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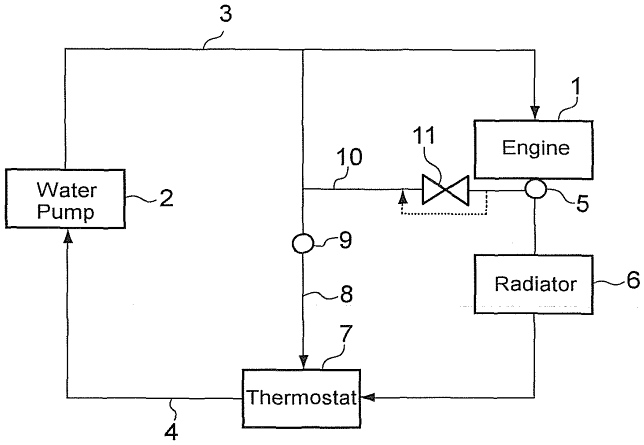
(54) COOLING CONTROLLER FOR INTERNAL COMBUSTION ENGINES

(57) A cooling control system for an engine is provided. Cooling water circulate within a cooling circuit via a water pump and the engine, and a bypass circuit is formed to circulate the cooling water without passing through the engine. A first temperature sensor is disposed on the cooling circuit, and a second temperature sensor is disposed on the bypass circuit to detect a temperature of the cooling water. A switching valve controls a flow rate of the cooling water flowing through the cooling circuit, and the switching valve is provided with a water passage that allows the cooling water to flow therethrough when is closed. The cooling control system is configured to estimate an amount of clogging of the water passage based on a temporal change in a temperature difference between temperatures of the cooling water detected by the first temperature sensor and the second temperature sensor, under a condition in that the engine is stopped, the switching valve is closed, and the water pump is driven.

Fig. 12



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Description

TECHNICAL FIELD

[0001] The present invention relates to a controller for a cooling system of an internal combustion engine, and more particularly, to a system for controlling circulation of cooling water.

BACKGROUND ART

[0002] An internal combustion engine is heated by burning fuel, and if a temperature thereof is raised excessively, an abnormal combustion is caused and an energy efficiency of the engine is worsened. Therefore, the engine is provided with a cooling system. In the conventional art, the engine is cooled by a water cooling method, an oil cooling method, and an air cooling method. The abnormal combustion would be caused if the engine is cooled insufficiently, and by contrast, fuel combustion would be hindered if the engine is cooled excessively regardless of the cooling method.

[0003] For example, Japanese Patent No.4883225 describes a cooling system for a vehicle comprised of a first water circuit for circulating cooling water through an internal combustion engine, and a second water circuit for circulating the cooling water through a waste heat recovery system without passing through the internal combustion engine. According to the teachings of Japanese Patent No.4883225, a flow rate of the cooling water circulating in the first water circuit is reduced by reducing an opening degree of a valve, and the cooling waters in those circuits are mixed by increasing an opening degree of the valve. To this end, a valve element of the valve has a hole for letting through the cooling water even if the valve is closed. The cooling system is configured to judge the valve stuck at a closing position if a temperature of the water in the first cooling circuit is higher than a predetermined value, and a difference between temperatures of the cooling waters in the first cooling circuit and the second cooling water circuit is greater than a predetermined other value.

[0004] Japanese Patent Laid-Open No.2007-46469 describes a waste heat recovery system having a cooling passage branching out of a radiation circuit for cooling an engine to let the cooling water through a heat recovery device. A valve is disposed on the cooling passage, and the valve is comprised of a through hole for flowing cooling water, and a narrow hole perpendicular to the through hole. Given that the valve is turned to be opened, the through hole is connected to the cooling passage so that the cooling water is allowed to flow through the cooling passage. By contrast, given that the valve is turned to be closed, the through hole is oriented to be perpendicular to the cooling passage. In this case, however, the narrow hole is connected to the cooling passage so that the cooling water is still allowed to be delivered to the cooling passage in a small amount through the narrow hole.

[0005] According to the cooling system taught by Japanese Patent No.4883225, the cooling water is still allowed to flow through the hole formed in the valve element even if a valve sticks at a position where an opening degree of the valve is narrow. However, if the hole is clogged by foreign matter, the cooling water would not be allowed to circulate within the first cooling circuit.

DISCLOSURE OF THE INVENTION

[0006] In order to solve the foregoing technical problems, it is therefore an object of this invention to provide a cooling control system for an internal combustion engine that can estimate a clogging amount of a hole for letting through coolant with improved accuracy even if a valve is closed.

[0007] The cooling control system is comprised of: a cooling circuit for circulating cooling water via a water pump and the engine to cool the engine; a bypass circuit for circulating the cooling water without passing through the engine; a first temperature sensor that is disposed on the cooling circuit to detect a temperature of the cooling water flowing therethrough; a second temperature sensor that is disposed on the bypass circuit to detect a temperature of the cooling water flowing therethrough; a switching valve that is closed to reduce a flow rate of the cooling water flowing through the cooling circuit, and that is opened to increase the flow rate of the cooling water flowing through the cooling circuit; and a water passage that allows the cooling water to flow through the cooling circuit in a small amount when the switching valve is closed. In order to achieve the above-explained objective, according to the present invention, the cooling control system is provided with an estimation means that is configured to estimate an amount of clogging of the water passage based on a temporal change in a temperature difference between a temperature of the cooling water detected by the first temperature sensor and a temperature of the cooling water detected by the second temperature sensor, under a condition in that the engine is stopped, the switching valve is closed, and the water pump is driven.

[0008] The estimation means may be configured to estimate the amount of clogging of the water passage by subtracting the temperature difference of a case in which the water pump is not driven from the temperature difference of a case in which the water pump is driven, in case an external temperature is lower than a predetermined temperature.

[0009] The estimation means may also be configured to estimate a current amount of clogging of the water passage while reducing a drive frequency of the water pump to be less than that of the previous case if a current estimated value of the amount of clogging is smaller than a first threshold value. In this case, if the current estimated value of the amount of clogging is larger than the first threshold value, the estimation means estimates a current amount of clogging of the water passage while increasing the drive frequency of the water pump to be more than that of the previous case.

[0010] The estimation means may also be configured to estimate the amount of clogging of the water passage by increasing the drive frequency of the water pump with an increase in a speed of a vehicle having the engine.

[0011] The estimation means may also be configured to estimate the amount of clogging of the water passage while increasing the drive frequency of the water pump if the estimated value of the amount of clogging is larger than the first threshold value but smaller than a second threshold value. In this case, the estimation means opens the switching valve if the estimated value of the amount of clogging is smaller than the second threshold value.

[0012] In the cooling system to which the present invention is applied, the heat would not be transported by the cooling water in the cooling circuit if the water passage is clogged and the switching valve is closed. Consequently, the difference between the temperature of the cooling water detected by the first temperature sensor and the temperature detected by the second temperature sensor is widened. By contrast, if the water passage is not clogged, the cooling water is allowed to transport the heat so that the above-mentioned temperature difference is reduced. That is, a temporal change in the above-mentioned temperature difference is increased with an increase in an amount of clogging of the water passage, and reduced with a reduction in the amount of clogging of the water passage. According to the present invention, the control system is configure to estimate an amount of clogging of the water passage based on such temporal change in the temperature difference so that an accuracy for estimating the amount of clogging can be improved.

[0013] According to the present invention, the drive frequency of the water pump is reduced to be less than the previous value if a current estimated value of the amount of clogging is smaller than a first threshold value. Therefore, accuracy for estimating a current amount of clogging can be improved in comparison with that for estimating a previous amount of clogging.

[0014] The cooling control system of the present invention may be applied to a hybrid vehicle in which a prime mover is comprised of an internal combustion engine and an electric motor. In case of propelling the hybrid vehicle at a high speed, the vehicle is powered mainly by the engine. In this case, therefore, the amount of clogging can be estimated promptly by increasing the drive frequency of the water pump. By contrast, in case of propelling the vehicle at a low speed, the vehicle is powered mainly by the motor rather than the engine. In this case, therefore, the accuracy for estimating the amount of clogging can be improved by reducing the drive frequency of the water pump.

[0015] If the switching valve is opened under a condition where the engine has not yet been warmed-up sufficiently and the amount of clogging of the water passage is larger than the first threshold value but smaller than a second threshold value, the engine may be overly cooled. In this case, therefore, a flow rate of the cooling water circulating within the cooling circuit is increased by increasing the drive frequency of the water pump. If the amount of clogging of the water passage is larger than the second threshold value, the flow rate of the cooling water circulating within the cooling circuit is increased by opening the switching valve.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Fig. 1 is a flowchart showing a first example of a control carried out by the cooling control system of the present invention.

Fig. 2 is an example of a map determining waiting time for commencement of temperature change in the cooling water with respect to a duty cycle.

Fig. 3 is a graph indicating a relation between an initial temperature difference ΔTini and a current temperature difference ΔTnow.

Fig. 4 is an example of a map determining a clogging amount with respect to a temperature difference ΔTd1.

Fig. 5 is a flowchart showing a second example of a control carried out by the cooling control system of the present invention.

Fig. 6 is an example of a map determining a clogging amount with respect to a temperature difference ΔTd2.

Fig. 7 is a flowchart showing a third example of a control carried out by the cooling control system of the present invention.

Fig. 8 is a flowchart showing a fourth example of a control carried out by the cooling control system of the present invention.

Fig. 9 is an example of a map determining a pulse duty of a water pump with respect to a vehicle speed.

Fig. 10 is a flowchart showing a fifth example of a control carried out by the cooling control system of the present invention.

Fig. 11 is an example of a map for correcting a pulse duty of a water pump with respect to the clogging amount.

Fig. 12 is a view schematically showing a preferred example of the cooling control system of engine according to the present invention.

DESCRIPTION OF THE PREFERRD EMBODIMENT(S)

[0017] Next, the present invention will be explained in more detail. The cooling control system according to the present invention is comprised of a circuit for circulating cooling water passing through an internal combustion engine of a vehicle, and a circuit for circulating the cooling water without passing through the engine. In order to switch the circuits depending on a temperature of the engine and a running condition of the vehicle including a launching condition, a stopping condition, and a vehicle speed, a solenoid valve is disposed in the cooling control system. Specifically, the solenoid valve is adapted not to completely block a flow of the cooling water circulating within the circuit passing through the engine, even if it is closed to block the circuit passing through the engine.

[0018] For example, the cooling control system of the present invention is applied to a hybrid vehicle in which a prime mover is comprised of an internal combustion engine and a plurality of electric motors. In the hybrid vehicle, a drive mode can be selected from a hybrid mode where the vehicle is powered by both of the engine and the motor, a motor mode where the vehicle is powered by the motor(s) while stopping the engine and so on depending on a vehicle speed. In the hybrid vehicle, the engine may be driven when launching the vehicle, and stopped when stopping the vehicle. Thus, the engine is selectively operated depending on the selected drive mode and the running condition of the vehicle. For example, a gasoline engine, a diesel engine, a natural gas engine may be used as the engine 1 of the invention, and a rotational speed and an output torque of the engine 1 can be controlled electrically. On the other hand, a conventional AC motor serves as a motor and a generator may be used as the electric motor.

[0019] Fig. 12 shows a preferred example of the cooling control system of the present invention. In order to conduct heat away from the engine 1, a not shown water jacket is attached to a cylinder block and a cylinder head. To this end, the cooling control system is provided with an electric water pump 2 for supplying the cooling water to the water jacket. Although not shown in detail, the water pump 2 is comprised of a motor and an impeller rotated by the motor to deliver the cooling water. A discharging amount and a discharging pressure of the water pump 2 can be altered by electrically changing a rotational speed of the motor.

[0020] Here will be briefly explained a structure of the water pump 2. Although not especially shown, the water pump 2 is comprised of a PWM (Pulse Width Modulation) circuit for controlling a motor speed of the water pump 2 by a PWM method in response to a command signal from a below-mentioned electronic control unit. For example, a rotational speed of the motor is raised by increasing a duty cycle thereof, and lowered by decreasing the duty cycle thereof.

[0021] A discharging port of the water pump 2 is connected with the water jacket of the engine 1 through a feeding conduit 3, and a suction port of the water pump 2 is connected with the water jacket of the engine 1 through a return conduit 4. In order to measure a temperature of the cooling water flowing out of the water jacket, a first temperature sensor is arranged in the vicinity of a connection between the water jacket and the return conduit 4. The return conduit 4 is also connected to a radiator 6. As known in the prior art, the radiator 6 is adapted to exchange heat between the cooling water warmed as a result of drawing heat from the engine 1 and the external air thereby cooling the cooling water. The cooling water thus cooled by the radiator 6 is delivered to the suction port of the water pump 2 through a conventional thermostat 7.

[0022] The thermostat 7 is adapted to allow the cooling water to flow toward the radiator 6 if the temperature of the cooling water is higher than a predetermined temperature, and to inhibit the cooling water to flow toward the radiator 6 if the temperature of the cooling water is lower than a predetermined temperature. Specifically, the predetermined temperature is set to a value that can determine whether or not warm-up of the engine 1 has been completed. In the following explanation, the predetermined temperature thus determined will be called the "warm-up temperature". In addition, the thermostat 7 always allows the cooling water to flow from a below-mentioned bypass conduit 8 toward the return conduit 4.

[0023] The bypass conduit 8 connects the feeding conduit 3 to the return conduit 4, and a second temperature sensor 9 is disposed on the bypass conduit 8. A branch conduit 10 branches out from the return conduit 4 between the engine 1 and the radiator 6 to be connected to the bypass conduit 8, and a solenoid valve 11 is disposed on the branch conduit 10 to alter a flow rate of the cooling water supplied to the water jacket by selectively opening and closing the branch conduit 10.

[0024] Here will be briefly explained a structure of the solenoid valve 11. The solenoid valve 11 is closed when energized so that the flow rate of the cooling water flowing toward the water jacket is reduced. By contrast, the solenoid valve 11 is opened when unenergized so that the flow rate of the cooling water flowing toward the water jacket is increased. The solenoid valve 11 is provided with a water passage indicated by a broken line in Fig. 12 for allowing the cooling water to flow through the branch conduit 10 when the solenoid valve 11 is closed. For example, the water passage may be formed by forming a through hole or a notch penetrating through a valve element that selectively opens and closes input and output ports of the solenoid valve 11. Alternatively, an additional pipe may be arranged to connect an upstream side and a downstream side of the solenoid valve 11 to serve as the water passage. A cross-section of the water passage is smaller than that of the branch conduit 10. Although not especially illustrated, the solenoid valve 11 is connected to an auxiliary battery. The auxiliary battery is also connected to a main battery through a DC-DC converter to provide power to auxiliaries such as an air conditioner and a headlight.

[0025] In order to electrically control the solenoid valve 11 and the water pump 2, the hydraulic control unit is provided with an electronic control unit 12 serving as the controller of the present invention. In the following description, the electronic control unit 12 will be abbreviated as the "ECU" 12 for the sake of convenience. The ECU 12 is comprised mainly of a microcomputer configured to carry out a calculation on the basis of input data and preinstalled data, and calculation results are sent to the solenoid valve 11 and the water pump 2 in the form of command signals. For example, signals from the temperature sensors 5 and 9, an engine speed sensor, a vehicle speed sensor, an igniter and so on are sent to the ECU 12.

[0026] Next, here will be briefly explained an action of the cooling control system shown in Fig. 12. For example, temperatures of the engine 1 and the cooling water are low just after starting-up the engine 1. In this situation, the cooling water is prevented from flowing toward the radiator 6 by the thermostat 7, and an electromagnetic coil of the solenoid valve 11 is energized to close the solenoid valve 11 so as to expedite warming-up of the engine 1. Accordingly, the cooling water discharged from the water pump 2 mostly circulates within the feeding conduit 3, the bypass conduit 8, and the return conduit 4, but partially flows through the water passage of the solenoid valve 11. Consequently, a flow rate of the cooling water flowing through the water jacket is reduced so that the temperature of the cooling water in the water jacket can be raised promptly. In addition, since the cooling water is still allowed to flow through the water jacket in small amount, a local temperature difference in the water jacket can be reduced.

[0027] Given that the temperature of the cooling water is lower than the warm-up temperature but higher than another reference temperature that is slightly lower than the warm-up temperature, the temperature of the cooling water has not yet been raised sufficiently. In the following description, such another reference temperature will be called the "pre-warm-up temperature". In this case, the cooling water is prevented from flowing toward the radiator 6 by the thermostat 7 but the solenoid valve 11 is unenergized to be opened to raise the temperature of the cooling water in the water jacket in a mild manner. In this situation, specifically, the cooling water partially flows through the feeding conduit 3, the water jacket, the branch conduit 10 and the return conduit 4, and remaining cooling water flows through the feeding conduit 3, the bypass conduit 8 and the return conduit 4. Consequently, the cooling water flowing through the water jacket is mixed with the cooling water flowing through the bypass conduit 8 at the bypass conduit 8 and the return conduit 4. As a result, the temperature of the cooling water in the water jacket is raised mildly in comparison with a case in which the solenoid valve 11 is closed.

[0028] Given that the temperature of the cooling water is higher than the warm-up temperature, the cooling water is allowed by the thermostat 7 to flow toward the radiator 6. In this case, the solenoid valve 11 is opened so that the cooling water is partially delivered to the radiator 6 to be cooled. That is, a mixture of the cooling water thus cooled by the radiator 6 and the cooling water circulating within another circuit is discharged from the water pump 2 to circulate within each circuit. For this reason, the temperature of the cooling water in the water jacket will not be raised excessively. Accordingly, the circuit passing through the water jacket serves as the cooling circuit of the invention, and the circuit passing through the bypass conduit 8 serves as the bypass circuit of the invention.

[0029] The cooling control system of the present invention is configured to estimate an amount of clogging of the water passage for delivering the cooling water to the water jacket in case the solenoid valve 11 is closed. For example, an amount of clogging can be represented by a reduction percentage (%) of a cross-sectional area of the water passage that is clogged by foreign material such as water stain and dust. Specifically, if the amount of clogging is 15%, this means that 15% of the cross-sectional area of the water passage is closed by the foreign material. Referring now to Fig. 1, there is shown a flowchart explaining the first control example of the cooling control system for the engine. The routine shown in Fig. 1 is repeated at predetermined internal.

[0030] First of all, a temperature Thw of the cooling water flowing out of the water jacket of the engine 1 is detected by the first temperature sensor 5. Meanwhile, a temperature Thb of the cooling water flowing through the bypass conduit 8 is detected by the second temperature sensor 9. Then, a temperature difference ΔTini is calculated by subtracting the temperature Thb of the cooling water flowing through the bypass conduit 8 from the temperature Thw of the cooling water flowing out of the engine 1. The temperature difference ΔTini thus calculated will be called the "initial temperature difference" ΔTini in the following description. At step S1, accordingly, it is determined whether or not the initial temperature difference ΔTini is larger than a predetermined reference value Tdet, and whether or not the engine 1 is stopped.

[0031] Specifically, the reference value Tdet is a temperature difference determined based on a result of experimentation or simulation that is possible to determine an amount of clogging of the water passage within a predetermined period of time. In the example shown in Fig. 1, the reference value Tdet is set to 20 degrees C. For example, an engine stop can be determined based on a current running condition of the vehicle, a current driving mode, a current vehicle speed and so on. If the initial temperature difference ΔTini is smaller than the reference value Tdet, or if the engine 1 is under operation so that the answer of step S1 is NO, the routine is returned without carrying out any specific control.

[0032] By contrast, if the initial temperature difference ΔTini is larger than the reference value Tdet and the engine 1 is stopped so that the answer of step S1 is YES, the initial temperature difference ΔTini is saved to be used at after-mentioned step S4. In addition, the water pump 2 is activated and the solenoid valve 11 is closed (at step S2). Specifically, the solenoid valve 11 is closed to block the bypass conduit 10. In this case, however, the cooling water is still allowed to flow through the water passage of the solenoid valve 11. In this situation, the drive duty cycle of the water pump 2 may be adjusted arbitrarily depending on the running condition of the vehicle.

[0033] Then, it is determined whether or not a preset time t1 has elapsed (at step S3). Given that the water passage is clogged heavily, a flow rate of the cooling water flowing therethrough is reduced. This means that a heat transfer via the cooling water is reduced. Consequently, a difference between the detection values of the temperature sensors 5 and 9 is widened. By contrast, given that the water passage is clogged not so heavily, the flow rate of the cooling water flowing therethrough is comparatively larger than that of the case in which the water passage is clogged heavily. That is, a heat transfer via the cooling water is comparatively large so that the difference between the detection values of the temperature sensors 5 and 9 is decreased. In any cases, however, it takes some time before the temperature of the cooling water flowing through the water passage starts changing since the solenoid valve 11 was closed. That is, the above-mentioned preset time t1 is the waiting time until the temperature of the cooling water flowing through the water passage starts changing. Fig. 2 shows an example of a map determining the waiting time with respect to the drive duty cycle of the water pump 2. As can be seen from Fig. 2, in case the drive duty cycle of the water pump 2 is large, the flow rate of the cooling water flowing through the water passage is increased. In this case, therefore, the waiting time is set to a short period of time. By contrast, in case the drive duty cycle of the water pump 2 is small, the flow rate of the cooling water flowing through the water passage is decreased. In this case, therefore, the waiting time is set to a long period of time.

[0034] If the preset time t1 has not elapsed yet so that the answer of step S3 is NO, the determination of step S3 is repeated until the preset time t1 has elapsed. By contrast, if the preset time t1 has elapsed so that the answer of step S3 is YES, the temperature Thw (now) of the cooling water flowing out of the engine 1 is detected again by the first temperature sensor 5, and the temperature Thb (now) of the cooling water flowing through the bypass conduit 8 is detected again by the second temperature sensor 9. Then, a temperature difference ΔTnow is calculated by subtracting the temperature Thb (now) of the cooling water flowing through the bypass conduit 8 from the temperature Thw (now) of the cooling water flowing out of the engine 1 (at step S4).

[0035] Thereafter, an estimated value of an amount of clogging of the water passage is calculated (at step S5). The estimated value of an amount of clogging is calculated by the following procedures. Referring now to Fig. 3, there is shown a graph indicating a relation between the initial temperature difference ΔTini and the current temperature difference ΔTnow. As can be seen from Fig. 3, in case the water passage is not clogged with foreign matter or an amount of clogging is small, the cooling water is allowed to flow through the water jacket smoothly so that the current temperature difference ΔTnow is small. By contrast, in case the water passage is completely clogged with the foreign matter or the amount of clogging is large, the cooling water remains in the water jacket. In this case, therefore, heat transfer via the cooling water is rather small. Consequently, the current temperature difference ΔTnow is widened in comparison with that of the case in which the amount of clogging is small. In Fig. 3, the vertical axis represents a difference ΔTd1 between the initial temperature difference ΔTini and the current temperature difference ΔTnow. As can be seen from Fig. 3, the difference ΔTd1 is large in case the amount of clogging of the water passage is small, and the difference ΔTd1 is small in case the amount of clogging of the water passage is large. This means that the amount of clogging is large if the difference ΔTd1 between ΔTini and ΔTnow is small. Accordingly, the amount of clogging of the water passage can be estimated with reference to a map shown in Fig. 4 that determines a relation between the clogging amount and the difference ΔTd1.

[0036] Then, it is determined whether or not the amount of clogging of the water passage estimated at step S5 is larger than a predetermined threshold value PV1 (at step S6). According to the preferred example, the threshold value PV1 is set to 15%. If the amount of clogging of the water passage estimated at step S5 is smaller than the threshold value PV1 so that the answer of step S6 is NO, the routine is returned without carrying out any specific control. By contrast, if the amount of clogging of the water passage estimated at step S5 is larger than the threshold value PV1 so that the answer of step S6 is YES, the solenoid valve 11 is opened (at step S7). Consequently, the cooling water flowing out of the water jacket is allowed to flow through the branch conduit 10. Accordingly, the threshold value PV1 corresponds to the first threshold value of the present invention.

[0037] Thus, the cooling control system of the present invention is configured to estimate an amount of clogging of the water passage, and to open the solenoid valve 11 if the estimated value of the clogging amount is larger than the threshold value PV1. According to the present invention, therefore, the cooling water is allowed to circulate through the water jacket even if the water passage is clogged with foreign material.

[0038] Referring now to Fig. 5, there is shown a flowchart explaining the second control example of the cooling control system for the engine. The routine shown in Fig. 5 is also repeated at predetermined interval. Here, in the flowchart shown in Fig. 5, common numbers are allotted to the steps identical to those in Fig. 1. According to the example shown in Fig. 5, if the answer of step S1 is YES, it is determined whether or not an external temperature measured by a not shown sensor is lower than a predetermined threshold value (at step S8). Given that the external temperature is low, a temperature of the cooling water is lowered naturally and an accuracy of the above-explained estimation of clogging amount based on the temperature difference may be deteriorated. Therefore, the threshold value for the external temperature is set to a value sufficiently lower than the above-mentioned warm-up temperature. If the external temperature is higher than the threshold value so that the answer of step S8 is NO, the routine advances to step S1 of Fig. 1 to carry out the control shown in Fig. 1.

[0039] By contrast, if the external temperature is lower than the threshold value so that the answer of step S8 is YES, the routine advances sequentially to steps S2 and S9 to stop the water pump 2 (at step S9). Then, it is determined whether or not a preset time t2 has elapsed from a point at which the water pump 2 was stopped (at step S10). As the preset time t1 used at step S3 shown in Fig. 1, the preset time t2 is the waiting time until the temperature of the cooling water flowing through the water passage starts changing. The determination of step S10 is also repeated until the preset time t2 has elapsed.

[0040] If the preset time t2 has elapsed so that the answer of step S10 is YES, a lowered amount ΔTcold of the temperature of the cooling water lowered by the external temperature is calculated (at step S11). To this end, specifically, a temperature Thw (c) of the cooling water flowing out of the engine 1, and a temperature Thb (c) of the cooling water flowing through the bypass conduit 8 are detected when the preset time t2 has elapsed. Then the lowered amount ΔTcold is calculated by subtracting a difference between the temperatures Thw (c) and Thb (c) from the initial temperature difference ΔTini.

[0041] Subsequently, the water pump 2 is activated (at step S12). Thereafter, the routine advances to above-explained step S3 to determine whether or not the preset time t1 has elapsed. If the preset time t1 has elapsed so that the answer of step S3 is YES, the routine advances to above-explained step S4. At step S4, specifically, the current temperatures Thw (now) of the cooling water flowing out of the engine 1 and Thb (now) of the cooling water flowing through the bypass conduit 8 under the condition where the water pump 2 is activated are detected by the temperature sensors 5 and 9. As described, at step S4, a current temperature difference ΔTnow is calculated by subtracting the temperature Thb (now) from the temperature Thw (now).

[0042] Then, an estimated value of an amount of clogging of the water passage is calculated while eliminating an influence of the external temperature such as the lowered amount ΔTcold (at step S13). To this end, the difference ΔTd1 between the initial temperature difference ΔTini and the current temperature difference ΔTnow is calculated. In this case, however, the difference ΔTd1 thus calculated is affected by the external temperature. Therefore, a difference ΔTd2 from which an influence of the external temperature is eliminated is calculated as expressed by the following expression:

$$\Delta Td2 = (\Delta Tini - \Delta Tnow) - (t1 + t2) \cdot \Delta Tcold.$$

[0043] Although not especially indicated in the accompanying drawings, as the case of the difference ΔTd1, the amount of clogging is large if the difference ΔTd2 is large. In this case, accordingly, the amount of clogging of the water passage can be estimated with reference to a map shown in Fig. 6 that determines a relation between the clogging amount and the difference ΔTd2. Then, the routine advances to step S6 shown in Fig. 1.

[0044] Thus, according to the control example shown in Fig. 5, the estimated value of an amount of clogging of the water passage can be calculated while eliminating an influence of the external temperature so that the accuracy of estimating the amount of clogging can be improved. That is, the cooling control system will not erroneously estimate a fact that the clogging amount of the water passage is small or zero if the water passage is clogged with the foreign material.

[0045] Referring now to Fig. 7, there is shown a flowchart explaining the third control example of the cooling control system configured to accurately estimate an amount of clogging of the water passage in case the amount of clogging during previous trip is larger than the threshold value PV1. That is, the example shown in Fig. 7 is configured to estimate the clogging amount of the water passage without determining a clogging of the water passage erroneously under a situation where the water passage is not clogged with foreign material. Here, in the flowchart shown in Fig. 7, common numbers are allotted to the steps identical to those in Fig. 1.

[0046] After the determination at step S1, it is determined whether or not an estimated value of an amount of clogging of the water passage calculated during the previous trip is smaller than the threshold value PV1 (at step S14). If the estimated value of an amount of clogging calculated during the previous trip is smaller than the threshold value PV1 so that the answer of step S14 is YES, the drive duty cycle of the water pump 2 for the current trip is set to be less than that for the previous trip (at step S15). If the estimated value of an amount of clogging calculated during the previous trip is smaller than the threshold value PV1, the control system estimates a fact that the amount of clogging is smaller than the threshold value PV1 also during the current trip. In this case, following controls are carried out while reducing the drive duty cycle of the water pump 2 to reduce electric consumption. For example, given that the drive duty cycle of the water pump 2 was 50% during the previous trip, the drive duty cycle of the water pump 2 is reduced to 40% during the current trip.

[0047] By contrast, if the estimated value of an amount of clogging calculated during the previous trip is larger than the threshold value PV1 so that the answer of step S14 is NO, the drive duty cycle of the water pump 2 is set to the maximum value (at step S16). Consequently, the discharging amount of the water pump 2 can be increased to increase the flow rate of the cooling water flowing through the water jacket without opening the solenoid valve 11.

[0048] Thereafter, the initial temperature difference ΔTini is saved and the solenoid valve 11 is closed (at step S17). Then, the routine advances to step S3 to determine whether or not the preset time t1 has elapsed.

[0049] An amount of clogging during the current trip is estimated at step S5, and then, it is determined whether or not the estimated value of the amount of clogging of the water passage during the current trip is larger than another threshold value PV2 (at step S18). The threshold value PV2 is set to a value larger than the threshold value PV1, for example, set to 60%. If the estimated value of an amount of clogging during the current trip is larger than the threshold value PV2, the control system determines a fact that the water passage is clogged abnormally with foreign material. In this case, the solenoid valve 11 is opened (at step S19).

[0050] If the estimated value of an amount of clogging of the water passage is smaller than the threshold value PV2 so that the answer of step S18 is NO, it is determined whether or not the estimated value of an amount of clogging is larger than the threshold value PV1 (at step S20). If the estimated value of an amount of clogging of the water passage is smaller than the threshold value PV1 so that the answer of step S20 is NO, the control system determines a fact that the water passage is in a normal condition without being clogged with foreign material (at step S21). By contrast, if the estimated value of an amount of clogging of the water passage is larger than the threshold value PV1 so that the answer of step S20 is YES, the routine advances to step S22. In this case, specifically, the estimated value of an amount of clogging of the water passage is larger than the threshold value PV1 but smaller than the threshold value PV2. Consequently, the control system makes a determination of a quasi-clogging of the water passage. At step S22, optionally, a drive duty cycle of the water pump 2 may be calculated in a manner such hat the accuracy for estimating an amount of clogging for the next trip will be improved in comparison with that during the current trip. In this case, the amount of clogging will be estimated based on the drive duty cycle of the water pump 2 calculated at step S22.

[0051] Thus, given that the amount of clogging during the previous trip was larger than the threshold value PV1, the amount of clogging during the current trip is estimated while increasing the drive duty cycle of the water pump 2. According to the third example shown in Fig. 7, therefore, the cooling water is allowed to flow through the water jacket smoother than the case in which the drive duty cycle of the water pump 2 is small so that the accuracy for estimating the amount of clogging can be improved in comparison with that during the previous trip.

[0052] Referring now to Fig. 8, there is shown a flowchart explaining the fourth control example of the cooling control system configured to alter the drive duty cycle of the water pump 2 depending on the vehicle speed to estimate an amount of clogging of the water passage. For example, the control example shown in Fig. 8 may be applied to a hybrid vehicle in which a prime mover is comprised of an engine and a motor. Here, in the flowchart shown in Fig. 8, common numbers are allotted to the steps identical to those in Fig. 1. After making a determination of step S1, the initial temperature difference ΔTini is saved and the drive duty cycle of the water pump 2 is adjusted according to the vehicle speed (at step S23). For example, the drive duty cycle of the water pump 2 may be determined with reference to a preinstalled map shown in Fig. 9. Given that the vehicle speed is higher than a predetermined speed, the engine 1 will be operated frequently and heated significantly. In this case, therefore, the drive duty cycle of the water pump 2 is increased to the maximum value. To this end, the vehicle speed can be detected by a not shown speed sensor. Then, the routine advances to step S3.

[0053] Specifically, given that the hybrid vehicle runs at a low speed, the vehicle is powered by the motor more frequently rather than powered by the engine. In this case, the drive duty cycle of the water pump 2 can be reduced in comparison with the case in which the vehicle runs at a high speed so that the amount of clogging of the water passage can be estimated more accurately without operating the engine 1. In addition, a flow rate of the cooling water can be reduced so that the engine 1 can be prevented from being cooled excessively. By contrast, given that the hybrid vehicle runs at a high speed, the vehicle is powered by the engine more frequently rather than powered by the motor. In this case, therefore, an amount of clogging of the water passage can be estimated promptly while stopping the engine 1 by increasing the drive duty cycle of the water pump 2.

[0054] Referring now to Fig. 10, there is shown a flowchart explaining the fifth control example of the cooling control system configured to alter a flow rate of the cooling water flowing through the water jacket while closing the solenoid valve 11 depending on an estimated value of clogging of the water passage. Here, in the flowchart shown in Fig. 10, common numbers are allotted to the steps identical to those in Fig. 1.

[0055] According to the control example shown in Fig. 10, after step S5, it is determined whether or not an estimated value of an amount of clogging is larger than a still another threshold value PV3 (at step S24). For example, the threshold value PV3 is set to 50% that is larger than the threshold value PV 1 but smaller than the threshold value PV2. If the estimated value of the amount of clogging is larger than the threshold value PV3 so that the answer of step S24 is YES, the solenoid valve 11 is opened (at step S25). That is, if the estimated value of an amount of clogging is large, the cooling water flowing out of the water jacket is allowed to circulate through the branch conduit 10.

[0056] By contrast, if the estimated value of the amount of clogging is smaller than the threshold value PV3 so that the answer of step S24 is NO, it is determined whether or not the estimated value of the amount of clogging is larger than the threshold value PV1 (at step S26). If the estimated value of the amount of clogging is smaller than the threshold value PV1 so that the answer of step S26 is NO, the routine is returned.

[0057] By contrast, if the estimated value of the amount of clogging is larger than the threshold value PV1 so that the answer of step S26 is YES, a coefficient for correcting the drive duty cycle of the water pump 2 is calculated to alter the drive duty cycle in accordance with the estimated value of the amount of clogging (at step S27). For example, the correction coefficient may be determined according to the estimated value of an amount of clogging with reference to a preinstalled map shown in Fig. 11.

[0058] Then, the drive duty cycle is corrected by the correction coefficient thus calculated (at step S28). Specifically, the drive duty cycle of the water pump 2 is calculated by multiplying the current drive duty cycle by the correction coefficient, and the water pump 2 is driven in accordance with the drive duty cycle thus corrected. In this case, if the estimated value of the amount of clogging is larger than 15% but smaller than 50%, a discharging amount of the water pump 2 is increased in accordance with the correction coefficient determined according to the estimated value of the amount of clogging. It is to be noted that the maximum value of the drive duty cycle to be corrected by the correction coefficient is limited to a value that can drive the water pump 2 without reducing fuel economy, on the basis of a result of experimentation or simulation. That is, given that the estimated value of the amount of clogging falls within a range between the threshold values PV1 and PV3, the fuel economy will not be reduced even if the drive duty cycle of the water pump 2 is increased to increase a flow rate of the cooling water flowing through the water jacket. However, if the estimated value of the amount of clogging is larger than the threshold value PV3, the fuel economy may be deteriorated. In this case, the solenoid valve 11 is opened to avoid such reduction in the fuel economy.

[0059] Thus, according to the example shown in Fig. 10, the solenoid valve 11 will not be opened if the estimated value of the amount of clogging is smaller than the threshold value PV3 so that the engine 1 can be prevented from being cooled overly. By contrast, if the estimated value of the amount of clogging is larger than the threshold value PV3, the solenoid valve 11 is opened. In this case, therefore, the drive duty cycle of the water pump 2 does not have to be increased so that the fuel economy will not be reduced.

[0060] Here will be briefly explained a relation between the foregoing examples and the present invention. Functional means of steps S2 to S6, S8 to S13, S14 to S16, and S23 serve as the estimation means of the present invention.

Claims

1. A cooling control system for an engine, comprising:

    a cooling circuit for circulating cooling water via a water pump and the engine to cool the engine;
    a bypass circuit for circulating the cooling water without passing through the engine;
    a first temperature sensor that is disposed on the cooling circuit to detect a temperature of the cooling water flowing therethrough;
    a second temperature sensor that is disposed on the bypass circuit to detect a temperature of the cooling water flowing therethrough;
    a switching valve that is closed to reduce a flow rate of the cooling water flowing through the cooling circuit, and that is opened to increase the flow rate of the cooling water flowing through the cooling circuit; and
    a water passage that allows the cooling water to flow through the cooling circuit in a small amount when the switching valve is closed,
    characterized by:

        an estimation means that is configured to estimate an amount of clogging of the water passage based on a temporal change in a temperature difference between a temperature of the cooling water detected by the first temperature sensor and a temperature of the cooling water detected by the second temperature sensor, under a condition in that the engine is stopped, the switching valve is closed, and the water pump is driven.

2. The cooling control system as claimed in claim 1,
wherein the estimation means includes a means configured to estimate the amount of clogging of the water passage by subtracting the temperature difference of a case in which the water pump is not driven from the temperature difference of a case in which the water pump is driven, in case an external temperature is lower than a predetermined temperature.

3. The cooling control system as claimed in claim 1 or 2, wherein the estimation means includes a means configured to:

   estimate a current amount of clogging of the water passage while reducing a drive frequency of the water pump to be less than the previous value if a current estimated value of the amount of clogging is smaller than a first threshold value, and
   estimate a current amount of clogging of the water passage while increasing the drive frequency of the water pump to be more than that of the previous case if the current estimated value of the amount of clogging is larger than the first threshold value.

4. The cooling control system as claimed in any of claims 1 to 3,
   wherein the estimation means includes a means configured to estimate the amount of clogging of the water passage by increasing the drive frequency of the water pump with an increase in a speed of a vehicle having the engine.

5. The cooling control system as claimed in any of claims 1 to 4, wherein the estimation means includes a means configured to:

   estimate the amount of clogging of the water passage while increasing the drive frequency of the water pump if the estimated value of the amount of clogging is larger than the first threshold value but smaller than a second threshold value, and
   open the switching valve if the estimated value of the amount of clogging is smaller than the second threshold value.

Fig. 1

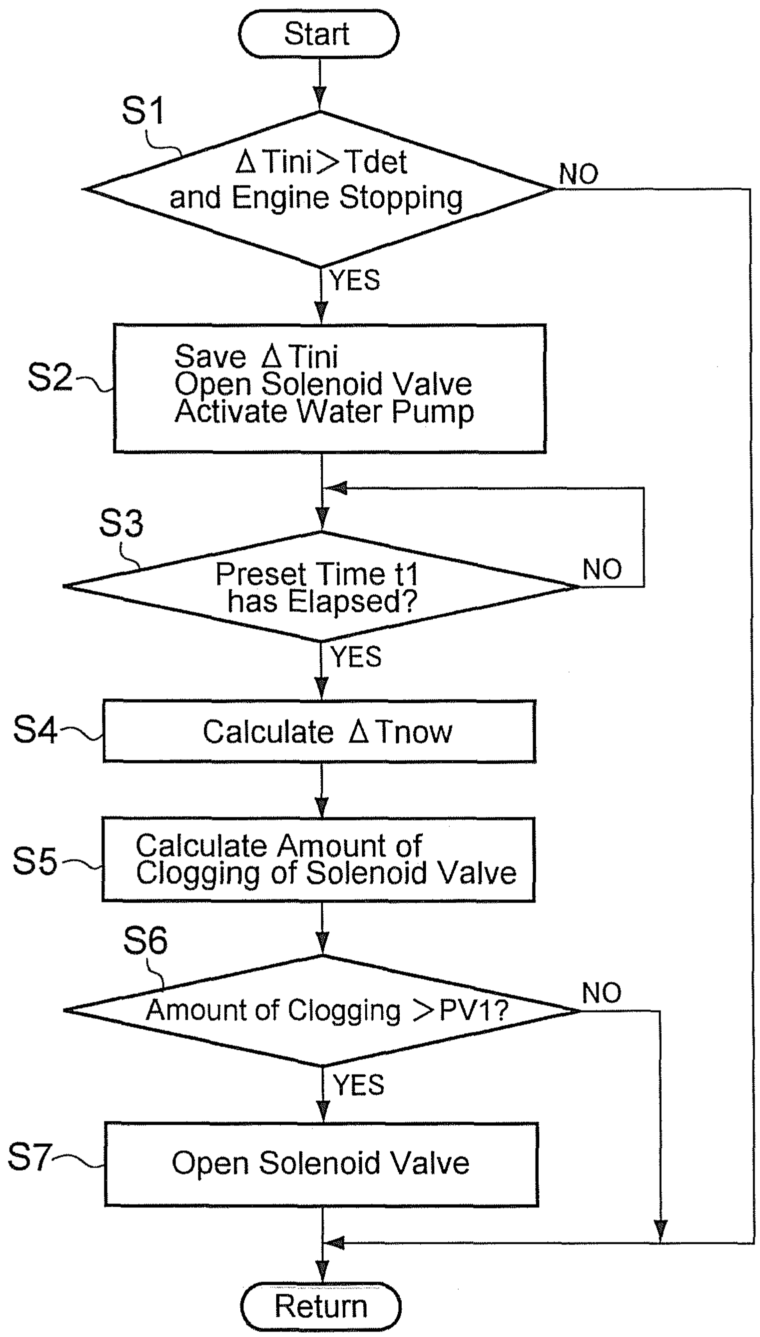

Start
S1
ΔTini>Tdet
and Engine Stopping
NO
YES
S2
Save ΔTini
Open Solenoid Valve
Activate Water Pump
S3
Preset Time t1
has Elapsed?
NO
YES
S4
Calculate ΔTnow
S5
Calculate Amount of
Clogging of Solenoid Valve
S6
Amount of Clogging >PV1?
NO
YES
S7
Open Solenoid Valve
Return

Fig. 2

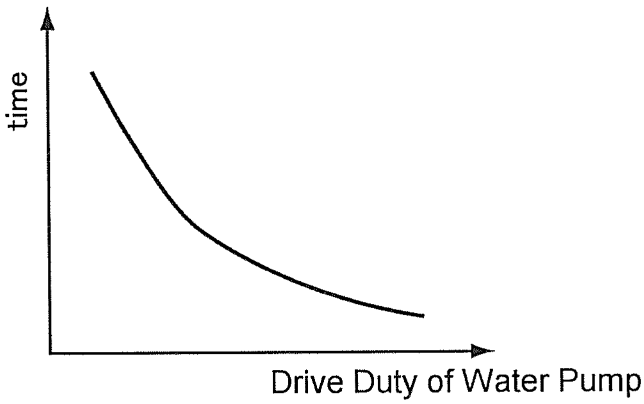


Fig. 3

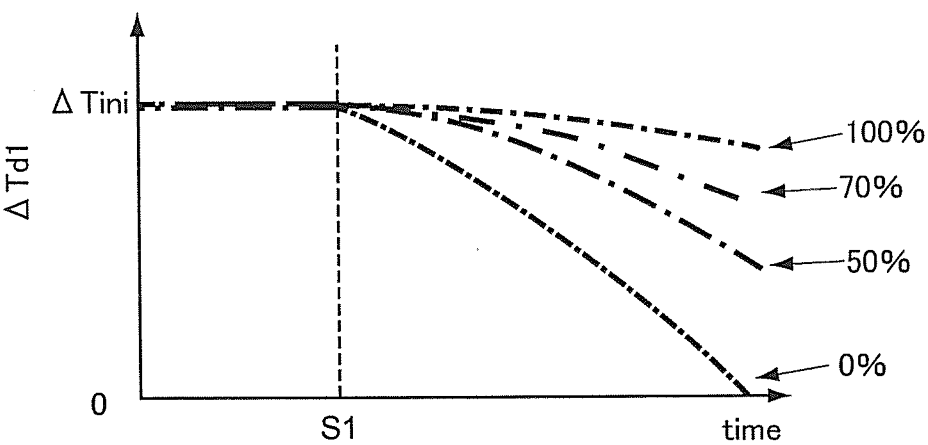


Fig. 4

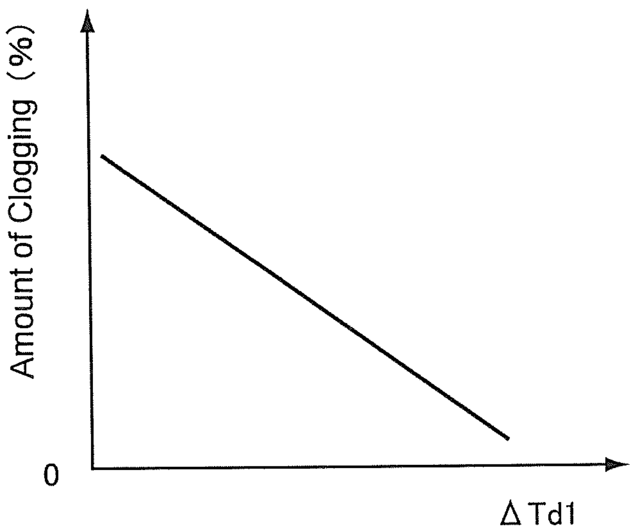


Fig. 5

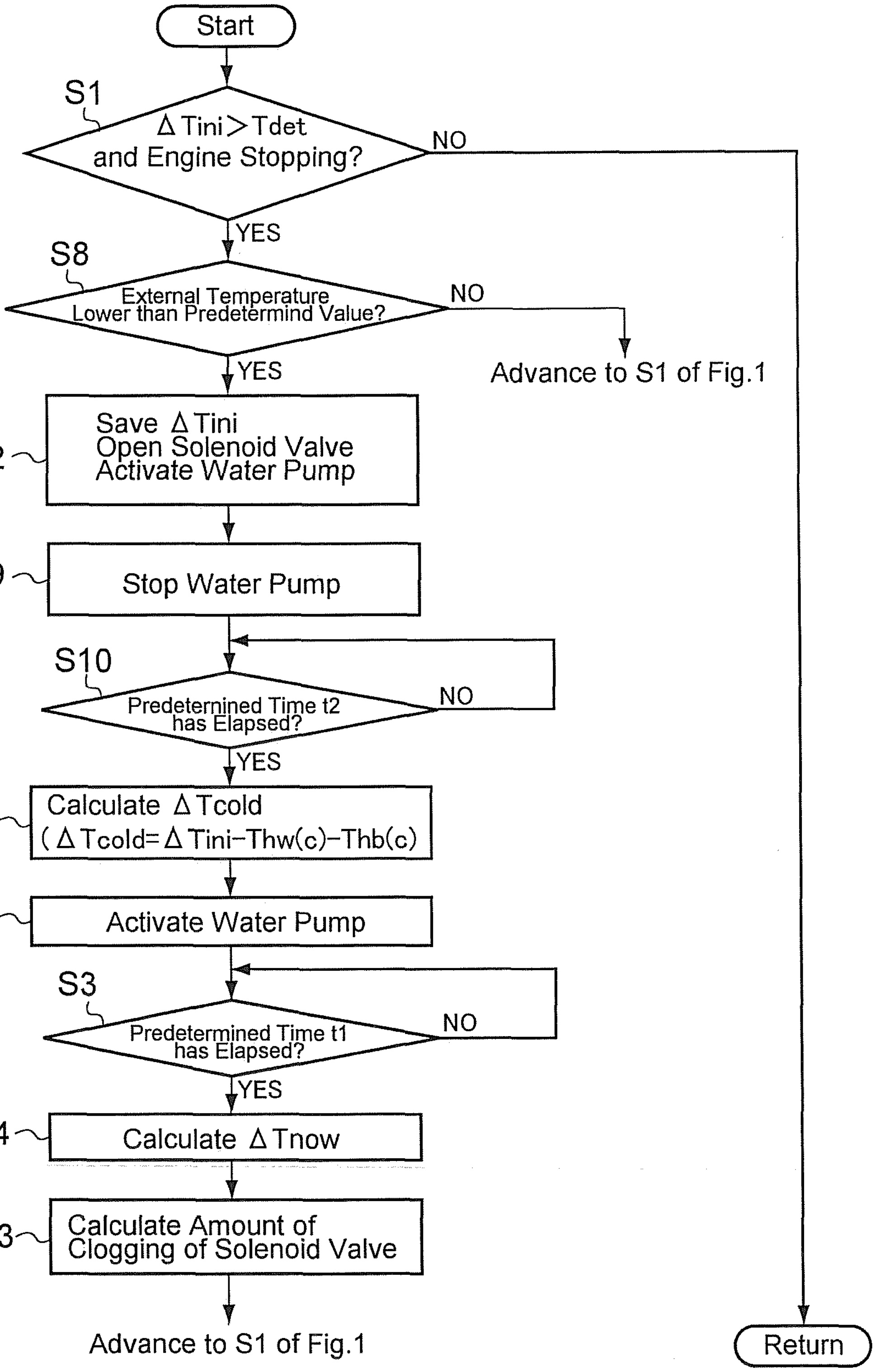

Start
S1
ΔTini>Tdet
and Engine Stopping?
NO
YES
S8
External Temperature
Lower than Predetermind Value?
NO
Advance to S1 of Fig.1
YES
S2
Save ΔTini
Open Solenoid Valve
Activate Water Pump
S9
Stop Water Pump
S10
Predetermined Time t2
has Elapsed?
NO
YES
S11
Calculate ΔTcold
(ΔTcold=ΔTini−Thw(c)−Thb(c)
S12
Activate Water Pump
S3
Predetermined Time t1
has Elapsed?
NO
YES
S4
Calculate ΔTnow
S13
Calculate Amount of
Clogging of Solenoid Valve
Advance to S1 of Fig.1
Return

Fig. 6

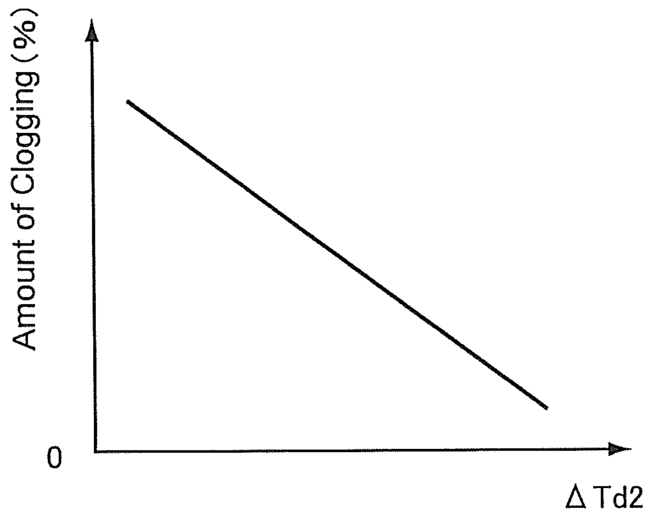


Fig. 7

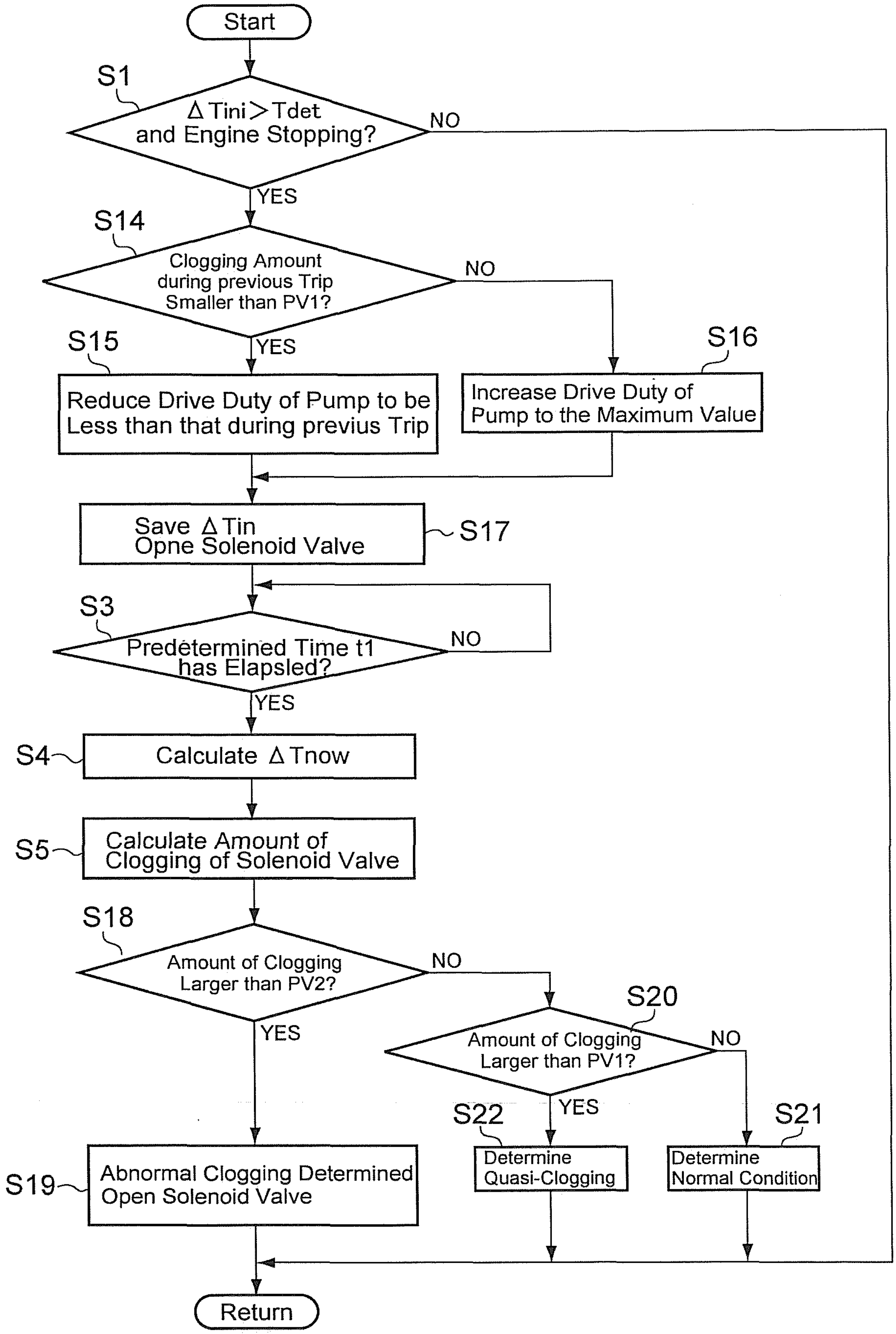

Start
S1
ΔTini＞Tdet
and Engine Stopping?
NO
YES
S14
Clogging Amount
during previous Trip
Smaller than PV1?
NO
YES
S15
Reduce Drive Duty of Pump to be
Less than that during previus Trip
S16
Increase Drive Duty of
Pump to the Maximum Value
Save ΔTin
Opne Solenoid Valve
S17
S3
Predetermined Time t1
has Elapsled?
NO
YES
S4
Calculate ΔTnow
S5
Calculate Amount of
Clogging of Solenoid Valve
S18
Amount of Clogging
Larger than PV2?
NO
YES
S20
Amount of Clogging
Larger than PV1?
NO
YES
S22
Determine
Quasi-Clogging
S21
Determine
Normal Condition
S19
Abnormal Clogging Determined
Open Solenoid Valve
Return

Fig. 8

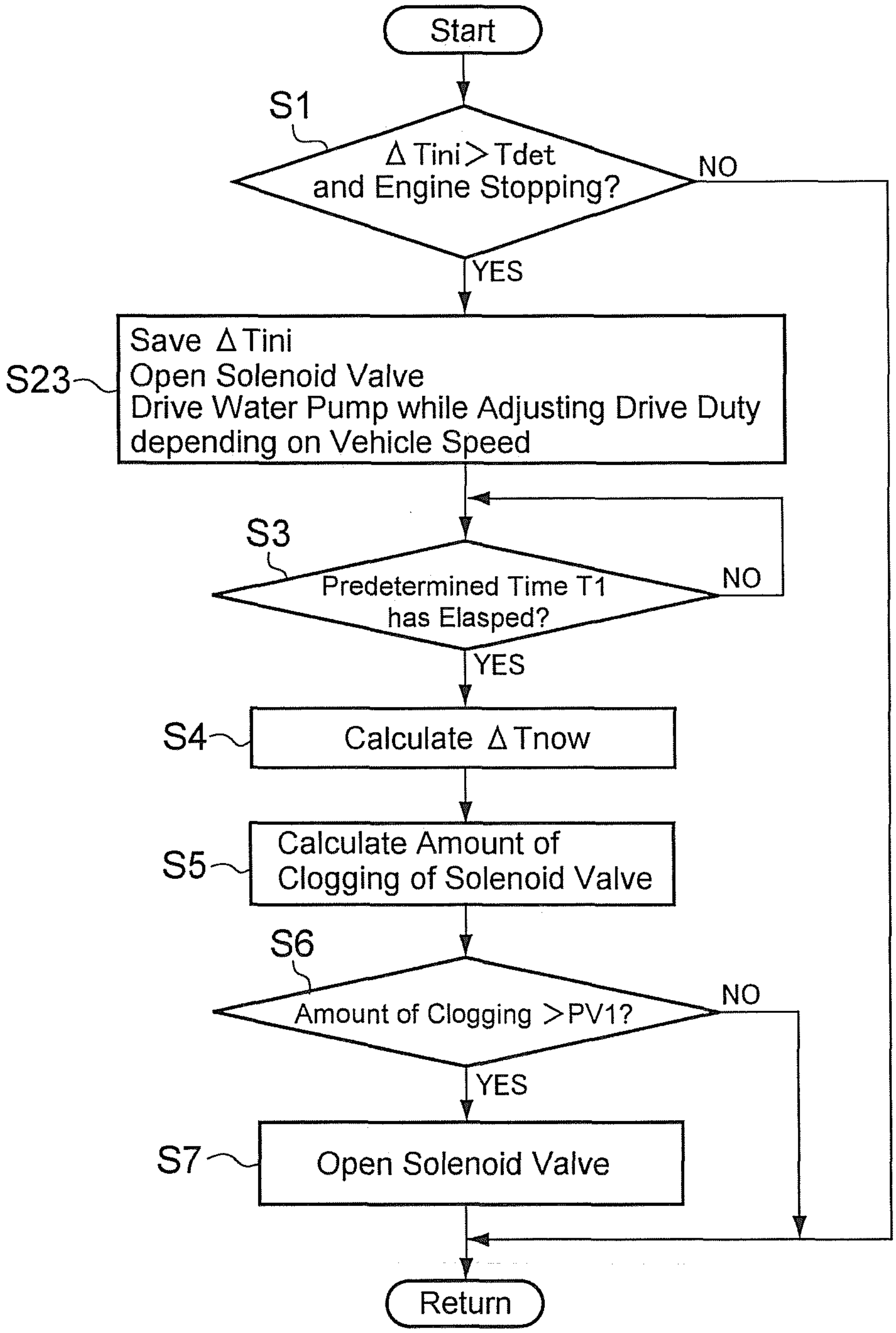

Start
S1
ΔTini>Tdet
and Engine Stopping?
NO
YES
S23
Save ΔTini
Open Solenoid Valve
Drive Water Pump while Adjusting Drive Duty
depending on Vehicle Speed
S3
Predetermined Time T1
has Elasped?
NO
YES
S4
Calculate ΔTnow
S5
Calculate Amount of
Clogging of Solenoid Valve
S6
Amount of Clogging >PV1?
NO
YES
S7
Open Solenoid Valve
Return

Fig. 9

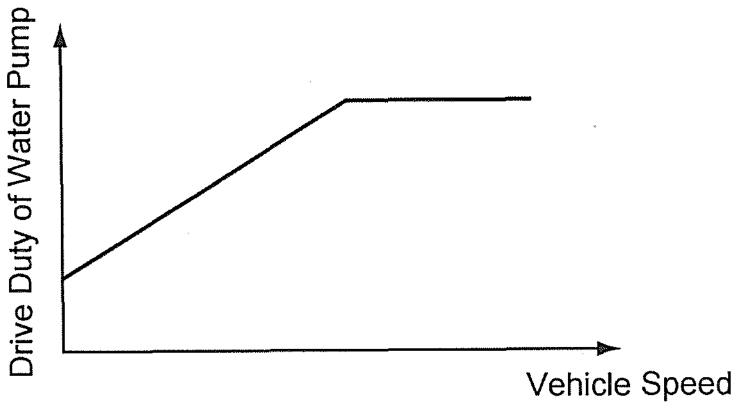


Fig. 10

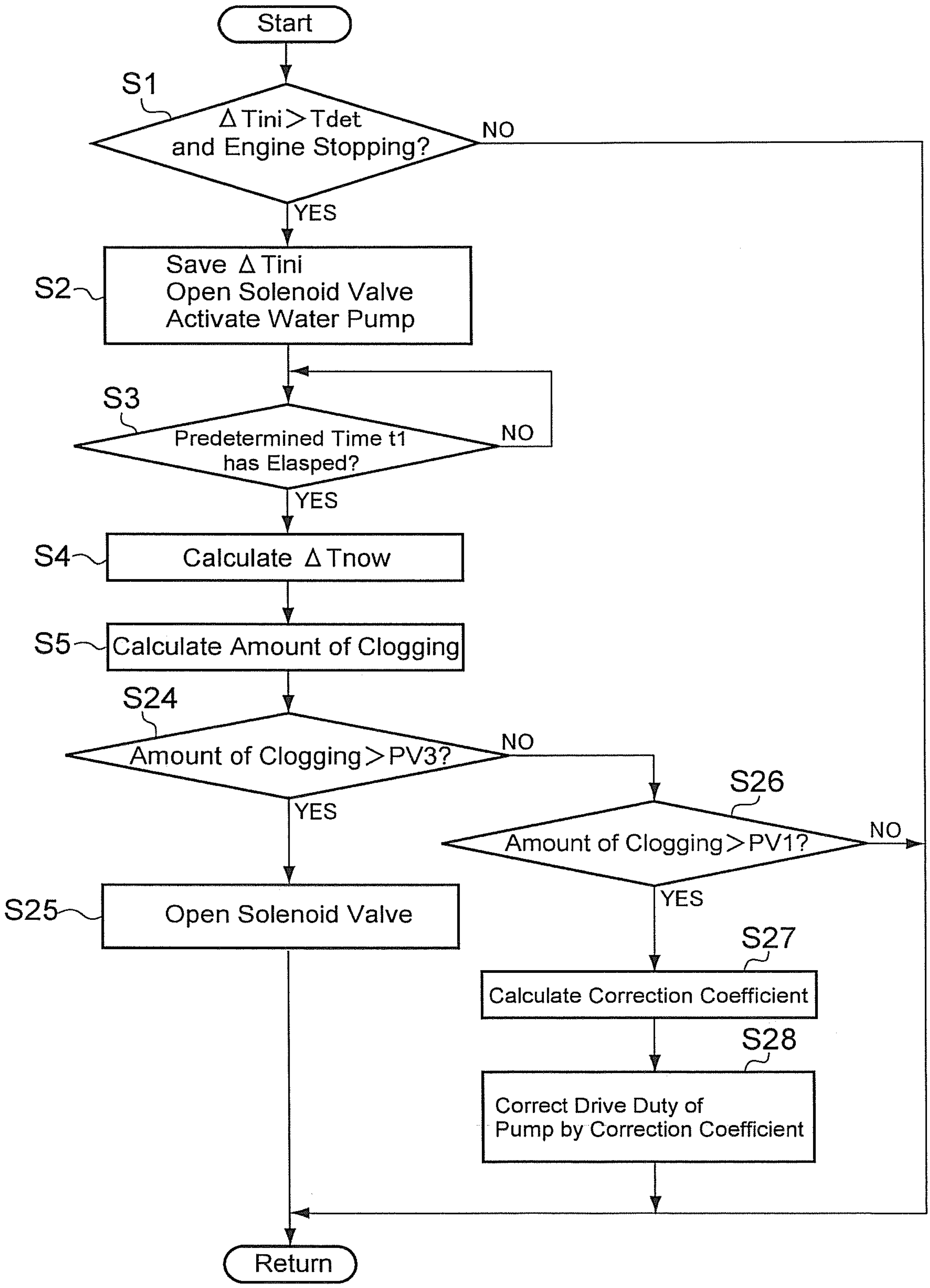

Start
S1
ΔTini > Tdet
and Engine Stopping?
NO
YES
S2
Save ΔTini
Open Solenoid Valve
Activate Water Pump
S3
Predetermined Time t1
has Elasped?
NO
YES
S4
Calculate ΔTnow
S5
Calculate Amount of Clogging
S24
Amount of Clogging > PV3?
NO
YES
S26
Amount of Clogging > PV1?
NO
YES
S25
Open Solenoid Valve
S27
Calculate Correction Coefficient
S28
Correct Drive Duty of
Pump by Correction Coefficient
Return

Fig. 11

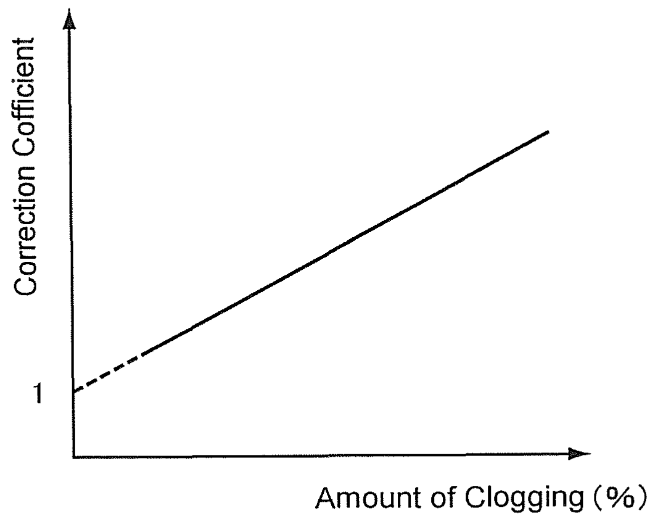
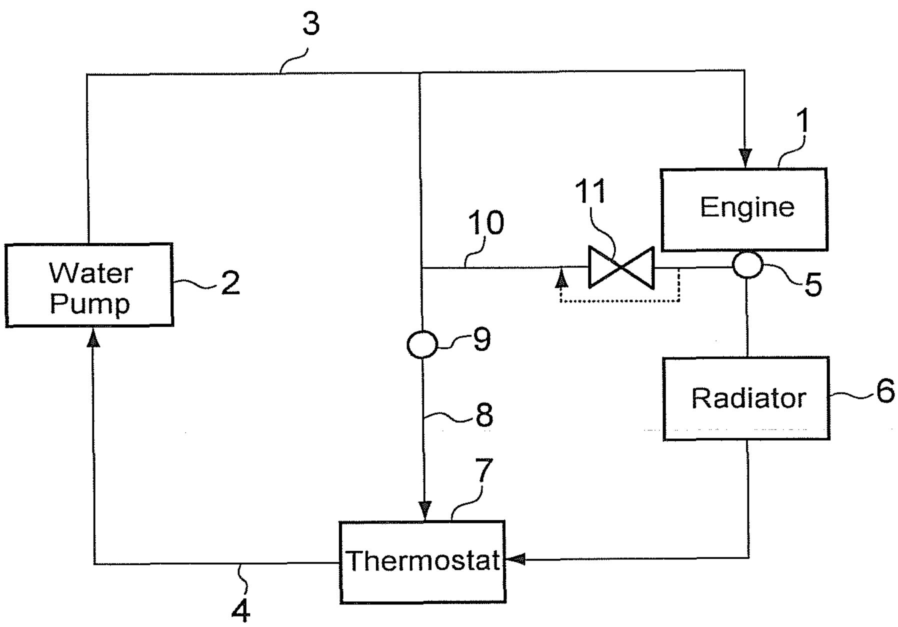

Correction Cofficient
1
Amount of Clogging (%)

Fig. 12


3
1
Engine
11
10
Water
Pump
2
5
9
Radiator
6
8
7
Thermostat
4

INTERNATIONAL SEARCH REPORT	International application No. PCT/JP2012/065530

A. CLASSIFICATION OF SUBJECT MATTER
F01P7/16(2006.01)i, *F01P7/04*(2006.01)i, *F01P7/14*(2006.01)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, F01P7/04, F01P7/14

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	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

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.
A	JP 2004-076689 A (Denso Corp.), 11 March 2004 (11.03.2004), paragraph [0031]; fig. 1 & US 2004/0035194 A1	1-5
A	JP 2010-190142 A (Hitachi Automotive Systems, Ltd.), 02 September 2010 (02.09.2010), abstract; fig. 1, 5 (Family: none)	1-5
A	JP 2004-211573 A (Toyota Motor Corp.), 29 July 2004 (29.07.2004), abstract; fig. 1, 2 (Family: none)	1-5

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"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
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"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
24 July, 2012 (24.07.12)	25 September, 2012 (25.09.12)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2012/065530

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2009-127478 A (Toyota Motor Corp.), 11 June 2009 (11.06.2009), abstract; claim 1 & US 2010/0236502 A1 & EP 2224110 A1 & WO 2009/066509 A1	1-5
A	JP 2008-308124 A (Toyota Motor Corp.), 25 December 2008 (25.12.2008), abstract; claim 1 (Family: none)	1-5

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Patent documents cited in the description

- JP 4883225 B **[0003] [0005]**
- JP 2007046469 A **[0004]**