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

(11) EP 1 564 392 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
17.08.2005 Bulletin 2005/33

(51) Int Cl.7: **F02D 15/04**, F01P 7/16

(21) Application number: **05002837.2**

(22) Date of filing: **10.02.2005**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR LV MK YU

(30) Priority: **13.02.2004 JP 2004036955**

(71) Applicant: **Toyota Jidosha Kabushiki Kaisha**
Toyota-shi, Aichi-ken 471-8571 (JP)

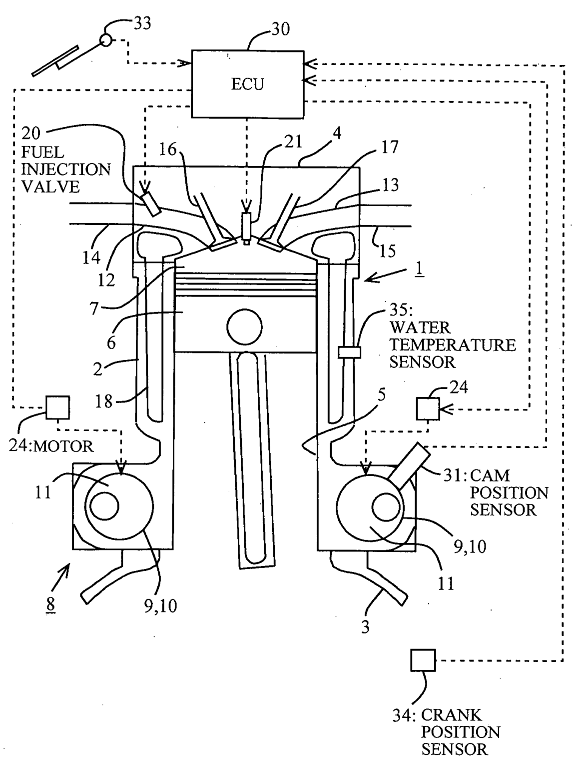
(72) Inventors:
- **Akihisa, Daisuke**
  Toyota-shi Aichi-ken, 471-8571 (JP)
- **Kamiyama, Eiichi**
  Toyota-shi Aichi-ken, 471-8571 (JP)
- **Kashiwa, Masaaki**
  Toyota-shi Aichi-ken, 471-8571 (JP)

(74) Representative: **KUHNEN & WACKER**
Patent- und Rechtsanwaltsbüro
Prinz-Ludwig-Strasse 40A
85354 Freising (DE)

(54) **Variable compression ratio internal combustion engine**

(57) In a variable compression ratio internal combustion engine whose compression ratio is varied by changing the volume of a combustion chamber, the present invention is intended to enable the engine to operate at a high compression ratio under a much higher load while suppressing an excessive rise in the temperature of the combustion chamber. A cooling system is provided for cooling the variable compression ratio internal combustion engine, and when the load of the variable compression ratio internal combustion engine is equal to a specified value or above at a high compression ratio (S101, S102), the cooling capacity of the cooling system is increased more than when the load of the variable compression ratio internal combustion engine is lower than the specified value (S103), whereby a temperature rise in the combustion chamber can be suppressed.

FIG. 1



EP 1 564 392 A1

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a variable compression ratio internal combustion engine whose compression ratio is varied by changing the volume of a combustion chamber.

2. Description of the Related Art

[0002] In recent years, for the purpose of improving the fuel mileage performance, the output performance or the like of internal combustion engines, there have been developed variable compression ratio internal combustion engines with their compression ratio being varied by changing the volume of a combustion chamber.

[0003] In addition, in a variable compression ratio internal combustion engine whose compression ratio is changed or varied by controlling the amount of stroke of a piston in a variable manner, there has also been known a technique in which the amount of circulation of engine cooling water is decreased when the amount of piston stroke is set to a small side, (see, for example, Japanese patent application laid-open No. 2003-129817). By controlling the engine in this manner, it is possible to reduce cooling loss.

[0004] Moreover, another type of variable compression ratio internal combustion engine has been developed in which a piston is constructed of an inner piston member and an outer piston member, so that the compression ratio of the engine is changed by supplying pressure oil to a space defined between the inner and outer piston members. In such a variable compression ratio internal combustion engine, there has been known a technique in which the piston is cooled by supplying pressure oil to the space between the inner and outer piston members, or discharging it therefrom (see, for example, Japanese patent application laid-open No. S63-186926).

[0005] Further, as documents relevant to the present invention, there are the following ones: Japanese patent application laid-open Nos. S63-195340, S63-302150, and 2003-206771.

[0006] In variable compression ratio internal combustion engines, the volume of a combustion chamber is increased at low compression ratio and decreased at high compression ratio by, for example, relatively moving a cylinder block and a crankcase, or changing the amount of stroke of a piston through the folding of a connecting rod connected to the piston.

[0007] Therefore, at high compression ratio, the ratio of the area of the wall of the combustion chamber in an engine cylinder to the entire wall of a cylinder bore defined therein becomes smaller in comparison with that at low compression ratio. As a result, at high compression ratio, the amount of heat radiated from the bore wall decreases, so it becomes easier for the temperature of the combustion chamber to rise. In particular, when the load on the variable compression ratio internal combustion engine becomes high in the state of a high compression ratio, there is fear that the temperature of the combustion chamber might rise excessively, thus resulting in a fear that trouble such as knocking, etc., might occur.

SUMMARY OF THE INVENTION

[0008] Accordingly, the present invention has been made in view of the problem as referred to above, and has for its object to provide a technique that is capable of improving the fuel mileage performance, the output performance or the like of a variable compression ratio internal combustion engine, in which the compression ratio thereof can be changed through variable control on the volume of a combustion chamber, by enabling high compression ratio operation under a much higher load while suppressing an excessive rise in the temperature of the combustion chamber.

[0009] According to the present invention, in a variable compression ratio internal combustion engine whose compression ratio is changed or varied by controlling the volume of a combustion chamber in a variable manner, the cooling capacity to cool the variable compression ratio internal combustion engine is increased when the compression ratio is high and when the engine load is high.

[0010] More specifically, a variable compression ratio internal combustion engine according to the present invention in which the compression ratio thereof is varied by changing the volume of a combustion chamber, characterized by: cooling means for cooling the variable compression ratio internal combustion engine; and cooling capacity increasing means for increasing the cooling capacity of the cooling means when the load of the variable compression ratio internal combustion engine is higher than or equal to a specified value at a high compression ratio to a value greater than that when the load of the variable compression ratio internal combustion engine is lower than the specified value.

[0011] Here, note that the specified value can be an engine load under which the temperature of the combustion chamber rises excessively at a high compression ratio, and it may be a value which is determined in advance by experiments, etc. Also, this specified value may be a fixed value, or a variable value which is changed in accordance with the value of the compression ratio.

[0012] According to the present invention, when the engine load becomes high at the high compression ratio, the cooling capacity to cool the variable compression ratio internal combustion engine (hereinafter simply referred to as an internal combustion engine) is increased more than when the engine load is low. As a result, a temperature rise in the combustion chamber is suppressed. Accordingly, the internal combustion engine can be operated at the high compression ratio under a much higher load while suppressing an excessive rise in the temperature of the combustion chamber.

[0013] In the present invention, in case where the cooling means includes heating medium supply means for supplying a heating medium to the internal combustion engine, the cooling capacity increasing means increases the cooling capacity of the cooling means by increasing the amount of the heating medium supplied to the internal combustion engine by the heating medium supply means when the load of the internal combustion engine is higher than or equal to the specified value at the high compression ratio.

[0014] When the amount of the heating medium supplied to the internal combustion engine is increased, the cooling effect of the internal combustion engine due to the heating medium can be improved. That is, the cooling capacity of the cooling means can be increased.

[0015] At this time, the heating medium supply means may include heating medium circulation passages through which the heating medium circulates while passing through the internal combustion engine, and pressure feed means for pressure feeding the heating medium to the heating medium circulation passages. In addition, the cooling capacity increasing means may include pressure feed amount changing means for changing the amount of heating medium to be pressure fed by the pressure feed means per unit time. In such a case, the cooling capacity increasing means increases the amount of heating medium to be pressure fed by the pressure feed means per unit time under the action of the pressure feed amount changing means when the load of the internal combustion engine is higher than or equal to the specified value at the high compression ratio.

[0016] By increasing the amount of the heating medium to be pressure fed by the pressure feed means per unit time, the amount of the heating medium supplied to the internal combustion engine per unit time can be increased.

[0017] In addition, in the present invention, in case where the cooling means includes heating medium supply means for supplying the heating medium to the internal combustion engine, the cooling capacity increasing means may increase the cooling capacity of the cooling means by lowering the temperature of the heating medium supplied to the internal combustion engine by the heating medium supply means when the load of the internal combustion engine is higher than or equal to the specified value at the high compression ratio.

[0018] When the temperature of the heating medium supplied to the internal combustion engine is lowered, the cooling effect of the internal combustion engine due to the heating medium can be improved. That is, the cooling capacity of the cooling means can be increased.

[0019] At this time, the heating medium supply means may include heating medium circulation passages through which the heating medium circulates while passing through the internal combustion engine. In addition, the cooling capacity increasing means may include: a radiator; communication passages through which the radiator and the heating medium circulation passages are placed in communication with each other; communication switch valve disposed in the communication passages for opening and closing the communication passages; a temperature detection means for detecting the temperature of the heating medium that flows through the heating medium circulation passages; valve switching control means for opening the communication switch valve when the temperature of the heating medium detected by the temperature detection means becomes higher than or equal to a preset temperature, whereby the communication passages are opened to circulate the heating medium while passing through the internal combustion engine and the radiator; and preset temperature change means for changing the preset temperature. In such a case, when the load of the internal combustion engine is higher than or equal to the specified value at the high compression ratio, the cooling capacity increasing means decreases, through the preset temperature change means, the preset temperature to a value lower than that when the load of the internal combustion engine is lower than the specified value.

[0020] By decreasing the preset temperature, the heating medium becomes able to circulate through the radiator when the heating medium is at a much lower temperature. As a result, the temperature of the heating medium supplied to the internal combustion engine can be decreased.

[0021] Moreover, when the compression ratio is low, the amount of heat radiated from the wall of a cylinder bore is larger than when the compression ratio is high, so it is not easy to raise the temperature of the combustion chamber. Therefore, there is fear that when the cooling capacity of the cooling means is increased at a low compression ratio as in the case where the load of the internal combustion engine is larger than the specified value at the high compression ratio, the temperature of the internal combustion engine might excessively decrease regardless of the load of the internal combustion engine.

[0022] Accordingly, in the present invention, an increase in the cooling capacity of the cooling means may be inhibited at a low compression ratio.

[0023] As a consequence, it becomes possible to suppress an excessive decrease in the temperature of the internal combustion engine at the low compression ratio.

[0024] Here, note that in the past, in an internal combustion engine, the compression ratio is often made high when the engine is operated under a low load, and in such a case, there is a low possibility that the temperature of the combustion chamber rises excessively, as stated above. However, in order to improve the fuel mileage performance, the output performance or the like of the internal combustion engine, it is preferable to make the compression ratio high even under a much higher load.

[0025] Further, when the internal combustion engine is operated to rotate at a high rotational speed, a stream of intake air in the engine cylinder is liable to be disturbed, so an air fuel mixture therein becomes easily distributed in a substantial uniform manner, and the time of one cycle of the combustion cycle is also shortened. As s result, when the speed or number of revolutions per minute of the engine is high, the temperature of the combustion chamber becomes less prone to rise as compared with the case where the engine speed is low. Accordingly, the compression ratio can be made high when the internal combustion engine is operated at a high rotational speed instead of when the internal combustion engine is operated under a high load. Even in such a case, by performing the control according to the present invention, the internal combustion engine is able to carry out high compression ratio operation under a much higher load while suppressing an excessive rise in the temperature of the combustion chamber in a more reliable manner.

[0026] According to the internal combustion engine of the present invention, it becomes possible to perform high compression ratio operation under a much higher load while suppressing an excessive rise in the temperature of the combustion chamber, thus making it possible to further improve the fuel mileage performance, the output performance and the like of the internal combustion engine.

[0027] The above and other objects, features and advantages of the present invention will become more readily apparent to those skilled in the art from the following detailed description of preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028]

Fig. 1 is a view showing the schematic construction of a variable compression ratio internal combustion engine according to the present invention.

Fig. 2 is a view showing the schematic construction of a cooling water circulation system in the variable compression ratio internal combustion engine according to a first embodiment of the present invention.

Figs. 3A and 3B are views respectively showing the different operating states of a combustion chamber when the compression ratio is changed according to the present invention, wherein Fig. 3A illustrates one state of the combustion chamber at a high compression ratio, and Fig. 3B illustrates another state of the combustion chamber at a low compression ratio.

Fig. 4 is a flow chart showing a routine for controlling the amount of cooling water to be pressure fed by a water pump per unit time according to the first embodiment of the present invention.

Fig. 5 is a view showing the schematic construction of a cooling water circulation system in a variable compression ratio internal combustion engine according to a second embodiment of the present invention.

Fig. 6 is a flow chart showing an switching control routine for a communication switch valve according to the second embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0029] Hereinafter, preferred embodiments of a variable compression ratio internal combustion engine according to the present invention will be described while referring to the accompanying drawings.

EMBODIMENT 1

[0030] First, a variable compression ratio internal combustion engine according to a first embodiment of the present invention will be described. Fig. 1 is a view that illustrates the schematic construction of the variable compression ratio internal combustion engine according to this embodiment.

[0031] In Fig. 1, the variable compression ratio internal combustion engine, generally designated at reference numeral 1 (hereinafter simply referred to as an internal combustion engine 1), includes a cylinder block 2 having a cylinder 5, a cylinder head 4 mounted on a the cylinder block 2, and a lower casing 3 with which a piston 6 is connected through a connecting rod and a crankshaft (not shown). In such a construction, the volume of a combustion chamber 7, which is defined in a cylinder bore by the piston 6 and the cylinder head 4, is varied to change the compression ratio by moving the cylinder block 2 relative to the lower casing 3 in an axial direction of the cylinder 5 by means of a compression ratio variable mechanism 8.

[0032] The compression ratio variable mechanism 8 has a pair of cam receiving bores 9 formed in the cylinder block 2 at its left and right side lower portions in Fig. 1, and a pair of bearing receiving bores 10 formed in the lower casing 3 at its left and right side upper portions in Fig. 1. A pair of camshafts 11 is inserted into the cam receiving bores 9 and the bearing receiving bores 10 at the right and left sides, respectively. The right and left side camshafts 11 are driven to rotate by a pair of motors 24, respectively, so that the cylinder block 2 is caused to move with respect to the lower casing 3 in the axial direction of the cylinder 5. At this time, the cylinder head

4 is also caused to move integrally with the cylinder block 2. Here, note that details of this compression ratio variable mechanism 8 are disclosed in Japanese patent application laid-open No. 2003-206771.

[0033] An intake port 12 and an exhaust port 13 are formed in the cylinder head 4 so as to open into the combustion chamber 7 in the cylinder 5. The intake port 12 is connected with an intake passage 14, and the exhaust port 13 is connected with an exhaust passage 15. The intake port 12 and the exhaust port 13 have their opening portions into the combustion chamber 7 adapted to be opened and closed by an intake valve 16 and an exhaust valve 17, respectively.

[0034] A fuel injection valve 20 is arranged in the intake port 12, and a spark plug 21 for igniting or firing an air fuel mixture formed in the combustion chamber 7 is arranged in the combustion chamber 7. Also, a water jacket 18 through which cooling water circulate is formed in the cylinder head 4 and the cylinder block 2.

[0035] In addition, the internal combustion engine 1 includes various kinds of sensors such as a cam position sensor 31 that outputs an electric signal corresponding to the angle of rotation of one of the camshafts 11 of the compression ratio variable mechanism 8, an accelerator opening sensor 33 that outputs an electric signal corresponding to the degree of opening of an accelerator pedal (not shown), a crank position sensor 34 that outputs an electric signal corresponding to the angle of rotation of the unillustrated crankshaft with which the piston 6 arranged in the lower casing 3 is connected, a water temperature sensor 35 that outputs an electric signal corresponding to the temperature of cooling water which flows in the water jacket 18, etc.

[0036] An electronic control unit (ECU) 7 for controlling the internal combustion engine 1 is provided in conjunction with the engine 1. This ECU 30 serves to control the operating conditions of the internal combustion engine 1 and the like in accordance with the operating state of the internal combustion engine 1 and driver's requirements. The various kinds of sensors such as the cam position sensor 31, the accelerator opening sensor 33, the crank position sensor 34, the water temperature sensor 35, etc., are connected to the ECU 30 through electric wiring, so that the output signals of these sensors are input to the ECU 30. The ECU 30 derives the load of the internal combustion engine 1 from a detection value (i.e., the amount of opening or depression of the accelerator pedal) of the accelerator opening sensor 33, and also derives the number of revolutions per minute of the internal combustion engine 1 from a detection value (i.e., the crank angle or rotational angle of the crankshaft) of the crank position sensor 34.

[0037] Moreover, the fuel injection valve 20, the spark plug 21, the motors 24 and so on are also electrically connected to the ECU 30, so that they can be controlled by the ECU 30. The ECU 30 changes the volume of the combustion chamber 7 by controlling the rotation of the camshafts 11 by means of the motors 24, whereby the compression ratio of the internal combustion engine 1 is changed. At this time, the ECU 30 derives the compression ratio from the output value of the cam position sensor 31.

[0038] Next, reference will be made to the schematic construction of the cooling water circulation system in the internal combustion engine according to this embodiment while referring to Fig. 2. Fig. 2 is a view that illustrates the schematic construction of the cooling water circulation system in the internal combustion engine 1 according to this embodiment.

[0039] A first cooling water passage 41 is connected at its one end with one end of the water jacket 18 in the internal combustion engine 1, and at its other end with one end of an engine related device 43. As the engine related device 43, there can be exemplified a cooling water tank in which cooling water is stored, a heater core of a passenger compartment heater, etc. In addition, a second cooling water passage 42 is connected at its one end with the other end of the water jacket 18 in the internal combustion engine 1, and at its other end with the other end of the engine related device 43.

[0040] A water pump 44 for pressure feeding the cooling water from the engine related device 43 side to the internal combustion engine 1 side is arranged on the first cooling water passage 41. This water pump 44 is electrically connected to the ECU 30, so that the amount of cooling water to be pressure fed per unit time can be changed under the control of the ECU 30.

[0041] Thus, in the cooling water circulation system according to this embodiment, a first cooling water circulation passage 45 through which the cooling water circulates is formed by the water jacket 18, the first cooling water passage 41, the second cooling water passage 42, and the engine related device 43. The internal combustion engine 1 is cooled by the cooling water which circulates through the first cooling water circulation passage 45.

[0042] Here, reference will be made to the state of the combustion chamber 7 when the compression ratio 1 has been changed in the internal combustion engine while referring to Fig. 3. Fig. 3A is a view that illustrates one state of the combustion chamber 7 at a high compression ratio, and Fig. 3B is a view that illustrates another state of the combustion chamber 7 at a low compression ratio.

[0043] In the internal combustion engine 1, the volume of the combustion chamber 7 is decreased to raise or increase the compression ratio by causing the cylinder block 2 to move toward the lower casing 3 under the action of the compression ratio variable mechanism 8, as shown in Fig. 3A. Also, in the internal combustion engine 1, the volume of the combustion chamber 7 is increased to lower or decrease the compression ratio by causing the cylinder block 2 to move away from the lower casing 3 by means of the compression ratio variable mechanism 8, as shown in Fig. 3B.

[0044] Therefore, at the high compression ratio, the ratio of the area of the wall of the combustion chamber 7 to the entire wall of the cylinder bore becomes smaller in comparison with that at the low compression ratio. As a result, at the high compression ratio, the amount of heat radiated from the bore wall decreases, so it becomes easier for the temperature of the combustion chamber 7 to rise. In particular, when the load of the internal combustion engine 1 becomes high in the state of the high compression ratio, there is fear that the temperature of the combustion chamber 7 might rise excessively, thus resulting in a fear that trouble such as knocking, etc., might occur.

[0045] Accordingly, in this embodiment, when the load of the internal combustion engine 1 becomes high at the high compression ratio, the amount of cooling water to be pressure fed by the water pump 44 per unit time is increased to enlarge the cooling capacity to cool the internal combustion engine 1. Hereinafter, a routine for controlling the amount of cooling water to be pressure fed by the water pump 44 per unit time according to this embodiment will be described based on a flow chart shown in Fig. 4. This routine is beforehand stored in the ECU 30, and is executed at a specified time interval during the operation of the internal combustion engine 1.

[0046] In this routine, first in step S101, the ECU 30 determines whether the compression ratio of the internal combustion engine 1 is high. Here, when the value of the compression ratio of the internal combustion engine is higher than or equal to a specified compression ratio which is determined in advance, the ECU 30 may determine that the compression ratio of the internal combustion engine 1 is high. When a positive determination is made in step S101, the control flow advances to step S102, whereas when a negative determination is made in step S101, the ECU 30 once terminates the execution of this routine.

[0047] In step S102, it is determined whether the load of the internal combustion engine 1 is higher than or equal to a specified value Q. Here, note that the specified value Q is an engine load under which the temperature of the combustion chamber 7 might rise excessively at the high compression ratio, and it can be a value which is determined in advance by experiments, etc. Also, this specified value Q may be a fixed value, or a variable value which is changed in accordance with the value of the compression ratio. When a positive determination is made in step S102, the control flow advances to step S103, whereas when a negative determination is made in step S102, the ECU 30 once terminates the execution of this routine.

[0048] In step S103, the ECU 30 increases the amount of cooling water to be pressure fed by the water pump 44 per unit time to a value more than that when the load of the internal combustion engine 1 is lower than the specified value Q, and thereafter once terminates this routine.

[0049] In the above-mentioned control, when the load of the internal combustion engine 1 is higher than or equal to the specified value Q at the high compression ratio, the amount of cooling water passing through the internal combustion engine 1 (the water jacket 18) per unit time increases. Accordingly, the cooling effect of the internal combustion engine 1 due to the cooling water is improved.

[0050] That is, according to this embodiment, when the load of the internal combustion engine 1 is high at the high compression ratio, the cooling capacity to cool the internal combustion engine 1 becomes greater than when the engine load is low, so the temperature rise of the combustion chamber 7 is suppressed. Therefore, the internal combustion engine 1 becomes able to perform high compression ratio operation under a much higher load while suppressing an excessive rise in the temperature of the combustion chamber 7, thus making it possible to further improve the fuel mileage performance, the output performance and the like of the internal combustion engine 1.

[0051] In the above-stated routine for controlling the amount of cooling water to be pressure fed by the water pump 44 per unit time, when a negative determination is made in step S101, that is, when the compression ratio of the internal combustion engine 1 is low, the execution of this routine is once stopped, so the amount of cooling water to be pressure fed by the water pump 44 per unit time is not increased. In other words, when the compression ratio of the internal combustion engine 1 is low, the increase of the cooling capacity to cool the internal combustion engine 1 is inhibited.

[0052] As a consequence, it becomes possible to suppress an excessive decrease in the temperature of the internal combustion engine 1 at the low compression ratio.

EMBODIMENT 2

[0053] Next, reference will be made to a variable compression ratio internal combustion engine according to a second embodiment of the present invention. Since the schematic construction (see Fig. 1) of the variable compression ratio internal combustion engine according to this embodiment and the state of the combustion chamber (see Fig. 3) when the compression ratio is changed are similar to those of the above-mentioned first embodiment, an explanation thereof is omitted.

[0054] Now, reference will be made to the schematic construction of a cooling water circulation system in the internal combustion engine according to this embodiment while referring to Fig. 5. Fig. 5 is a view that illustrates the schematic construction of the cooling water circulation system in the internal combustion engine 1 according to this embodiment. The component parts or members of this embodiment similar to those of the above-mentioned first embodiment are identified by the same symbols, while omitting an explanation thereof.

[0055] In this embodiment, a radiator 46 is provided in combination with the internal combustion engine 1, and the first cooling water passage 41 between the engine related device 43 and the water pump 44 is placed in communication with one end of the radiator 46 through a first communication passage 47. Also, the second cooling water passage 42 is placed in communication with the other end of the radiator 46 through a second communication passage 48.

[0056] At a junction between the second cooling water passage 42 and the second communication passage 48, there is provided a communication switch valve 49 that serves to open and close communication between the second cooling water passage 42 and the second communication passage 48. This communication switch valve 49 is electrically connected to the ECU 30.

[0057] When the temperature of the cooling water detected by the water temperature sensor 35 becomes a preset temperature Tc or above, the ECU 30 opens the communication switch valve 49 thereby to place the second cooling water passage 42 and the second communication passage 48 into communication with each other. On the other hand, when the temperature of the cooling water detected by the water temperature sensor 35 becomes lower than the preset temperature Tc, the ECU 30 closes the communication switch valve 49 thereby to interrupt or break communication between the second cooling water passage 42 and the second communication passage 48. Here, note that the preset temperature Tc can be changed by the ECU 30.

[0058] In the cooling water circulation system according to this embodiment, when the communication switch valve 49 is opened by the ECU 30 thereby to place the second cooling water passage 42 and the second communication passage 48 into communication with each other, a second cooling water circulation passage 50 for circulation of cooling water is formed by the water jacket 18, the radiator 46, a part of the first cooling water passage 41, a part of the second cooling water passage 42, the first communication passage 47 and the second communication passage 48. As the cooling water circulates through the second cooling water circulation passage 50, the cooling water is cooled by the radiator 46 so that the temperature thereof is lowered.

[0059] In this embodiment, when the load of the internal combustion engine 1 becomes high at a high compression ratio, the preset temperature Tc, which is a threshold for switching or opening and closing the communication switch valve 49, is lowered so as to increase the cooling capacity to cool the internal combustion engine 1. Hereinafter, reference will be made to a switching control routine for the communication switch valve 49 according to this embodiment based on a flow chart shown in Fig. 6. This routine is beforehand stored in the ECU 30, and is executed at a specified time interval during the operation of the internal combustion engine 1. Here, note that steps S101 and S102 in this routine are the same as those in the above-mentioned first embodiment, so an explanation thereof is omitted, and only step S203, being different from the first embodiment, will be described.

[0060] In this routine, when a positive determination is made in step S102, the control flow advances to step S203.

[0061] In step S203, the ECU 30 decreases the preset temperature Tc to a value lower than that when the load of the internal combustion engine 1 is lower than the specified value Q, and thereafter once terminates this routine.

[0062] In the above-mentioned control, in case where the load of the internal combustion engine 1 is higher than or equal to the specified value Q at the high compression ratio, communication between the second cooling water passage 42 and the second communication passage 48 is opened when the cooling water is at a much lower temperature. Accordingly, when the temperature of the cooling water is much lower, the cooling water comes to circulate through the second cooling water circulation passage 50 to pass through the radiator 46. As a result, the temperature of the cooling water supplied to the internal combustion engine 1 is lowered, so that the cooling effect of the internal combustion engine 1 due to the cooling water can be improved.

[0063] That is, according to this embodiment, similar to the above-mentioned first embodiment, when the load of the internal combustion engine 1 is high at the high compression ratio, the cooling capacity to cool the internal combustion engine 1 becomes greater than when the engine load is low, so the temperature rise of the combustion chamber 7 is suppressed. Accordingly, the internal combustion engine 1 becomes able to perform high compression ratio operation under a much higher load while suppressing an excessive rise in the temperature of the combustion chamber 7, thus making it possible to further improve the fuel mileage performance, the output performance and the like of the internal combustion engine 1.

[0064] In the switching control routine for the communication switch valve 49 as stated above, when a negative determination is made in step S101, that is, when the compression ratio of the internal combustion engine 1 is low, the execution of this routine is once stopped and the preset temperature Tc is not lowered. In other words, similar to the first embodiment, when the compression ratio of the internal combustion engine 1 is low, an increase in the cooling capacity to cool the internal combustion engine 1 is inhibited.

[0065] As a result, an excessive decrease in the temperature of the internal combustion engine 1 can be suppressed at the low compression ratio.

[0066] In the above-mentioned first and second embodiments, the compression ratio can be made high when the internal combustion engine 1 is operated at a high rotational speed instead of when the internal combustion engine 1 is operated under a high load. Even in such a case, by performing the above-mentioned respective control operations, the internal combustion engine 1 is able to carry out high compression ratio operation under a much higher load while suppressing an excessive rise in the temperature of the combustion chamber 7.

[0067] In addition, the first embodiment and the second embodiment can be combined with each other.

[0068] While the invention has been described in terms of preferred embodiments, those skilled in the art will recognize that the invention can be practiced with modifications within the spirit and scope of the appended claims.

Claims

1. A variable compression ratio internal combustion engine whose compression ratio is varied by changing the volume of a combustion chamber, **characterized by**:

cooling means (41, 42, 44) for cooling said variable compression ratio internal combustion engine (1); and

cooling capacity increasing means (30, 46, 47, 48, 49) for increasing the cooling capacity of said cooling means (41, 42, 44) when the load of said variable compression ratio internal combustion engine (1) is higher than or equal to a specified value at a high compression ratio to a value greater than that when the load of said variable compression ratio internal combustion engine (1) is lower than said specified value.

2. The variable compression ratio internal combustion engine as set forth in claim 1, **characterized in that**

said cooling means includes heating medium supply means (41, 42, 44) for supplying a heating medium to said variable compression ratio internal combustion engine (1), and

said cooling capacity increasing means (30) increases the cooling capacity of said cooling means by increasing the amount of the heating medium supplied to said variable compression ratio internal combustion engine (1) by said heating medium supply means (41, 42, 44) when the load of said variable compression ratio internal combustion engine (1) is higher than or equal to said specified value at a high compression ratio.

3. The variable compression ratio internal combustion engine as set forth in claim 2, **characterized in that**

said heating medium supply means includes:

heating medium circulation passages (41, 42) through which said heating medium circulates while passing through said variable compression ratio internal combustion engine (1); and

pressure feed means (44) for pressure feeding said heating medium to said heating medium circulation passages (41, 42);

wherein said cooling capacity increasing means includes pressure feed amount changing means (30) for changing an amount of heating medium to be pressure fed by said pressure feed means (44) per unit time; and

said cooling capacity increasing means increases the amount of heating medium to be pressure fed by said pressure feed means (44) per unit time under the action of said pressure feed amount changing means (30) when the load of said variable compression ratio internal combustion engine (1) is higher than or equal to said specified value at a high compression ratio.

4. The variable compression ratio internal combustion engine as set forth in claim 1, **characterized in that**

said cooling means includes heating medium supply means (41, 42, 44) for supplying a heating medium to said variable compression ratio internal combustion engine (1); and

said cooling capacity increasing means (30, 46, 47, 48, 49) increases the cooling capacity of said cooling means by lowering the temperature of the heating medium supplied to said variable compression ratio internal combustion engine (1) by said heating medium supply means (41, 42, 44) when the load of said variable compression ratio internal combustion engine (1) is higher than or equal to said specified value at a high compression ratio.

5. The variable compression ratio internal combustion engine as set forth in claim 4, **characterized in that**

said heating medium supply means includes heating medium circulation passages (41, 42) through which said heating medium circulates while passing through said variable compression ratio internal combustion engine (1); and

said cooling capacity increasing means includes:

a radiator (46);

communication passages (47, 48) through which said radiator (46) and said heating medium circulation passages (41, 42) are placed in communication with each other;

a communication switch valve (49) disposed in said communication passages (47, 48) for opening and closing said communication passages (47, 48);

a temperature detection means (35) for detecting the temperature of said heating medium that flows through said heating medium circulation passages (41, 42);

valve switching control means (30) for opening said communication switch valve (49) when the temperature of said heating medium detected

by said temperature detection means (35) becomes higher than or equal to a preset temperature, whereby said communication passages (47, 48) are opened to circulate said heating medium while passing through said variable compression ratio internal combustion engine (1) and said radiator (46); and
preset temperature change means (30) for changing said preset temperature;

wherein when the load of said variable compression ratio internal combustion engine (1) is higher than or equal to said specified value at a high compression ratio, said cooling capacity increasing means decreases, through said preset temperature change means (30), said preset temperature to a value lower than that when the load of said variable compression ratio internal combustion engine (1) is lower than said specified value.

6. The variable compression ratio internal combustion engine as set forth in any one of claims 1 through 5, **characterized in that**

said specified value is changed in accordance with the value of the compression ratio of said variable compression ratio internal combustion engine (1).

7. The variable compression ratio internal combustion engine as set forth in any one of claims 1 through 6, **characterized in that**

an increase in the cooling capacity of said cooling means (41, 42, 44) is inhibited at a low compression ratio.

FIG. 1

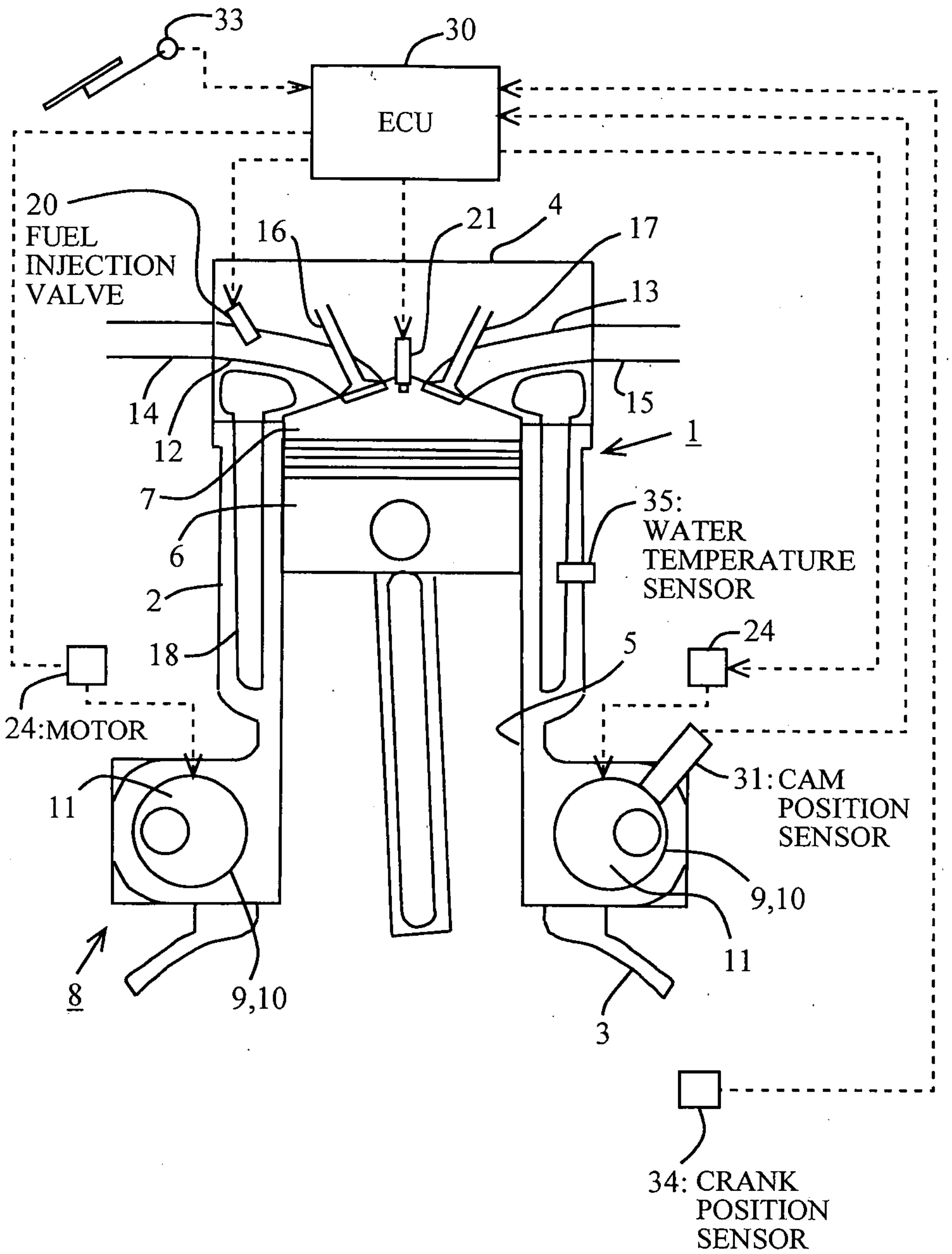

33
30
ECU
20
FUEL
INJECTION
VALVE
16
21
4
17
13
14
12
15
1
7
6
35:
WATER
TEMPERATURE
SENSOR
2
18
24
5
24:MOTOR
11
31: CAM
POSITION
SENSOR
9,10
11
8
9,10
3
34: CRANK
POSITION
SENSOR

FIG. 2

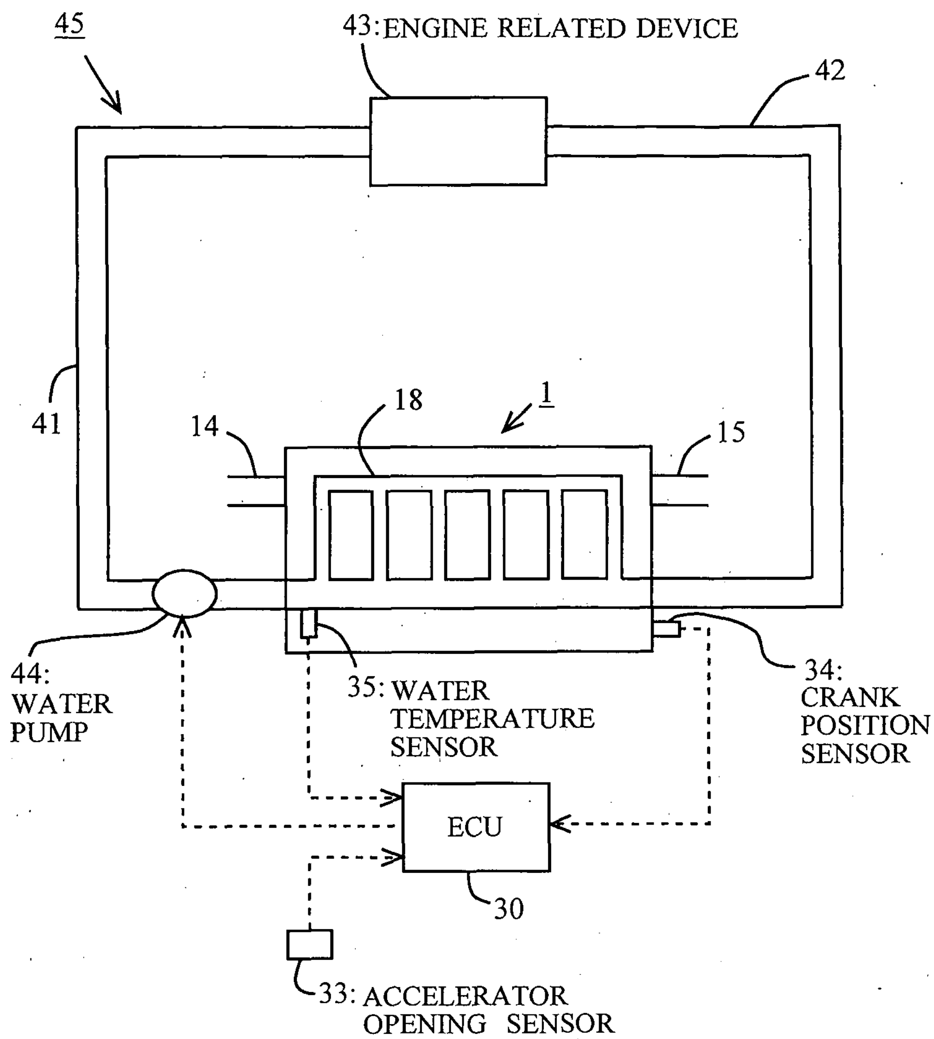

45
43: ENGINE RELATED DEVICE
42
41
14
18
1
15
44: WATER PUMP
35: WATER TEMPERATURE SENSOR
34: CRANK POSITION SENSOR
ECU
30
33: ACCELERATOR OPENING SENSOR

FIG. 3

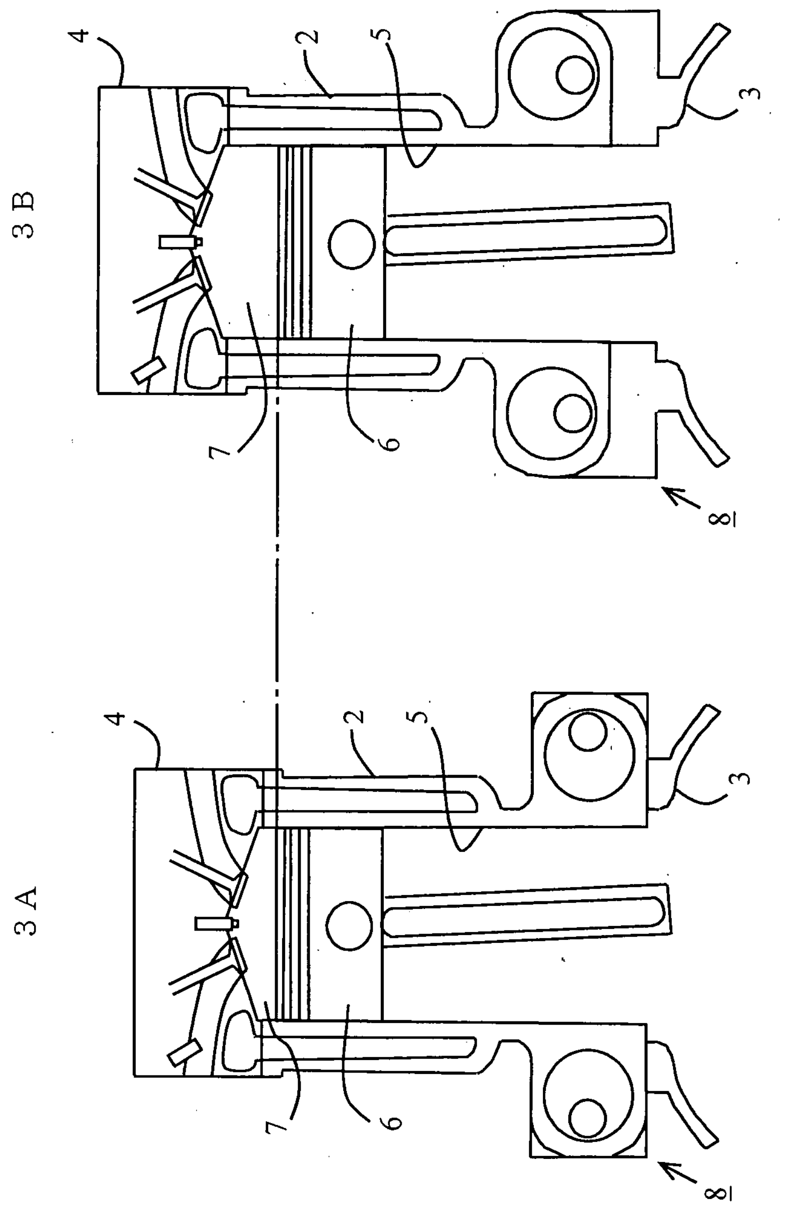


FIG. 4

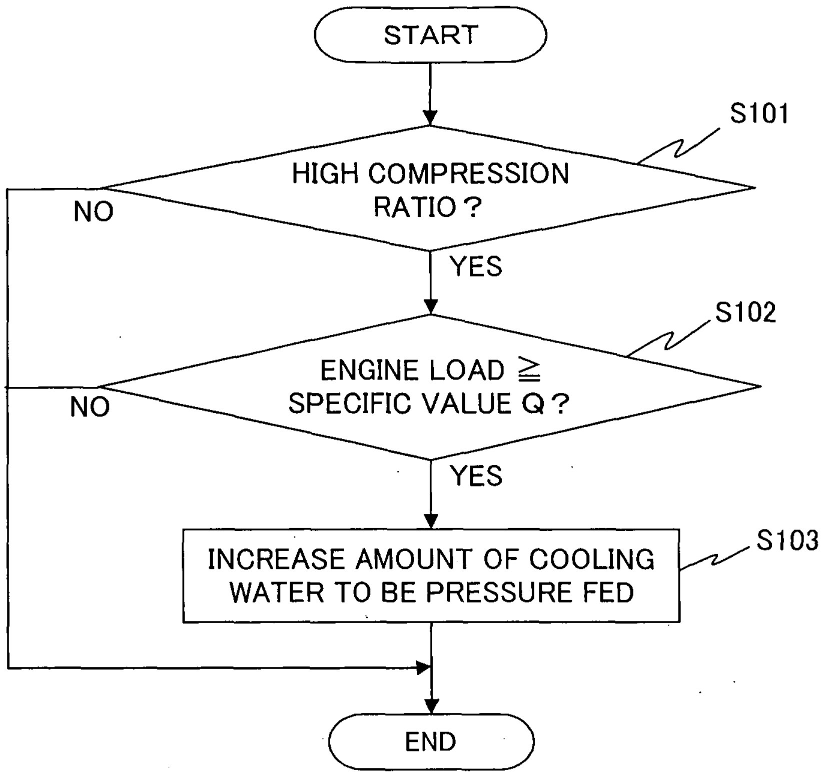

START
S101
HIGH COMPRESSION RATIO ?
NO
YES
S102
ENGINE LOAD ≧ SPECIFIC VALUE Q ?
NO
YES
S103
INCREASE AMOUNT OF COOLING WATER TO BE PRESSURE FED
END

FIG. 5

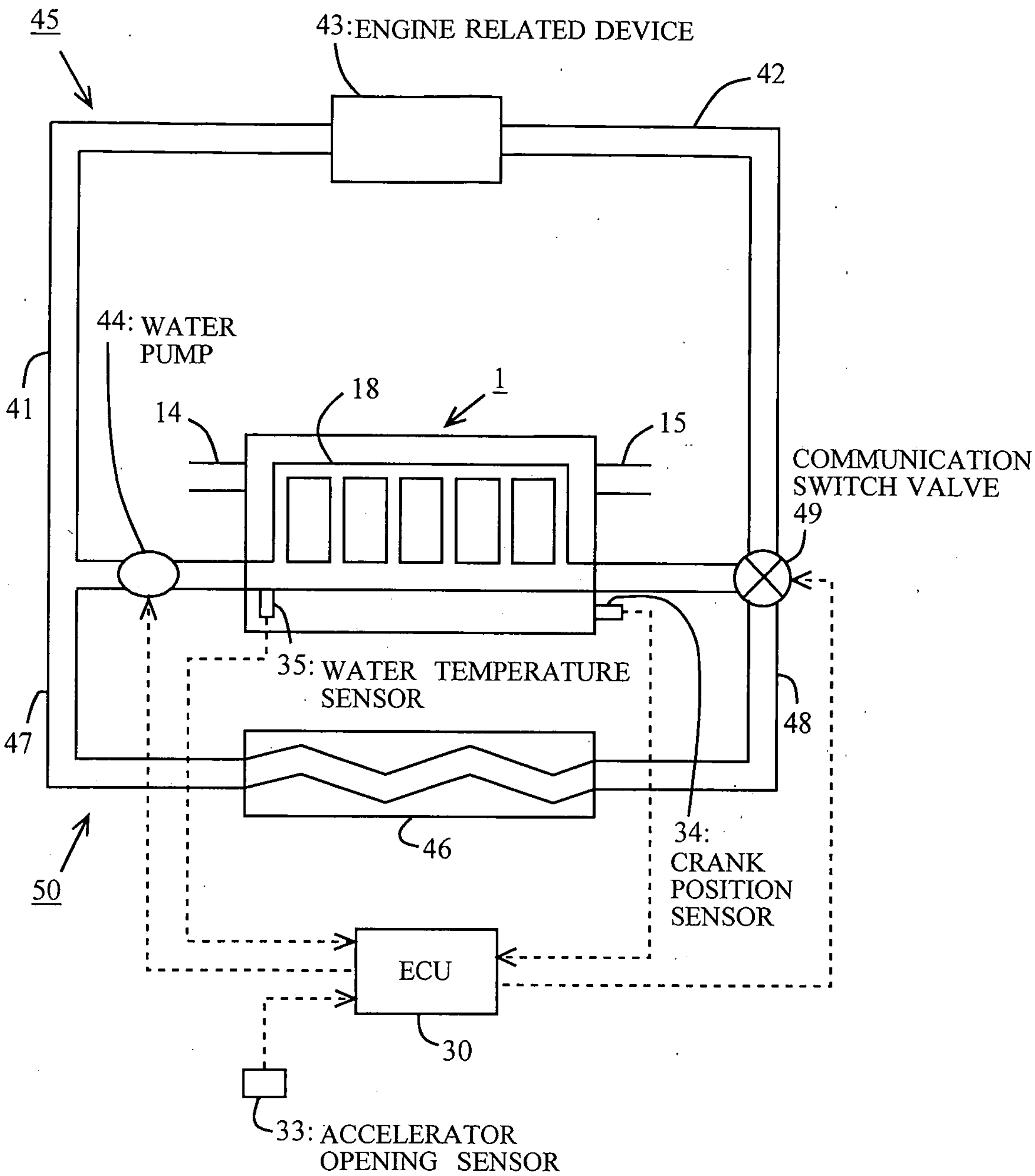
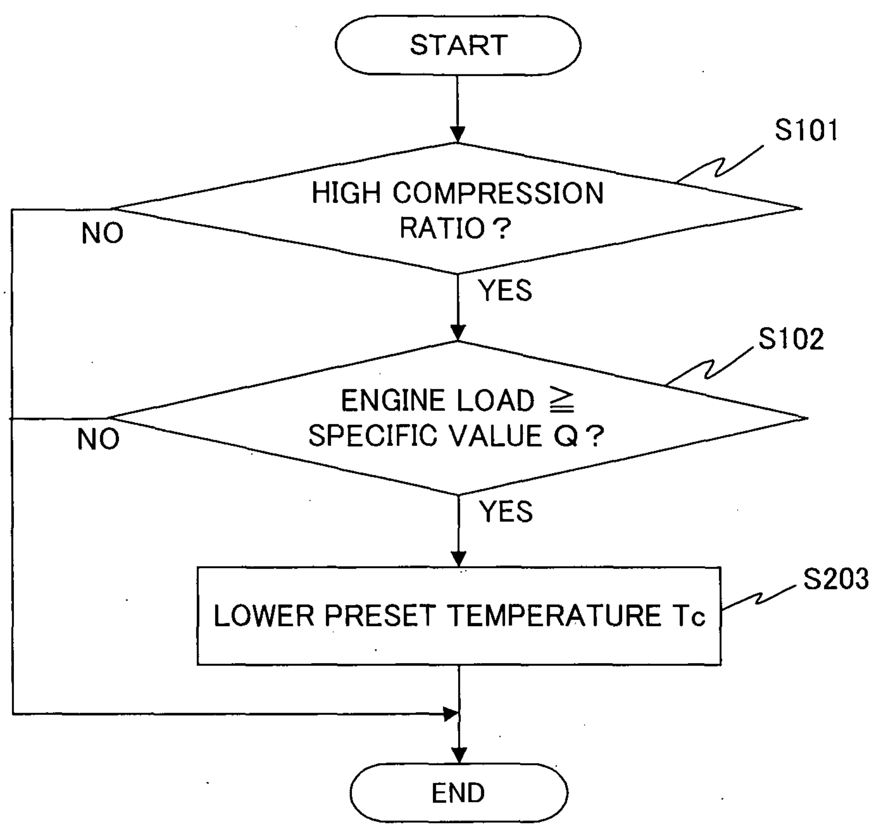

45
43:ENGINE RELATED DEVICE
42
44: WATER PUMP
41
18
1
14
15
COMMUNICATION SWITCH VALVE
49
35: WATER TEMPERATURE SENSOR
47
48
46
50
34: CRANK POSITION SENSOR
ECU
30
33: ACCELERATOR OPENING SENSOR

FIG. 6


START
S101
HIGH COMPRESSION RATIO ?
NO
YES
S102
ENGINE LOAD ≧ SPECIFIC VALUE Q ?
NO
YES
S203
LOWER PRESET TEMPERATURE Tc
END

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 00 2837

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	EP 1 318 286 A (NISSAN) 11 June 2003 (2003-06-11) * paragraph [0028] - paragraph [0032]; figures * -----	1	F02D15/04 F01P7/16
A	PATENT ABSTRACTS OF JAPAN vol. 010, no. 092 (M-468), 9 April 1986 (1986-04-09) & JP 60 230525 A (MAZDA KK), 16 November 1985 (1985-11-16) * abstract * -----	1	
A	WO 99/42718 A (CUMMINS) 26 August 1999 (1999-08-26) * page 30 - page 37; figures * -----	1-4	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
F02D
F01P
F02B

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	2 May 2005	Kooijman, F

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 00 2837

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

02-05-2005

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1318286 A	11-06-2003	JP 2003232233 A	22-08-2003
		EP 1318286 A2	11-06-2003
		US 2003106542 A1	12-06-2003
JP 60230525 A	16-11-1985	JP 1961850 C	25-08-1995
		JP 6092749 B	16-11-1994
WO 9942718 A	26-08-1999	BR 9904839 A	18-07-2000
		CN 1263583 A	16-08-2000
		EP 0983433 A1	08-03-2000
		JP 3421059 B2	30-06-2003
		JP 2000513788 T	17-10-2000
		JP 2001020784 A	23-01-2001
		WO 9942718 A1	26-08-1999
		US 6276334 B1	21-08-2001

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82