopping of the engine is closest to the bottom dead center, the predetermined value is set so as to reduce the engine temperature while the engine is stopped to a value at which pre-ignition does not occur when starting of the engine is initiated. In this manner, the pre-ignition the initiation of starting of the engine is reliably avoided.

**[0012]** However, when the predetermined value is set as described above, if the piston position in the cylinder when stopping of the engine is completed is at a position closer to the top dead center than the position closest to the bottom dead center, the engine is cooled more than necessary in suppressing the occurrence of pre-ignition. This is because, when the piston position is at the position closer to the top dead center, the temperature of gas and the pressure in the combustion chamber is low during the compression stroke when the initial explosion takes place after the initiation of starting of the engine, compared to a case where the piston position is at the position closer to the bottom dead center. Thus the possibility for the pre-ignition to occur is reduced. If the engine is cooled more than necessary as described above, energy for driving the cooling apparatus is wasted, and the cooling apparatus is driven for a long time that is more than necessary while the engine is stopped, which causes a driver of the vehicle to feel uncomfortable.

Patent Document 1: Japanese Laid-Open Patent Publication No. 2001-182580. US 6 986 331 B2 is also aiming to avoid pre-ignition.

## DISCLOSURE OF THE INVENTION

**[0013]** Accordingly, it is an objective of the present invention to provide a cooling control apparatus of an internal combustion engine that, while suppressing pre-ignition at the initiation of starting of the engine, reliably suppresses the internal combustion engine from being cooled more than necessary while the engine is being stopped.

**[0014]** To achieve the above objective, and in accordance with a first aspect of the present invention, a cooling control apparatus is provided that is applied to an internal combustion engine that includes cylinders provided with pistons, and in which initial explosion takes place in one of a first compression stroke and a second compression stroke after the initiation of starting of the engine. The cooling control apparatus includes a cooling apparatus, a control section, and a setting section. The cooling apparatus is driven by a driving source different from the engine and cools the engine. The control section drives the cooling apparatus at and after the completion of stopping of the engine and when the engine temperature is greater than or equal to a predetermined value that might cause pre-ignition at starting of the engine. The setting section sets the predetermined value in accordance with the crank angle at the completion of stopping of the engine. When the crank angle at the completion of stopping of the engine is a crank angle at which the piston position of the cylinder in which the initial explosion takes place after the subsequent initiation of starting of the engine is closer to the top dead center, the setting section sets the predetermined value to a value higher than that in a case where the crank angle at the completion of stopping of the engine is a crank angle at which the piston position of the cylinder in which the initial explosion takes place after the subsequent initiation of starting of the engine is closer to the bottom dead center.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0015]**

Fig. 1 is a schematic view illustrating the entire configuration of an engine and a cooling apparatus according to a first embodiment of the present invention;

Fig. 2 is a time chart showing changes of strokes in a combustion cycle of the cylinders, changes of the coolant temperature, changes of the driving state of the electric water pump, and changes of the driving state of the electric cooling fan;

Figs. 3(a) and 3(b) are schematic views showing pis-

ton positions at the completion of stopping of the engine in the cylinder in which the compression stroke takes place for the first time after the subsequent initiation of starting of the engine;

Fig. 4 is a graph showing changes of a threshold value with respect to changes of the piston position at the completion of stopping of the engine;

Fig. 5 is a flowchart showing the procedure for executing cooling control of the engine by the cooling apparatus;

Fig. 6 is a graph showing changes of the flow rate of the electric water pump with respect to changes of the temperature difference between the coolant temperature and the threshold value;

Fig. 7 is a graph showing changes of the blowing amount of the electric cooling fan with respect to changes of the temperature difference between the coolant temperature and the threshold value;

Fig. 8 is a time chart showing changes of strokes in a combustion cycle of the cylinders, changes of the coolant temperature, changes of the driving state of the electric water pump, and changes of the driving state of the electric cooling fan according to a second embodiment of the present invention;

Figs. 9(a) and 9(b) are schematic views showing piston positions at the completion of stopping of the engine in the cylinder in which the compression stroke takes place for the second time after the subsequent initiation of starting of the engine;

Fig. 10 is a graph showing changes of the threshold value with respect to changes of the piston position at the completion of stopping of the engine;

Fig. 11 is a graph showing changes of the threshold value with respect to changes of the piston position at the completion of stopping of the engine; and

Fig. 12 is a graph showing changes of the threshold value with respect to changes of the piston position at the completion of stopping of the engine.

## BEST MODE FOR CARRYING OUT THE INVENTION

**[0016]** A first embodiment of the present invention will now be described with reference to Figs. 1 to 7.

**[0017]** An engine 1 shown in Fig. 1 is an in-line four-cylinder engine that is mounted on an automobile and is automatically stopped and restarted. In the engine 1, fuel is injected from fuel injection valves 2 to corresponding combustion chambers 3 during operation. By combustion of fuel in the combustion chambers 3, pistons 4 reciprocate, thereby rotating a crankshaft 5, which is an output shaft of the engine 1. The rotation of the crankshaft 5 is transmitted to a camshaft 6, for example, by a belt. The rotation of the camshaft 6 selectively opens and closes engine valves such as intake valves 7 and exhaust valves 8. During the operation of the engine 1, a combustion cycle including an intake stroke, a compression stroke, an expansion stroke, and an exhaust stroke is repeated. The intake stroke, compression stroke, expansion stroke, and exhaust stroke are performed in the order of a first cylinder, a third cylinder, a fourth cylinder, and a second cylinder (refer to Fig. 2). When starting self-sustaining operation (combustion operation) of the engine 1 that is being stopped, fuel is injected from the fuel injection valves 2 to the combustion chambers 3 in a state where the crankshaft 5 is forced to rotate (cranking) by driving a starter 15 coupled to the crankshaft 5.

**[0018]** Devices for acquiring the crank angle of the engine 1 will now be described.

**[0019]** A rotor 9 made of a magnetic body is secured to the crankshaft 5 of the engine 1, and protrusions 9a are formed on the periphery of the rotor 9 at equal intervals in the circumferential direction. Also, two crank position sensors 11, 12 are provided in the vicinity of the rotor 9. When the rotor 9 is rotated with the crankshaft 5, signals corresponding to the protrusions 9a are output from the crank position sensors 11, 12. As the crank position sensors 11, 12, devices are used that can output pulse signals corresponding to the protrusions 9a even when the rotation speed of the rotor 9 is extremely slow such as immediately before stopping of the engine 1 is completed. For example, magnetoresistive element (MRE) sensors are used. Also, the relative positions of the crank position sensor 11 and the crank position sensor 12 with respect to the circumferential direction of the rotor 9 are set such that the phases of the pulse signals output from the sensors 11, 12 are displaced from each other.

**[0020]** A rotor 13 made of a magnetic body is secured also to the camshaft 6, and protrusions 13a having different circumferential length from one another are formed on the periphery of the rotor 13 at different intervals in the circumferential direction. A cam position sensor 14 is provided in the vicinity of the rotor 13. When the rotor 13 is rotated with the camshaft 6, signals corresponding to the protrusions 13a of the rotor 13 are output from the cam position sensor 14. As the cam position sensor 14, a device is used that can output pulse signals corresponding to the protrusions 13a even when the rotation speed of the rotor 13 is extremely slow such as immediately before stopping of the engine 1 is completed. For example, a magnetoresistive element (MRE) sensor that is the same as the crank position sensors 11, 12 is used.

**[0021]** Based on the pulse signals from the crank position sensors 11, 12, and the pulse signal from the cam position sensor 14, the crank angle of the engine 1 is acquired. Since, as the sensors 11, 12, 14, the MRE sensors, which can output pulse signals corresponding to the protrusions 9a, 13a of the rotors 9, 13 even immediately before stopping of the engine 1, are used, the crank angle is reliably acquired even immediately before stopping of the engine 1 is completed. Therefore, based on the pulse signals from the crank position sensors 11, 12, and the pulse signal from the cam position sensor 14, the crank angle of the engine 1 at the completion of stopping of the engine 1 is acquired.

**[0022]** The cooling apparatus for cooling the engine 1

will now be described.

**[0023]** The cooling apparatus is provided with a circulation passage 16 for letting a coolant to flow to the engine 1. An electric water pump 17 and a radiator 18 are provided in the circulation passage 16, and an electric cooling fan 19 is provided in the vicinity of the radiator 18. The electric water pump 17 and the electric cooling fan 19 are driven by a motor through power supply from a battery 20 of the automobile, that is, by a driving source different from the engine 1.

**[0024]** When the electric water pump 17 is driven, the coolant in the circulation passage 16 starts to flow, and the coolant circulates in the circulation passage 16 passing through the radiator 18 and the engine 1. The coolant is cooled by heat exchange with the external air when passing through the radiator 18. Also, when the electric cooling fan 19 is driven and air is blown toward the radiator 18, heat exchange between the coolant and the external air at the radiator 18 is promoted. The coolant cooled by the radiator 18 draws heat by heat exchange with the engine 1 when passing through the engine 1, thereby cooling the engine 1.

**[0025]** The cooling efficiency of the engine 1 by the cooling apparatus is increased as the flow rate of the electric water pump 17 is increased to increase the amount of the coolant passing through the engine 1. The cooling efficiency is also increased as the amount of air blown by the electric cooling fan 19 is increased to increase the amount of heat exchange at the radiator 18 between the coolant and the external air.

**[0026]** The electrical configuration of a cooling control apparatus that controls the cooling apparatus will now be described.

**[0027]** The cooling control apparatus includes an electronic control unit (ECU) 21, which controls various types of on-board equipment such as the engine 1 in the automobile. The ECU 21, which functions as a control section and a setting section, includes a CPU, which executes various types of computation processes related to control of the various types of on-board equipment, a ROM, which stores programs and data required for the control, a RAM, which temporarily stores computation results of the CPU and the like, and input/output ports for outputting and receiving signals to and from external devices.

**[0028]** In addition to the signals from the crank position sensors 11, 12 and the cam position sensor 14, various types of sensors such as a gas pedal position sensor 22, which detects the gas pedal depression amount, a vehicle speed sensor 23, which detects the speed of the automobile, and a coolant temperature sensor 26, which detects the coolant temperature in the circulation passage 16, are connected to the input ports of the ECU 21. Furthermore, a brake switch 24, which detects whether the brake pedal is being depressed, and an ignition switch 25 are connected to the input ports of the ECU 21. The ignition switch 25 is switched by a driver of the automobile among four switching positions including "OFF", "ACCESSORY", "ON", and "STAR", and outputs a signal corresponding to the current switching position. Drive circuits for driving the fuel injection valve 2, the electric water pump 17, the electric cooling fan 19, and the starter 15 are connected to the output ports of the ECU 21.

**[0029]** The ECU 21 outputs command signals to the drive circuits of the devices connected to the output ports in accordance with the operating condition of the automobile and the engine 1 acquired by detection signals input from the sensors. In this manner, the ECU 21 performs various controls such as control of fuel injection from the fuel injection valves 2, drive control of the starter 15 at the starting of the engine, automatic stop and restart control of the engine 1, and drive control of the electric water pump 17 and the electric cooling fan 19.

**[0030]** The ECU 21 cools the engine 1, for example, as follows through drive control of the electric water pump 17 and the electric cooling fan 19. That is, during normal combustion operation of the engine 1, the coolant temperature in the circulation passage 16 detected by the coolant temperature sensor 26 is used as a value corresponding to the engine temperature, and the electric water pump 17 and the electric cooling fan 19 are controlled such that the coolant temperature becomes less than or equal to a target value (for example, 95°C). When the coolant temperature becomes less than or equal to the target value, the electric water pump 17 and the electric cooling fan 19 are stopped. Thus, the engine 1 is appropriately cooled during normal combustion operation of the engine 1, and the engine temperature is prevented from being excessively increased.

**[0031]** Starting and stopping of the engine 1 performed through drive control of the fuel injection valves 2 and the starter 15 by the ECU 21 will now be described.

**[0032]** Such starting and stopping of the engine 1 is performed based on manipulation of the ignition switch 25 by the driver. Also, besides this, for the purpose of improving the fuel efficiency of the engine 1, the engine 1 is automatically stopped and restarted in accordance with the output demand of the engine 1. Hereinafter, the procedure for starting and stopping the engine 1 will be described separately in [Starting and stopping based on manipulation of the ignition switch 25] and [Automatic stopping and restarting based on existence of engine output demand].

[Starting and stopping based on manipulation of the ignition switch 25]

**[0033]** While the engine 1 is stopped, when the ignition switch 25 is sequentially switched from "OFF" through "ACCESSORY" and "ON" to "STAR" by the driver, at the time when the switch 25 is turned to "START", a start command for the engine 1 is generated. Based on the start command, the starter 15 is driven and cranking of the engine 1 is started, and fuel is injected from the fuel injection valves 2 to the combustion chambers 3 during the cranking. Then, when fuel is burned in the combustion chambers 3 and the engine 1 performs self-sustaining

operation, starting of the engine 1 is completed. Also, during operation of the engine 1, when the ignition switch 25 is sequentially turned by the driver from "ON" through "ACCESSORY" to "OFF", at the time when the switch 25 is turned to "ACCESSORY", a stop command of the engine 1 is generated. Based on the stop command, combustion of fuel in the combustion chambers 3 is stopped, and stopping of the engine 1 is initiated. Thereafter, the engine rotation speed is reduced from the idling rotation speed to "0", and stopping of the engine 1 is completed.

[Automatic stop and restart based on the existence of engine output demand]

**[0034]** During operation of the engine 1, when there is no output demand of the engine 1, combustion of fuel in the combustion chambers 3 is stopped, and the engine 1 is automatically stopped. The existence of the output demand to the engine 1 is determined based on whether conditions such as (A) the gas pedal depression amount is "0", (B) the brake pedal is depressed, and (C) the vehicle speed is less than a predetermined value "a" that is close to "0" are all satisfied. When all the conditions (A) to (C) are satisfied, there is no output demand to the engine 1, in other words, it is determined that the engine 1 does not need to be operated. Thus, a stop command for the engine 1 is generated, and the engine 1 is automatically stopped. If the output demand to the engine 1 is generated after the engine 1 is automatically stopped, that is, if any one or more of the conditions (A) to (C) are no longer satisfied, a start command of the engine 1 is generated. Based on the start command, the starter 15 is driven, and cranking of the engine 1 is started. During the cranking, fuel is injected from the fuel injection valves 2 to the combustion chambers 3. Then, when fuel is burned in the combustion chambers 3 and the self-sustaining operation of the engine 1 is started, the engine 1 is automatically restarted.

**[0035]** In recent years, regardless of whether starting of the engine 1 is performed by manipulation of the ignition switch 25, or performed automatically in accordance with the output demand of the engine 1, it is desired that starting of the engine be completed at an early stage after the initiation of starting of the engine. To meet such demand, in the engine 1, fuel is burned in the cylinder in which the first compression stroke is performed after the initiation of starting of the engine, and the initial explosion after the initiation of starting of the engine is performed during the compression stroke. The fuel injection manner and the fuel combustion manner in the first to fourth cylinders of the engine 1 after stopping of the engine 1 is initiated until after the subsequent starting of the engine is initiated are shown in (a) in Fig. 2.

**[0036]** As apparent from the figure, fuel injection from the fuel injection valves 2 to the combustion chambers 3 is performed during the intake strokes, and fuel in the combustion chambers 3 is burned in the subsequent compression strokes, and then the cylinders proceed to the expansion strokes. In the example of (a) in Fig. 2, after fuel injection from the fuel injection valve 2 to the combustion chamber 3 is performed during the intake stroke of the first cylinder, stopping of the engine 1 is completed in a state where the first cylinder has proceeded to the compression stroke (time T1). Thereafter, when the start command of the engine 1 is generated (time T3), starting of the engine 1 is initiated. Then, in the first cylinder in which the compression stroke takes place for the first time after the initiation of starting of the engine, the fuel in the combustion chamber 3 is burned, and the initial explosion after the initiation of starting of the engine takes place. Thus, when the initial explosion takes place in the cylinder in which the compression stroke takes place for the first time after the initiation of starting of the engine 1, the engine 1 performs self-sustaining operation at the early stage after the initiation of starting of the engine 1. Hereinafter, the cylinder in which the compression stroke takes place for the first time after the initiation of starting of the engine 1 is referred to as a "initial explosion cylinder" when necessary.

**[0037]** In the first compression stroke after the initiation of starting of the engine 1, the temperature of gas in the combustion chamber 3 and the pressure in the combustion chamber 3 are higher than those in the normal combustion operation of the engine 1 for the reasons described in [BACKGROUND ART]. Therefore, in the cylinder in which the compression stroke takes place for the first time after the initiation of starting of the engine, self ignition (pre-ignition) of fuel in the combustion chamber 3 might occur.

**[0038]** Therefore, cooling of the engine 1 by the above-mentioned cooling apparatus is executed not only during the normal combustion operation, but also at and after the completion of stopping of the engine 1. More specifically, as shown in (b) in Fig. 2, at and after the completion of stopping of the engine 1 (time T1 and thereafter), and when the coolant temperature in the circulation passage 16 representing the temperature of the engine 1 is greater than or equal to a predetermined threshold value, the electric water pump 17 is driven as shown (c) in Fig. 2, and the electric cooling fan 19 is driven as shown in (d) in Fig. 2. Thus, the engine 1 is cooled, which suppresses the occurrence of pre-ignition during the first compression stroke after the subsequent initiation of starting of the engine. Thereafter, when the coolant temperature becomes less than the threshold value (time T2), the electric water pump 17 and the electric cooling fan 19 are stopped, and cooling of the engine 1 by the cooling apparatus is stopped.

**[0039]** As described in [BACKGROUND ART), the possibility of the occurrence of pre-ignition in the cylinder (initial explosion cylinder) in which the compression stroke takes place for the first time after the initiation of starting of the engine 1 is changed in accordance with the position of the piston 4 in the initial explosion cylinder at the completion of stopping of the engine 1 immediately before the starting of the initiation of the engine 1. That

is, when the position of the piston 4 in the initial explosion cylinder is at the bottom dead center as shown in Fig. 3(a), the temperature of gas in the combustion chamber 3 and the pressure in the combustion chamber 3 during the first compression stroke are the highest. The possibility of the occurrence of the pre-ignition thus becomes the highest. Also, when the position of the piston 4 in the initial explosion cylinder is at the position closer to the top dead center than the bottom dead center as shown in Fig. 3(b), the closer to the top dead center the piston, the lower the temperature of gas in the combustion chamber 3 and the pressure in the combustion chamber 3 during the first compression stroke become. Accordingly, the possibility of the occurrence of the pre-ignition is gradually reduced. Therefore, by setting the threshold value to a low value so as to avoid the pre-ignition on the assumption that the position of the piston 4 in the initial explosion cylinder is at the bottom dead center, the pre-ignition is reliably suppressed.

**[0040]** However, when the actual position of the piston 4 of the initial explosion cylinder is closer to the top dead center than the bottom dead center, the threshold value is too low for suppressing the pre-ignition reliably. Thus, at and after the completion of stopping of the engine 1, the engine 1 is cooled by driving the cooling apparatus more than necessary. This results in wasting the electric power for driving the electric water pump 17 and the electric cooling fan 19. Furthermore, since it takes a long time to reduce the coolant temperature of the engine 1 to a value less than the threshold value, a drive stopping time point (time T2 in Fig. 2) of the electric water pump 17 and the electric cooling fan 19 is delayed, which causes the driver to feel uncomfortable.

**[0041]** In the first embodiment, the threshold value is variably set in accordance with the crank angle at the completion of stopping of the engine 1. More specifically, when the crank angle at the completion of stopping of the engine 1 is a crank angle at which the position of the piston 4 in the cylinder (initial explosion cylinder) in which the compression stroke takes place for the first time after the subsequent initiation of starting of the engine is at the bottom dead center, the threshold value is set to the lowest value, which is a value (coolant temperature) that reliably suppresses the occurrence of pre-ignition in the initial explosion cylinder at the subsequent initiation of starting of the engine. Also, when the crank angle at the completion of stopping of the engine 1 is a crank angle at which the position of the piston 4 in the cylinder (initial explosion cylinder) in which the compression stroke takes place for the first time after the subsequent initiation of starting of the engine is closer to the top dead center than the bottom dead center, the closer to the top dead center the position of the piston 4 provided by a crank angle, the more gradually the threshold value is set to a higher value.

**[0042]** Fig. 4 shows the relationship between the above-mentioned threshold value and the position of the piston 4 at the completion of stopping of the engine in the cylinder (initial explosion cylinder) in which the compression stroke takes place for the first time after the subsequent initiation of starting of the engine. That is, when the position of the piston 4 in the initial explosion cylinder is at the bottom dead center, the threshold value takes a low value that reliably suppresses pre-ignition in the initial explosion cylinder at the subsequent starting of the engine. Also, when the position of the piston 4 in the initial explosion cylinder is closer to the top dead center than the bottom dead center, the closer to the top dead center the position of the piston 4, the more gradually the threshold value is changed to a higher value. Thus, the threshold value does not take a value that is too low for reliably suppressing the occurrence of pre-ignition in the initial explosion cylinder at the subsequent starting of the engine. Also, at and after the completion of stopping of the engine 1, the engine 1 is prevented from being cooled more than necessary by the cooling apparatus.

**[0043]** As described above, while reliably suppressing the occurrence of pre-ignition in the initial explosion cylinder at the subsequent starting of the engine, the engine 1 is suppressed from being cooled more than necessary by the cooling apparatus while the engine is stopped, thus avoiding the occurrence of the above-mentioned problem.

**[0044]** The procedure for controlling the cooling apparatus will now be described with reference to the flowchart of Fig. 5 showing a cooling control routine . The cooling control routine is periodically executed by the ECU 21 in an interrupting manner, for example, at predetermined time intervals.

**[0045]** In step S101, the ECU 21 determines whether it is the time when stopping of the engine 1 is completed, and if it is determined that it is the time when stopping of the engine 1 is completed, the ECU 21 proceeds to step S102. In step S102, the ECU 21 detects the crank angle at the completion of stopping of the engine based on the signals from the crank position sensors 11, 12 and the cam position sensor 14, and sets the threshold value based on the crank angle. In subsequent step S103, the ECU 21 determines whether the engine 1 is stopped. If the decision outcome is negative, the engine 1 is in the normal combustion operation. In this case, the ECU 21 proceeds to step S109, and executes the normal cooling control, that is, the electric water pump 17 and the electric cooling fan 19 are controlled such that the coolant temperature becomes less than or equal to the target value (95°C in this embodiment).

**[0046]** If the decision outcome of step S103 is positive, it is the time when stopping of the engine 1 is completed or the engine 1 is in the stopped state after stopping of the engine 1 is completed. In this case, on conditions that the coolant temperature is greater than or equal to the threshold value (S104: YES), and that the reserves of power of the battery 20, which is the battery remaining amount, is greater than or equal to the lower limit value (S105: YES), the ECU 21 executes processes for driving the cooling apparatus while the engine is stopped (S106,

S107). The battery remaining amount is obtained based on the charged capacity of the battery 20 by a generator mounted on the automobile, and the discharged capacity from the battery 20 when operating electric devices mounted on the automobile.

**[0047]** The processes for driving the cooling apparatus when the engine is stopped include the process of step S106 for calculating the temperature difference between the threshold value and the coolant temperature, and the process of step S107 for controlling the flow rate of the electric water pump 17 and the blowing amount of the electric cooling fan 19 in accordance with the temperature difference. More specifically, as the temperature difference is increased, the electric water pump 17 is controlled such that the flow rate of the pump 17 is more gradually increased as shown in Fig. 6, and the electric cooling fan 19 is controlled such that the blowing amount of the fan 19 is more gradually increased as shown in Fig. 7. Thus, the cooling of the engine 1 by the coolant while the engine is stopped is performed more intensely as the coolant temperature is increased with respect to the threshold value, and is performed more weakly as the coolant temperature approaches the threshold value.

**[0048]** As a result of cooling the engine 1 with the coolant, when the coolant temperature becomes less than the threshold value in step S104, the ECU 21 proceeds to step S108, and stops driving the electric water pump 17 and the electric cooling fan 19.

**[0049]** The first embodiment has the following advantages.

(1) When the crank angle at the completion of stopping of the engine 1 is a crank angle at which the piston 4 of the cylinder (initial explosion cylinder) in which the compression stroke takes place for the first time after the subsequent initiation of starting of the engine is at the bottom dead center, the occurrence of the pre-ignition is reliably suppressed since the threshold value is set to a coolant temperature (lower limit value) at which the pre-ignition does not occur in the initial explosion cylinder at the subsequent the initiation of starting of the engine. Furthermore, when the crank angle at the completion of stopping of the engine 1 is a crank angle at which the position of the piston 4 of the cylinder in which the compression stroke takes place for the first time after the subsequent initiation of starting of the engine is closer to the top dead center than the bottom dead center, the closer to the top dead center the position of the piston 4 provided by a crank angle, the higher the threshold value, which is higher than the above-mentioned lower limit value, becomes. Thus, while reliably suppressing the occurrence of the pre-ignition, the threshold value is suppressed from being too low for reliably suppressing the pre-ignition. This suppresses the engine 1 from being cooled more than necessary while the engine 1 is stopped.

(2) In the case of cooling the engine 1 while it is stopped, the flow rate of the electric water pump 17 and the blowing amount of the electric cooling fan 19 are increased when the coolant temperature is higher than the threshold value. Also, the closer to the threshold value the coolant temperature, the more gradually the flow rate of the electric water pump 17 and the blowing amount of the electric cooling fan 19 are reduced. Thus, the cooling of the engine 1 while the engine is stopped is performed more intensely as the coolant temperature is increased with respect to the threshold value, and is weakened as the coolant temperature approaches the threshold value. Therefore, the electric water pump 17 and the electric cooling fan are not driven wastefully, and the coolant temperature is promptly reduced to be less than the threshold value.

(3) The engine 1, which automatically stops and restarts the combustion operation, is frequently started without enough time after being stopped, which increases the possibility for pre-ignition to occur at the initiation of starting of the engine. However, while reliably suppressing such occurrence of pre-ignition, the engine 1 that is stopped is suppressed from being cooled more than necessary.

**[0050]** A second embodiment of the present invention will now be described with reference to Figs. 8 and 10.

**[0051]** In the second embodiment, to complete starting of the engine 1 in a short period of time, fuel is burned in the cylinder in which the compression stroke takes place for the second time after the initiation of starting of the engine. During the compression stroke, the initial explosion after the initiation of starting of the engine takes place.

(a) in Fig. 8 is a time chart showing the fuel injection manner and the fuel combustion manner of the first to fourth cylinders of the engine 1 according to the second embodiment from after the initiation of stopping of the engine 1 to after the subsequent initiation of starting of the engine. In the example of (a) in Fig. 8, in a state where the first cylinder has proceeded from the intake stroke to the compression stroke and the third cylinder has proceeded from the exhaust stroke to the intake stroke, the stopping of the engine 1 is completed (time T1). In the second embodiment, in the cylinder (first cylinder in (a) in Fig. 8) in which the compression stroke takes place at the completion of stopping of the engine 1, fuel injection is not performed in the intake stroke immediately before stopping of the engine is completed. Subsequently, when the start command of the engine 1 is generated (time T3), starting of the engine 1 is initiated. Then, in the cylinder (third cylinder in (a) in Fig. 8) in which the intake stroke takes place for the first time after the initiation of starting of the engine, fuel injection

from the fuel injection valve 2 to the combustion chamber 3 is performed. When the compression stroke takes place in the third cylinder, that is, when the second compression stroke takes place after the initiation of starting of the engine, the fuel in the combustion chamber 3 of the third cylinder is burned, and the initial explosion after the initiation of starting of the engine 1 takes place. Hereinafter, the cylinder in which the compression stroke takes place for the second time after the initiation of starting of the engine 1 is referred to as an "initial explosion cylinder" when necessary.

**[0052]** During the second compression stroke after the initiation of starting of the engine 1, the temperature of gas in the combustion chamber 3 and the pressure in the combustion chamber 3 are also high as compared to those when the engine 1 is in the normal combustion operation for the reasons described in [BACKGROUND ART] . Thus, even in the cylinder in which the compression stroke takes place for the second time after the initiation of starting of the engine, pre-ignition might occur in the combustion chamber 3. To suppress the pre-ignition, the cooling apparatus is driven such that the coolant temperature of the engine 1 becomes less than the threshold value as shown in Fig. 8 at and after the completion of stopping of the engine 1.

**[0053]** The threshold value is set in accordance with the crank angle at the completion of stopping of the engine 1 so that, while reliably suppressing the occurrence of pre-ignition at the initiation of starting of the engine, the engine 1 is suppressed from being cooled more than necessary by the cooling apparatus while the engine is stopped.

**[0054]** More specifically, when the crank angle at the completion of stopping of the engine 1 is a crank angle at which the position of the piston 4 in the cylinder (initial explosion cylinder) in which the compression stroke takes place for the second time after the subsequent initiation of starting of the engine is closest to the bottom dead center as shown in Fig. 9(a), the threshold value is set to the lowest value and a value (coolant temperature) that reliably suppresses the occurrence of pre-ignition in the initial explosion cylinder at the subsequent initiation of starting of the engine. This is because when the position of the piston 4 in the initial explosion cylinder is closest to the bottom dead center as shown in Fig. 9(a), the temperature of gas in the combustion chamber 3 and the pressure in the combustion chamber 3 during the second compression stroke are the highest, and thus the possibility for the pre-ignition to occur is the highest.

**[0055]** Also, when the crank angle at the completion of stopping of the engine 1 is a crank angle at which the position of the piston 4 in the cylinder (initial explosion cylinder) in which the compression stroke takes place for the second time after the subsequent initiation of starting of the engine is closer to the top dead center as shown in Fig. 9(b) than the position closest to the bottom dead center (Fig. 9 (a)), the closer to the top dead center the position of the piston 4 provided by a crank angle, the more gradually the threshold value is set to a higher value. This is because, when the position of the piston 4 is closer to the top dead center as shown in Fig. 9(b) than the position closest to the bottom dead center (Fig. 9(a)), the closer to the top dead center the position of the piston 4, the lower the temperature of gas in the combustion chamber 3 and the pressure in the combustion chamber 3 during the second compression stroke become. Thus, the possibility for the pre-ignition to occur is gradually reduced.

**[0056]** Fig. 10 shows the relationship between the threshold value and the position of the piston 4 at the completion of stopping of the engine in the cylinder (initial explosion cylinder) in which the compression stroke takes place for the second time after the subsequent initiation of starting of the engine. That is, when the position of the piston 4 in the initial explosion cylinder is the closest to the bottom dead center, the threshold value takes a low value that reliably suppresses pre-ignition in the initial explosion cylinder at the subsequent starting of the engine. Also, when the position of the piston 4 in the initial explosion cylinder is at the position closer to the top dead center than the position closest to the bottom dead center, the closer to the top dead center the position of the piston 4, the more gradually the threshold value is changed to a higher value. Thus, the threshold value does not become a value that is too low for reliably suppressing the occurrence of pre-ignition in the initial explosion cylinder at the subsequent starting of the engine, and the engine 1 is prevented from being cooled more than necessary by the cooling apparatus at and after completion of stopping of the engine 1.

**[0057]** The second embodiment has the following advantages.

(4) When the crank angle of the engine 1 at the completion of stopping of the engine is a crank angle at which the piston 4 of the cylinder (initial explosion cylinder) in which the compression stroke takes place for the second time after the subsequent initiation of starting of the engine is closest to the bottom dead center, the threshold value is set to a coolant temperature (lower limit value) at which pre-ignition does not occur in the initial explosion cylinder at the subsequent initiation of starting of the engine. Thus, the occurrence of pre-ignition is reliably suppressed. Furthermore, when the crank angle of the engine 1 at the completion of stopping of the engine is a crank angle at which the position of the piston 4 of the cylinder in which the compression stroke takes place for the second time after the subsequent initiation of starting of the engine is closer to the top dead center than the position closest to the bottom dead center, the closer to the top dead center the position of the piston 4 provided by a crank angle, the higher the threshold value, which is higher than the lower limit

value, becomes. Thus, while reliably suppressing the occurrence of the pre-ignition, the threshold value is suppressed from being too low for reliably suppressing the pre-ignition. This suppresses the engine 1 from being cooled more than necessary while the engine 1 is stopped.

(5) The advantages (2) and (3) of the first embodiment are obtained.

**[0058]** The above embodiments may be modified as follows, for example.

**[0059]** In the first embodiment, the threshold value is linearly changed as shown in Fig. 4. Instead, the threshold value may be changed stepwise. For example, the threshold value may be changed in two steps as shown in Fig. 11, or may be changed in three or more steps. In this case also, the advantage equivalent to the advantage (1) of the first embodiment is obtained. If the threshold value is linearly changed as in the first embodiment, the engine 1 is suppressed from being cooled more than necessary while the engine 1 is stopped, and the occurrence of pre-ignition is suppressed at the subsequent initiation of starting of the engine 1 in a more suitable manner.

**[0060]** In the second embodiment, the threshold value is changed linearly as shown in Fig. 10. Instead, the threshold value may be changed stepwise. For example, the threshold value may be changed in two steps as shown in Fig. 12, or may be changed in three or more steps. In this case also, the advantage equivalent to the advantage (4) of the second embodiment is obtained. If the threshold value is linearly changed as in the second embodiment, the engine 1 is suppressed from being cooled more than necessary while the engine 1 is stopped, and the occurrence of pre-ignition is suppressed at the subsequent initiation of starting of the engine 1 in a more suitable manner.

**[0061]** The flow rate of the electric water pump 17 while the engine 1 is stopped does not need to be changed gradually in accordance with the temperature difference between the threshold value and the coolant temperature as shown in Fig. 6, but may be changed stepwise in accordance with the temperature difference.

**[0062]** The flow rate of the electric water pump 17 may be fixed.

**[0063]** The blowing amount of the electric cooling fan 19 while the engine 1 is stopped also does not need to be changed gradually in accordance with the temperature difference as shown in Fig. 7, but may be changed stepwise in accordance with the temperature difference.

**[0064]** The blowing amount of the electric cooling fan 19 may be fixed.

**[0065]** As the parameter representing the temperature of the engine 1, the coolant temperature in the circulation passage 16 is used. Instead, other parameters such as the lubricant temperature of the engine 1 may be used.

**[0066]** The present invention is applied to the engine 1 that automatically stops and restarts in accordance with the output demand, but the present invention may be applied to an engine that is stopped and started only by the ignition switch 25 manipulated by the driver.

**[0067]** The present invention is applied to the direct injection engine 1 that injects fuel in the combustion chambers 3, but the present invention may be applied to a port injection engine that injects fuel in intake ports.

**[0068]** The present invention may be applied to an engine other than four-cylinder engine such as an in-line six-cylinder engine, a V6 engine, and a V8 engine.

## Claims

1. A cooling control apparatus of an internal combustion engine that includes a plurality of cylinders provided with pistons, wherein initial explosion takes place in one of a first compression stroke and a second compression stroke after the initiation of starting of the engine, the cooling control apparatus comprising:

   a cooling apparatus, which is driven by a driving source different from the engine and cools the engine;
   a control section, which drives the cooling apparatus at and after the completion of stopping of the engine and when the engine temperature is greater than or equal to a predetermined value that might cause pre-ignition at the initiation of starting of the engine; **characterised in that** it further comprises a setting section, which sets the predetermined value in accordance with the crank angle at the completion of stopping of the engine, wherein, when the crank angle at the completion of stopping of the engine is a crank angle at which the piston position of the cylinder in which the initial explosion takes place after the subsequent initiation of starting of the engine is closer to the top dead center, the setting section sets the predetermined value to a value higher than that in a case where the crank angle at the completion of stopping of the engine is a crank angle at which the piston position of the cylinder in which the initial explosion takes place after the subsequent initiation of starting of the engine is closer to the bottom dead center.

2. The cooling control apparatus according to claim 1, wherein the closer to the top dead center the position of the piston, which is provided by the crank angle at the completion of stopping of the engine, in the cylinder in which the initial explosion takes place after the subsequent initiation of starting of the engine, the more gradually setting section sets the predetermined value to a higher value.

3. The cooling control apparatus according to claim 1

or 2, wherein the cooling apparatus includes an electric pump, which supplies a coolant to the engine, and the control section increases the flow rate of the electric pump as the engine temperature increases with respect to the predetermined value.

**4.** The cooling control apparatus according to claim 1 or 2, wherein the cooling apparatus includes an electric pump, which circulates a coolant to pass through the engine, and an electric fan, which cools the coolant by blowing air, and wherein the control section increases the blowing amount of the electric fan as the engine temperature increases with respect to the predetermined value.

**5.** The cooling control apparatus according to any one of claims 1 to 4, wherein combustion operation of the engine is automatically stopped when automatic stop conditions are satisfied while the combustion operation is being executed, and the combustion operation is automatically restarted when automatic restart conditions are satisfied while the combustion operation is stopped.

**Patentansprüche**

**1.** Kühlungssteuerungsvorrichtung eines Verbrennungsmotors mit mehreren mit Kolben versehenen Zylindern, wobei eine einleitende Explosion in einem ersten Kompressionshub oder einem zweiten Kompressionshub nach Einleiten des Motorstarts stattfindet, wobei die Kühlungssteuerungsvorrichtung versehen ist mit
einer Kühlungsvorrichtung, welche durch eine Antriebsquelle angetrieben wird, die sich vom Motor unterscheidet, und welche den Motor kühlt; und
einem Steuerungsabschnitt, welcher die Kühlungsvorrichtung während und nach der Ausführung des Motorstopps steuert, wenn die Motortemperatur größer oder gleich einem vorbestimmten Wert ist, welcher beim Einleiten des Motorstarts eine Frühzündung verursachen könnte;
**gekennzeichnet durch**
einen Einstellabschnitt, welcher den vorbestimmten Wert entsprechend dem Kurbelwinkel bei der Ausführung des Motorstopps einstellt, wobei, wenn der Kurbelwinkel bei der Ausführung des Motorstopps ein Kurbelwinkel ist, bei welchem die Kolbenposition des Zylinders, in dem die einleitende Explosion nach dem darauffolgenden Einleiten des Motorstarts stattfindet, näher am oberen Totpunkt ist, der Einstellabschnitt den vorbestimmten Wert auf einen Wert einstellt, welcher größer ist als in einem Fall, bei dem der Kurbelwinkel bei der Ausführung des Motorstopps ein Kurbelwinkel ist, bei welchem die Kolbenposition des Zylinders, in dem die einleitende Explosion nach dem darauffolgenden Einleiten des Motorstarts stattfindet, näher am unteren Totpunkt ist.

**2.** Kühlungssteuerungsvorrichtung gemäß Anspruch 1, wobei je näher die Position des Kolbens, welche durch den Kurbelwinkel bei der Ausführung des Motorstopps geliefert wird, in dem Zylinder, in dem die einleitende Explosion nach dem darauffolgenden Einleiten des Motorstarts stattfindet, zum oberen Totpunkt ist, desto langsamer stellt der Einstellabschnitt den vorbestimmten Wert auf einen größeren Wert ein.

**3.** Kühlungssteuerungsvorrichtung gemäß Anspruch 1 oder 2, wobei die Kühlungsvorrichtung eine elektrische Pumpe aufweist, welche den Motor mit einem Kühlungsmittel versorgt, und der Einstellabschnitt die Flussrate der elektrischen Pumpe vergrößert, wenn sich die Motortemperatur bezüglich des vorbestimmten Werts vergrößert.

**4.** Kühlungssteuerungsvorrichtung gemäß Anspruch 1 oder 2, wobei die Kühlungsvorrichtung versehen ist mit einer elektrischen Pumpe, welche ein Kühlungsmittel zirkuliert, um den Motor zu durchlaufen, und mit einem Ventilator, welcher das Kühlungsmittel durch Blasen von Luft kühlt, und wobei der Einstellabschnitt die Blasmenge des elektrischen Ventilators vergrößert, wenn sich die Motortemperatur bezüglich des vorbestimmten Werts vergrößert.

**5.** Kühlungssteuerungsvorrichtung gemäß einem der Ansprüche 1 bis 4, wobei der Verbrennungsbetrieb des Motors automatisch gestoppt wird, wenn während der Ausführung des Verbrennungsbetriebs Bedingungen für das automatische Stoppen erfüllt sind, und der Verbrennungsbetrieb automatisch wieder aufgenommen wird, wenn, während der Verbrennungsbetrieb gestoppt ist, Bedingungen für das automatische Wiederaufnehmen erfüllt sind.

**Revendications**

**1.** Dispositif de commande de refroidissement d'un moteur à combustion interne qui comprend une pluralité de cylindres équipés de pistons, dans lequel une explosion initiale a lieu pendant une course de compression parmi une première course de compression et une seconde course de compression après l'initiation du démarrage du moteur, le dispositif de commande de refroidissement comprenant :

un dispositif de refroidissement qui est entraîné par une source d'entraînement qui est différente du moteur et qui refroidit le moteur ;
une section de commande, qui entraîne le dispositif de refroidissement pendant et après l'arrêt complet du moteur et quand la température

du moteur est supérieure ou égale à une valeur prédéterminée qui pourrait provoquer un pré-allumage à l'initiation du démarrage du moteur ; **caractérisé en ce qu'**il comprend en outre une section de configuration qui configure la valeur prédéterminée en fonction de l'angle du vilebrequin à l'arrêt complet du moteur, dans lequel quand l'angle du vilebrequin au moment de l'arrêt complet du moteur est un angle de vilebrequin où la position du piston du cylindre dans lequel a lieu l'explosion initiale après l'initiation subséquente du démarrage du moteur est plus à proximité du point mort supérieur, la section de configuration configure la valeur prédéterminée à une valeur supérieure à celle d'un cas où l'angle de vilebrequin au moment de l'arrêt complet du moteur est un angle de vilebrequin où la position du piston du cylindre dans lequel a lieu l'explosion initiale après l'initiation subséquente du démarrage du moteur est plus à proximité du point mort inférieur.

**2.** Dispositif de commande de refroidissement selon la revendication 1, dans lequel plus la position du piston est proche du point mort supérieur, qui est fournie par l'angle de vilebrequin au moment de l'arrêt complet du moteur, dans le cylindre dans lequel a lieu l'explosion initiale du moteur après l'initiation subséquente du démarrage du moteur, plus la section de configuration configure de manière graduelle la valeur prédéterminée à une valeur supérieure.

**3.** Dispositif de commande de refroidissement selon la revendication 1 ou 2, dans lequel le dispositif de refroidissement comprend une pompe électrique qui fournit un agent refroidissant au moteur et la section de commande augmente le débit de la pompe électrique au fur et à mesure que la température du moteur augmente par rapport à la valeur prédéterminée.

**4.** Dispositif de commande de refroidissement selon la revendication 1 ou 2, dans lequel le dispositif de refroidissement comprend une pompe électrique, qui fait circuler un agent refroidissant de façon à ce qu'il passe à travers le moteur, et un ventilateur électrique, qui refroidit l'agent refroidissant en soufflant de l'air, et dans lequel la section de commande augmente la quantité de souffle du ventilateur électrique au fur et à mesure que la température du moteur augmente par rapport à la valeur prédéterminée.

**5.** Dispositif de commande de refroidissement selon l'une quelconque des revendications 1 à 4, dans lequel l'opération de combustion du moteur est automatiquement arrêtée quand des conditions d'arrêt automatique sont remplies tandis que l'opération de combustion est en cours d'exécution, et l'opération de combustion est automatiquement remise en marche quand des conditions de redémarrage automatique sont remplies tandis que l'opération de combustion est arrêtée.

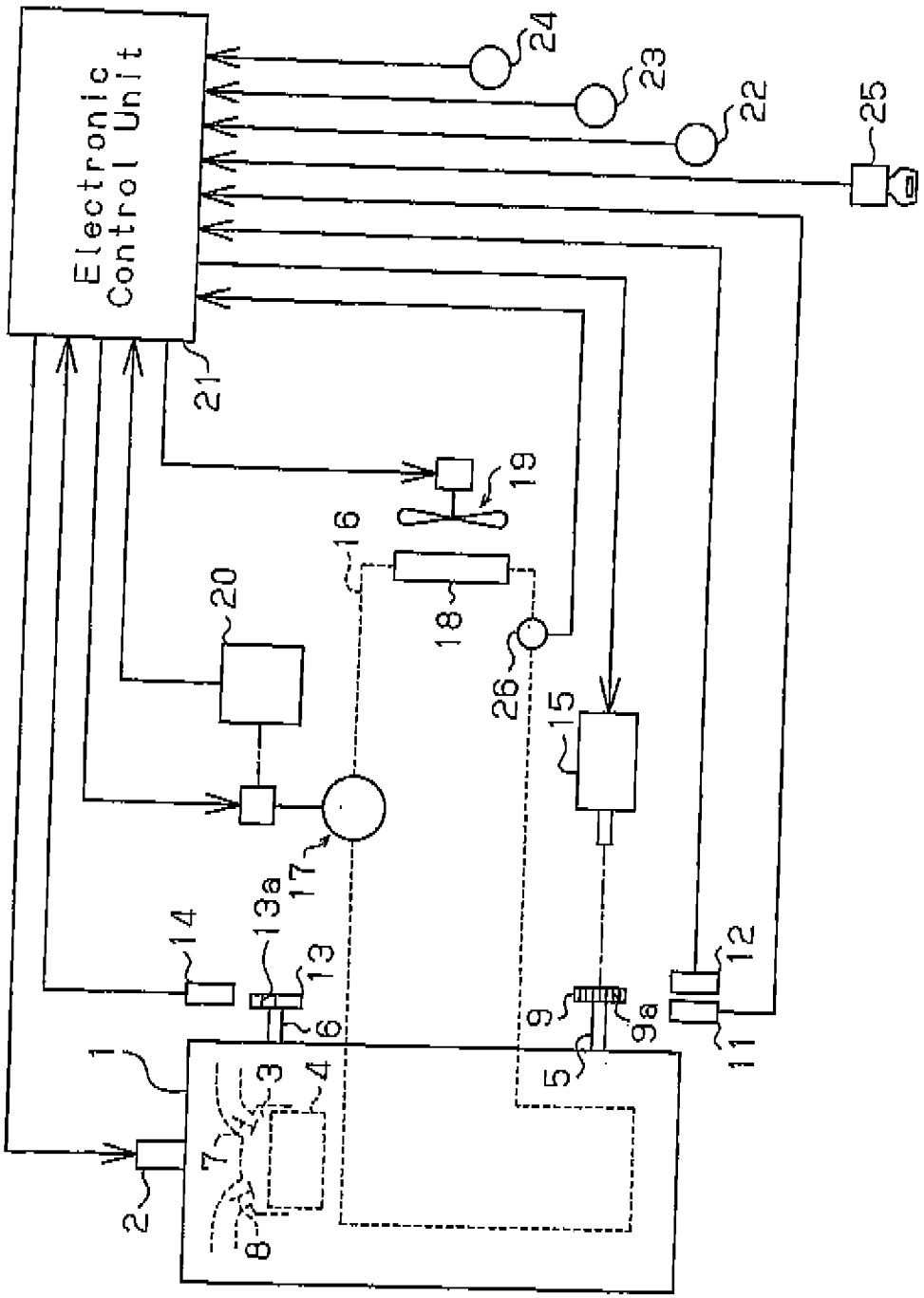

Electronic Control Unit
21
24
23
22
25
19
16
18
20
26
15
17
13a
14
13
12
6
9
9a
11
1
3
4
5
7
2
8

Fig.1

**Fig.2**

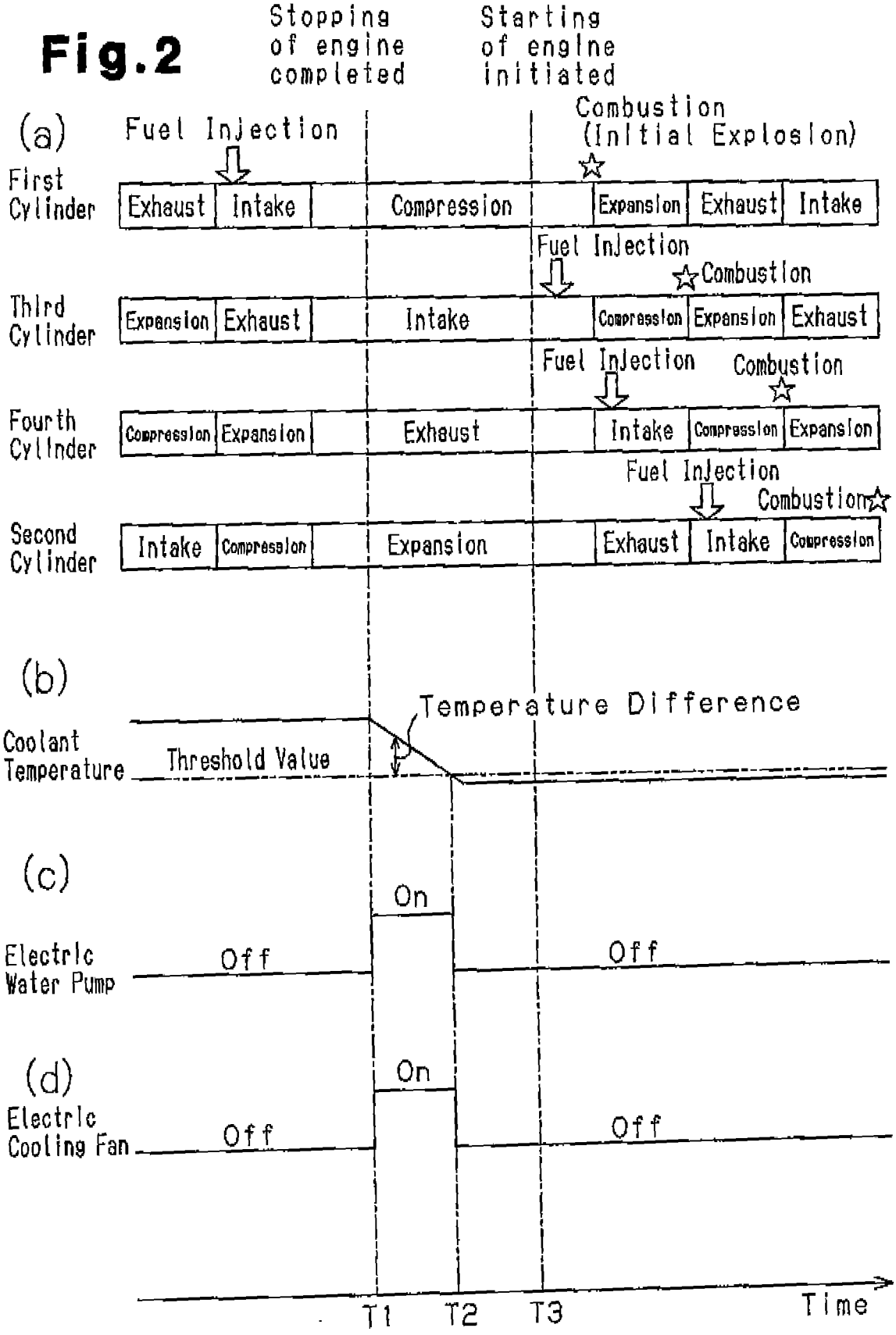

Stopping of engine completed
Starting of engine initiated
(a)
Fuel Injection
Combustion (Initial Explosion)
First Cylinder
Exhaust
Intake
Compression
Expansion
Exhaust
Intake
Fuel Injection
Combustion
Third Cylinder
Expansion
Exhaust
Intake
Compression
Expansion
Exhaust
Fuel Injection
Combustion
Fourth Cylinder
Compression
Expansion
Exhaust
Intake
Compression
Expansion
Fuel Injection
Combustion
Second Cylinder
Intake
Compression
Expansion
Exhaust
Intake
Compression
(b)
Temperature Difference
Coolant Temperature
Threshold Value
(c)
On
Electric Water Pump
Off
Off
(d)
On
Electric Cooling Fan
Off
Off
T1
T2
T3
Time

Fig.3(a)

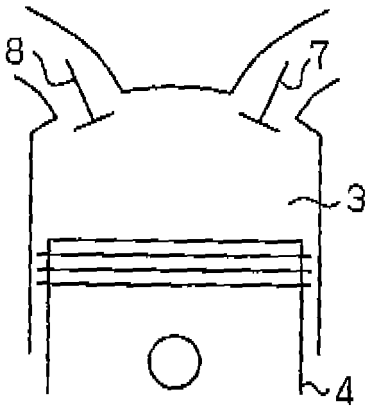



Fig.3(b)

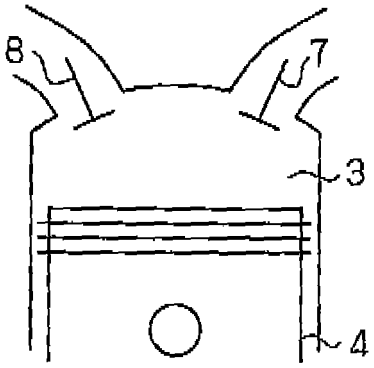



Fig.4

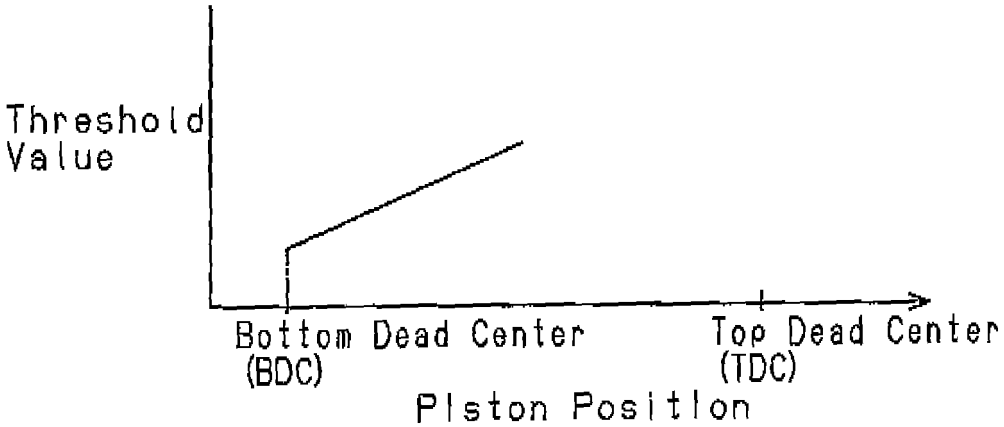


Fig.5

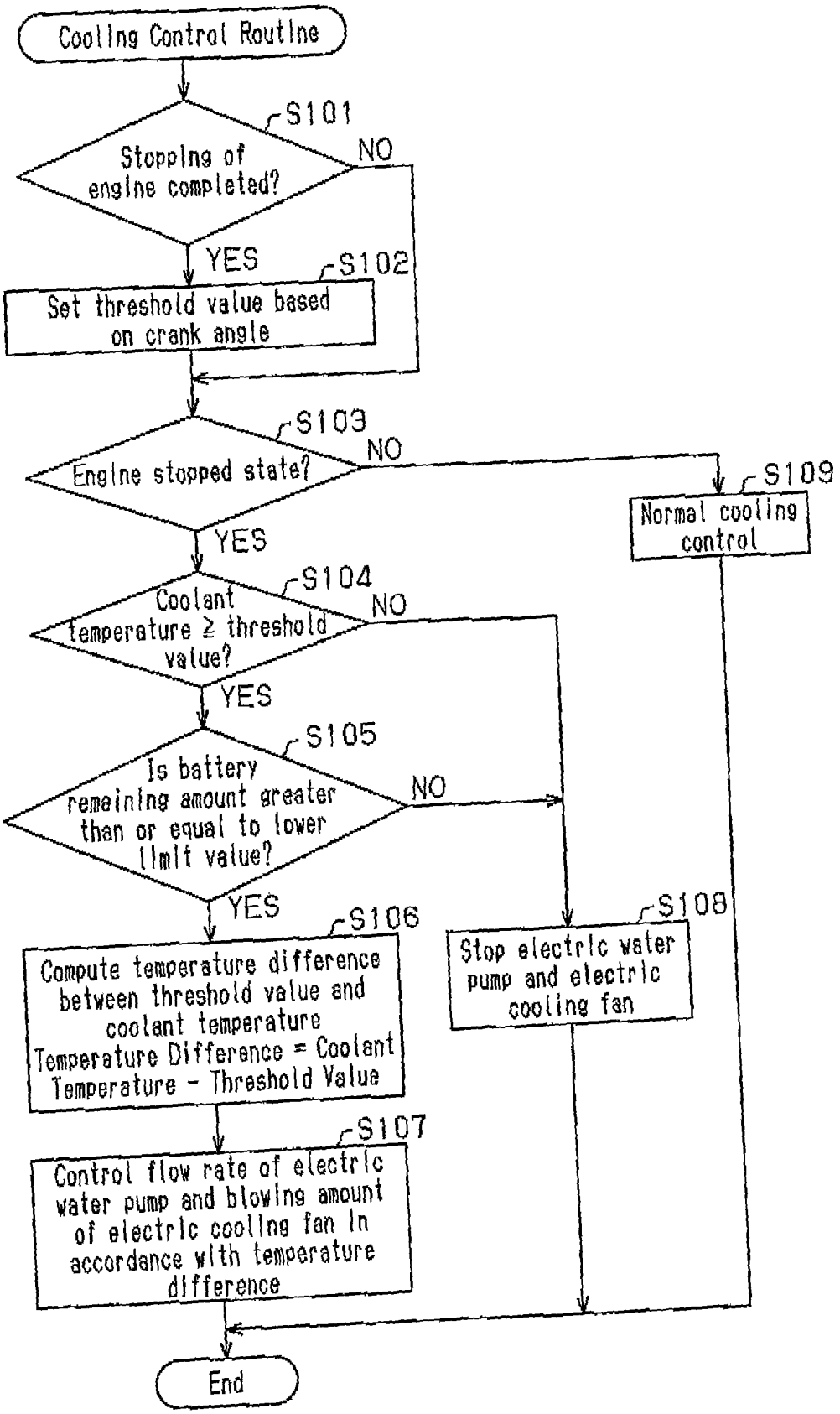

Cooling Control Routine
S101
Stopping of engine completed?
NO
YES
S102
Set threshold value based on crank angle
S103
Engine stopped state?
NO
S109
Normal cooling control
YES
S104
Coolant temperature ≥ threshold value?
NO
YES
S105
Is battery remaining amount greater than or equal to lower limit value?
NO
YES
S106
Compute temperature difference between threshold value and coolant temperature
Temperature Difference = Coolant Temperature - Threshold Value
S108
Stop electric water pump and electric cooling fan
S107
Control flow rate of electric water pump and blowing amount of electric cooling fan in accordance with temperature difference
End

Fig.6

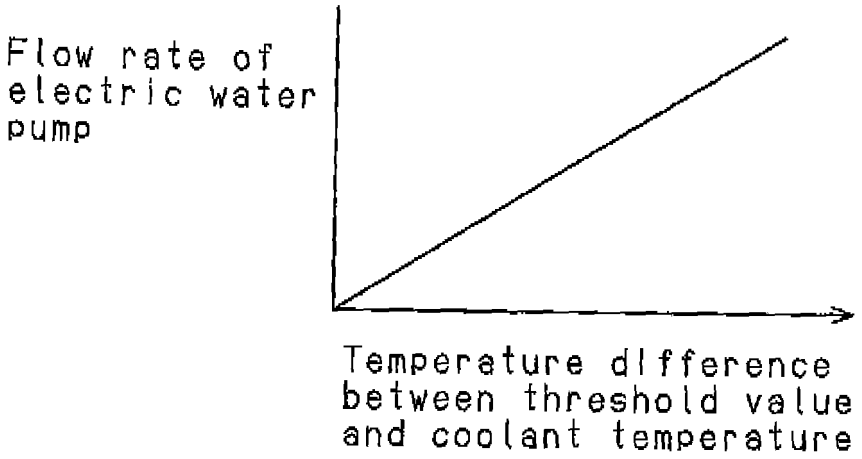

Flow rate of electric water pump
Temperature difference between threshold value and coolant temperature

Fig.7

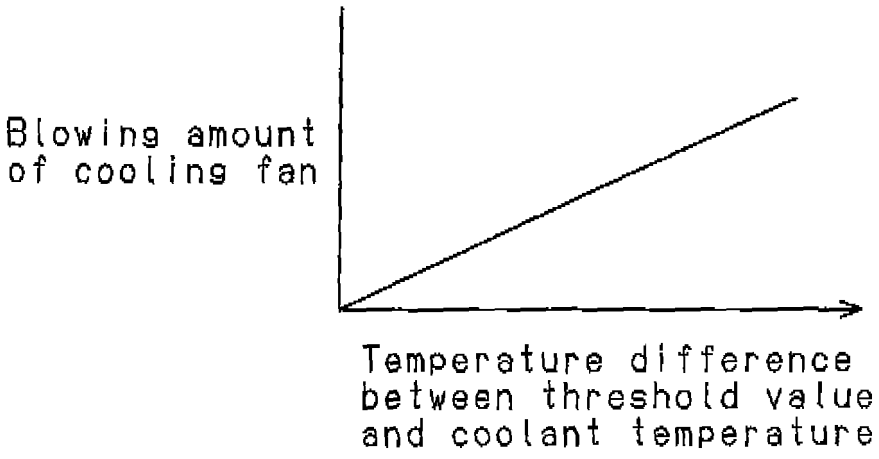

Blowing amount of cooling fan
Temperature difference between threshold value and coolant temperature

**Fig.8**

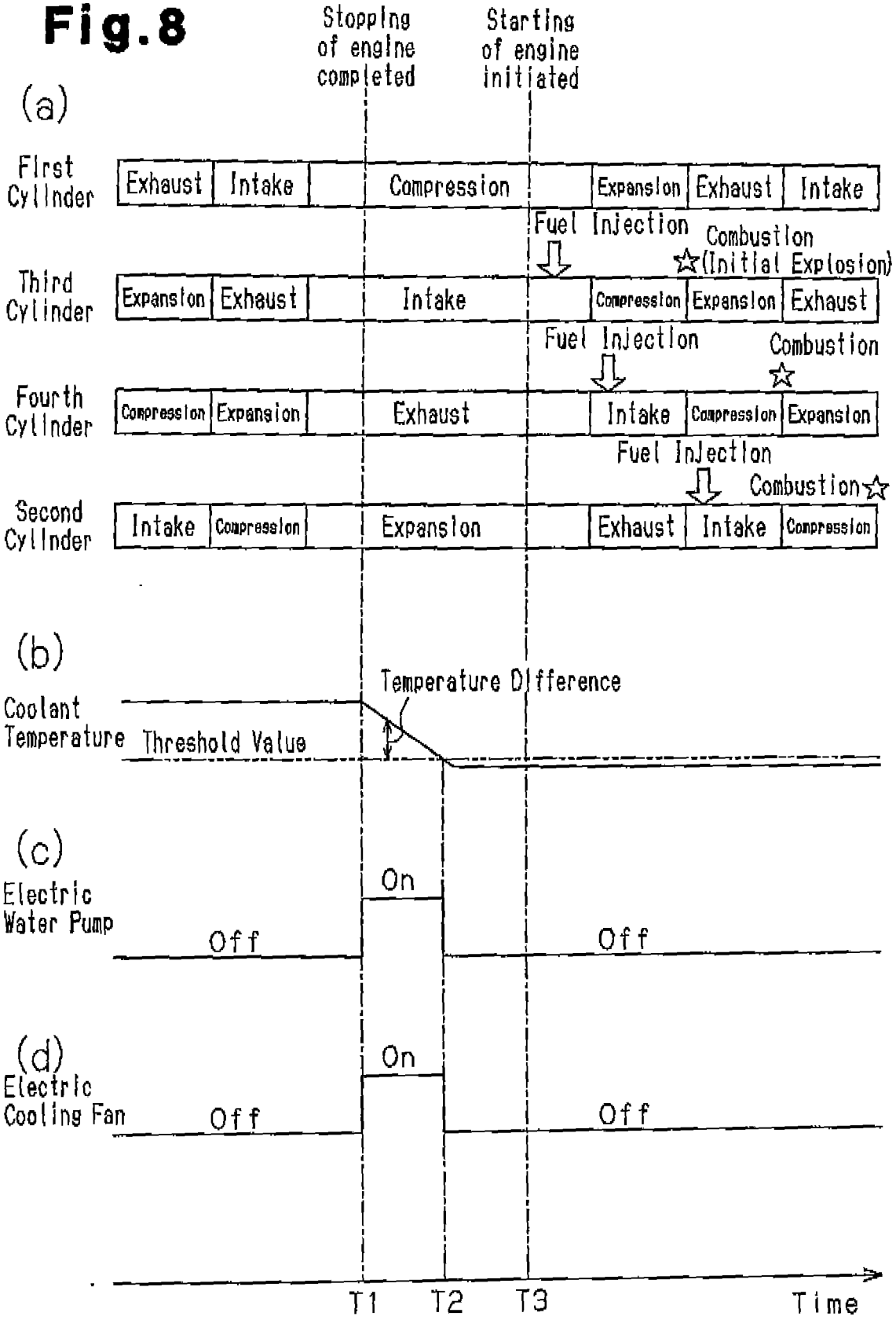

Stopping of engine completed
Starting of engine initiated
(a)
First Cylinder
Exhaust
Intake
Compression
Expansion
Exhaust
Intake
Fuel Injection
Combustion
(Initial Explosion)
Third Cylinder
Expansion
Exhaust
Intake
Compression
Expansion
Exhaust
Fuel Injection
Combustion
Fourth Cylinder
Compression
Expansion
Exhaust
Intake
Compression
Expansion
Fuel Injection
Combustion
Second Cylinder
Intake
Compression
Expansion
Exhaust
Intake
Compression
(b)
Temperature Difference
Coolant Temperature
Threshold Value
(c)
Electric Water Pump
On
Off
Off
(d)
Electric Cooling Fan
On
Off
Off
T1
T2
T3
Time

Fig.9(a)

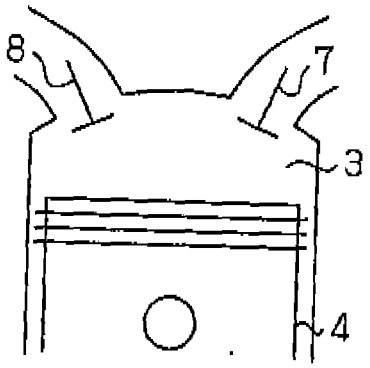



Fig.9(b)

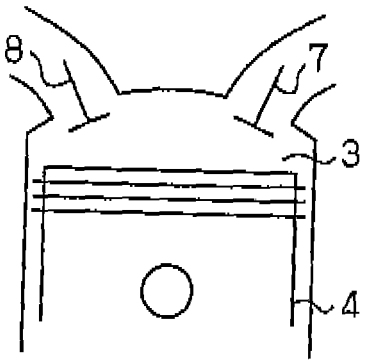



Fig.10

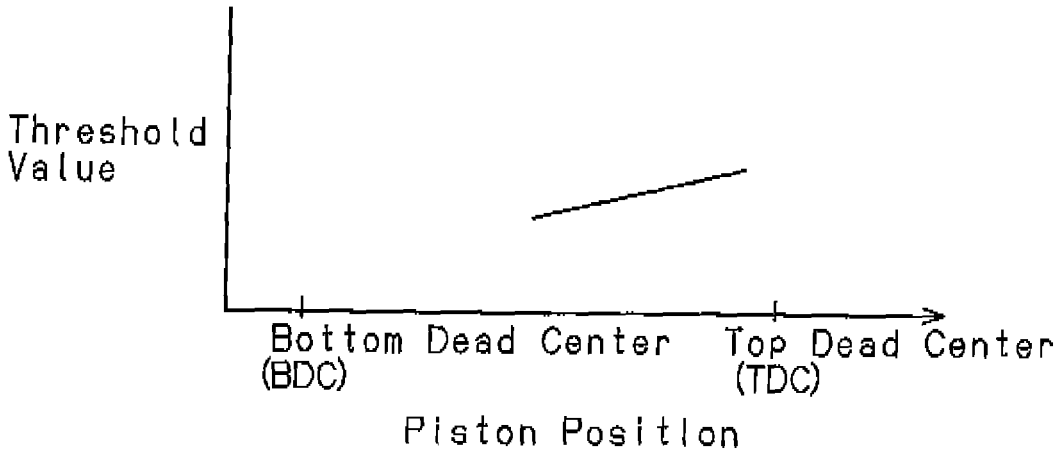


Fig.11

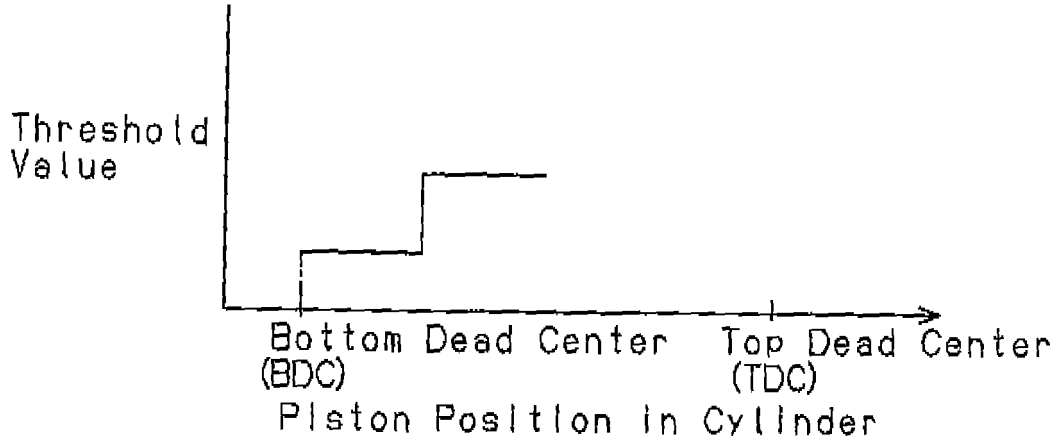
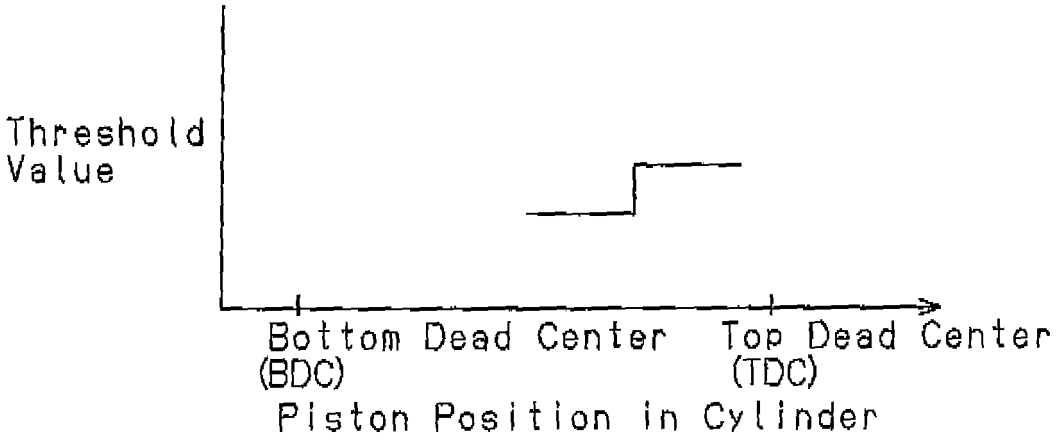

Threshold Value
Bottom Dead Center (BDC)
Top Dead Center (TDC)
Piston Position in Cylinder

Fig.12


Threshold Value
Bottom Dead Center (BDC)
Top Dead Center (TDC)
Piston Position in Cylinder

## REFERENCES CITED IN THE DESCRIPTION

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

### Patent documents cited in the description


- JP 2001182580 A **[0012]**
- US 6986331 B2 **[0012]**