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

(11) EP 3 358 163 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
08.08.2018 Bulletin 2018/32

(21) Application number: **16851118.6**

(22) Date of filing: **12.09.2016**

(51) Int Cl.:
F01P 7/16 *(2006.01)* ***F01P 3/20*** *(2006.01)*
F02M 26/23 *(2016.01)*

(86) International application number:
PCT/JP2016/076811

(87) International publication number:
WO 2017/056944 (06.04.2017 Gazette 2017/14)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **30.09.2015 JP 2015194810**

(71) Applicant: **Aisin Seiki Kabushiki Kaisha**
Kariya-shi Aichi 448-8650 (JP)

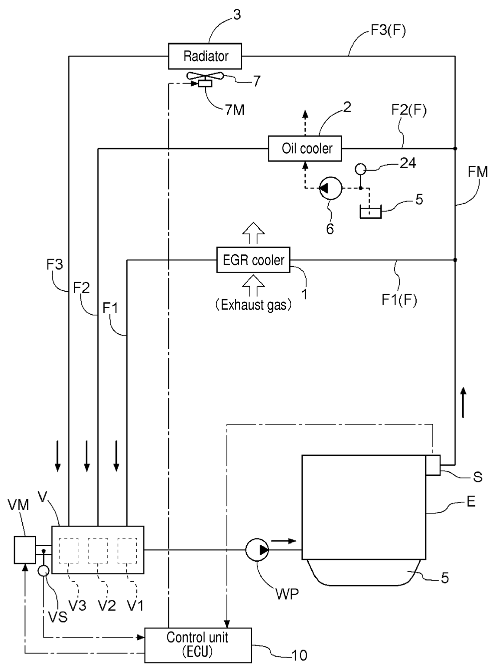
(72) Inventors:
- **WATANABE, Hirotaka**
  Kariya-shi
  Aichi 448-8650 (JP)
- **TOYODA, Yasunobu**
  Kariya-shi
  Aichi 448-8650 (JP)
- **YOSHIDA, Masahiro**
  Kariya-shi
  Aichi 448-8650 (JP)
- **SHIMATANI, Kazuyoshi**
  Kariya-shi
  Aichi 448-8650 (JP)

(74) Representative: **Kramer Barske Schmidtchen**
Patentanwälte PartG mbB
European Patent Attorneys
Landsberger Strasse 300
80687 München (DE)

(54) **COOLING CONTROL DEVICE**

(57) A cooling control device includes a first heat exchanger to which a coolant of an internal combustion engine is supplied, a radiator to which the coolant of is supplied, a coolant pump supplying the coolant, a flow amount control valve controlling a flow amount of the coolant, and a control unit controlling the flow amount control valve. The control unit acquires a first amount of heat which is accumulated in the coolant, a second amount of heat which is accumulated in the coolant by a heat exchange with the first heat exchanger, and a third amount of heat for changing a temperature level of the coolant to a targeted temperature level. A targeted dissipation amount is set from the first, second and third amounts of heat, and an opening of the flow amount control valve is set by a feedforward control.

FIG. 1



EP 3 358 163 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a cooling control device managing a temperature level of an internal combustion engine using a coolant.

BACKGROUND ART

[0002] As a cooling control device of an aforementioned configuration, Patent reference 1 discloses a technology, which sets a targeted temperature level of a cooling water based on an operation state of an internal combustion engine, which acquires a cooling amount operated by an electric cooling device from a dissipation model to achieve a targeted dissipation efficiency, and which controls the electric cooling device based on the acquired cooling amount, is disclosed.

[0003] Patent reference 1 also discloses a processing mode which sets the targeted dissipation efficiency by a feedback control based on a deviation between the targeted temperature level and an actual temperature level, and a feed forward control based on an amount of heat of an engine. A radiator fan, a water pump and a thermostat are disclosed as the electric cooling devices that are controlled to achieve the cooling in the cooling amount.

[0004] Patent reference 2 discloses a control mode which estimates a total amount of heat of a cooling system by an amount of heat of the cooling system accumulated by the cooling system of an internal combustion engine (drive source) in response to a water temperature level of a cooling water, and a dissipation amount of a vehicle drive force dissipated by the internal combustion engine in a drive state, and which determines a targeted total amount of heat of a radiator and a flow amount of the radiator in response to the total amount of heat of the cooling system.

[0005] In Patent reference 2, an electric water pump setting an amount of cooling water is provided, a thermo valve is provided at a connection part between an outlet of the cooling water of an internal combustion engine and a radiator lower horse, and a bypass passage is provided between the thermo valve and the electric water pump. In Patent reference 2, it is configured to adjust a mixing ratio of a cooling water from the outlet of the internal combustion engine and a cooling water from the radiator horse by the opening of the thermo valve.

DOCUMENT OF PRIOR ART

PATENT DOCUMENT

[0006]

Patent document 1: JP2014-218938A
Patent reference 2: JP2005-248903A

OVERVIEW OF INVENTION

PROBLEM TO BE SOLVED BY INVENTION

[0007] Considering a control inhibiting a temperature level of an internal combustion engine from increasing by supplying a coolant to a radiator, even though the radiator dissipates heat, the dissipation does not promptly show as the decrease of the temperature level of the coolant. Thus, for example, in a feedback control adjusting a flow amount of the coolant by the detection of the temperature level of the cooling water by a temperature sensor, an excessive dissipation or a delay of a timing of the dissipation may be considered, leading to a hunting. Thus, it is difficult to maintain the temperature level of the coolant constant.

[0008] From this reason, the technologies of the aforementioned Patent reference 1 and Patent reference 2 may be configured to manage the temperature level of the cooling water by a feedforward control.

[0009] Here, in a case of a vehicle including an Exhaust Gas Recirculation cooler or an EGR cooler, a part of the heat exhausted with an exhaust gas is removed by the coolant water at the EGR cooler. In a vehicle including an oil cooler, the heat of lubricating oil is removed by the coolant of the oil cooler, or, conversely, the lubricating oil is heated by the heat of the coolant. Specifically, because the EGR cooler is supplied with an exhaust gas with high temperature level, the amount of heat transmitted from the EGR cooler to the coolant cannot be largely ignored.

[0010] In addition, a device including a mechanical water pump includes a configuration that is simple and cheap, the mechanical water pump including a cooling circuit that circulates the coolant and that is driven by an engine. However, because the amount of cooling water varies in response to the change of the speed of the engine, it is difficult to manage the temperature level.

[0011] That is, a cooling control device, which includes a mechanical pump and which performs, with high precision, a management of a temperature level of an internal combustion engine having a heat exchanger of, for example EGR cooler, is required.

MEANS FOR SOLVING PROBLEM

[0012] A characteristic of the present invention is that a cooling control device includes a radiator to which a coolant of an internal combustion engine is supplied, a first heat exchanger, other than the radiator, exchanging heat with the coolant, a coolant pump being driven by the internal combustion engine to circulate the coolant, a flow amount control valve setting a flow amount of the coolant, and a control portion setting an opening of the flow amount control valve. The control portion includes a heat amount acquiring portion acquiring a first amount of heat, a second amount of heat, and a third amount of heat, the first amount of heat that is applied to the coolant by the internal combustion engine in response to a speed of the internal combustion engine and a load applied thereto, the second amount of heat that is applied to the coolant by the first heat exchanger, the third amount of heat that is delivered and received to change a temperature level of the coolant to a targeted temperature level, a targeted dissipation amount setting portion setting a targeted dissipation amount based on an added value of the first amount of heat, the second amount of heat, and a third amount of heat per unit time acquired by the heat amount acquiring portion, and an opening setting portion setting a targeted flow amount of the coolant that is to be supplied to the radiator based on the targeted dissipation amount being set by the targeted heat dissipation amount setting portion and based on a heat exchanging efficiency of the radiator, the opening setting portion setting a targeted opening of the flow amount control valve by a feedforward control.

[0013] For example, when an acceleration pedal is operated, a consumption amount of a fuel at the internal combustion engine increases in response to the increase of the speed of the internal combustion engine and a load acted on the internal combustion engine, and the first amount of heat generated at the internal combustion engine increases. In a case where the load of the internal combustion engine increases, the first heat exchanger supplies the second amount of heat to the coolant. The heat amount acquiring portion acquires the first amount of heat, the second amount of heat, and the third amount of heat delivered and received in order to change the temperature level of the coolant to the targeted temperature level. After the acquisition, the targeted dissipation amount setting portion sets the targeted dissipation amount based on the value calculated by adding the first amount of heat, the second amount of heat and the third amount of heat per unit time. The opening setting portion sets the targeted flow amount that is to be supplied to the radiator based on the targeted dissipation amount and the heat exchanging efficiency of the radiator, and the feedforward control setting the opening of the flow amount control valve to the targeted opening is performed.

[0014] That is, in the control, the temperature level of the coolant does not promptly increase like immediately after the operation of the acceleration pedal. Even in a case where the temperature level of the coolant increases after a period of time, the supplying amount of the coolant that is to be supplied to the radiator increases before the temperature level of the coolant increases. Thus, the timing of the dissipation does not delay by the feedforward control that reflects the amount of heat acted on the coolant from the first heat exchanger, and the appropriate heat dissipation amount may be set. Because the flow amount of the coolant is set by the opening of the flow amount control valve, the appropriate heat dissipation amount may be set even through the device uses the coolant pump driven by the internal combustion engine. Accordingly, the cooling control device is configured to include a mechanical pump and manage the temperature level of the internal combustion engine having the heat exchanger of, for example, the EGR cooler, with high precision.

[0015] In the present invention, an amount of heat acquired by the heat amount acquiring portion may include a fourth amount of heat that is exchanged between the coolant and a block part of the internal combustion engine, and a fifth amount of heat that is acquired by a temperature difference between the coolant inside a second heat exchanger and a heat exchanging target and by flow amounts thereof, the second heat exchanger that is separately provided from the radiator and the first heat exchanger.

[0016] The fourth amount of heat and the fifth amount of heat are not as great as the first amount of heat and the second amount of heat, however, influence the temperature level of the coolant. Thus, by the reflection of the fourth amount of heat and the fifth amount of heat to the targeted flow amount of the coolant, the precise management of the temperature level may be achieved with high precision.

[0017] In the present invention, the second heat exchanger may be an oil cooler.

[0018] Accordingly, the heat exchange between the coolant flown inside the oil cooler and the lubricating oil is available.

[0019] In the present invention, in a case where a deviation between the targeted dissipation amount and an amount of heat acquired by the heat amount acquiring portion decreases lower than a predetermined threshold value, a feedback control may be operated to decrease the deviation while a feedforward control is operated.

[0020] By the operation of the feedforward control, the targeted heat amount is dissipated from the coolant and the deviation of the temperature level of the coolant may be decreased. However, because of the control based on the amount of heat, the control may be difficult to be concluded. Accordingly, the precision of the control of the temperature level may be enhanced by switching to the feedback control that decreases the deviation of the temperature level of the coolant further while the feedforward control is performed.

[0021] In the present invention, a targeted response time in which a temperature level of the internal combustion engine is managed may be set, and the opening setting portion may set a targeted opening of the flow amount control valve in response to the targeted response time.

[0022] In a state where the temperature level of the internal combustion engine increase in a short time, for example, when the acceleration pedal is promptly operated, it is difficult to manage the temperature level appropriately even though the control based on the temperature level of the internal combustion engine is performed due to the deficiency of the thermal conduction of the internal combustion engine. Accordingly, the targeted response time is required to be set, the targeted response time for dissipating the required amount of heat until the timing when the boiling of the coolant is assumed. In a case where the temperature level of the internal combustion engine is inhibited from increasing even in a state where the excessive deficiency of the cooling when the acceleration pedal is released is experienced, the targeted response time is required for the dissipation having enough time until elapsing the assumed timing. In this configuration, in a case where the targeted flow amount is set, the temperature level of the internal combustion engine may be appropriately set by setting the opening of the flow amount control valve based on the targeted response time.

DESCRIPTION OF DRAWINGS

[0023]

[Fig. 1] is a view of a configuration of a cooling control device;
[Fig. 2] is a chart illustrating an opening of each of valve portions relative to each of operating amounts of valve bodies;
[Fig. 3] is a block circuit chart of the cooling control device;
[Fig. 4] is a flowchart of cooling control;
[Fig. 5] is a block chart illustrating the relationship of an amount of heat of cooling water;
[Fig. 6] is a chart illustrating a relationship between a valve opening and a water temperature level when controlled; and
[Fig. 7] is a view illustrating a relationship between an amount of wind and an dissipation amount of a radiator.

MODE FOR CARRYING OUT THE INVENTION

[0024] An embodiment of a present invention will hereunder be explained with reference to the drawings.

[Basic configuration]

[0025] As shown in Fig. 1, a cooling control device is configured with a cooling circuit and a control unit 10 (an example of a control portion). The cooling circuit includes a water pump WP, plural flow paths F, heat exchangers, and a flow amount control valve V. The water pump WP sends cooling water (an example of a coolant) of an engine E serving as an internal combustion engine. The plural flow paths F (a superordinate concept of a first flow path F1, a second flow path F2, and a third flow path F3) are formed in parallel to one another. The heat exchangers each is provided at each of the plural flow paths F. The flow amount control valve V controls the flow of the cooling water (an example of the coolant).

[0026] In the cooling control device, a water temperature sensor S (an example of a fluid temperature sensor) detects the water temperature level of the cooling water (coolant), and the control unit 10 controls the flow amount control valve V in response to the detected result to manage the heat exchange between a first supply mode M1 and a second supply mode M2 which will be described later.

[0027] An EGR cooler 1 (a concrete example of a first heat exchanger), an oil cooler 2 (a concrete example of a second heat exchanger), and a radiator 3 are provided as heat exchangers in which the cooling water is controlled by the flow amount control valve V. The water pump WP (a coolant pump) is driven by a crankshaft of the engine E, and is disposed between the flow amount control valve V and the engine E.

[0028] The cooling control device is configured to manage the temperature level of the engine E (the internal combustion engine) of a vehicle of, for example, an automobile. The engine E is assumed to include a configuration having, for example, like a reciprocating engine, a water jacket formed at an area over a cylinder block and a cylinder head. The cooling control device is configured to send the cooling water of the water jacket to the flow paths F, and to return the cooling water to the water jacket by the water pump WP after the supply of the cooling water to the heat exchanger to exchange heat. In addition, the engine E is configured to transmit a drive force from the crankshaft serving as an output shaft to a transmission device. The engine E may not be limited to a reciprocating engine. The engine E does not necessarily apply the drive force directly to the transmission device, and may transmit the drive force to an electric motor of, for example, a hybrid-type vehicle.

[Flow path, heat exchanger]

[0029] The water temperature sensor S is provided at the engine E, and the plural flow paths F are formed in a mode of being divided from a main flow path FM to which the cooling water is sent from the engine E. In the embodiment, the first flow path F1, the second flow path F2, and the third flow path F3 are formed as the plural flow paths F. The EGR cooler 1 is provided at the first flow path F1 as the heat exchanger. The oil cooler 2 is provided at the second flow path F2 as the heat exchanger. The radiator 3 is provided at the third flow path F3 as the heat exchanger.

[0030] A technology, which performs the improvement of an element within a combustion gas by retrieving a part of the combustion gas of the engine E and by returning the part to an intake system, the technology improving the energy consumption, is referred to as Exhaust Gas Recirculation (EGR). The EGR cooler 1 exchanges heat (cools) the part of the exhaust gas retrieved from the engine E by the cooling water.

[0031] The oil cooler 2 includes a configuration in which the lubricating oil reserved in an oil pan 5 of the engine E is supplied by an oil pump 6, and exchanges the heat between the lubricating oil and the coolant. The lubricating oil having the heat exchange at the oil cooler 2 is supplied to an oil pressure operation device of, for example, a variable valve timing control device, or lubricating parts of parts of the engine E. The oil pump 6 corresponds to a variable oil pressure mechanical oil pump that can control the oil pressure level in equal to or higher than two stages, and is driven by the engine E.

[0032] The radiator 3 includes a function managing the temperature level of the engine E by radiating heat of the cooling water, and is supplied with cooling wind by a radiator fan 7. The radiator fan 7 is driven by a fan motor 7M configured as an electric motor.

[Flow amount control valve]

[0033] The flow amount control valve V is rotational type, and houses valve bodies that are rotatable inside a valve case. The flow amount control valve V includes a valve motor VM and a valve sensor VS. The valve motor VM corresponds to the electric motor that rotates the valve bodies. The valve sensor VS detects a rotational angle of the valve bodies. The valve sensor VS corresponds to a hall element and a potentiometer, and can detect the opening of the valve portion of the flow amount control valve V at each of supply modes by detecting the rotational angle of the valve bodies of the flow amount control valve V. Alternatively, the flow amount control valve V may be slide operation type that houses the valve bodies sliding inside the valve case.

[0034] The flow amount control valve V includes a first valve portion V1 opening and closing the first flow path F1, a second valve portion V2 opening and closing the second flow path F2, and a third valve portion V3 opening and closing the third flow path F3. In the flow amount control valve V of this configuration, Fig. 2 illustrates the openings of the first valve portion V1, the second valve portion V2, and the third valve portion V3 relative to the operating amount of the valve bodies. The first valve portion V1, the second valve portion V2, and the third valve portion V3 are collectively referred to as the valve portion.

[0035] Fig. 2 illustrates the openings of the first valve portion V1, the second valve portion V2, and the third valve portion V3 in a longitudinal axis (the opening is shown by percentage), and the operating amounts (rotational amounts) of the valve bodies in a lateral axis. As understood from Fig. 2, when the valve bodies are in the initial position, the first valve portion V1, the second valve portion V2, and the third valve portion V3 are in a fully-closed mode M0 where the first valve portion V1, the second valve portion V2, and the third valve portion V3 are closed, and the cooling water does not flow in the first flow path F1, the second flow path F2, and the third flow path F3.

[0036] Next, by the operation of the valve body in an opening direction from the fully-closed mode M0, the control unit 10 shifts to the first supply mode M1 where the opening of the first valve portion V1 is adjustable while maintaining the second valve portion V2 and the third valve portion V3 in a closed state.

[0037] In addition, by the operation of the valve body from the first supply mode M1 in the opening direction that is beyond the fully-open state of the first supply mode M1, the control unit 10 shifts to the second supply mode M2 in which the opening of the second valve portion V2 is adjustable in a state where the opening of the first valve portion V1 is maintained in a fully-open state (while maintaining the third valve portion V3 in the closed state).

[0038] By operating the valve body from the second supply mode M2 in the opening direction that is beyond the fully-open state of the second supply mode M2, the control unit 10 shifts to the third supply mode M3 in which the opening of the third valve portion V3 is adjustable in a state where the opening of the first valve portion V1 and the opening of the second valve portion V2 are maintained in the fully-open state.

[0039] Specifically, the flow amount control valve V does not supply the cooling water at the second valve portion V2 before the opening of the first valve portion V1 reaches the fully-opening state. Similarly, the flow amount control valve V does not supply the cooling water at the third valve portion V3 before the opening of the second valve portion V2 reaches the fully-opening state.

[Control unit, control mode]

[0040] The control unit 10 manages the whole engine E and manages an amount of heat exchanged in the heat exchanger by controlling the amount of cooling water flown in the flow path F at the flow amount control valve V when the engine E is driven. Specifically, in a case of managing the temperature level of the engine E, the control unit 10 is configured to optimally set the flow amount of cooling water supplied to the radiator 3 by the control of the flow amount control valve V.

[0041] As illustrated in Fig. 3, the control unit 10 is inputted with detected signals from a throttle sensor 21, an engine speed sensor 22, an outside temperature sensor 23, an oil temperature sensor 24, the water temperature sensor S (the example of the fluid temperature sensor), and a valve sensor VS. The control unit 10 outputs control signals to the valve motor VM that controls the opening of the flow amount control valve V, and to the fan motor 7M that drives the radiator fan 7.

[0042] The throttle sensor 21 is configured as, for example, a potentiometer detecting a position (opening) of a throttle of the engine E. The engine speed sensor 22 is configured as, for example, a contactless sensor measuring the speed of a crankshaft of the engine E. The outside temperature sensor 23 is configured as, for example, a thermistor detecting an outside temperature level of a vehicle. The oil temperature sensor 24 is configured as, for example, a thermistor detecting the temperature level of the lubricating oil supplied to the oil cooler 2. The water temperature sensor S is provided at the engine E and is configured as a thermistor.

[0043] The control unit 10 includes, for example, a Central Processing Unit (CPU), a Digital Signal Processor (DSP), and an Application Specific Integrated Circuit (ASIC). The control unit 10 includes a warm-up control portion 11, a heat amount acquiring portion 12, a targeted dissipation amount setting portion 13, an opening setting portion 14, an opening correction portion 15, a wind amount estimation portion 16, and a targeted water temperature setting portion 17. Control modes by these portions will be explained based on a flow chart in Fig. 4, a block diagram in Fig. 5, and a chart in Fig. 6.

[0044] Fig. 5 is a block diagram illustrating a relationship between an amount of heat accumulated in the cooling water and an amount of heat that is to be dissipated by the radiator 3. A first amount of heat Q1 corresponds to an amount of heat acquired from the engine E to the cooling water per unit time when the engine E operates (hereinafter referred to as an engine heat amount), and includes a relationship that is proportional to the speed of the engine E and a load applied thereto. A second amount of heat Q2 corresponds to an amount of heat acquired from the EGR cooler 1 to the cooling water per unit time when the engine E operates (hereinafter referred to as an EGR heat amount), and is calculated by a predetermined EGR percentage relative to the speed of the engine E and the load applied thereto. Here, the amount of intake air may be acquired based on the position (the opening) of the throttle of the throttle sensor 21. When the EGR percentage increases, the second amount of heat Q2 increases, and when the EGR percentage decreases, the second amount of heat Q2 decreases.

[0045] A third amount of heat Q3 corresponds to a total amount of heat of the cooling water delivered and received to change the current temperature level of the cooling water to a targeted water temperature level (hereinafter referred to as a cooling water heat amount), and basically, corresponds to be a value calculated by multiplying the total amount of the cooling water by a value of the difference between the actual water temperature and the targeted water temperature.

[0046] A fourth amount of heat Q4 corresponds to an amount of heat applied per unit time relative to the cooling water via an engine block part constituting an outer wall portion including a cylinder head and a cylinder block of the engine E (hereinafter referred to as an engine block heat amount) and is calculated based on a temperature level of an engine wall and a temperature level of actual water. The engine block heat amount deprives the amount of heat from the cooling water when the engine E is in a low temperature level, and gives the amount of heat to the cooling water when the temperature level of the engine E increases greater than a predetermined temperature level. Because the relationship between the temperature level of the engine wall and the temperature level of actual water is difficult to be identified, the amount of heat is set by a calculation or a table data based on data previously acquired from, for example, the relationship of the operation time of the engine E or the temperature level of actual water. In a case where the engine E is not the reciprocating engine, a part being applied with the amount of heat of the cooling water corresponds to an outer wall part of the engine.

[0047] A fifth amount of heat Q5 corresponds to an amount of heat (hereinafter referred to as an oil heat amount) delivered and received between the oil cooler 2 and the cooling water per unit time when the engine E operates after the warm up, and is calculated by a temperature level of the lubricating oil (lubricating oil is an example of the heat exchanging target), by an amount of lubricating oil flown in the oil cooler 2, by an actual water temperature level, and by an amount of cooling water.

[0048] A third amount of heat Q3' corresponds to a value per unit time in which the third amount of heat Q3 is divided by a targeted response time T, and the amount of heat that is to be dissipated is calculated by the calculation of the total amount (added value) of the first amount of heat Q1, the second amount of heat Q2, the third amount of heat Q3' per unit time, the fourth amount of heat Q4, and the fifth amount of heat Q5. The targeted flow amount of the cooling water that is to be supplied to the radiator 3 is set by considering, for example, the outside temperature and the targeted response time T (see Fig. 6) at a radiator model in order to dissipate the required amount of heat, and the targeted opening of the flow amount control valve V is set in response to the targeted flow amount of the cooling water.

[0049] Two kinds of the targeted response times T for quickly dissipating the heat (quick dissipation) and for dissipating the heat with an enough length of time (controlled dissipation) are set. That is, the targeted response time T for quick dissipation corresponds to a value showing the time that cannot be elapsed until the dissipation of the amount of heat to be dissipated is completed when the control increasing the flow amount of the cooling water is operated by the flow amount control valve V. The targeted response time T for controlled dissipation corresponds to a value showing the time that cannot be less until the dissipation of the amount of heat to be dissipated is completed when the control decreasing the flow amount of the cooling water is operated by the flow amount control valve V. The targeted response times T are set based on, for example, the acceleration operation, the speed of the engine, and the opening of the flow amount control valve V.

[0050] The reason why the targeted response times T are set is as follows. For example, like a case where the acceleration pedal is operated rapidly, in a state where the temperature level of the engine E increases in a short time, the appropriate management of the temperature level is difficult even the control based on the temperature level of the engine E is performed because of the lack of the thermal conduction of the engine E. Thus, it is required to assume the timing of the boiling of the coolant and to dissipate the amount of heat required to inhibit the coolant from boiling until the assumed timing. Hence, the targeted response time T for the quick dissipation is set.

Similarly, in a state where the excessive failure of cooling is incurred in a case where the operation of the acceleration pedal is released, the targeted response time T for inhibiting the temperature level of the engine E from increasing is set.

[0051] Accordingly, for example, in a case where the flow amount of the cooling water increases, the target opening of the flow amount control valve V is largely set as the targeted response time T for quick dissipation decreases.

[0052] In the cooling control device, when the control of any one of the first supply mode M1, the second supply mode M2, and the third supply mode M3 is operated, the opening setting portion 14 sets the opening of the flow amount control valve V based on the speed of the engine E (the speed per unit time) and the targeted response time T (see Fig. 6). That is, the speed of the engine E is considered because the water pump P is driven at the engine E. The targeted response time T shown in Fig. 6 is used as a switching timing for control in which the feedforward control FF and the feedback control FB are concurrently operated from the feedforward control FF.

[0053] As a specific control mode, as shown in a flowchart in Fig. 4, a cooling control is performed in response to the startup of the engine E, and in a case where the water temperature level (the actual water temperature level) detected by the water temperature level sensor S is lower than a set value, and in a case where the warm up operation is required, the warm up operation is performed by the maintenance of the flow amount control valve V in the fully-closed mode M0 (Step #01 to Step #03).

[0054] This warm up operation is achieved by the control of the warm up control portion 11. In this warm up operation, the first valve portion V1 is released after the actual water temperature level increases up to a value suitable for the heat exchange at the EGR cooler 1. In the first supply mode M1, the flow amount of the cooling water supplied to the first flow path F1 increases by the increase of the opening of the first valve portion V1 in response to the increase of the actual water temperature level.

[0055] Subsequently, after the actual water temperature level further increases and the opening of the first valve portion V1 exceeds 100 percent (after the actual water temperature level reaches equal to or greater than a predetermined value), the second valve portion V2 opens. In the second supply mode M2, the flow amount of the cooling water supplied to the second flow path F2 may be increased by the increase of the opening of the second valve portion V2 in response to the increase of the actual water temperature level.

[0056] Next, when the actual water temperature level further increases and exceeds a predetermined value, the cooling control device shifts to the third supply mode M3 and the third valve portion V3 starts opening. As such, in a case where the radiator 3 is supplied with the cooling water, the radiator 3 is supplied with a cooling wind by the drive of the fan motor 7M. In a case where the vehicle runs fast enough for the radiator 3 to receive the cooling wind enough, or in a case where the water temperature level is low enough, the fan motor 7M is not driven.

[0057] Specifically, in the third supply mode M3, as illustrated in Fig. 6, the feedforward control FF starts to have an appropriate flow amount without an incurrence of the hunting. To establish the feedforward control FF, as described before, the first heat amount Q1 per unit time as the engine heat amount, the second amount of heat Q2 per unit time as the EGR cooler heat amount, the third amount of heat Q3' per unit time, and the fourth amount of heat Q4 per unit time as the engine block heat amount, and the fifth amount of heat per unit time as the oil heat amount are acquired.

[0058] A positive reference numeral (plus) is added for the ones of the first amount of heat Q1, the second amount of heat Q2, the fourth amount of het Q4, the fifth amount of heat Q5, the ones that apply the amount of heat to the cooling water. A negative reference numeral (minus) is added for the others of the first amount of heat Q1, the second amount of heat Q2, the fourth amount of heat Q4, the fifth amount of heat Q5, the ones that deprive the amount of heat from the cooling water. The third amount of heat Q3 is applied with the positive reference numeral (plus) when the radiator 3 dissipates heat to be changed to a target temperature level, and is applied with the negative reference numeral (minus) when the radiator 3 receives heat to be changed to a targeted temperature level. Furthermore, the targeted dissipation amount setting portion 13 calculates the targeted dissipation amount that is to be dissipated from a total value of these amounts of heat (total of Q1, Q2, Q3', Q4, Q5) (Step #04, Step #05).

[0059] For example, in a case where the speed of the engine E and the load acted on the engine E increase, or in a case where the EGR percentage increases by the operation of the acceleration pedal, the fuel consumption of the engine E increases. Accordingly, the amount of heat generated at the engine E increases, and the first amount of heat Q1 applied to (accumulated in) the cooling water increases in response to the increase of the consumption of the engine E. Because a part of an exhaust gas of the engine E is supplied to the EGR cooler 1, the second amount of heat Q2 applied to the cooling water increases at the EGR cooler 1 in a case where the speed of the engine E and the load applied to the engine E increases.

[0060] That is, because the second amount of heat Q2 applied to the cooling water at the EGR cooler 1 is in proportion to the first amount of heat Q1, the second amount of heat Q2 is acquired by the multiplication of the first amount of heat Q1 by a coefficient preset as the EGR percentage. The first amount of heat Q1 and the second amount of heat Q2 are acquired based on detection results of the throttle sensor 21.

[0061] For example, in a case where the temperature level of the engine E increases, and the amount of heat is applied to the cooling water from the oil cooler 2 (in a case where the lubricating oil temperature level increases greater than the actual water temperature level), the fifth amount of heat Q5 includes a relationship corresponding to the temperature level of the lubricating oil, the lubricating oil amount supplied to the oil cooler 2, the temperature level of the cooling water, and the amount of the cooling water. Thus, the amount of lubricating oil supplied to the oil cooler 2 by the discharging pressure level of the oil pump 6 is acquired, and the temperature level of the lubricating oil is detected by the oil temperature sensor 24, and the fifth amount of heat Q5 is acquired by the calculation using the amount and the temperature level of the lubricating oil.

[0062] The fourth amount of heat Q4 is acquired by the calculation and the table data as described above.

[0063] The third amount of heat Q3' per unit time corresponds to the cooling water heat amount per unit time calculated by the division of the third amount of heat Q3 by the targeted response time T.

[0064] The amount of heat acquired by the total sum of the first amount of heat Q1, the second amount of heat Q2, the third amount of heat Q3' per unit time, the fourth amount of heat Q4, and the fifth amount of heat Q5 corresponds to the amount of heat that is to be dissipated. The targeted dissipation amount setting portion 13 sets the total amount of heat acquired by the calculation as a targeted dissipation amount. The opening setting portion 14 sets the flow amount of the cooling water supplied to the radiator 3. The opening setting portion 14 sets the targeted opening of the third valve portion V3 of the flow amount control valve V, and the opening of the third valve portion V3 of the flow amount control valve V is set based on the setting of the targeted opening of the third valve portion V3, and the flow amount control valve V is controlled (Step #06, Step#07).

[0065] As described above, because the water pump WP is driven by the engine E, the discharging amount varies in response to the speed of the engine E (the speed per unit time). The amount of heat exchanged in the radiator 3 is influenced by, for example, the outside temperature, the temperature level of the cooling water, the amount of wind supplied to the radiator 3, and the radiation heat efficiency of the radiator 3.

[0066] Accordingly, in a case where the opening setting portion 14 controls the opening of the flow amount control valve V, the targeted opening is set based on the outside temperature detected by the outside temperature sensor 23 and a radiator model in which the amount of cooling wind relative to the radiator 3 estimated by the wind amount estimation portion 16, and the amount and the targeted temperature level of the cooling water supplied by the water pump WP.

[0067] An example of a concept of the radiator model is illustrated in Fig. 7. The dissipation amount of the radiator is determined by a three dimensional map of the amount of wind, the flow amount, and the difference between the water temperature and the outside temperature. Among all, the dissipation amount of the radiator is in proportion to the difference between the water temperature and the outside temperature. That is, the dissipation level of the radiator per Celsius of the difference between the water temperature and the external temperature is determined by the amount of wind and the flow amount by the normalization of per Celsius of the difference between the water temperature and the external temperature. Thus, the flow amount that is a control target may be acquired by a two dimensional map of the dissipation amount of the radiator per Celsius of the difference between the water temperature and the amount of wind acquired by the relationship of the receipt and dissipation of the heat. As illustrated in Fig. 7, a longitudinal axis (Y axis) corresponds to ΔT (targeted water temperature minus outside temperature), that is, the dissipation amount per Celsius, and a lateral axis (X axis) corresponds to the amount of wind. The targeted dissipation amount Ex corresponds to ΔT, that is, the targeted dissipation amount per Celsius, and is calculated by a formula of EX = (Q1+Q2+Q3'+Q4+Q5/(the targeted water temperature minus the outside temperature).

[0068] The wind amount estimation portion 16 estimates a wind amount Fx when the vehicle runs and a wind amount Fx when the vehicle is in a stop state by the running speed of the vehicle and the driving speed of the fan motor 7M. The targeted dissipation amount setting portion 13 sets the targeted dissipation amount EX based on the outside temperature, the targeted water temperature, and a required dissipation amount.

[0069] The calculation setting the targeted opening is operated based on the wind amount Fx and the targeted dissipation amount Ex. As a means setting the targeted opening, the table data in which the opening of the flow amount control valve V relative to the plural targeted flow amounts is previously calculated may be referred.

[0070] Then, as illustrated in Fig. 6, the feedforward control FF is operated, and at the timing when the targeted response time T elapses from the start of the operation, the control shifts to the feedback control FB while the feedforward control FF is performed (control performing two controls concurrently) (Step #08, Step #09).

[0071] It is assumed that the above-described feedback control FB is reflected to the valve control by generating, for example, a correction coefficient for correcting the opening of the flow amount control valve V in the control performing the feedforward control FF. Even in a state where the feedforward control FF and the feedback control FB operate concurrently, the control shifts to the feedforward control FF only in a case where, for example, the targeted water temperature varies.

[0072] That is, as illustrated in Fig. 6, the feedforward control FF operates until the targeted response time T elapses from the start of the operation, and when the targeted response time T elapses, the feedforward control FF and the feedback control FB operate concurrently (an area illustrated with FF+FB in Fig. 6). By this control, an added value of the openings is set as the opening of the flow amount control valve V, the added value in which the opening set by the feedforward control FF illustrated as FF component in Fig. 6 is added to the opening set by the feedback control FB illustrated as FB component in Fig. 6.

[0073] Furthermore, in a case where the targeted water temperature varies, the feedforward control FF operates again. By the shift to the control in which the feedforward control FF and the feedback control FB operate concurrently as described above after the targeted response time T elapses from the reoperation of the feedforward control FF, the added value of the opening set by the feedforward control FF illustrated as the FF component and the opening degree of the valve set at the feedback control FB illustrated as the FB component is set as the opening of the flow amount control valve V.

[0074] The control operates repeatedly until being reset (basically, until the engine E stops) (#Step 010).

[0075] As is clear from Fig. 6, it is understood that the actual water temperature is concluded to the targeted water temperature by the operation of the feedback control FB concurrent with the feedforward control FF.

[Action and effect of the embodiment]

[0076] As such, in a case where the temperature management of the engine E is operated by the supply of the cooling water to the radiator 3, because the first amount of heat Q1 generated in response to the drive of the engine E by calculating the load acted on the engine E by the throttle sensor 21, and the second amount of heat Q2 supplied from the EGR cooler to the cooling water, are calculated, the first amount of heat Q1 and the second amount of heat Q2 are relatively easily acquired.

[0077] The third amount of heat Q3 is acquired by the current water temperature (the actual water temperature), the total amount of cooling water set as a fixed number, a specific heat of the cooling water, and the targeted water temperature.

[0078] In addition, the fourth amount of heat Q4 dissipated from the engine E may be easily expressed as variables based on the actual measured value based on the outside temperature. The fifth amount of heat Q5 may be calculated by the lubricating oil temperature, the lubricating oil amount flown in the oil cooler 2, the actual water temperature and the amount of the cooling water.

[0079] From this, by the calculation of the first amount of heat Q1, the second amount of heat Q2, the third amount of heat Q3 per unit time, the fourth amount of heat Q4, and the fifth amount of heat Q5, and by the summation of Q1, Q2, Q3', Q4, Q5, the amount of heat that is to be dissipated may be set, and the feedforward control FF setting the opening of the flow amount control valve V may be established.

[0080] In the feedforward control FF, the cooling water dissipates the targeted amount of heat, and the deviation of the water temperature is decreased. However, because the control is based on the amount of heat, the control may be difficult to be concluded. Accordingly, the feedforward control FF operates concurrently at the timing when the targeted response time T elapses from the start of the feedforward control FF, and the targeted opening of the flow amount control valve V is corrected by the feedback control FB in response to the detection result of the water temperature sensor S based on the decrease of the deviation of the temperature level of the cooling water. Accordingly, the steady-state deviation may be concluded by the temperature control of the cooling water within the variation width of the cooling water, the accuracy of the temperature control may be enhanced, and the hunting does not occur.

[0081] The supplying amount of the cooling water may be considered to be controlled with high precision by the use of the water pump driven by the electric motor for the management of the temperature level of the engine E. However, as the configuration of the present invention, the device setting the flow amount of the cooling water by the setting of the opening of the flow amount control valve V may use of the water pump WP that is driven by the engine E, which leads to cost reduction.

[Other embodiments]

[0082] The present invention may be configured as below other than the aforementioned embodiment (components including the same functions as those of the embodiment are marked with common numbers or reference numerals as those of the embodiment).

(a) In the embodiment, the first flow path F1, the second flow path F2, and the third flow path F3 are formed in parallel to one another. Alternatively, a part of the first flow path F1, the second flow path F2, and the third flow path F3 may be disposed in series. Moreover, a flow path F other than the first flow path F1, the second flow path F2, and the third flow path F3 may be formed, and for example, a heat exchanger such as a heater core may be provided. In a case where such a heater core is provided, the temperature management may be achieved by the control that is basically common to the control of the embodiment only by the setting of the control mode of the heat amount acquiring portion 12 so as to decrease the amount of heat deprived from the cooling water by the heat exchange by the heater core from the total amount of heat explained in the embodiment.

(b) In the embodiment, the first valve portion V1, the second valve portion V2, and the third valve portion V3 are provided as the flow amount control valve V. In the present invention, because the amount of the cooling water supplied to the radiator 3 has only to be able to be controlled, a device, including a configuration that can control the flow amount of the cooling water that is flown only in the flow path F1, may be applied.

(c) The first heat exchanger may be a turbo charger, the second heat exchanger may be an automatic transmission fluid cooler or an ATF, or a heater, and the outside temperature sensor may be an intake air temperature sensor.

INDUSTRIAL APPLICABILITY

[0083] The present invention may be applied to a cooling control device performing a temperature management of an internal combustion engine using a coolant.

EXPLANATION OF REFERENCE NUMERALS

[0084]

1 first heat exchanger (EGR cooler)
2 second heat exchanger (oil cooler)
3 radiator
10 control portion (control unit)
12 heat amount acquiring portion
13 targeted dissipation amount setting portion
14 opening setting portion
15 opening correcting portion
E internal combustion engine (engine)
F flow path (first flow path)
V flow amount control valve
WP coolant pump (water pump)
Q1 first amount of heat
Q2 second amount of heat
Q3 third amount of heat
Q4 fourth amount of heat
Q5 fifth amount of heat

Claims

1. A cooling control device comprising:

a radiator to which a coolant of an internal combustion engine is supplied;
a first heat exchanger, other than the radiator, exchanging heat with the coolant;
a coolant pump being driven by the internal combustion engine to circulate the coolant;
a flow amount control valve setting a flow amount of the coolant; and
a control portion setting an opening of the flow amount control valve; wherein

the control portion includes

a heat amount acquiring portion acquiring a first amount of heat, a second amount of heat, and a third amount of heat, the first amount of heat that is applied to the coolant by the internal combustion engine in response to a speed of the internal combustion engine and a load applied thereto, the second amount of heat that is applied to the coolant by the first heat exchanger, the third amount of heat that is delivered and received to change a temperature level of the coolant to a targeted temperature level;
a targeted dissipation amount setting portion setting a targeted dissipation amount based on an added value of the first amount of heat, the second amount of heat, and a third amount of heat per unit time acquired by the heat amount acquiring portion; and
an opening setting portion setting a targeted flow amount of the coolant that is to be supplied to the radiator based on the targeted dissipation amount being set by the targeted heat dissipation amount setting portion and based on a heat exchanging efficiency of the radiator, the opening setting portion setting a targeted opening of the flow amount control valve by a feedforward control.

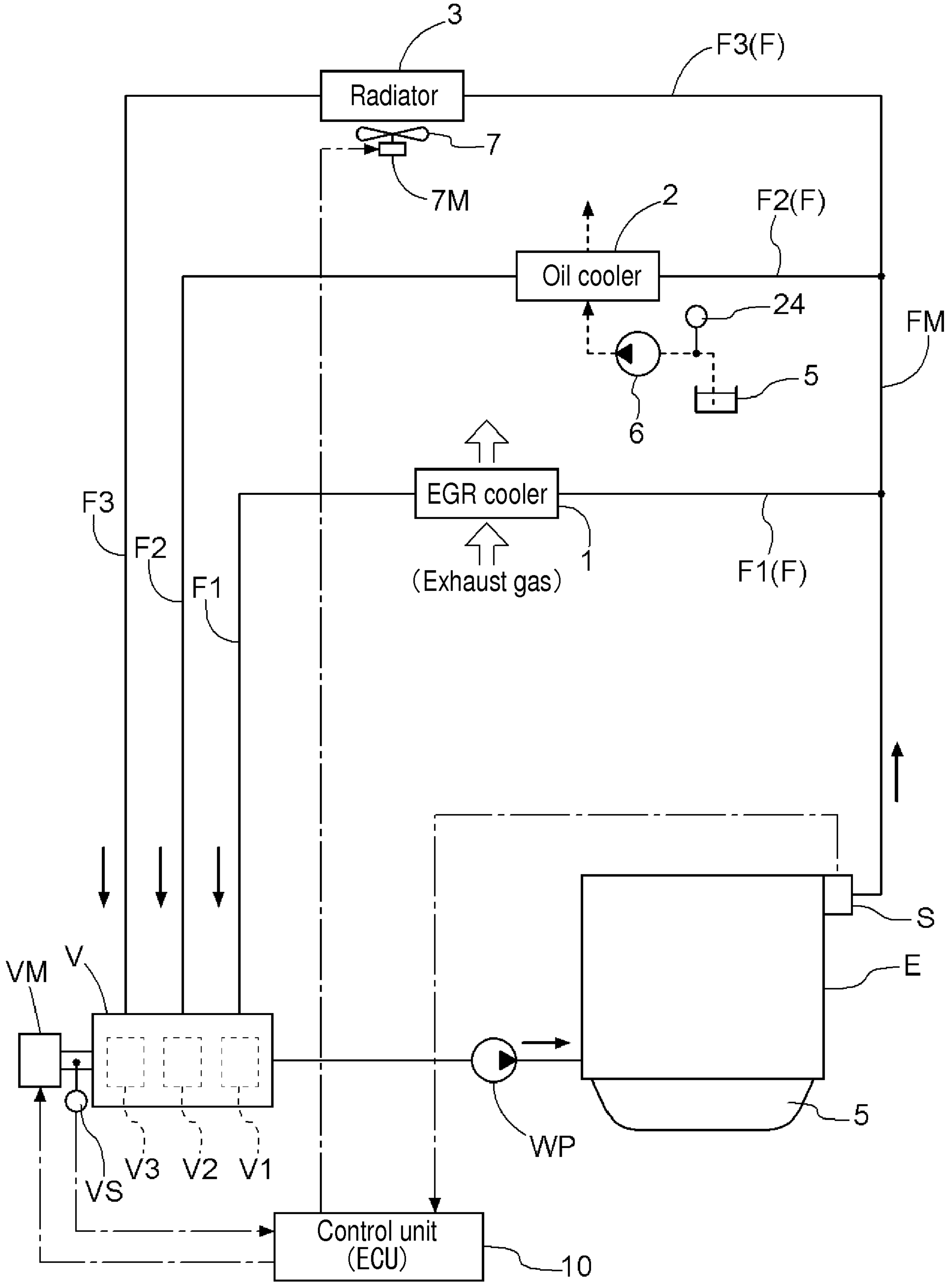
2. The cooling control device according to claim 1, wherein
an amount of heat acquired by the heat amount acquiring portion includes a fourth amount of heat that is exchanged between the coolant and a block part of the internal combustion engine, and a fifth amount of heat that is acquired by a temperature difference between the coolant inside a second heat exchanger and a heat exchanging target and by flow amounts thereof, the second heat exchanger that is separately provided from the radiator and the first heat exchanger.

3. The cooling control device according to claim 2, wherein the second heat exchanger corresponds to an oil cooler.

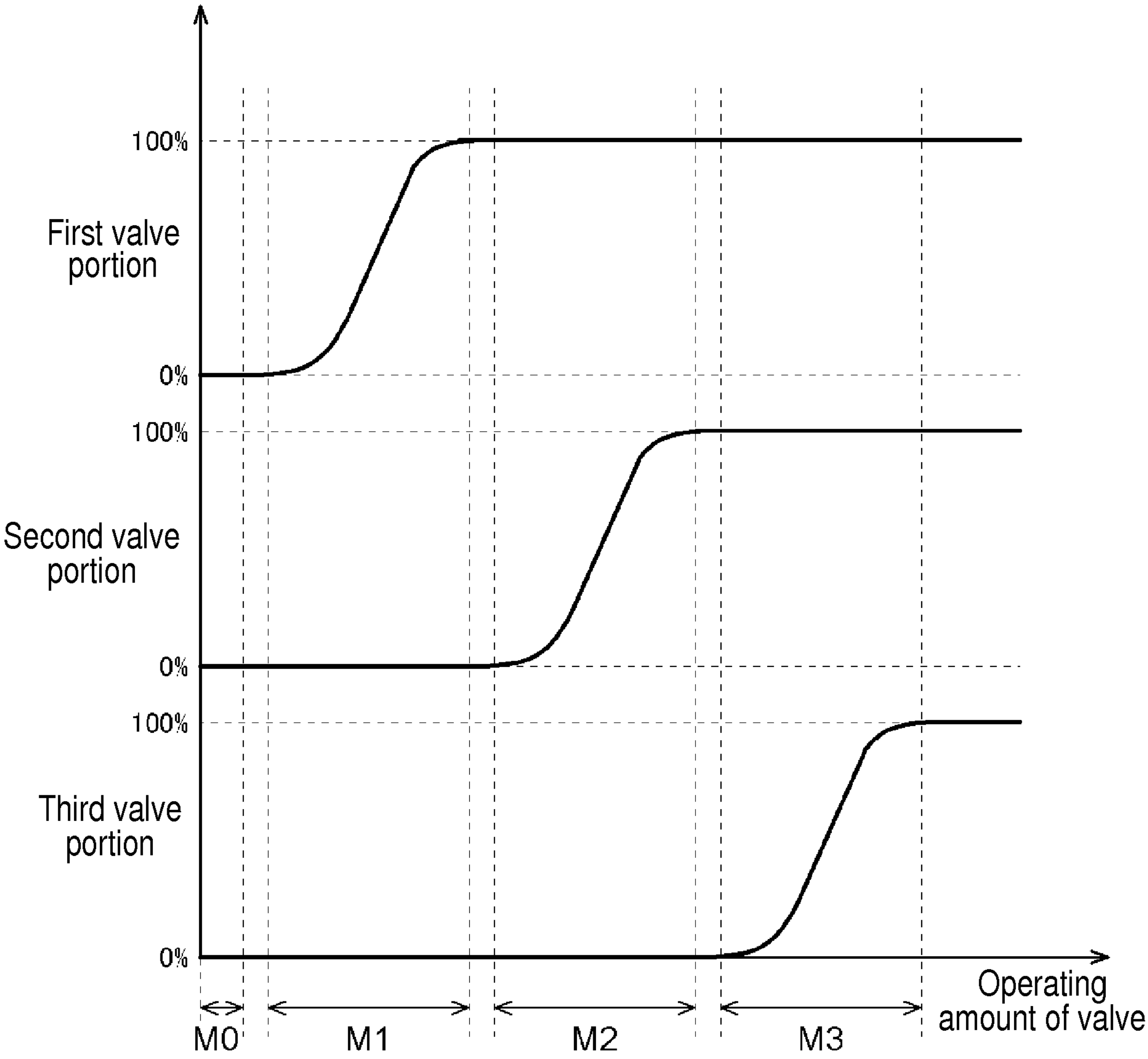
4. The cooling control device according to one of claims 1 to 3, wherein in a case where a deviation between the targeted dissipation amount and an amount of heat acquired by the heat amount acquiring portion decreases lower than a predetermined threshold value, a feedback control is operated to decrease the deviation while a feedforward control is operated.

5. The cooling control device according to one of claims 1 to 4, wherein
a targeted response time in which a temperature level of the internal combustion engine is managed is set; and
the opening setting portion sets a targeted opening of the flow amount control valve in response to the targeted response time.

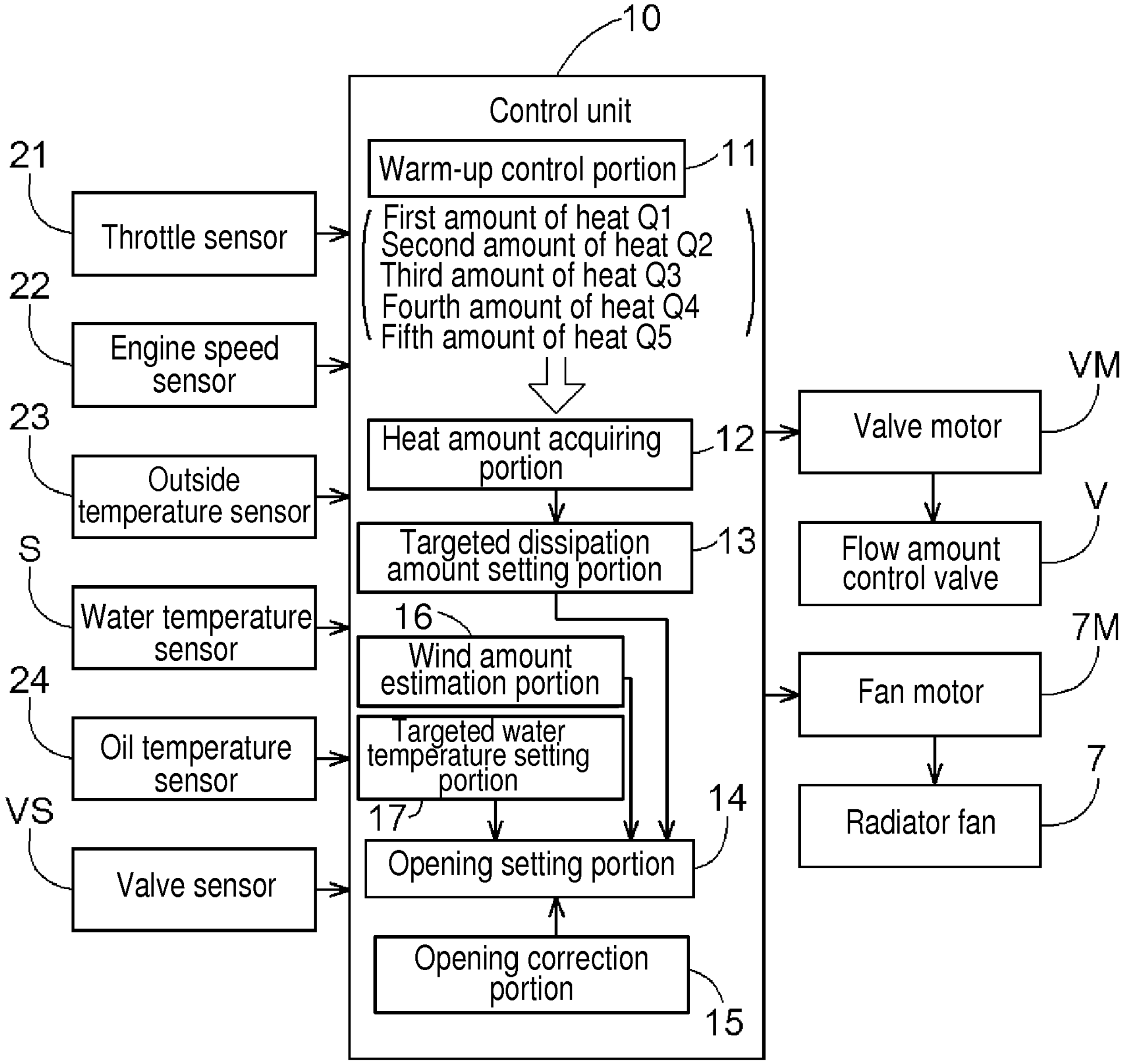
FIG. 1


3
Radiator
F3(F)
7
7M
2
F2(F)
Oil cooler
24
FM
5
6
EGR cooler
F3
F2
F1
1
(Exhaust gas)
F1(F)
S
E
VM
V
5
WP
V3
V2
V1
VS
Control unit
(ECU)
10

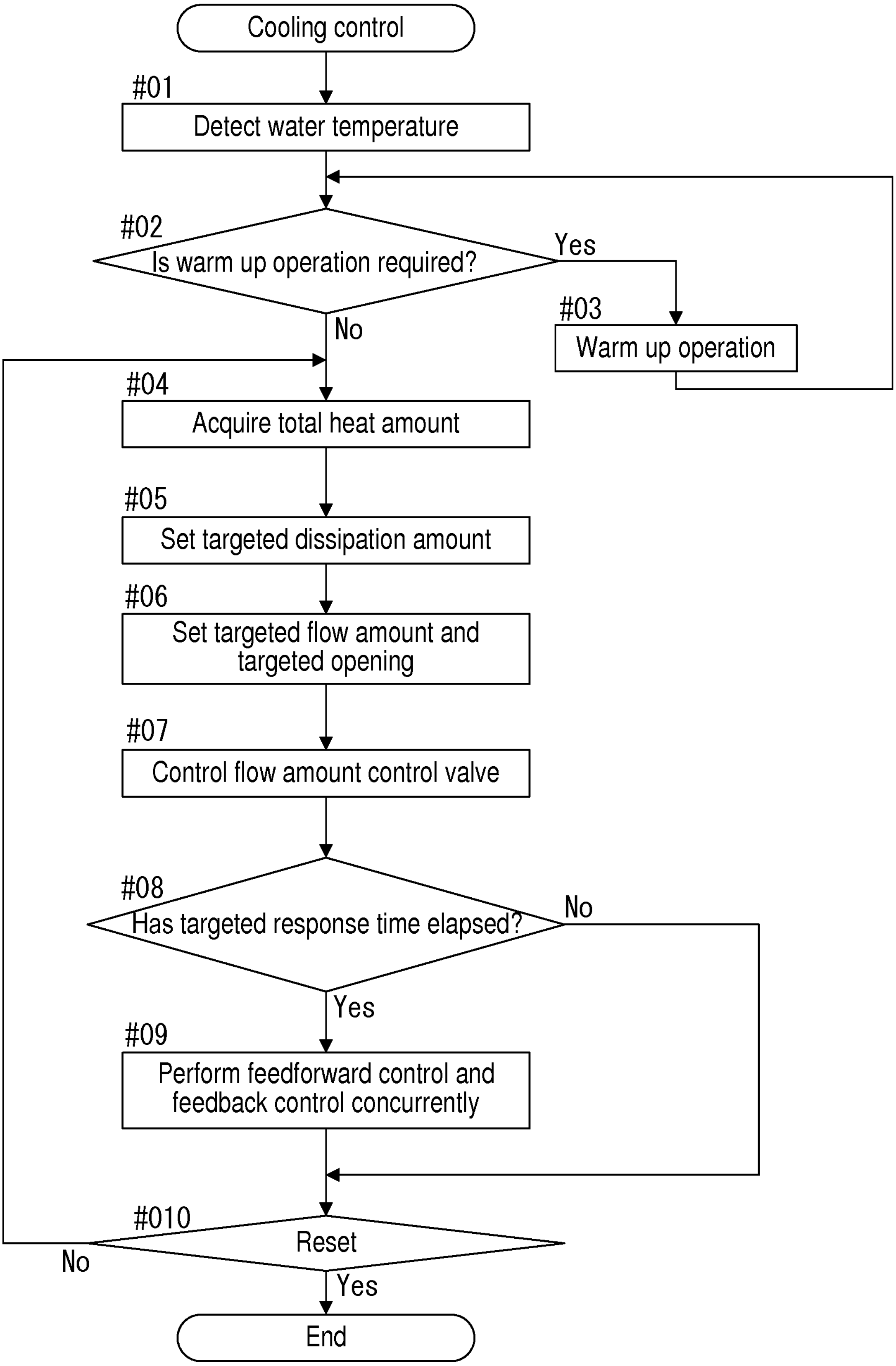
F I G. 2


100%
First valve portion
0%
100%
Second valve portion
0%
100%
Third valve portion
0%
Operating amount of valve
M0
M1
M2
M3

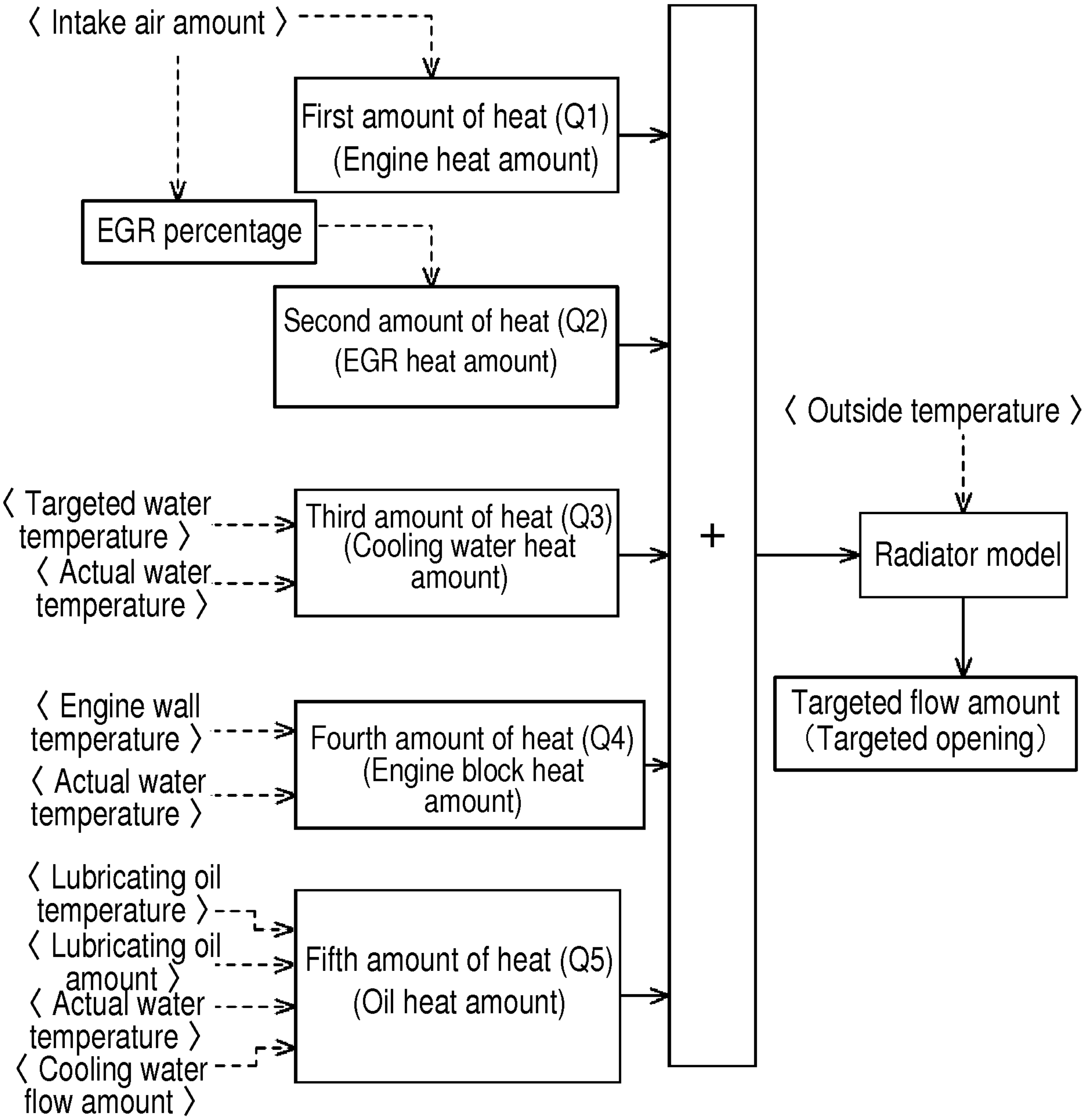
F I G. 3


10
Control unit
Warm-up control portion
11
First amount of heat Q1
Second amount of heat Q2
Third amount of heat Q3
Fourth amount of heat Q4
Fifth amount of heat Q5
Heat amount acquiring portion
12
Targeted dissipation amount setting portion
13
16
Wind amount estimation portion
Targeted water temperature setting portion
17
Opening setting portion
14
Opening correction portion
15
21
Throttle sensor
22
Engine speed sensor
23
Outside temperature sensor
S
Water temperature sensor
24
Oil temperature sensor
VS
Valve sensor
VM
Valve motor
V
Flow amount control valve
7M
Fan motor
7
Radiator fan

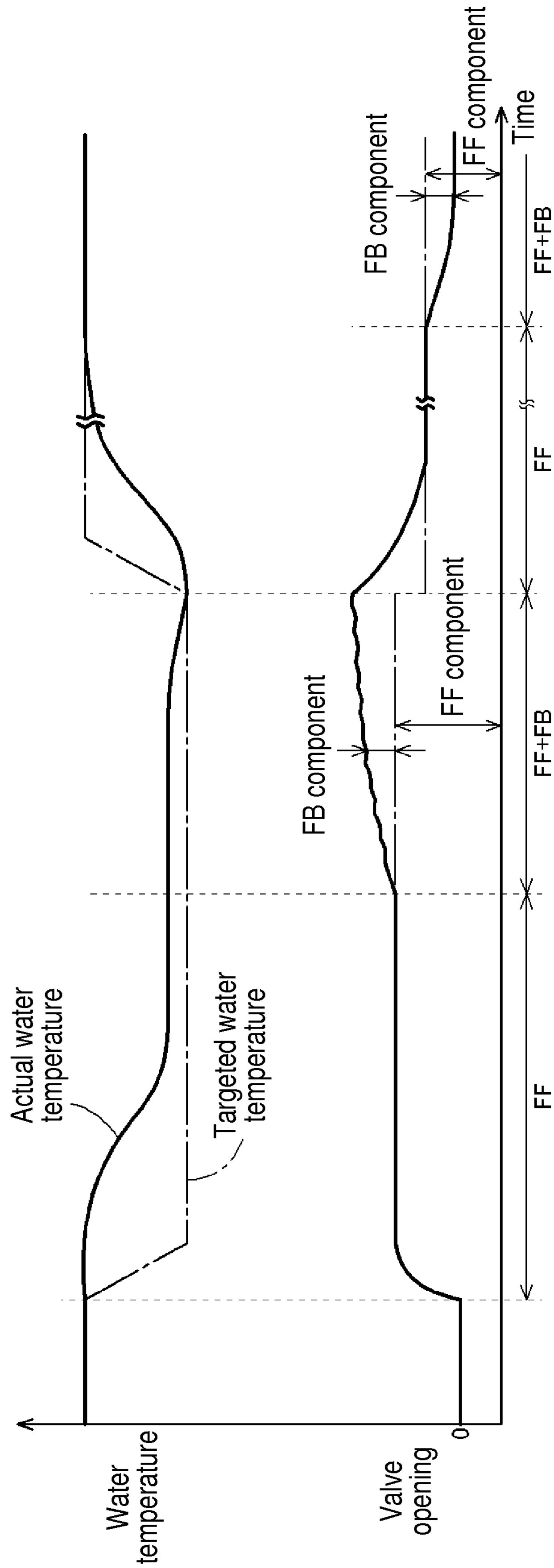
F I G. 4


Cooling control
#01
Detect water temperature
#02
Is warm up operation required?
Yes
#03
Warm up operation
No
#04
Acquire total heat amount
#05
Set targeted dissipation amount
#06
Set targeted flow amount and targeted opening
#07
Control flow amount control valve
#08
Has targeted response time elapsed?
No
Yes
#09
Perform feedforward control and feedback control concurrently
#010
Reset
No
Yes
End

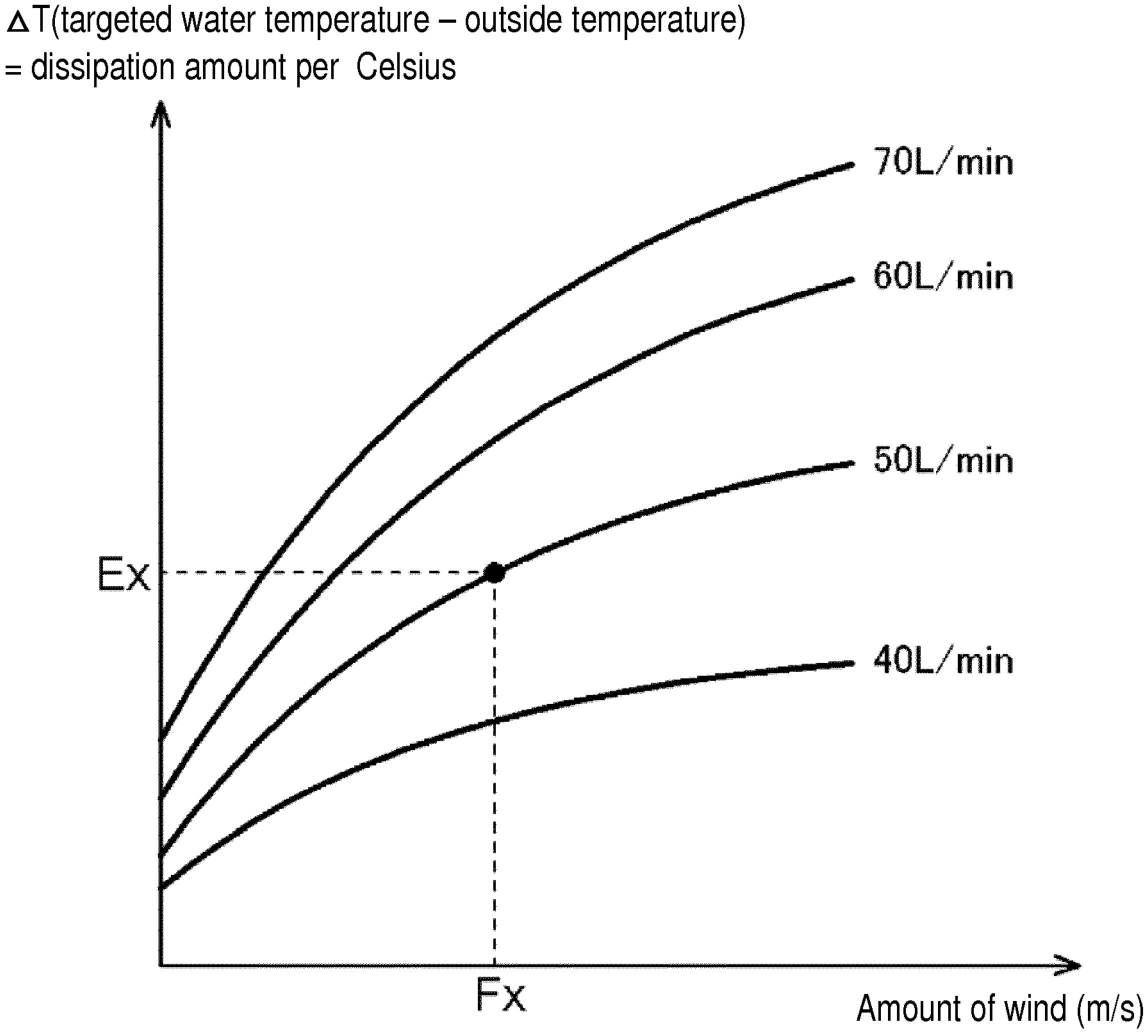
F I G. 5


〈 Intake air amount 〉
First amount of heat (Q1)
(Engine heat amount)
EGR percentage
Second amount of heat (Q2)
(EGR heat amount)
〈 Targeted water temperature 〉
〈 Actual water temperature 〉
Third amount of heat (Q3)
(Cooling water heat amount)
〈 Engine wall temperature 〉
〈 Actual water temperature 〉
Fourth amount of heat (Q4)
(Engine block heat amount)
〈 Lubricating oil temperature 〉
〈 Lubricating oil amount 〉
〈 Actual water temperature 〉
〈 Cooling water flow amount 〉
Fifth amount of heat (Q5)
(Oil heat amount)
+
〈 Outside temperature 〉
Radiator model
Targeted flow amount
(Targeted opening)

F I G. 6


Water temperature
Valve opening
0
Actual water temperature
Targeted water temperature
FB component
FF component
FB component
FF component
Time
FF
T
FF+FB
FF
T
FF+FB

F I G. 7


ΔT(targeted water temperature – outside temperature)
= dissipation amount per Celsius
70L/min
60L/min
50L/min
40L/min
Ex
Fx
Amount of wind (m/s)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/076811

A. CLASSIFICATION OF SUBJECT MATTER
F01P7/16(2006.01)i, *F01P3/20*(2006.01)i, *F02M26/23*(2016.01)i

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)
F01P7/16, F01P3/20, F02M26/23

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-239742 A (Toyota Motor Corp.), 27 August 2003 (27.08.2003), paragraphs [0039] to [0057]; fig. 5 to 7 & US 2003/0150406 A1 paragraphs [0062] to [0083]; fig. 5 to 7 & EP 1336734 A2	1-5
Y	JP 10-8960 A (Mitsubishi Motors Corp.), 13 January 1998 (13.01.1998), paragraphs [0019] to [0033]; fig. 1 to 4 (Family: none)	1-5
Y	JP 2012-102639 A (Daihatsu Motor Co., Ltd.), 31 May 2012 (31.05.2012), paragraphs [0026] to [0032]; fig. 3 (Family: none)	4

☒ 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
14 October 2016 (14.10.16)	25 October 2016 (25.10.16)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/076811

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2006/0288967 A1 (JOYCE, Steven), 28 December 2006 (28.12.2006), entire text; all drawings & GB 2425619 A	1-5

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

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 2014218938 A **[0006]**
- JP 2005248903 A **[0006]**