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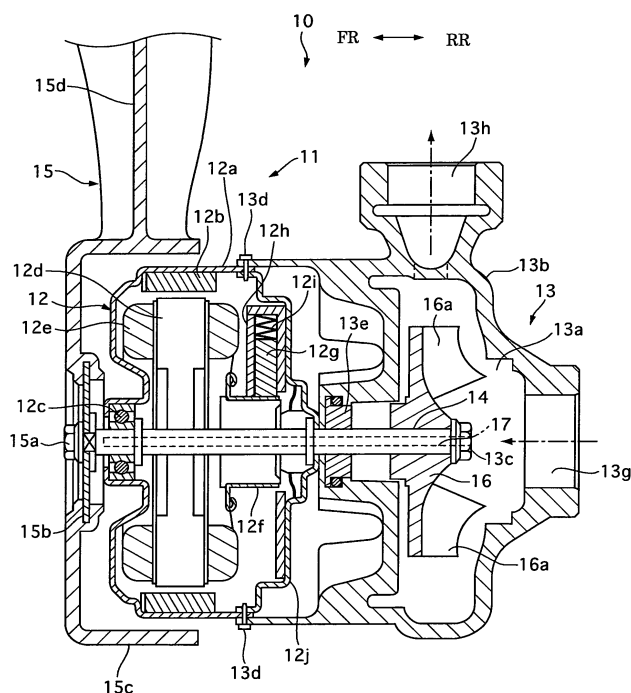
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(54) **Cooling system for motor vehicle**

(57) A cooling system includes a cooling circuit (R2), a pump (13; 32), an electric fan (11; 31), an electric motor (12) connected with the electric fan (11; 31), and a controller (20) for controlling the electric motor (12). The pump (13; 32) is capable of being driven by the electric fan (11; 31) that receives a ram airflow generated when the motor vehicle is running. The controller (20) controls the electric motor (12) to be shifted between in a first

operation state where electric power is supplied to the motor (12) and in a second operation state where no electric power is supplied to the motor (12). The pump (13; 32) is driven by a rotating torque of the ram airflow and a rotating torque of the motor (12) in the first operation state, and the pump (13; 32) is driven by the rotating torque generated by the ram airflow without the rotating torque of the motor (12) in the second operation state.

FIG. 2



Description

[0001] The present invention relates to a cooling system that includes an electric fan and an electrically drivable pump and is mounted on a motor vehicle.

[0002] Motor vehicles are generally provided with a cooling system. In conventional cooling systems for cooling engines, a cooling medium is circulated in a cooling circuit of a motor vehicle by a water pump driven by an engine, and it is cooled down in a heat exchanger cooled by an electric fan and/or airflow due to heat transfer between the cooling medium and the air, such as an airflow generated when the motor vehicle is running and/or an airflow generated by an electric fan supplied with electric power, while it passes through an inside of a heat exchanger. The conventional electric fan is disclosed in Japanese patent applications laid-open Publication No. 2000 - 333411 and No. 2002 - 300751.

[0003] Another cooling system is used for cooling an intercooler in a motor vehicle with a turbocharger for example. Japanese patent application laid-open Publication No. 2004 - 132277 discloses a cooling system having a water-cooled intercooler for cooling intake air, which is compressed by a turbocharger, to be supplied to an engine, so as to improve its supercharging efficiency. A conventional intercooler pump is driven by an electric motor. Such a conventional one is disclosed in Japanese patent application laid-open Publication No. 2005 - 315224, although this pump is not used in an intercooler cooling circuit. The electrically driven pump is suitable for a cooling circuit of an intercooler of a turbocharger because of its easy controllability.

[0004] The conventional cooling system using the electrically-driven pump, however, encounters a problem in that the cooling system exhausts much electricity power and becomes large-sized. This conventional cooling system for cooling the intercooler requires an additional electric motor to drive an intercooler pump, thus increasing its size, manufacturing costs and electric power consumption. In addition, the cooling medium always needs to be circulated to ensure a quick response to a sudden rise of engine output, thus further increasing the electric power consumption.

[0005] It is, therefore, an object of the present invention to seek to provide a cooling system of a motor vehicle which overcomes at least one of the problems associated with the prior art, preferably the foregoing drawbacks and can decrease electric power consumption of the electric motor and use a downsized electric motor at low cost, cooling the cooling medium in the cooling circuit.

[0006] According to a first aspect of the present invention there is provided a cooling system for a motor vehicle including a cooling circuit in which a cooling medium is capable of flowing, a pump for pressurizing the cooling medium to circulate in the cooling circuit, an electric fan having a plurality of blade portions, an electric motor that is connected with the electric fan to be capable of driving the electric fan to rotate, and a controller for controlling

the electric motor. The pump is capable of being driven by the electric fan that receives a ram airflow generated when the motor vehicle is running. The controller controls the electric motor to be shifted between in a first operation state where electric power is supplied to the electric motor and in a second operation state where no electric power is supplied to the electric motor. The pump is driven by a rotating torque of the ram airflow and a rotating torque of the electric motor in the first operation state, while the pump is driven by the rotating torque generated by the ram airflow without the rotating torque of the electric motor in the second operation state.

[0007] Therefore, electric power consumption of the electric motor can be decreased, and the electric motor can be downsized and manufactured at low costs.

[0008] Features and advantages of embodiments of the present invention will become apparent as the description proceeds when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic view showing a cooling system adapted for a motor vehicle of a first embodiment according to the present invention;

FIG. 2 is a cross sectional view showing an electric fan and a pump which are constructed as one unit and used in the cooling system shown in FIG. 1;

FIG. 3 is a flow chart showing a flow of a pump drive control executed in the cooling system of the first embodiment;

FIG. 4 is a front perspective view showing an electric fan with a pump used in a cooling system of a second embodiment according to the present invention;

FIG. 5 is a rear perspective view showing the electric fan with the pump shown in FIG. 4;

FIG. 6 is a partly cross-sectional rear perspective view showing the electric fan with the pump shown in FIG. 4; and

FIG. 7 is an exploded front perspective view showing the electric fan with the pump shown in FIG. 4.

[0009] Throughout the following detailed description, similar reference characters and numbers refer to similar elements in all figures of the drawings, and their descriptions are omitted for eliminating duplication.

[0010] In the figures, "FR" means "forward" and "RR" means "rearward".

[0011] A cooling system for motor vehicles of a first preferred embodiment according to the present invention will be described with reference to the accompanying drawings.

[0012] Referring to FIGS. 1 to 3 of the drawings, there are shown cooling systems provided on a motor vehicle

equipped with an engine 1 equipped with a turbocharger 8, where the cooling systems include the cooling system of the first embodiment.

[0013] The cooling systems has a main radiator 2, an engine pump 4, a water-cooled intercooler 5, a sub radiator 6, an intercooler pump 13, an electric fan 11 and a plurality of pipes 9a to 9o, thereby forming an engine cooling circuit R1 for cooling the engine 1, an intercooler cooling circuit R2 for cooling the air to be supplied to the engine 1 and a turbocharger gas circuit R3 for actuating the turbocharger 8 and supplying the air to the engine 1. The intercooler cooling circuit R2 corresponds to a cooling circuit of the present invention.

[0014] The engine cooling circuit R1 has a first pipe 9a, a second pipe 9b, a third pipe 9c, a fourth pipe 9d, a fifth pipe 9e and a sixth pipe 9f, where the first and second pipes 9a and 9b fluidically connect the engine 1 and the main radiator 2, the third pipe 9c fluidically connects the engine 1 and the thermostat 3, the fourth pipe 9d fluidically connects the thermostat 3 and the engine pump 4, namely a water pump, the fifth pipe fluidically connects the engine pump 4 and the engine 1, and the sixth pipe 9f fluidically connects an intermediate portion of the fourth pipe 9d and a connected portion of the first and second pipes 9a and 9b. The engine pump 4 is driven by the engine 1, and a not shown electric fan is provided behind the main radiator 2 to cool coolant flowing therein.

[0015] The coolant at high temperature is discharged from the engine 1 and is introduced to the main radiator 2 through the first and second pipes 9a and 9b. The main radiator 2 cools the coolant due to heat transfer between the coolant and airflow generated when the motor vehicle is running (and/or airflow generated by the electric fan 11 supplied with electric power) while the coolant passes through the main radiator 2. The cooled coolant discharged from the main radiator 2 is conducted to the thermostat 3 through the third pipe 9c, then to the engine pump 4 through the fourth pipe 9d, where the engine pump 4 pressures the coolant to enter the engine 1 through the fifth pipe 9e so as to cool the engine 1.

[0016] The thermostat 3 closes its valve, when a temperature of the coolant is low, so as to circulate the coolant in the first, sixth, fourth and fifth pipes 9a, 9f, 9d and 9e in turn, preventing the coolant discharged from the engine 1 from being introduced to the main radiator 2. This avoids overcooling of the engine 1. Incidentally, flow directions of the coolant in the first to sixth pipes 9a to 9f are indicated by arrows in FIG. 1, respectively.

[0017] The intercooler cooling circuit R2 has a seventh pipe 9g, an eighth pipe 9h and a ninth pipe 9i, where the seventh pipe 9g fluidically communicates the intercooler 5 and the sub radiator 6, the eighth pipe 9h fluidically connects the sub radiator 6 and the intercooler pump 13, and the ninth pipe fluidically connects the intercooler pump 13 and the intercooler 5. Specifically, the seventh pipe 9g and the ninth pipe 9i are fluidically communicated with an inner chamber 5c formed between an intercooler casing 5a and a heat exchanging part 5b. The intercooler

pump 13 is capable of being driven by the electric motor 12 and/or by an airflow generated when the motor vehicle is running. This airflow generated when the vehicle is running is called ram airflow. Note that the intercooler pump 13 is not driven by the engine 1, while the engine pump 4 is driven by the engine 1. The intercooler pump 13 corresponds to a pump of the present invention.

[0018] A coolant at high temperature is discharged from the intercooler 5, and is introduced to the sub radiator 2 through the seventh pipe 9g, where the sub radiator 2 cools the coolant due to heat transfer between the coolant and the ram airflow (and/or the airflow generated by the electric fan 11 supplied with the electric power). The cooled coolant is discharged from the sub radiator 6 to be conducted to the intercooler pump 13 through the eighth pipe 9h, where it is pressurized to enter the intercooler 5 through the ninth pipe 9i, where the intercooler 5 cools the air, pressurized by the turbocharger 8, to be supplied to the engine 1. The seventh pipe 9g is provided at its intermediate portion with a temperature sensor C1 for detecting a temperature of the coolant. Flow directions of the coolant in the seventh to ninth pipes 9g to 9i are indicated by arrows in FIG. 1, respectively. The temperature sensor C1 is electrically connected to a controller 20 and outputs a temperature signal. The controller 20 is also electrically connected to an electric motor 12, shown in FIG. 2, of the electric fan 11. Incidentally, the temperature sensor C1 may be located at any appropriate position. The coolant in the intercooler cooling circuit R2 corresponds to a cooling medium of the present invention.

[0019] The turbocharger gas circuit R3 has a tenth pipe 9j, an eleventh pipe 9k and twelfth pipe 9m, where the tenth pipe 9j fluidically connects a not-shown air cleaner and a compressor chamber 8a of the turbocharger 8, the eleventh pipe 9m fluidically connects the compressor chamber 8a of the turbocharger and the heat exchanging part 5b of the intercooler 5.

[0020] The outside air is introduced to the compressor chamber 8a of the turbocharger 8 through the air cleaner so as to be pressurized. The air becomes hot due to compression by a not-shown compressor in the compressor chamber 8a, and it is introduced to the inner chamber 5c of the intercooler 5. The intercooler 5 cools the air due to heat transfer between the air and the coolant in the inner chamber 5c when it passes through the heat exchanging part 5b. The cooled air is delivered to not-shown cylinders of the engine 1 with fuel through the twelfth pipe 9m and not-shown intake manifold to activate the engine 1.

[0021] The fuel is burned in the cylinders to be outputted as an exhaust gas, which is discharged from the engine 1 through a not-shown exhaust manifold and a thirteenth pipe 9n to a turbine chamber 8b of the turbocharger 8. A not-shown turbine in the turbine chamber 8b is driven by the discharged exhaust gas to drive the compressor of the turbocharger 8. The exhaust gas is then discharged to the outside through the fourteenth pipe 9o,

a not-shown catalytic converter, main muffler and so forth.

[0022] In the first embodiment, the main radiator 2 and the sub radiator 6 are assembled with each other so that the sub radiator 6 is placed on the main radiator 2, although they are illustrated so that they are offset in a forward and rearward direction (a longitudinal direction of the motor vehicle). They may be constructed as one unit so that the sub radiator 6 is an upper part of a radiator and the main radiator 2 is a lower part thereof. The sub radiator 6 may be constructed with a not-shown condenser as one unit to be an upper part thereof, and may be separated from the main radiator 2 and the condenser, being apart therefrom. The intercooler 5 may have a construction similar to a housing-type oil cooler or a housingless-type oil cooler.

[0023] Next, a detail construction of an integrated pump-fan 10 will be described with reference to FIG. 2.

[0024] In this embodiment, the intercooler pump 13 and the electric fan 11 are combined with each other as one unit to form the integrated pump-fan 10.

[0025] The electric fan 11 includes the electric motor 12 and a fan main body 15 which is capable of being driven when electric power is supplied to the electric motor 12.

[0026] The electric motor 12 is a typical brush-type motor, like described in Japanese Patent Application Laid-open No. 2000 - 350429 for example. In this embodiment the electric motor 12 is constructed to have a motor housing 12a, a pair of permanent magnets 12b, a rotor core 12d, a plurality set of coils 12e, a commutator 12f and a plurality of brushes 12g. The motor housing 12a is formed like a cylinder integrally formed with a dish flange portion that covers one end opening of the motor housing 12a. The permanent magnets 12b are formed like a part of a ring and are fixed on an inner surface of a cylinder portion of the motor housing 12, symmetrically relative to a center of the cylinder portion. The motor housing 12a is fixed to one end portion of a pump housing 13b by using screws 13d.

[0027] The rotor core 12d has the plurality sets of coils 12e electrically connected to the commutator 12f that is apart from the rotor core 12d toward the pump housing 13b. The rotor core 12d is fixed on an intermediate portion of a rotary shaft 14 in the permanent magnet 12b. The brushes 12g are capable of being contacted with the commutator 12f, being radially slidably inserted into brush holders 12h. The brushes 12g are elastically pushed onto an outer surface of the commutator 12f by springs 12i to shift directions of electric current according to a rotation angle of the rotor core 12d. The other end opening of the motor housing 12a is closed by an end plate 12 fixed to the pump housing 13b through the motor housing 12a by the screws 13d. The end plate 12 is not indispensable.

[0028] The rotary shaft 14 is arranged along a center axis of the cylinder portion of the motor housing 12a, being inserted through a central portion of the dish flange portion of the cylinder portion, a central portion of the end

plate 12 and a central boss portion of the pump housing 13b. A bearing 12c is placed on a central portion of the dish flange portion to rotatably support the rotary shaft 14. The rotary shaft 14 is fixed with the fan main body 15 at its one end portion by a nut 15a and is also fixed with an impeller 16 of the intercooler pump 13 at the other end portion thereof by a nut 13c. There is provided a speed sensor 21 for detecting a rotational speed of the rotary shaft 14 to output a rotational speed signal, and is electrically connected to the controller 20.

[0029] The fan main body 15 has a fixing plate 15b, a boss portion 15c and a plurality of blade portions 15d, where the fixing plate 15b is formed like a disc and is fixed to the one end portion of the rotary shaft 14, the boss portion 15c contains a part of the electric motor 12, and the blade portions 15d are formed on an outer peripheral surface of the boss portion 15c as one unit to extend outwardly radially. The fixing plate 15b and the boss portion 15c are integrally formed with each other by using an insert molding. The blade portions 15d are arranged behind the sub radiator 6 so that it can pull the air through the sub radiator 6.

[0030] The intercooler pump 13 has the pump housing 13b forming a pump chamber 13a inside thereof, and the impeller 16 having a plurality of blade portions 16a extending outwardly radially in the pump chamber 13a. A mechanical seal 13e is inserted by the rotary shaft 14 and is placed in the boss portion of the pump housing 13b to keep the pump chamber 13a liquid-tight from the exterior. The pump housing 13b is formed with an inlet port 13g in an axial direction of the rotary shaft 14 and an outlet port 13h in a radial direction of the rotary shaft 14, where the inlet port 13g fluidically connects the pump chamber 13a and the eighth pipe 9h with each other, and the outlet port 13h fluidically connects the pump chamber 13a and the tenth pipe 9i with each other.

[0031] A cooling hole 17 is formed, by machining, in the rotary shaft 14, extending in the axial direction thereof, and also in the nut 13c so as to be fluidically communicated with the pump chamber 13a, while an end portion of the cooling hole 17 is closed. The coolant in the pump chamber 13a enters the cooling hole 17 from the pump chamber 13a to cool the electric motor 12. Incidentally, the cooling hole 17 may be formed in any appropriate shape.

[0032] The integrated pump-motor 10 is provided with a not-shown bracket, with which it is fixed to a not-shown fan stay of a fan shroud attached on a rear side of the radiators 2 and 6.

[0033] As described above, in the integrated pump-fan 10, the electric fan 11 and the intercooler pump 13 are joined with each other by connecting the rotary shaft 14 of the electric motor 12 and the impeller 16 with each other.

[0034] Therefore, the rotary shaft 14 can be driven by a first rotating torque of the fan main body 15 receiving the ram airflow generated when the vehicle is running and/or a second rotating torque generated by the electric

motor 12, the fan main body 15 is rotated to pull the air through the sub radiator 6, thereby cooling the coolant in the intercooler cooling circuit R2. At the same time, the impeller 16 of the intercooler pump 13 is also rotated to pressurize the coolant, entered through the inlet port 13g, in the pump chamber 13a to output the pressurized coolant to the ninth pipe 9i through the outlet port 13h. This flow of the coolant is indicated by dashed- dotted lined arrows in FIG. 2. The coolant, outputted from the intercooler pump 13, enters the inner space 5c of the intercooler 5, where the air, pressurized by the compressor of the turbocharger 8, to be supplied to the engine 1 is cooled.

[0035] On the other hand, the coolant in the cooling hole 17 formed in the rotary shaft 14 effectively cools the electric motor 12 from its inside, although the bushes 12g easily rise the temperatures of the electric motor 12.

[0036] The coolant in the main radiator 2 is also cooled by using the not-shown electric fan to cool the engine 1.

[0037] Next drive control of the intercooler pump 13 in the cooling system of the first embodiment will be described.

[0038] The pump drive control is executed by the controller 20 repeatedly at certain intervals during engine running.

[0039] Referring to FIG. 3 showing a flow of the pump drive control, at step S 1, the controller 20 receives the temperature signal outputted from the temperature sensor C1 to detect a temperature T_c of the coolant in the intercooler cooling circuit R2, and then the flow goes to step S2.

[0040] At the step S2, the controller 20 judges whether or not the detected coolant temperature T_c is smaller than a first predetermined value $X1$. If the judgment is YES, the flow returns to the step S1, while if it is NO, the flow goes to step S3.

[0041] At the step S3, the controller 20 receives the rotational speed signal outputted from the speed sensor 21 to detect a rotational speed N_f of the rotary shaft 14, corresponding to that of the fan main body 15, and then the flow goes to step S4.

[0042] At the step S4, the controller 20 judges whether or not the detected rotational speed is lower than a second predetermined value $X2$. If the judgment is YES, the flow goes to step S5, while if it is NO, the flow goes to step S7.

[0043] At the step S5, an assist amount is calculated based on the rotational speed detected at the step S3, where the assist amount corresponds to a deficient rotational speed of the main shaft 14 connected with the impeller 16. In other words, the assist amount corresponds to a difference between the detected rotational speed of the rotary shaft 14 and a target rotational speed thereof for obtaining a necessary pump performance of the intercooler pump 13. The relationships among the rotational speed of the rotary shaft 14, the pump performance and the temperature of the coolant in the intercooler cooling circuit R2 are set in advance by experiments.

Then the flow goes to step S6.

[0044] At the step S6, the controller 20 controls the electric motor 12 to be supplied with the electric power so that the rotational speed becomes larger by the assist amount than the detected rotational speed. Accordingly, the electric motor 12 drives the rotary shaft 14, connected with the impeller 16, to increase up to the target rotational speed that is sufficient for obtaining necessary pump performance. Therefore, the impeller 16 is driven at the target rotating speed by rotating torque generated by the electric motor 12 supplied with the electric power, in addition to rotating torque of the fan main body 15 driven by the ram airflow generated when the vehicle is running, thereby increasing cooling capability of the intercooler cooling circuit R2 to cool the coolant therein. This can cool the hot air pressurized by the turbocharger 8. The step S6 corresponds to a first operation state of the present invention. Then, the flow returns to the step S 1.

[0045] At the step S7, the controller 20 controls the electric motor 12 to be supplied with no electric power, so that the rotary shaft 14 and the impeller 16 are rotated only by the rotating torque of the fan main body 15 which is driven by the ram airflow. This can decrease electric power consumption of the cooling system. The step S7 corresponds to a second operation state of the present invention. Then, the flow returns to the step S1.

[0046] Incidentally, the first and second predetermined values $X1$ and $X2$ may be set appropriately. An electrically operating rate of the electric motor 12 becomes higher, as the first predetermined value $X1$ is set to be smaller and the second predetermined value $X2$ is set to be larger.

[0047] Thus, in the first embodiment, the controller 20 detects the temperature T_c of the coolant in the intercooler cooling circuit R2 (at the step S1). When the detected temperature T_c is equal to or larger than the predetermined value $X1$, the controller 20 further detects the rotational speed N_f of the fan main body 15, corresponding to the rotational speed of the rotary shaft 14 (at the steps 2 and 3). If the rotational speed N_f is smaller than the predetermined value $X2$, the controller 20 judges that vehicle-running wind is weak and the rotational speed thereof is not one that is sufficient for obtaining the necessary pump performance (at the step S4).

[0048] Then the assist amount of the rotary shaft 14 is calculated to supply its corresponding electric power to the electric motor 12 so that its electrically generated rotating torque is applied to the rotary shaft 14 to increase the rotational speed of the impeller 16, in addition to the rotating torque of the fan main body 15 moving due to the ram airflow (at the steps 5 and 6). Therefore, actuations of the electric motor 12 and the electric fan 11 strongly cools the coolant, since the impeller 16 forcibly circulates the coolant and the fan main body 15 enhances a cooling performance of the sub radiator 6. The airflow generated by the fan main body 15 also strongly cools the coolant in the main radiator 2. The electric power consumption is reduced because of utilization of the ro-

tating torque generated by the fan main body 15 due to the ram airflow.

[0049] On the other hand, if the detected rotational speed N_f is equal to or larger than X_2 , the vehicle-running wind is strong so that the fan main body 15 driven by the ram airflow can sufficiently rotate the rotary shaft 14 and the impeller 16 to obtain the necessary pump performance of the impeller pump 13 and no electric power is supplied to the electric motor 12 (at the steps 4 and 7). In other words, the impeller 16 and the fan main body 15 are driven only by the rotating torque generated by the ram airflow, to circulate the coolant in the intercooler cooling circuit R2 and cool the coolant in the sub radiator 6. The electric motor 12 is not activated, which results in no electric power consumption, improvement in durability of the bushes 22g of the electric motor 12 and reduction in noise such as motor running noise.

[0050] As understood above, the cooling system of the first embodiment can cool the coolant by the intercooler 6, driving the intercooler pump 13 to circulate it. The coolant in the intercooler cooling circuit R2 is always kept under the temperature of the first predetermined value X_1 , so that a heat exchanger effectiveness of the intercooler 5. Accordingly, when the turbocharger 8 starts and the coolant temperature in the intercooler cooling circuit R2 rises, the coolant is forcibly cooled. In addition, the coolant temperature can be rapidly reduced immediately after the actuation end of the turbocharger 8, which brings the heat exchanger effectiveness of the intercooler 5 to be higher when the turbocharger 8 restarts. The cooling system of the first embodiment produces a remarkable effect, especially in operations where the turbocharger 8 repeats starting and stopping in a short period of time.

[0051] In the above example of the pump drive control, the pump drive control is not executed while the coolant temperature is below the first predetermined value X_1 , since during that period the intercooler pump 13 does not need to be driven and the drive thereof due to the ram airflow does not any problem.

[0052] Engine bench tests were made by using the cooling system of the first embodiment with a DC12V, 200W electric motor, which results in that it can sufficiently drive the fan main body 15 and the intercooler pump 13 even when there is no ram airflow.

[0053] Specifically, the rotational speed of the fan main body 15, when it receives the ram airflow at a normal vehicle speed, becomes higher than that of the DC 12V, 100W electric motor, and is sufficient to drive the impeller pump 13, correspondingly to an electric motor of appropriately DC12V, 50W. The electric motor 12 is normally sufficient to be driven with the electric power only when the motor vehicle is stopped and when it runs at very low vehicle speed where the vehicle-running wind cannot drive the fan main body 15. This shows an advantage of the cooling system of the first embodiment in reduction in the electric power consumption of the electric motor 12.

[0054] Incidentally, fan drive control is executed similarly to conventional one executed in conventional en-

gines with a turbocharger, and it is omitted herein.

[0055] The pump drive control is not limited to the above described example.

The electric motor 12 may be supplied with the electric power to decrease the rotational speed of the rotary shaft 14 when the ram airflow is too large to drive the impeller 6. As a threshold for determining the electric drive of the intercooler pump 13, a temperature of the air in the turbocharger gas circuit R3, vehicle speed and so forth may be used instead of the coolant temperature.

[0056] The cooling system of the first embodiment has the following advantages.

[0057] The cooling system of the first embodiment can decrease the electric power consumption of the electric motor 12 due to usage of the ram airflow as the rotating torque to drive the impeller 6, also reducing a size of the electric motor 12.

[0058] The impeller 6 is connected with the rotary shaft 14 of the electric motor 12, which can decrease design changes thereof and manufacturing costs.

[0059] The cooling system of the first embodiment is applied to the intercooler cooling circuit R2, which enables the electric motor 12 to decrease the electric power consumption, thus being downsized. In addition, the fan main body 15, the electric motor 12 and the intercooler pump 13 are constructed as one unit. Therefore, the intercooler cooling circuit R2 can be easily arranged in an engine room.

[0060] The coolant in the cooling hole 17 formed in the rotary shaft 14 can sufficiently cool the electric motor 12 from its inner side.

[0061] Next a cooling system of a second embodiment according to the present invention will be described with reference to the accompanying drawings. In the second embodiment, the parts similar to those of the first embodiment are indicated the same reference numbers, and their descriptions will be omitted to avoid duplication.

[0062] An intercooler cooling circuit of the second embodiment is constructed similarly to that of the first embodiment.

[0063] Referring to FIGS. 4 to 7, there is shown an integrated pump-fan 30 that is used in the intercooler cooling circuit.

[0064] In the pump-fan 30, an electric motor 12 of an electric fan 31 and an intercooler pump 32 are radially stacked relative to each other so that they are overlapped in the axial direction so that the intercooler pump 32 surrounds an outer periphery of the electric motor 12.

[0065] The electric motor 12 has in an axial length longer than that of the first embodiment, and is equipped with a rotary shaft 14 therein. A rear end portion of the rotary shaft 14a is contained in and supported by a rear portion of the motor housing 12a, and a front end portion thereof is projected forward from a front portion of the motor housing 12a.

[0066] A fan main body 15 is what is called a ring fan, having a plurality of blade portions 15d, whose radially outer end portions are integrally connected with a fan

ring 33 and their radially inner end portions are integrally connected with a boss portion 15c. The boss portion 15c is a cylinder with a front end portion closing a front end opening thereof, and a fixing plate 15b is fixed on a rear surface of the front end portion at this center to fix the front end portion of the rotary shaft 14 and the boss portion 15c of the fan main body 15 with each other.

[0067] A fan-side magnet 34 is shaped like a ring and has cross section shaped in a U-letter having a front side opening. A rear end portion of the boss portion 15c of the fan main body 15 is inserted into the front opening of the fan-side magnet 34, so that the fan-side magnet 34 is fixed to the boss portion 15c of the fan main body 15 so as to rotate together.

[0068] The intercooler pump 33 includes a pump housing 32b, an impeller-side magnet 35 and an impeller 36. The pump housing 32b is formed like a cylinder, which has an outer cylindrical portion 32d and an inner cylindrical portion 32c that form a pump chamber 32a therebetween. The outer and inner cylindrical portions 32d and 32c are integrally connected by a front side portion at their front end positions, and are attached with a rear side plate 32g to close their rear opening. The pump housing 32b is fitted on an outer periphery of the motor housing 12a, being apart from the fan-side magnet 34 in an axial direction thereof by a predetermined clearance. The pump housing 32b is provided with an inlet port 32 and an outlet port 32f, where the inlet port 32e is fluidically connected with an outlet port of a sub radiator 6 through an eighth pipe 9i, which are shown in FIG. 1, and the outlet port 32f is fluidically connected with an inlet port of an intercooler 5 through a ninth pipe 9i, which are also shown in FIG. 9. The inlet port 32e and the outlet port 32f are provided with not-shown check valves, respectively. The pump housing 32b forming the pump chamber 32a may be constructed appropriately. For example, the front side portion may be separated from the cylindrical portions 32e and 32f as a front side plate, and the rear side plate is integrally formed therewith as a rear side portion.

[0069] The impeller 36 has a plurality of blade portions 36a, and is fixed with the impeller-side magnet 35 at a front end portion of the impeller 36. The impeller 36 is placed in the pump chamber 32a, slidably in a rotational direction relative to the outer and inner cylindrical portions 32d and 32c, so that the impeller-side magnet 35 is located between the front side portion and the front end portion of the impeller 36 to face the fan-side magnet 34.

[0070] Therefore, the electric fan 31 and the intercooler pump 32 are magnetically connected with each other because of the fan-side magnet 34 and the impeller-side magnet 35.

[0071] When the fan main body 15 is driven by ram airflow generated when a motor vehicle is running and/or by airflow generated by the electric motor 12 supplied with electric power, the fan main body 15 cools the coolants in a main radiator 2 and the sub radiator 6, and the

impeller 36 is driven to rotate to circulate the coolant in the intercooler cooling circuit R2.

[0072] In the second embodiment, pump drive control similar to that of the first embodiment is executed, and its description is omitted.

[0073] Therefore, the integrated pump-fan 30 of the second embodiment has the following advantages.

[0074] The cooling system of the second embodiment can decrease the electric power consumption of the electric motor 12 due to usage of the ram airflow as the rotating torque to drive the impeller 36, also reducing a size of the electric motor 12.

[0075] The cooling system of the second embodiment is applied to the intercooler cooling circuit R2, which enables the electric motor 12 to decrease the electric power consumption, thus being downsized. In addition, the fan main body 15, the electric motor 12 and the intercooler pump 32 are assembled as one unit. The electric motor 12 and the intercooler pump 32 are arranged in the radial direction to overlap in the axial direction to reduce an axial length of the integrated pump-fan 30. Therefore, the intercooler cooling circuit R2 can be easily arranged in an engine room.

[0076] The coolant in the pump chamber 32a can sufficiently cool the electric motor 12 from its outer side.

[0077] While there have been particularly shown and described with reference to preferred embodiments thereof, it will be understood that various modifications and changes may be made therein.

[0078] For example, a connecting structure of the electric motor and the intercooler pump may be set appropriately in a detail configuration, a position and others as long as the pump can be driven by the fan main body rotated by ram airflow.

[0079] The cooling system may be applied not only to those of hybrid electric motor vehicles and fuel-cell electric vehicle to cool batteries, but also to motor vehicles without a turbocharger. In the latter case, preferably the pump and the electric fan may be connected with each other.

[0080] A variable speed change mechanism and/or a clutch may be provided between the fan main body and the impeller. The variable speed change mechanism changes a rotational speed ratio of those of the electric fan and the pump. The clutch can control the fan main body and the impeller to be shifted between in an engaging state and in a disengaging state thereof, and/or rotation of one of them may be stopped

Claims

1. A cooling system for a motor vehicle comprising:

- a cooling circuit (R2) where a cooling medium is capable of flowing therein;
- a pump (13, 32) for pressurizing the cooling medium to circulate in the cooling circuit (R2);

- an electric fan (11; 31) having a plurality of blade portions (15d);
 an electric motor (12) that is connected with the electric fan (11; 31) to be capable of driving the electric fan (11; 31) to rotate, and
 a controller (20) for controlling the electric motor (12), wherein
 the pump (13; 32) is capable of being driven by the electric fan (11; 31) that receives ram airflow generated when the motor vehicle is running, and wherein
 the controller (20) controls the electric motor to be shifted between in a first operation state where electric power is supplied to the electric motor (12) and in a second operation state where no electric power is supplied to the electric motor (12), the pump (13; 32) being driven by a rotating torque of the ram airflow and a rotating torque of the electric motor (12) in the first operation state, and the pump (13; 32) being driven by the rotating torque generated by the ram airflow without the rotating torque of the electric motor (12) in the second operation state.
2. The cooling system according to claim 1, wherein the pump (13; 32), the electric motor (12) and the electric fan (11; 31) are integrally assembled as one unit.
3. The cooling system according to claim 1 or claim 2, wherein
 the pump (13; 32) has an impeller (16; 36) connected with a rotary shaft (14) of the electric motor (12).
4. The cooling system according to claim 1 and claim 2, wherein
 the pump (13; 32) has a pump-side magnet (34) and the electric fan (11; 31) has a fan main body (15) including the blade portions (15d) and provided with a fan-side magnet (35) so that the pump (13; 32) and the electric fan (11; 31) are magnetically connected with each other.
5. The cooling system according to claim 4, wherein the pump (13; 32) and the electric motor (12) are radially stacked relative to each other so that a pump housing (13b; 32b) of the pump (13; 32) has a pump chamber (13a; 32a) surrounding an outer periphery of the electric motor (12), the pump (13; 32) and the electric motor (12) being overlapped with each other in an axial direction thereof.
6. The cooling system according to any one of claims 1 to 5, wherein
 the cooling circuit (R2) is a cooling circuit for cooling a water-cooled intercooler (5).
7. The cooling system according to claim 1, wherein

the cooling medium is introduced to one of an outer periphery of the electric motor (12) and an inner side of the electric motor (12) to cool the electric motor.

8. The cooling system according to any one of claims 1 to 7, further comprising:
 a rotational speed sensor (21) for detecting a rotational speed of the electric fan (11; 31), wherein
 the controller (20) controls the electric power to drive the pump (13; 32), based on the rotational speed outputted from the rotational speed sensor (21).
9. The cooling system according to any one of claims 1 to 8, further comprising:
 a variable speed change mechanism arranged between the electric fan (13; 32) and the pump (11; 31) so that a rotational speed ratio thereof can be changed.

FIG. 1

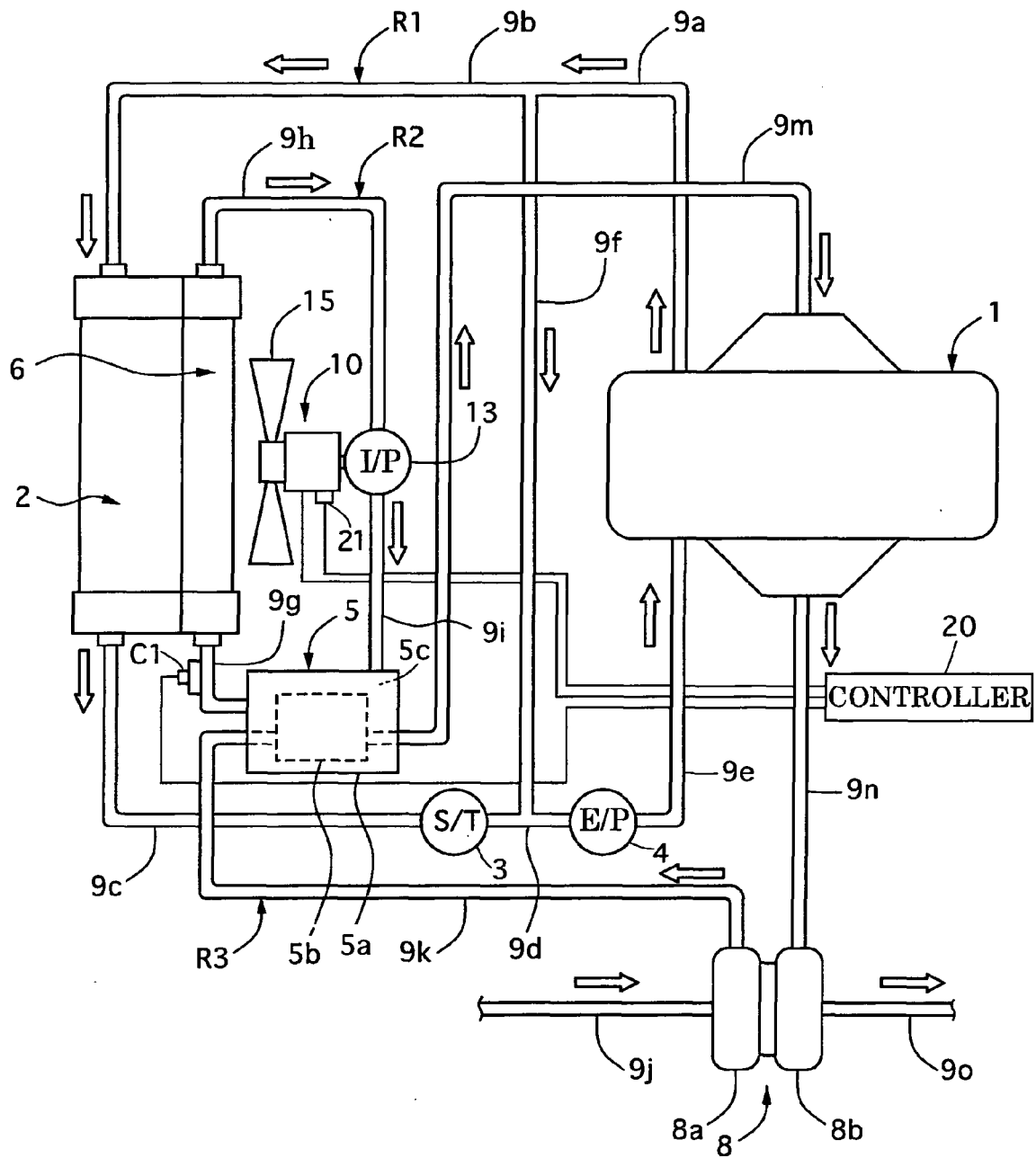


FIG. 2

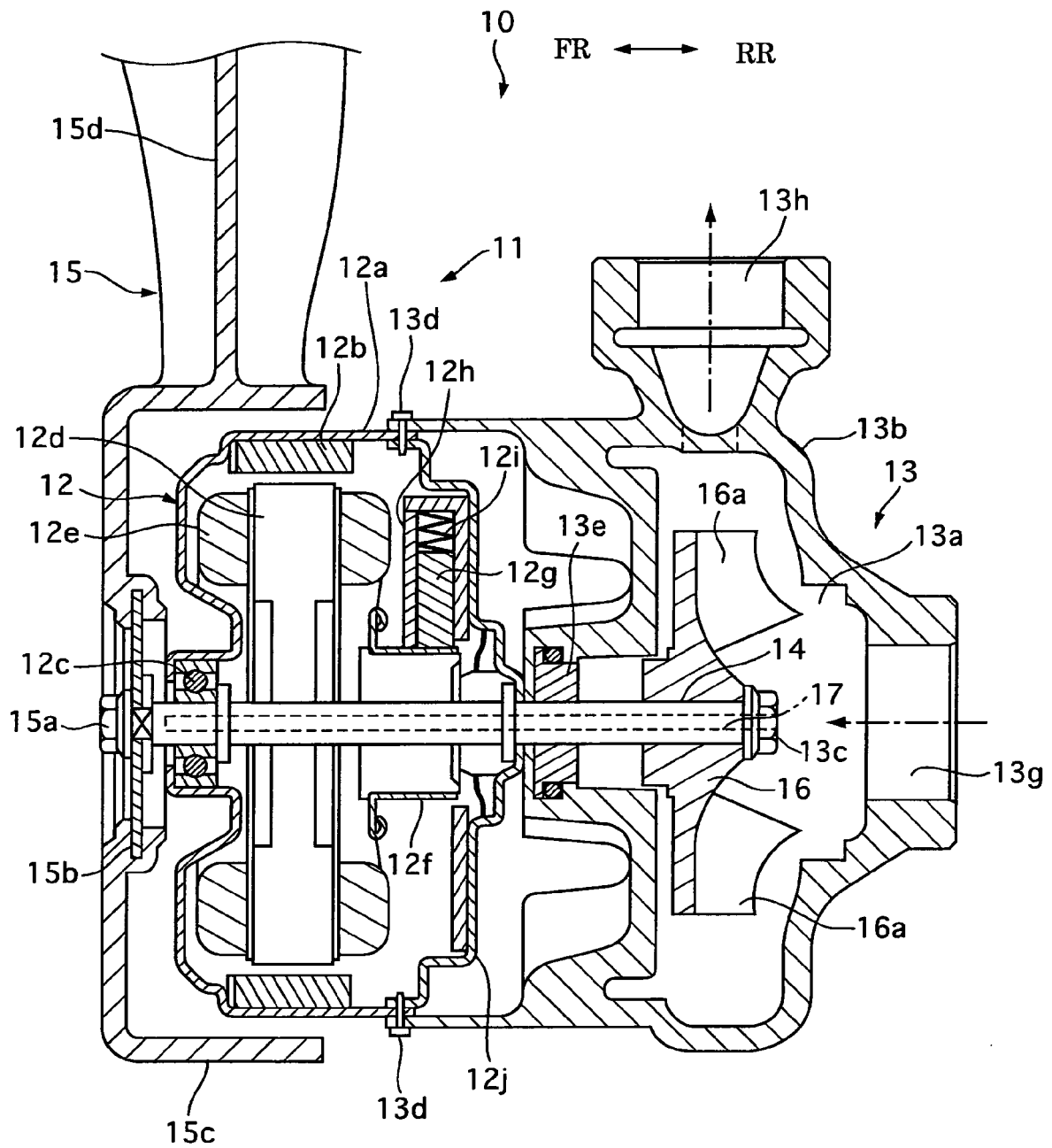


FIG. 3

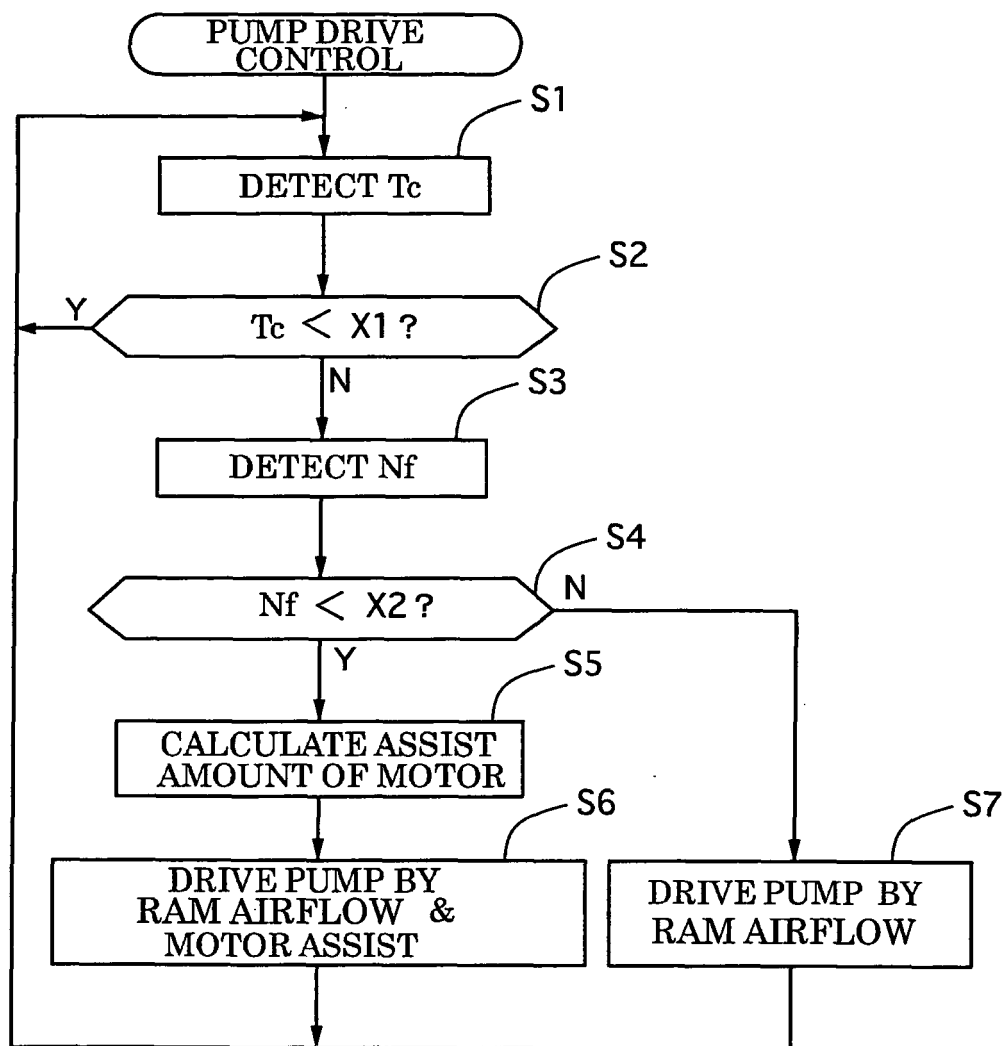


FIG. 4

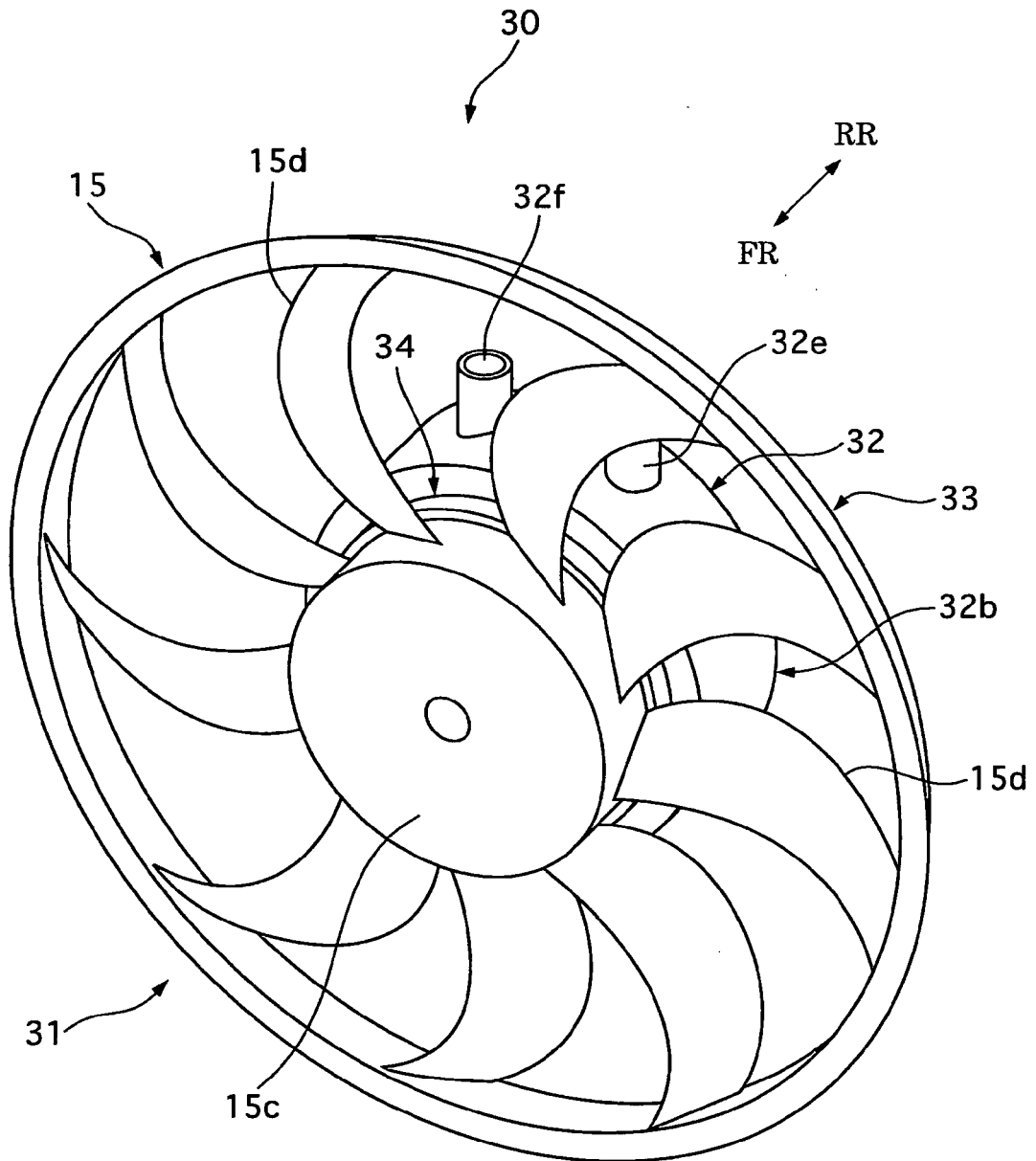


FIG. 5

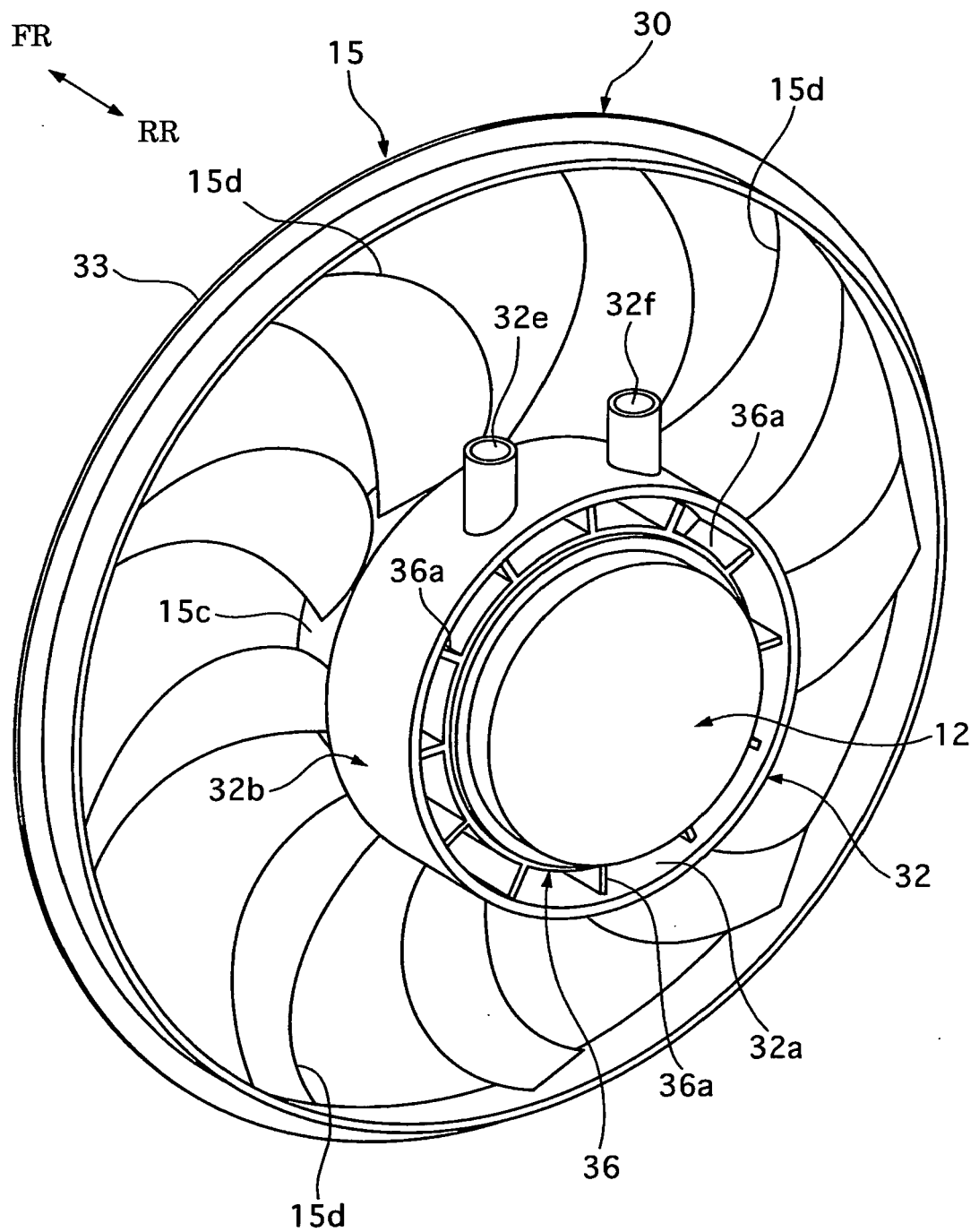
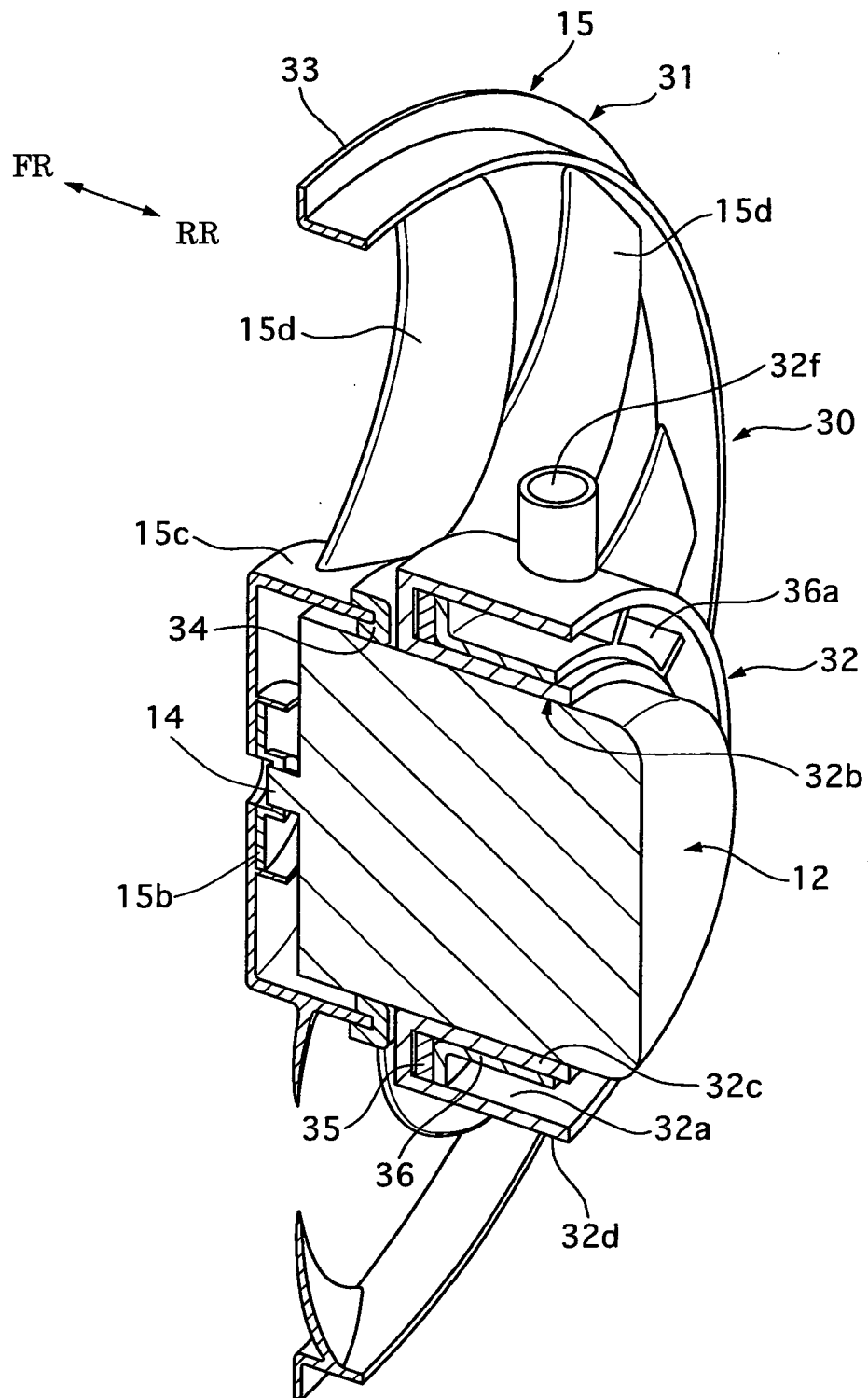


FIG. 6



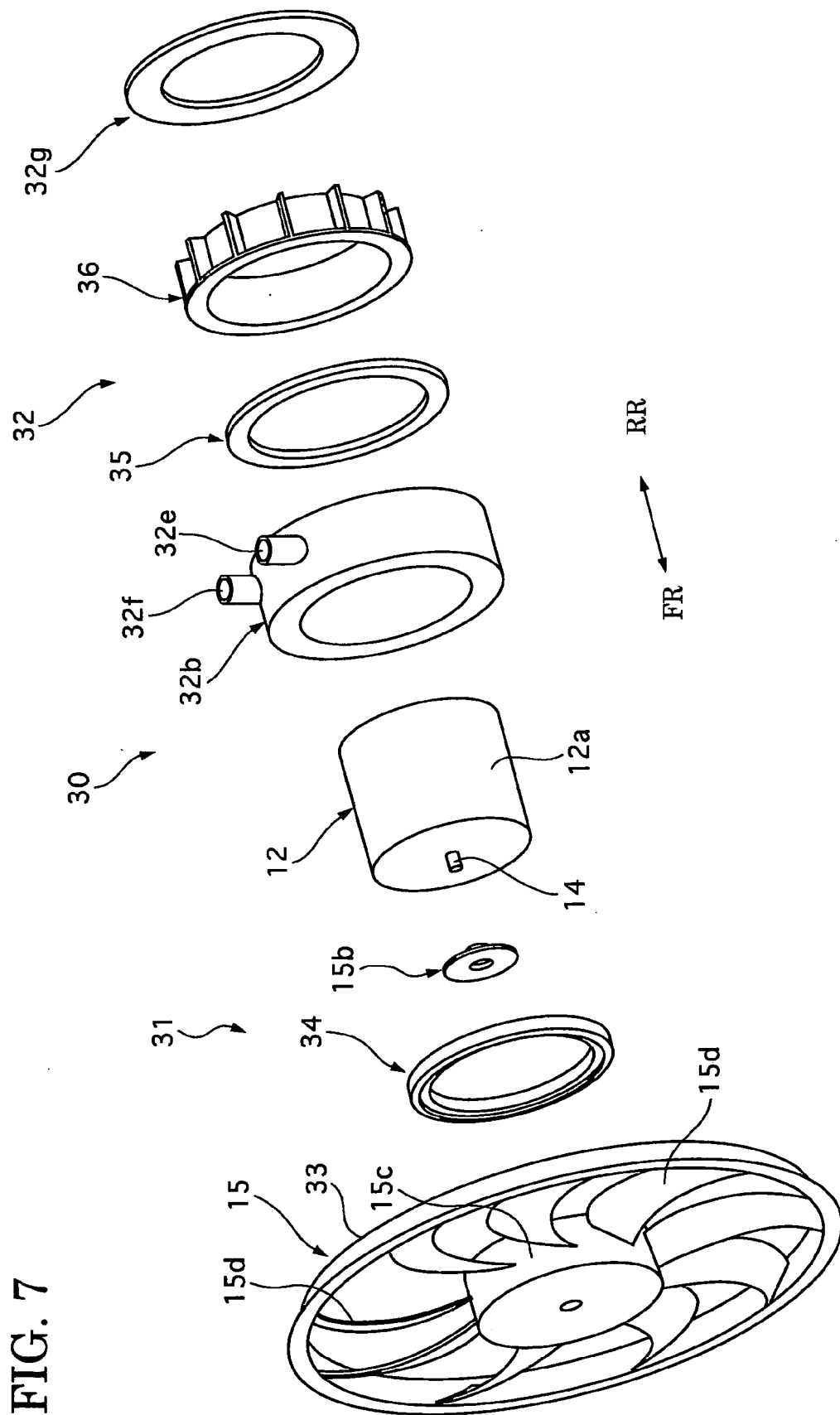


FIG. 7

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2000333411 A [0002]
- JP 2002300751 A [0002]
- JP 2004132277 A [0003]
- JP 2005315224 A [0003]
- JP 2000350429 A [0026]