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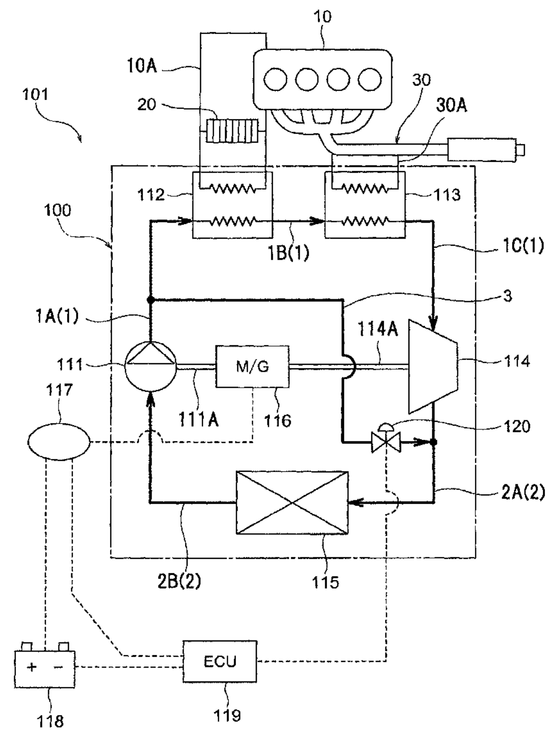
(54) Rankine cycle system

(57) A Rankine cycle system (101) mounted on a vehicle has a Rankine cycle circuit (100) through which working fluid circulates, a power generator, a power storage and a controller. The Rankine cycle circuit includes a fluid expansion device (114), a fluid transferring device (111), first and second passages (1,2), a heater (112,113), a cooling device (115), a bypass passage (3) and a flow regulating valve (120). The bypass passage connects the first passage to the second passage. The flow regulating valve is provided in the bypass passage for opening and closing the bypass passage. The power generator (116) converts the work generated by the fluid expansion device into electric power. The controller (119) monitors charge rate of the electric power charged in the power storage and controls an operation of the flow regulating valve based on the monitored charge rate. The controller causes the flow regulating valve to be opened when the monitored charge rate is greater than a predetermined value.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a Rankine cycle system including a Rankine cycle circuit and, more particularly, to a Rankine cycle system for a vehicle.

[0002] The Rankine cycle circuit for converting waste heat discharged from an internal combustion engine of a vehicle into power for a power generator has been developed. The Rankine cycle circuit has a boiler heating liquid at a constant pressure for generating overheated steam, an expansion device adiabatically expanding the overheated steam for generating power, a condenser cooling the expanded steam at a constant pressure for condensing the steam into liquid and a pump delivering the liquid to the boiler.

[0003] Japanese Patent Application Publication No. 2009-274513 discloses a Rankine cycle circuit for a vehicle. According to the Rankine cycle circuit disclosed in the above Publication, the drive shaft of the pump and the output shaft of the expansion device are disposed coaxially via an electromagnetic clutch, and power from the internal combustion engine is transferred to the drive shaft of the pump through another electromagnetic clutch. The expansion device is connected to the power generator through yet another electromagnetic clutch, and the power generator is connected to a vehicle battery. The three clutches are engaged or disengaged for controlling the respective operations of the pump, the expansion device and the power generator, thereby to control the operation and generation of electric power of the Rankine cycle circuit.

[0004] In such a Rankine cycle circuit mounted on a vehicle, when the pump and the expansion device are continued to operate and hence the generation of electric power by the power generator and the storage of the electric power in the vehicle battery are continued, the buttery will be overcharged or charged excessively if the amount of electric power charged in the battery is larger than the amount of power consumed by the vehicle. In order to prevent the vehicle battery from being overcharged in the Rankine cycle circuit of the above-described Publication, the generation of electric power by the power generator is controlled by disengaging the electromagnetic clutch connected between the expansion device and the power generator so as to stop the operation of the power generator. However, the vehicle having the above-described Rankine cycle circuit needs a large space for installation of the electromagnetic clutch.

[0005] The present invention is directed to providing a Rankine cycle system having a Rankine cycle circuit which requires a less space for installation and is capable of controlling the generation of electric power.

SUMMARY OF THE INVENTION

[0006] In accordance with the present invention, a Rankine cycle system mounted on a vehicle has a Rankine cycle circuit through which working fluid circulates, a power generator, a power storage and a controller. The Rankine cycle circuit includes a fluid expansion device, a fluid transferring device, a first passage, a second passage, a heater, a cooling device, a bypass passage and a flow regulating valve. The fluid expansion device expands the working fluid for generating work. The fluid transferring device transfers the working fluid to the fluid expansion device. The first passage connects the fluid transferring device to the fluid expansion device. The second passage connects the fluid expansion device to the fluid transferring device. The heater is provided in the first passage for heating the working fluid. The cooling device is provided in the second passage for cooling the working fluid. The bypass passage connects the first passage to the second passage. The flow regulating valve is provided in the bypass passage for opening and closing the bypass passage. The power generator converts the work generated by the fluid expansion device into electric power. The power storage stores the electric power converted by the power generator. The controller monitors charge rate of the electric power charged in the power storage and controls an operation of the flow regulating valve based on the monitored charge rate. The controller causes the flow regulating valve to be opened when the monitored charge rate is greater than a predetermined value.

[0007] Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The invention together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is an illustrative schematic view showing the configuration of a Rankine cycle system according to a first preferred embodiment of the present invention; and

Fig. 2 is an illustrative schematic view showing the configuration of a Rankine cycle system according to a second preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0009] The following will describe a Rankine cycle system according to a first preferred embodiment of the present invention with reference to Fig. 1. The following description will deal with an example in which a Rankine cycle system is used for a vehicle having an internal combustion engine. Referring to Fig. 1, numeral 10 designates an engine which is equipped with a Rankine cycle system 101 having a Rankine cycle circuit 100.

[0010] The Rankine cycle circuit 100 has a pump 111, a cooling water boiler 112, a waste gas boiler 113, an expansion device 114 and a condenser 115. Refrigerant flows through the Rankine cycle circuit 100 as a working fluid. The pump 111 serves as a fluid transferring device of the present invention, the cooling water boiler 112 and the waste gas boiler 113 as a heater, the expansion device 114 as a fluid expansion device and the condenser 115 as a cooling device.

[0011] The pump 111 is operated to pump and transfer fluid, i.e. liquid refrigerant in the first preferred embodiment of the present invention. The pump 111 is connected at the outlet thereof (not shown) to the cooling water boiler 112 serving as a heat exchanger through a passage 1A, and the refrigerant transferred by the pump 111 flows through the cooling water boiler 112.

[0012] The cooling water boiler 112 is connected to a cooling water passage 10A in which a radiator 20 is connected and through which engine cooling water as the fluid heated by waste heat from the engine 10 flows. In the cooling water boiler 112, the refrigerant is heated through heat exchange with the engine cooling water. Engine cooling water transferred by a pump (not shown) from the engine 10 to the cooling water passage 10A flows through the cooling water boiler 112, in which the engine cooling water is cooled through heat exchange with the refrigerant in the cooling water boiler 112, and then the cooled engine cooling water returns to the engine 10. Meanwhile, the refrigerant is heated through heat exchange with the engine cooling water in the cooling water boiler 112.

[0013] The cooling water boiler 112 is connected at the outlet thereof to the waste gas boiler 113 serving as a heat exchanger through a passage 1B, and the refrigerant from the cooling water boiler 112 flows through the waste gas boiler 113. The waste gas boiler 113 is connected to a bypass passage 30A. The bypass passage 30A is a passage branched from and returned to an exhaust system 30 that discharges out of the vehicle exhaust gas as the fluid heated by waste heat from the engine 10. In the waste gas boiler 113, heat exchange is performed between refrigerant and the exhaust gas. Part of exhaust gas discharged into the exhaust system 30 from the engine 10 flows into the bypass passage 30A and then flows through the waste gas boiler 113, in which the exhaust gas is cooled through heat exchange with the refrigerant in the waste gas boiler 113. Then, the cooled exhaust gas returns to the exhaust system 30 and discharged out of the vehicle. Meanwhile, in the waste gas boiler 113, the refrigerant is heated through heat exchange with the exhaust gas whose temperature is higher than the engine cooling water. Thus, the temperature of the refrigerant is further increased.

[0014] The waste gas boiler 113 is connected at the outlet thereof to the inlet of the expansion device 114 through a passage 1C, so that the high-temperature and high-pressure refrigerant heated in the cooling water boiler 112 and the waste gas boiler 113 flows through the expansion device 114. The expansion device 114 expands the high-temperature and high-pressure refrigerant to rotate rotors of a device (not shown) such as a turbine and the drive shaft 114A of the expansion device 114, so that the driving force of the rotation generates work. The expansion device 114 is connected through the drive shaft 114A to the motor generator 116 operable as a power generator.

[0015] The motor generator 116 is connected to the pump 111 through a drive shaft 111A of the pump 111. In the motor generator 116, the drive shaft 111A of the pump 111 and the drive shaft 114A of the expansion device 114 are connected to each other so that the driving force of rotation thereof are transmitted to each other. The motor generator 116 is connected electrically to an inverter 117 that is operable as an inverter or a converter, and the inverter 117 is connected electrically to a vehicle battery 118.

[0016] Thus, the expansion device 114 drives to rotate the drive shaft 114A thereby to start the operation of the motor generator 116. Therefore, the motor generator 116 is operated as a power generator for generating AC power and providing the AC power to the inverter 117. In this case, the inverter 117 functions as a converter that converts the AC power into DC power and supplies the DC power to the vehicle battery 118. The DC power is stored in the vehicle battery 118, or the vehicle battery 118 is charged with the DC power. The motor generator 116 serves as the power generator, and the vehicle battery 118 serves as the power storage.

[0017] When the inverter 117 functions as the inverter, the DC power stored in the vehicle battery 118 is converted into AC power, and the AC power is supplied to the motor generator 116. Thus, the motor generator 116 is operable as a power generator. The passages 1 A, 1B and 1C form a first passage 1 of the Rankine cycle circuit 100. The motor generator 116, the inverter 117 and the vehicle battery 118 form the Rankine cycle system 101.

[0018] The expansion device 114 is connected at the outlet thereof (not shown) to a condenser 115 serving as a heat exchanger through a passage 2A, and refrigerant flowing out from the expansion device 114 flows through the condenser 115. In the condenser 115, heat exchange is performed between the refrigerant flowing therethrough and ambient air. The refrigerant in the condenser 115 is cooled by the heat exchange with the ambient air thereby to be condensed. The condenser 115 is connected at the outlet thereof through a passage 2B to the inlet of the pump 111 (not shown). The liquid refrigerant flowing out from the condenser 115 is drawn into the pump 111, and the pump 111 transfers the refrigerant to the cooling water boiler 112 again. Therefore, refrigerant circulates in the Rankine cycle circuit 100. The passages 2A and 2B form a second passage 2 of the Rankine cycle circuit 100.

[0019] The Rankine cycle circuit 100 has a bypass passage 3 that connects the first passage 1 to the second passage 2. According to the first preferred embodiment of the present invention, one end of the bypass passage 3 is connected to the passage 1A of the first passage 1 and the other end of the bypass passage 3 is connected to the passage 2A of the second passage 2. A flow regulating valve 120 formed by an electromagnetic valve is provided in the bypass passage 3 for opening and closing the bypass passage 3 and controlling the flow passage area of the bypass passage 3.

[0020] The Rankine cycle system 101 has therein an electronic control unit (ECU) 119 serving as a controller. The ECU 119 is connected electrically to the vehicle battery 118 for monitoring voltage of the vehicle battery 118. The ECU 119 is also connected electrically to the inverter 117 for controlling the operation of the inverter 117 and for monitoring DC power supplied from the inverter 117 to the vehicle battery 118 and the amount of electric power in the vehicle battery 118. The ECU 119 is connected electrically to the flow regulating valve 120 for controlling the operation of the flow regulating valve 120. The ECU 119 is operable to monitor the state of operation of various devices installed in the vehicle and driven by electric power, such as headlights, a rear defogger, a blower fan, a compressor of an air-conditioner and a fuel supply device that supplying fuel to the engine 10, thereby to monitor their electric load (consumption of electric power).

[0021] The following will describe the operation of the Rankine cycle system 101 according to the first preferred embodiment of the present invention. Referring to Fig. 1, during the operation of the engine 10, engine cooling water in the engine 10 is transferred by a pump (not shown) for circulation in the cooling water passage 10A that connects the engine 10 and the cooling water boiler 112. Then, heat exchange is performed between the engine cooling water in the cooling water boiler 112 and refrigerant that circulates in the Rankine cycle circuit 100. Simultaneously, exhaust gas is discharged from the engine 10 into the exhaust system 30, and part of the exhaust gas in the exhaust system 30 flows through the bypass passage 30A and then returns to the exhaust system 30 to be discharged out of the vehicle with the exhaust gas flowing through the exhaust system 30. Thus, heat exchange is performed in the waste gas boiler 113 between the exhaust gas flowing in the bypass passage 30A and refrigerant circulating in the Rankine cycle circuit 100.

[0022] When the temperature of the exhaust gas being discharged from the engine 10 is increased higher than a predetermined level of temperature and also the temperature of the engine cooling water is increased higher than another predetermined level of temperature, the Rankine cycle circuit 100 is started. At this time, the inverter 117 is started to operate as the inverter by the ECU 119 so that DC power from the vehicle battery 118 is converted into AC power to be supplied to the motor generator 116 and the motor generator 116 is operated as the power generator.

[0023] The motor generator 116 drives to rotate the drive shaft 111A and the drive shaft 114A for driving the pump 111 and the expansion device 114, respectively. At this time, the flow regulating valve 120 in the bypass passage 3 is closed. The pump 111 driven by the motor generator 116 compresses liquid refrigerant at a constant temperature and transfers the compressed refrigerant to the cooling water boiler 112. Meanwhile, the expansion device 114 driven by the motor generator 116 rotates a rotor of the turbine (not shown) thereby to transfer refrigerant from the passage 1C to the passage 2A.

[0024] Low-temperature liquid refrigerant transferred by the pump 111 flows through the passage 1A to the cooling water boiler 112. In the cooling water boiler 112, the refrigerant is heated at a constant pressure through heat exchange with the engine cooling water circulating in the cooling water boiler 112, thereby being vaporized. As a result, the refrigerant becomes a gas-liquid mixture with a high-pressure and a relatively high-temperature.

[0025] The gas-liquid refrigerant flows out the cooling water boiler 112 and then enters into the waste gas boiler 113 through the passage 1B. In the waste gas boiler 113, the refrigerant is heated at a constant pressure through heat exchange with the exhaust gas flowing through the waste gas boiler 113 and having a temperature that is higher than that of the engine cooling water, thereby being vaporized. As a result, the refrigerant becomes overheated steam with a high-temperature and high-pressure.

[0026] The overheated steam refrigerant flows out the waste gas boiler 113 and through the passage 1C and then enters into the expansion device 114. In the expansion device 114, the high-temperature and high-pressure overheated steam refrigerant is adiabatically expanded, and the expanding energy of the refrigerant in reducing its pressure is converted into rotational energy as regenerative energy. In the expansion device 114, a rotor (not shown) driven to rotate by the motor generator 116 receives additional rotational drive force generated by the above-described rotational energy, and the rotational drive force is transmitted through the drive shaft 114A to the motor generator 116 and the drive shaft 111 A. The ECU 119 switches the operation of the inverter 117 as the inverter to the operation as the converter, so that power supply from the vehicle battery 118 to the motor generator 116 is stopped. The pump 111 is driven by the rotational drive force transferred from the expansion device 114 through the drive shaft 114A and the drive shaft 111A, and the motor generator 116 is driven as a power generator by the rotational drive force transferred from the expansion device 114 through the drive shaft 114A to generate AC power. The AC power generated by the motor generator 116 is converted into DC power by the inverter 117 and the DC power is charged in the vehicle battery 118.

[0027] The refrigerant flowing through the expansion device 114 is discharged out thereof as high-temperature and low-pressure refrigerant and flows through the passage 2A into the condenser 115. In the condenser 115, refrigerant is cooled at a constant pressure through heat exchange with ambient air around the condenser 115 thereby to be condensed into a liquid. The liquid refrigerant flows into the pump 111 through the passage 2B and then flows out from the pump 111. Thus, refrigerant circulates in the Rankine cycle circuit 100.

[0028] During the operation of the Rankine cycle circuit 100, the ECU 119 continues to monitor the voltage of the vehicle battery 118 and calculates charge rate of the vehicle battery 118 from the monitored voltage of the vehicle battery 118. The charge rate means the rate of the amount of electric power charged in the battery to the amount of electric power in the fully charged battery. The relation between the charge rate and the voltage of the vehicle battery 118 is stored previously in the ECU 119, and the ECU 119 calculates the charge rate based on the monitored voltage of the vehicle battery 118.

[0029] When the charge rate of the vehicle battery 118 is larger than a first predetermined level (or less than 100%), or the remaining charge rate of the vehicle battery 118 calculated by subtracting the amount of charge from the total amount of charge is smaller than another predetermined value, the ECU 119 causes the flow regulating valve 120 to be opened for preventing the vehicle battery 118 from continuing to be charged even after the charge rate has reached 100%. When the flow regulating valve 120 is opened, part of the refrigerant transferred by the pump 111 and flowing through the passage 1A flows into the bypass passage 3 toward the passage 2A, so that the amount of the refrigerant flowing through the passage 1A is decreased and the amount of the refrigerant flowing in the expansion device 114 is decreased, accordingly. Due to the decreased amount of the refrigerant in the passage 1C, the pressure of the refrigerant in the passage 1C is lowered and, therefore, the pressure differential between the inlet and outlet of the expansion device 114 is reduced. Since the regenerative energy generated as work in the expansion device 114 by expanding the refrigerant flowing into the expansion device 114 is reduced, the amount of electric power supplied to the vehicle battery 118 is also reduced. In this case, the opening of the flow regulating valve 120 is made larger for increasing the flow passage area of the bypass passage 3 thereby to increase the flow rate of the refrigerant flowing through the bypass passage 3, with the result that the reduction of the regenerative energy in the expansion device 114 is increased.

[0030] The ECU 119 constantly monitors the electric load of the vehicle. The amount of refrigerant flowing into the expansion device 114 is adjusted in such a way that the operation of the expansion device 114 is suppressed by adjusting the opening of the flow regulating valve 120 by the ECU 119 thereby to regulate the flow rate of refrigerant flowing through the bypass passage 3 so that the electric power generated by the motor generator 116 is less than the electric load of the vehicle being monitored by the ECU 119. The charge rate of the vehicle battery 118 is reduced with the consumption of the electric power charged in the vehicle battery 118 by the vehicle. When the charge rate reaches or is smaller than a second predetermined value which is smaller than the first predetermined vale, or the remaining charge rate of the vehicle battery 118 is increased to reach yet another predetermined value, the ECU 119 causes the flow regulating valve 120 to be closed, thereby stopping the flow of the refrigerant through the bypass passage 3.

[0031] In opening the flow regulating valve 120, the opening of the flow regulating valve 120 may be adjusted such that DC power supplied from the inverter 117 to the vehicle battery 118 is less than the electric load detected by the monitoring and more than the minimum electric load of the vehicle that is the electric load required only for operating the vehicle under normal conditions, including a fuel injection device and a fuel pump for the engine 10, and is set and stored in the ECU 119 of each individual vehicle. When the charge rate of the vehicle battery 118 reaches or is smaller than the second predetermined value, the ECU 119 causes the flow regulating valve 120 to be closed.

[0032] The Rankine cycle system 101 according to the first preferred embodiment of the present invention is mounted on a vehicle. The Rankine cycle system 101 includes the Rankine cycle circuit 100 through which refrigerant circulates. The Rankine cycle circuit 100 has the expansion device 114 expanding refrigerant for generating work, the pump 111 transferring refrigerant to the expansion device 114, the first passage 1 connecting the pump 111 to the expansion device 114, the second passage 2 connecting the expansion device 114 to the pump 111, the cooling water boiler 112 and the waste gas boiler 113 provided in the first passage 1 for heating refrigerant, the condenser 115 provided in the second passage 2 for cooling refrigerant, the bypass passage 3 connecting the first passage 1 to the second passage 2 and the flow regulating valve 120 provided in the bypass passage 3 for opening and closing the bypass passage 3. The Rankine cycle system 101 further includes the motor generator 116 converting the work generated by the expansion device 114 into electric power, the vehicle battery 118 storing the electric power converted by the motor generator 116 and the ECU 119 monitoring the charge rate of electric power charged in the vehicle battery 118 and controlling the operation of the flow regulating valve 120 based on the monitored charge rate. When the monitored charge rate is more than the first predetermined value, the ECU 119 causes the flow regulating valve 120 to be opened.

[0033] With the flow regulating valve 120 thus opened, refrigerant flows through the bypass passage 3, so that the flow rate of the refrigerant flowing through the expansion device 114 is reduced, and pressure differential between the inlet and the outlet of the expansion device 114 is reduced, accordingly. Therefore, the amount of the regenerative energy generated as work in the expansion device 114 by allowing the refrigerant in the expansion device 114 to expand is reduced, so that the generation of electric power by the motor generator 116 is decreased and the amount of electric power supplied to the vehicle battery 118 is also reduced. The amount of electric power to be supplied to the vehicle battery 118 may be controlled by adjusting the opening of the flow regulating valve 120. Thus, the vehicle battery 118 is prevented from being overcharged due to excessive charging after 100% charge rate is reached. Therefore, the generation of electric power by the motor generator 116 may be controlled only by providing the bypass passage 3 and the flow regulating valve 120 and the installation space for the Rankine cycle system 101 in a vehicle may be reduced. In the first preferred embodiment of the present invention, the first predetermined value of charge rate of the vehicle battery 118 for opening the flow regulating valve 120 should preferably be set at a value that is close to 100% at which the vehicle battery 118 is fully charged. Thus, the performance of the vehicle battery 118 is maintained at a relatively high level. Similarly, the second predetermined value of charge rate of the vehicle battery 118 for closing the flow regulating valve 120 should preferably be set at a value that is close to 100%.

[0034] The ECU 119 controls the opening of the flow regulating valve 120 based on the electric load of the vehicle monitored by the ECU 119, thereby adjusting the flow rate of refrigerant flowing through the bypass passage 3. Thus, the ECU 119 may control the generation of electric power by the motor generator 116 in such a way to suppress the increase of the charge rate. Thus, controlling the generation of electric power by the motor generator 116, further charging of the vehicle battery 118 is suppressed thereby to prevent an increase of the charge rate of the vehicle battery 118 effectively, with the result that the vehicle battery 118 is prevented from being overcharged.

[0035] The ECU 119 controls the opening of the flow regulating valve 120 based on the minimum electric load that is required for operating the vehicle under normal conditions, thereby adjusting the flow rate of refrigerant flowing through the bypass passage 3. Thus, the electric power to be generated by the motor generator 116 is controlled so as to suppress an increase of the charge rate of the vehicle battery 118. Therefore, the increase of charge rate of the vehicle battery 118 is prevented, effectively. The ECU 119 may control the opening of the flow regulating valve 120 by storing therein the data of minimum electric load of the vehicle without monitoring the electric load of the vehicle.

[0036] In the Rankine cycle circuit 100 of the Rankine cycle system 101, the bypass passage 3 connects the first passage 1 between the pump 111 and the cooling water boiler 112 to the second passage 2. If the bypass passage 3 is formed with a small diameter and the flow regulating valve 120 is made small in size, high-density refrigerant before being heated flows through the bypass passage 3, so that a sufficient flow rate of refrigerant is ensured. Therefore, the bypass passage 3 and the flow regulating valve 120 may be downsized. In the Rankine cycle circuit 100 of the Rankine cycle system 101, the bypass passage 3 connects the first passage 1 to the second passage 2 between the expansion device 114 and the condenser 115. Thus, all refrigerant in the second passage 2 flows through the condenser 115 to be cooled, which reduces the shortage of subcooled refrigerant fed into the pump 111 and, therefore, occurrence of cavitation in the pump 111 may be prevented.

[0037] The following will describe a Rankine cycle system 201 according to a second preferred embodiment of the present invention with reference to Fig. 2. The Rankine cycle system 201 of the second preferred embodiment differs from the Rankine cycle system 101 of the first preferred embodiment in that a bypass passage 23 that bypasses the expansion device is provided in the Rankine cycle circuit 200 of the Rankine cycle system 201, as shown in Fig. 2. Since the same reference numerals in Figs. 1 and 2 designate the same components or elements, detailed description of such components or elements of the second embodiment will be omitted.

[0038] Referring to Fig. 2, the bypass passage 23 is connected at one end thereof to the passage 1C of the first passage 1 and at the other end thereof to the passage 2A of the second passage 2 so as to bypass only the expansion device 114. The flow regulating valve 120 is provided in the bypass passage 23 for opening and closing the bypass passage 23 thereby to adjust the flow passage area of the bypass passage 23.

[0039] In the first preferred embodiment of Fig. 1, when the charge rate of the vehicle battery 118 becomes larger than the first predetermined level and the ECU 119 operates the flow regulating valve 120 to be opened, part of the refrigerant compressed by the pump 111 and heated by the cooling water boiler 112 and the waste gas boiler 113 into high-temperature and high-pressure refrigerant flows through the bypass passage 23 from the passage 1C to the passage 2A. Thus, the amount of refrigerant flowing through the expansion device 114 is reduced and the pressure differential between the inlet and outlet of the expansion device 114 is also reduced. Therefore, regenerative energy generated in the expansion device 114 by expansion of the refrigerant is reduced, with the result that the amount of electric power supplied to the vehicle battery 118 is reduced.

[0040] However, according to the Rankine cycle circuit 200 of the second preferred embodiment, the amount of refrigerant flowing through the passages 1A and 1 B and heated by the cooling water boiler 112 and the waste gas boiler 113 is not reduced. Especially in a case when the refrigerant for use in the Rankine cycle circuit 200 should not be heated over any upper limit, the provision of the bypass passage 23 helps to prevent an excessive increase of the temperature of refrigerant heated by the cooling water boiler 112 and the waste gas boiler 113.

[0041] The rest of the structures and the operation of the Rankine cycle system 201 of the second preferred embodiment are substantially the same as those of the Rankine cycle system 101 of the first preferred embodiment and, therefore, the description thereof will be omitted. The Rankine cycle system 201 of the second preferred embodiment offers the advantages similar to those of the first preferred embodiment as described above.

[0042] In the Rankine cycle systems 101 and 201, the ECU 119 may be operable to control the opening of the flow regulating valve 120 for adjusting the flow rate of refrigerant flowing through the bypass passages 3 and 23 such that electric power generated by the motor generator 116 substantially correspond to the electric load of the vehicle monitored by the ECU 119. In other words, when opening the flow regulating valve 120, the ECU 119 may control the opening of the flow regulating valve 120 such that AC power supplied from the inverter 117 to the vehicle battery 118 is close to the electric load of the vehicle monitored by the ECU 119. Therefore, charge rate of the vehicle battery 118 is maintained close to the first predetermined level, thereby preventing a change in the amount of charge of the vehicle battery 118, and durability of the vehicle battery 118 may be improved.

[0043] In the Rankine cycle systems 101 and 201 according to the first and second preferred embodiment, the ECU 119 may be operable to control the opening of the flow regulating valve 120 such that AC power supplied from the inverter 117 to the vehicle battery 118 is close to the minimum electric load of the vehicle stored in the ECU 119. Thus, the ECU 119 may control the amount of electric power supplied to the vehicle battery 118 so as to prevent the overcharge of the vehicle battery 118 without monitoring electric load of the vehicle.

[0044] In the Rankine cycle systems 101 and 201 according to the first and second preferred embodiments, the bypass passages 3 and 23 are not limited to the illustrated connections in Figs. 1 and 2, but they may be connected otherwise as long as the first passage 1 and the second passage 2 are connected by the bypass passages 3 and 23. In the Rankine cycle systems 101 and 201 according to the first and second preferred embodiments, a plurality of bypass passages may be provided, a plurality of the bypass passages may be provided, e. g. by combining the bypass passages 3 and 23, as long as the first passage 1 and the second passage 2 are connected by the bypass passages.

[0045] In the Rankine cycle systems 101 and 201 according to the first and second preferred embodiments, the pump 111, the motor generator 116 and the expansion device 114 are connected one another, but the present invention is not limited to this configuration. Alternatively, only the motor generator 116 and the expansion device 114 may be connected to each other. In this configuration, all regenerative energy generated as work in the expansion device 114 by expansion of refrigerant in the expansion device 114 is supplied to the vehicle battery 118 through generation of electric power by the motor generator 116 and conversion of electric power by the inverter 117. The pump 111 may be operated directly by electric power provided by the vehicle battery 118 or by power provided by the engine 10 through a drive belt.

[0046] In the Rankine cycle systems 101 and 201 according to the first and second preferred embodiments, the motor generator 116 may be replaced by an alternator, and the inverter 117 by a regulator. In this configuration, the alternator may be connected to the pump 111 and the expansion device 114 through a drive belt.

[0047] A Rankine cycle system mounted on a vehicle has a Rankine cycle circuit through which working fluid circulates, a power generator, a power storage and a controller. The Rankine cycle circuit includes a fluid expansion device, a fluid transferring device, first and second passages, a heater, a cooling device, a bypass passage and a flow regulating valve. The bypass passage connects the first passage to the second passage. The flow regulating valve is provided in the bypass passage for opening and closing the bypass passage. The power generator converts the work generated by the fluid expansion device into electric power. The controller monitors charge rate of the electric power charged in the power storage and controls an operation of the flow regulating valve based on the monitored charge rate. The controller causes the flow regulating valve to be opened when the monitored charge rate is greater than a predetermined value.

Claims

1. A Rankine cycle system (101, 201) mounted on a vehicle comprising:

   a Rankine cycle circuit (100, 200) through which working fluid circulates, the Rankine cycle circuit (100, 200) including;
   a fluid expansion device (114) expanding the working fluid for generating work;
   a fluid transferring device (111) transferring the working fluid to the fluid expansion device (114);
   a first passage (1) connecting the fluid transferring device (111) to the fluid expansion device (114);
   a second passage (2) connecting the fluid expansion device (114) to the fluid transferring device (111);
   a heater (112, 113) provided in the first passage (1) for heating the working fluid;
   a cooling device (115) provided in the second passage (2) for cooling the working fluid;
   a bypass passage (3, 23) connecting the first passage (1) to the second passage (2), and
   a flow regulating valve (120) provided in the bypass passage (3, 23) for opening and closing

the bypass passage (3, 23);
a power generator (116) converting the work generated by the fluid expansion device (114) into electric power;
a power storage (118) storing the electric power converted by the power generator (116), and
a controller (119) monitoring charge rate of the electric power charged in the power storage (118), the controller (119) controlling an operation of the flow regulating valve (120) based on the charge rate, the controller (119) causing the flow regulating valve (120) to be opened when the charge rate reaches or is greater than a first predetermined value.

2. The Rankine cycle system (101, 201) according to claim 1, **characterized in that** the controller (119) monitors an electric load of the vehicle and controls an opening of the flow regulating valve (120) based on the monitored electric load of the vehicle in opening the flow regulating valve (120), thereby adjusting a flow rate of the working fluid flowing through the bypass passage (3, 23) and the controller (119) controls generation of the electric power by the power generator (116) in such a way to suppress an increase of the charge rate of the power storage (118).

3. The Rankine cycle system (101, 201) according to claim 1, **characterized in that** the controller (119) controls an opening of the flow regulating valve (120) based on a minimum electric load required for operating the vehicle under normal conditions in opening the flow regulating valve, thereby adjusting the flow rate of the working fluid flowing through the bypass passage (3, 23) and the controller (119) controls generation of the electric power by the power generator (116) in such a way to suppress an increase of the charge rate of the power storage (118).

4. The Rankine cycle system (101, 201) according to claim 1, **characterized in that** the controller (119) monitors an electric load of the vehicle and controls an opening of the flow regulating valve (120) such that the amount of the electric power supplied to the power storage (118) is less than the monitored electric load of the vehicle and more than a minimum electric load required for operating the vehicle under normal conditions, thereby adjusting the flow rate of the working fluid flowing through the bypass passage (3, 23) and the controller (119) controls generation of the electric power by the power generator (116) in such a way to suppress an increase of the charge rate of the power storage (118).

5. The Rankine cycle system (101, 201) according to claim 1, **characterized in that** the controller (119) causes the flow regulating valve (120) to be closed when the charge rate reaches or is smaller than a second predetermined value which is smaller than the first predetermined value.

6. The Rankine cycle system (101) according to any one of claims 1 through 5, **characterized in that** the bypass passage (3) connects the first passage (1) between the fluid transferring device (111) and the heater (112, 113) to the second passage (2).

7. The Rankine cycle system (201) according to any one of claims 1 through 5, **characterized in that** the bypass passage (23) connects the first passage (1) between the heater (112, 113) and the fluid expansion device (114) to the second passage (2).

8. The Rankine cycle system (101, 201) according to any one of claims 1 through 5, **characterized in that** the bypass passage (3, 23) connects the first passage (1) to the second passage (2) between the fluid expansion device (114) and the cooling device (115).

9. The Rankine cycle system (101, 201) according to any one of claims 1 through 8, **characterized in that** the heater (112, 113) is a cooling water boiler in which the working fluid is heated through heat exchange with engine cooling water and/or a waste gas boiler in which the working fluid is heated through heat exchange with exhaust gas.

FIG. 1

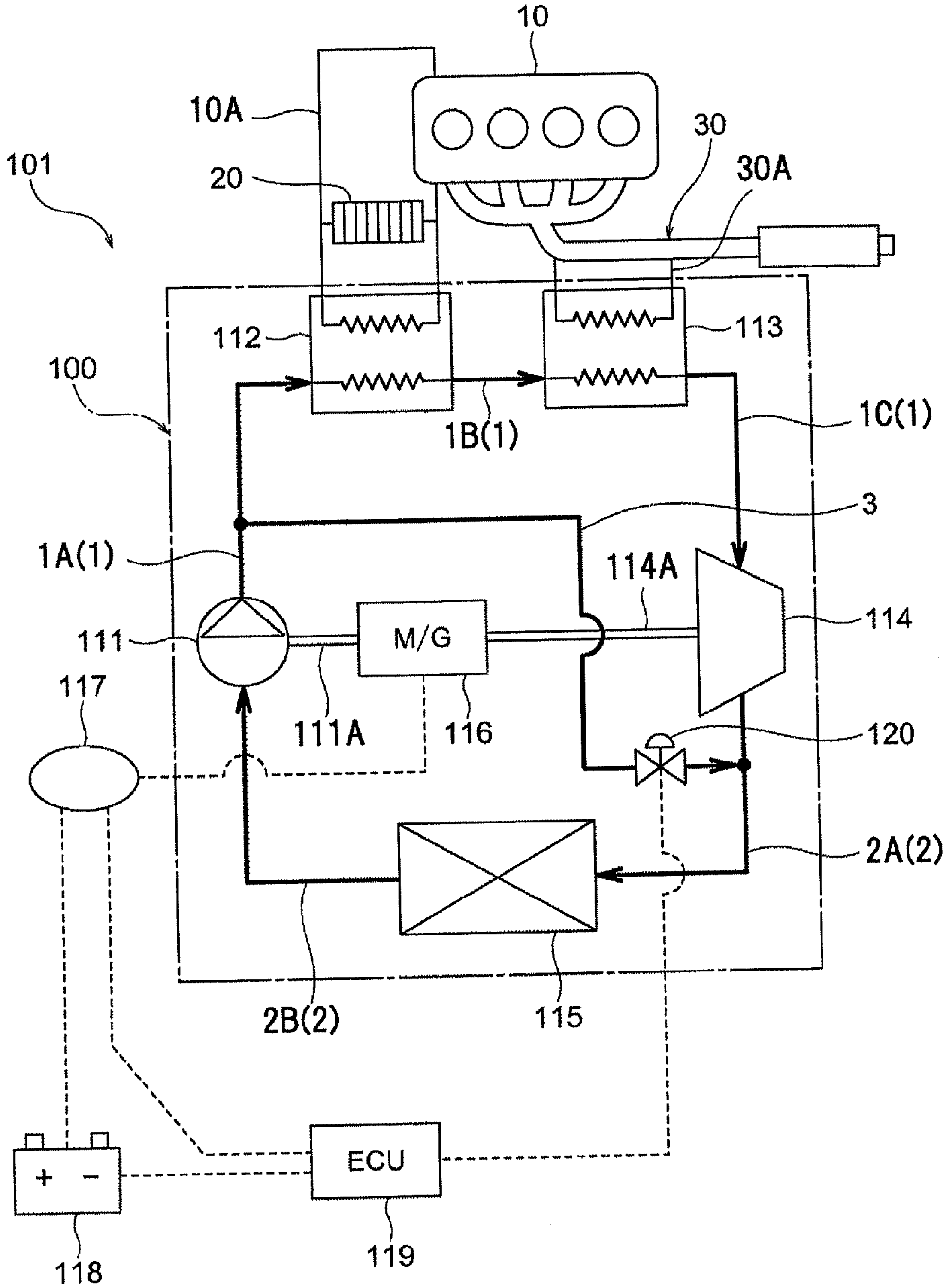
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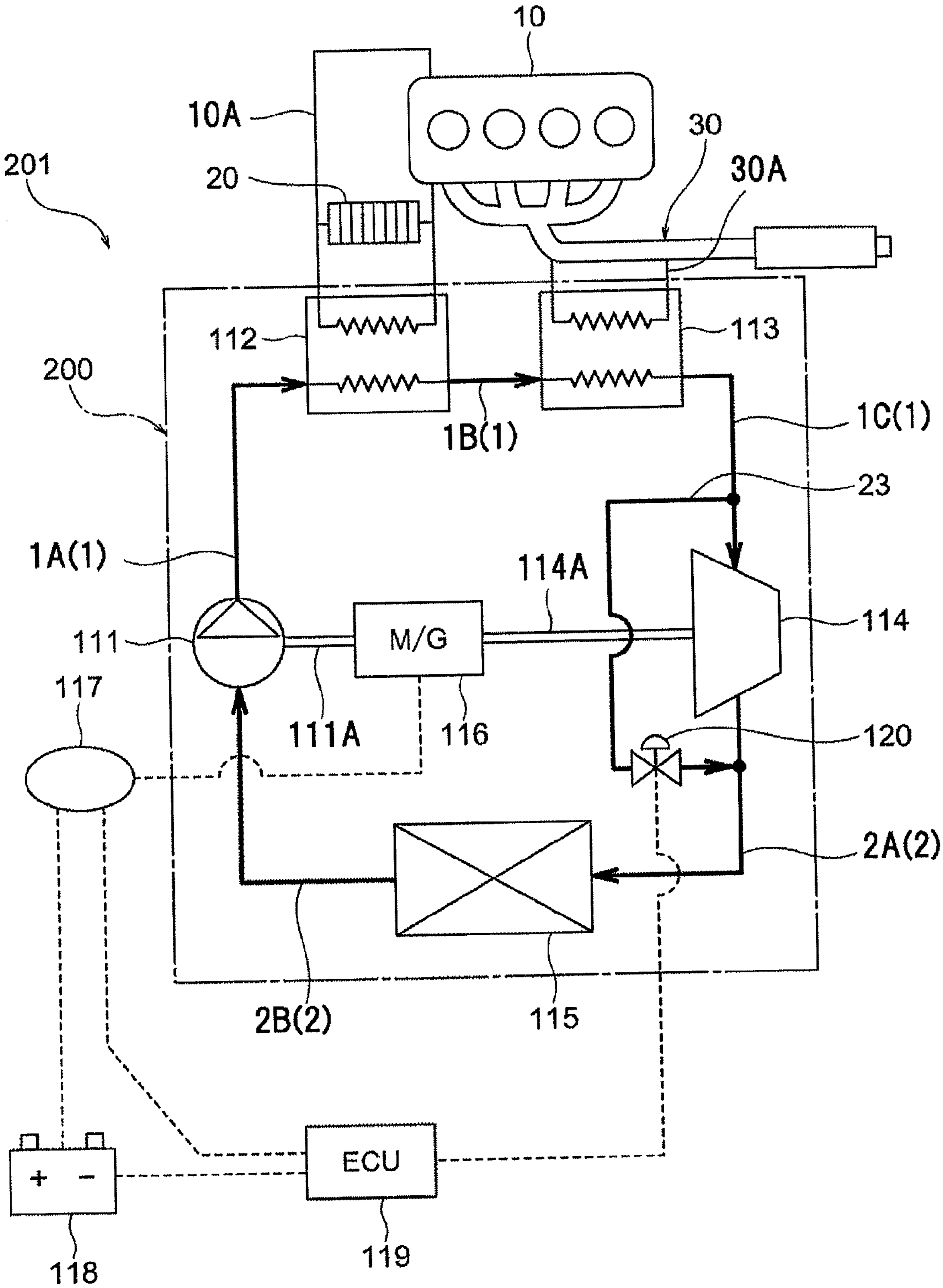
FIG. 2



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EUROPEAN SEARCH REPORT

Application Number
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Place of search	Date of completion of the search	Examiner
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