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(54) **HEAT EXCHANGER, HEAT ENGINE SYSTEM AND CONTROL METHOD USING THE SAME**

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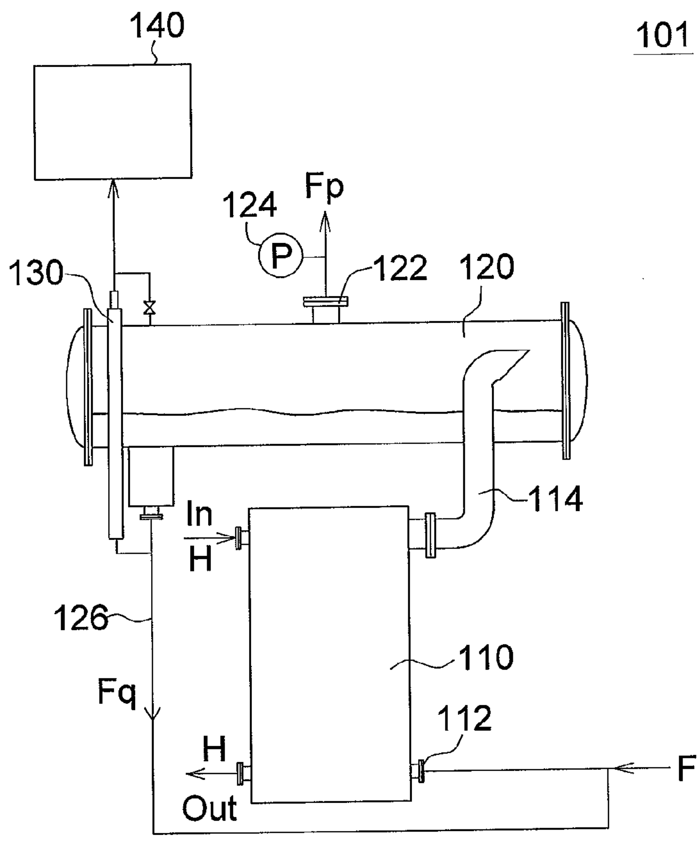
USPC **60/645**; 122/488; 60/667; 60/670

(57) **ABSTRACT**

A heat exchanger is provided. The heat exchanger comprises an evaporator, a vapor-liquid separator, a liquid level sensor and a controller. The evaporator is used for heating a working fluid up to a vapor-liquid state, and has a working fluid inlet pipe and a working fluid outlet pipe. The vapor-liquid separator is connected to the working fluid outlet pipe for separating the working fluid into a vapor working fluid and a liquid working fluid. The liquid level sensor detects a level of the liquid working fluid inside the vapor-liquid separator and outputs a liquid level signal. The controller receives the liquid level signal and controls the vapor quality of the working fluid inside the evaporator.



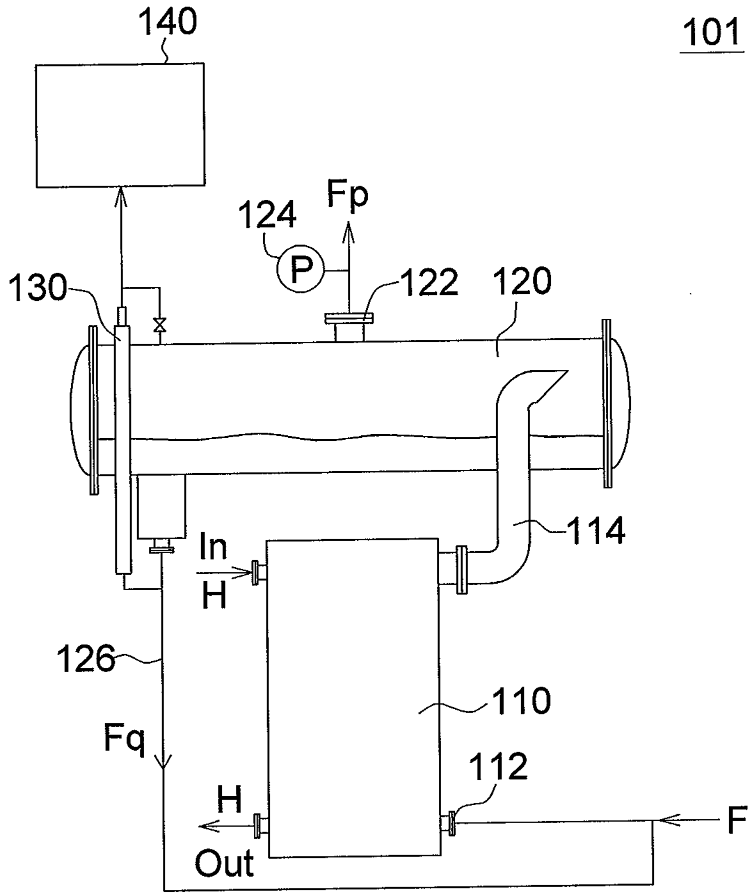


FIG. 1

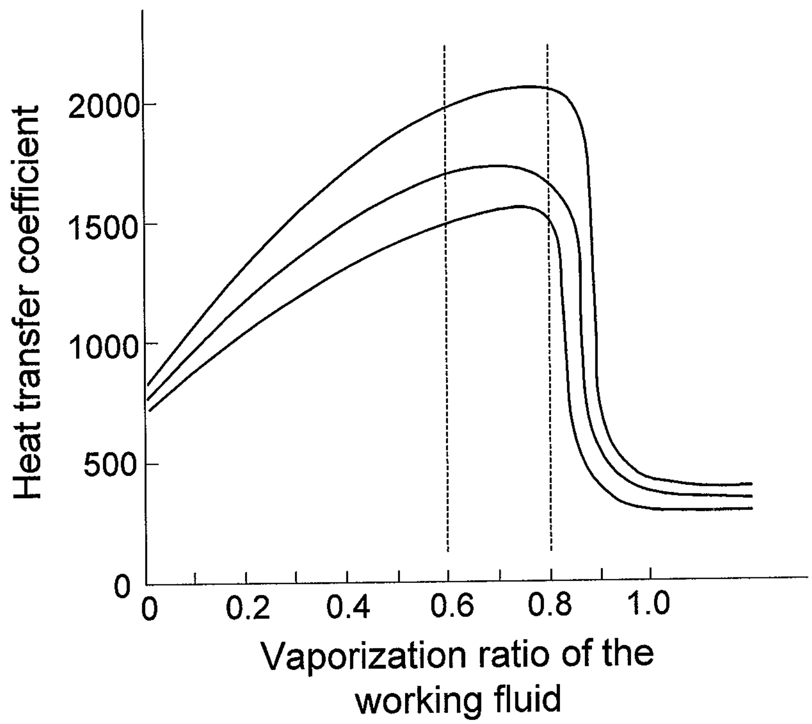

Heat transfer coefficient
2000
1500
1000
500
0
0
0.2
0.4
0.6
0.8
1.0
Vaporization ratio of the working fluid

FIG. 2

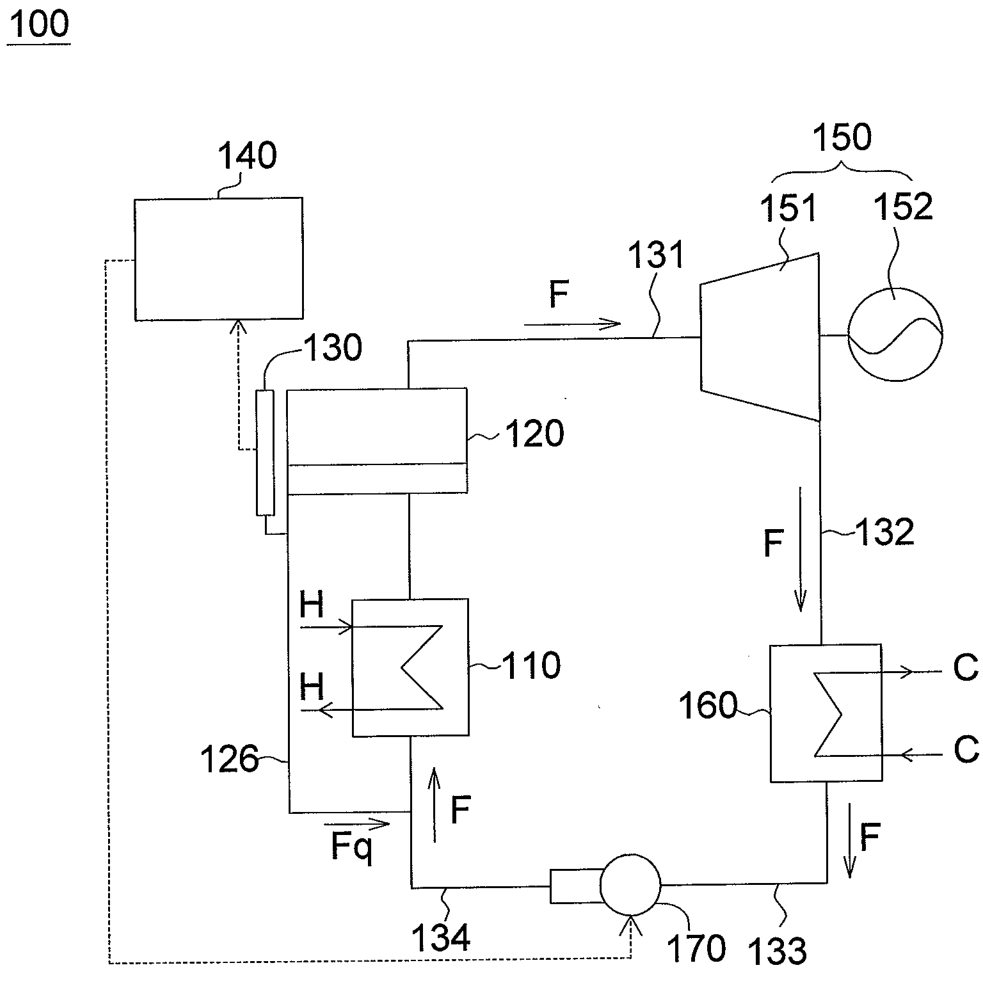

100
140
150
151
152
131
F
130
120
F
132
H
110
H
C
160
C
126
F
F
Fq
134
170
133

FIG. 3

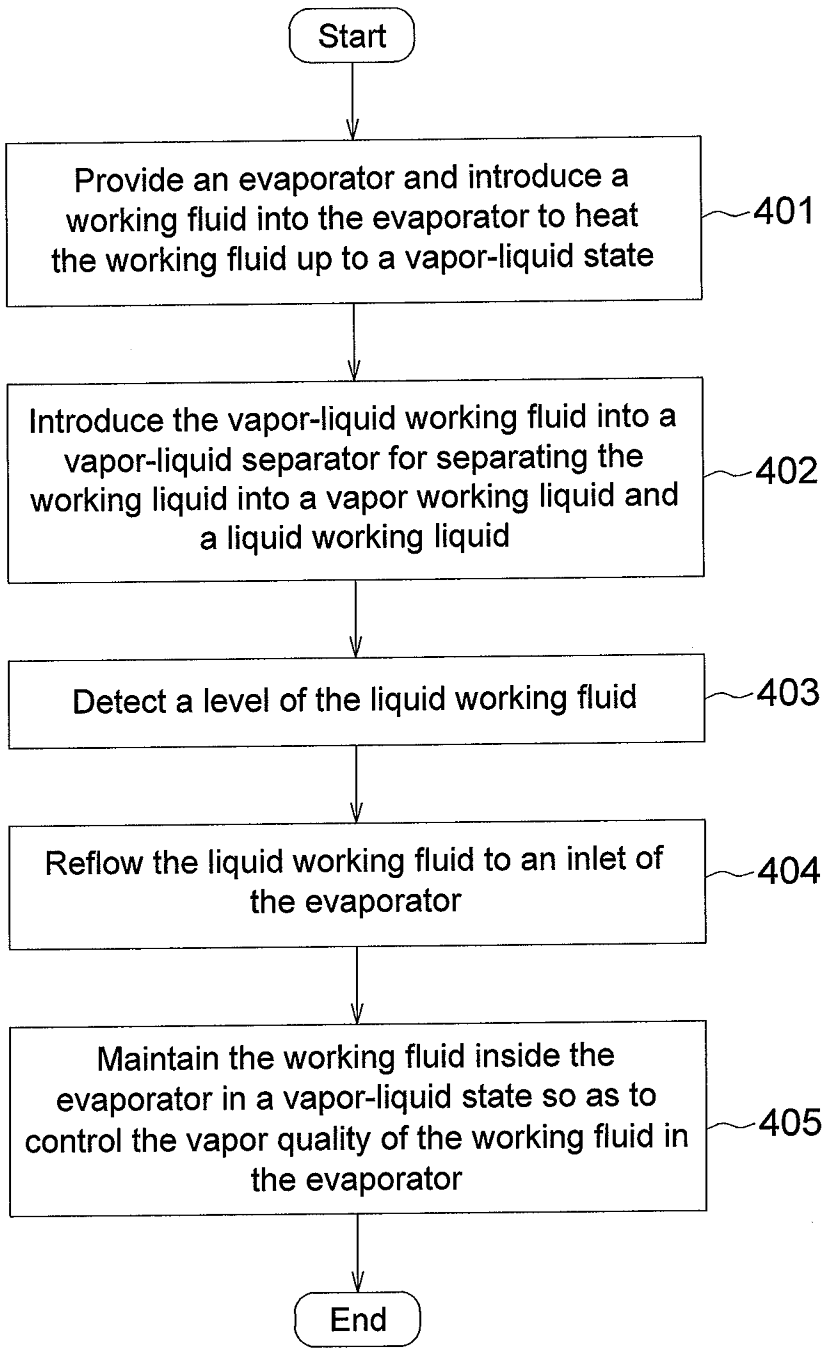

Start
Provide an evaporator and introduce a working fluid into the evaporator to heat the working fluid up to a vapor-liquid state
401
Introduce the vapor-liquid working fluid into a vapor-liquid separator for separating the working liquid into a vapor working liquid and a liquid working liquid
402
Detect a level of the liquid working fluid
403
Reflow the liquid working fluid to an inlet of the evaporator
404
Maintain the working fluid inside the evaporator in a vapor-liquid state so as to control the vapor quality of the working fluid in the evaporator
405
End

FIG. 4

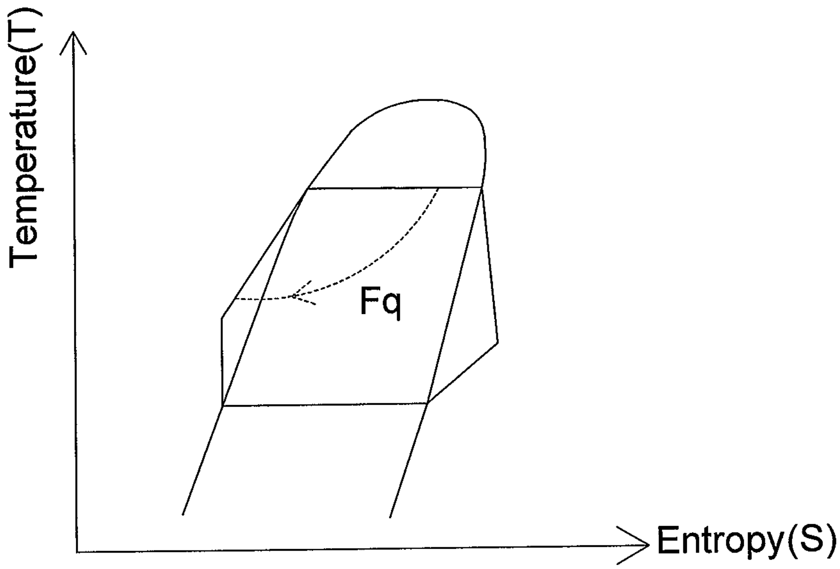


FIG. 5

HEAT EXCHANGER, HEAT ENGINE SYSTEM AND CONTROL METHOD USING THE SAME

[0001] This application claims the benefit of U.S. provisional application Ser. No. 61/868,588, filed Aug. 22, 2013 and Taiwan application Serial No. 102143184, filed Nov. 27, 2013, the disclosures of which are incorporated by references herein in its entirety.

TECHNICAL FIELD

[0002] The disclosure relates in general to a heat transfer system, and more particularly to a heat exchanger having a mechanism for controlling the vapor quality of a working fluid and a heat engine cycling system using the same.

BACKGROUND

[0003] Power generation market using middle and low temperature waste heat has gained rapid growth in recent years. Of the currently available power generation technologies using middle and low temperature waste heat, organic Rankine cycle (ORC) technology is most matured and cost-effective. ORC is a closed heat engine cycling system, and its key components and principles of operation thereof are as follows: (1) A working fluid booster pump: boosting a liquid working fluid and feeding the liquid working fluid into an evaporator to be heated therein. (2) An evaporator: absorbing the heat from the heat source to vaporize the working fluid. (3) An expander and a power generator: converting the heat and pressure energy of the working fluid into shaft power of the expander for the power generator to generate power. (4) A condenser: condensing a vapor working fluid into a liquid working fluid and sending the liquid working fluid to an inlet of the working fluid booster pump to complete the heat engine cycle.

[0004] Organic Rankine cycle (ORC) system is a binary cycle system. Firstly, a working fluid inside an ORC loop is boosted by a pump, vaporized by an evaporator, work-done by an expander, and liquefied by a condenser so as to complete a closed heat engine cycling system. Secondly, the heat of the hot stream from the heat source is transferred to the working fluid through the evaporator. Inside the evaporator, the heat of the hot stream is absorbed by a heat transfer medium (such as a heat transfer pipe of a shell and tube type heat exchanger or a heat transfer plate of a plate type heat exchanger). The hot stream, having been dissipated by the evaporator, flows to an external environment through a hot stream outlet of the evaporator. The hot stream can be directly discharged or reused depending on the temperature and flow rate in the outlet.

[0005] The working fluid at an outlet of the evaporator is normally designed to be in a saturated vapor state or a superheated vapor state. If the working fluid is in a saturated vapor state, the working fluid, having a high flow velocity at an outlet, may carry with droplets out of the outlet. The droplets in the working fluid will generate fluid expansion in the expander and make the expander vibrate during operation, and the output of power will become unstable. If the working fluid is in a superheated vapor state, the heat resistance of the working fluid inside the evaporator will be increased, and the overall heat transfer performance will deteriorate.

SUMMARY

[0006] The disclosure is directed to a heat exchanger and a heat engine cycling system capable of improving heat transfer performance of the working fluid inside the evaporator by controlling the vapor quality (i.e., dryness) of the working fluid.

[0007] The disclosure is directed to a control method in which the overall heat transfer performance of the evaporator is increased by controlling the vapor quality (i.e., dryness) of the working fluid inside the evaporator such that the heat transfer area required inside the evaporator can be reduced.

[0008] According to one aspect, a heat exchanger having a control mechanism is provided. The heat exchanger comprises an evaporator, a vapor-liquid separator, a liquid level sensor and a controller. The evaporator is for heating a working fluid up to a vapor-liquid state, and has a working fluid inlet pipe and a working fluid outlet pipe. The vapor-liquid separator is connected to the working fluid outlet pipe for separating the working fluid into a saturated vapor working fluid and a saturated liquid working fluid. The liquid level sensor detects a level of the liquid working fluid inside the vapor-liquid separator and outputs a liquid level signal. The controller receives the liquid level signal, and controls the vapor quality of the working fluid inside the evaporator. In an embodiment, the vapor-liquid separator has a vapor working fluid outlet pipe and a liquid working fluid reflow pipe, and the liquid working fluid reflow pipe is connected to the working fluid inlet pipe of the evaporator for reflowing the liquid working fluid into the evaporator.

[0009] According to another aspect, a heat engine cycling system is provided. The heat engine cycling system comprises an evaporator, a vapor-liquid separator, a liquid level sensor, a controller, a condenser, a power generation module and a pump. The evaporator is for heating a working fluid up to a vapor-liquid state, and has a working fluid inlet pipe and a working fluid outlet pipe. The vapor-liquid separator is connected to the working fluid outlet pipe for separating the working fluid into a vapor working fluid and a liquid working fluid. The liquid level sensor detects a level of the liquid working fluid inside the vapor-liquid separator and outputs a liquid level signal. The controller receives the liquid level signal, and controls the vapor quality of the working fluid inside the evaporator. The condenser cools the working fluid to a liquid state. The power generation module is connected to an outlet of the vapor-liquid separator through a first pipe and connected to an inlet of the condenser through a second pipe. The pump is connected to an outlet of the condenser through a third pipe and connected to an inlet of the evaporator through a fourth pipe. In an embodiment, the vapor-liquid separator has a vapor working fluid outlet pipe and a liquid working fluid reflow pipe, and the liquid working fluid reflow pipe is connected to the working fluid inlet pipe of the evaporator for reflowing the liquid working fluid into the evaporator.

[0010] According to an alternative aspect, a control method is provided. The method comprises following steps. An evaporator is provided, and a working fluid is introduced to the evaporator for heating the working fluid up to a vapor-liquid state. The vapor-liquid working fluid is introduced to a vapor-liquid separator for separating the vapor-liquid working fluid into a vapor working fluid and a liquid working fluid. A level of the liquid working fluid is detected and a liquid level signal is outputted. A controller is for receiving the liquid level signal and controlling the vapor quality of the working fluid inside the evaporator. In an embodiment, the liquid working fluid is reflowed to an inlet of the evaporator.

[0011] The above and other aspects of the disclosure will become better understood with regard to the following detailed description of the preferred but non-limiting embodiment(s). The following description is made with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. **1** is a heat exchanger having a mechanism for controlling the vapor quality of a working fluid according to an embodiment of the disclosure.

[0013] FIG. **2** is a relationship diagram between heat transfer coefficient and the vapor quality of a working fluid.

[0014] FIG. **3** is a heat engine cycling system having the vapor quality control mechanism according to an embodiment of the disclosure.

[0015] FIG. **4** is each step of a vapor quality control method according to an embodiment of the disclosure.

[0016] FIG. **5** is a temperature-entropy diagram of an organic Rankine cycle (ORC) system.

[0017] In the following detailed description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the disclosed embodiments. It will be apparent, however, that one or more embodiments may be practiced without these specific details.

[0018] In other instances, well-known structures and devices are schematically shown in order to simplify the drawing.

DETAILED DESCRIPTION

[0019] In an exemplary example of this embodiment, the heat transfer performance of the working fluid can be increased by controlling the vapor quality (i.e., dryness) of the working fluid. For instance, an evaporator, combined with a vapor-liquid separator, allows the vapor-liquid working fluid to enter the vapor-liquid separator after the vapor-liquid working fluid is discharged off the evaporator. When the working fluid inside the evaporator is in a vapor-liquid state, the vapor quality of the working fluid is preferably maintained between 60-80%. In comparison to the working fluid in a liquid state or a superheated vapor state, the vapor-liquid working fluid has better heat transfer coefficient and lower heat resistance, so that when the vapor quality of the working fluid is maintained between 60-80%, the heat transfer performance of the working fluid is hence improved.

[0020] In an embodiment, if the evaporator adopts a shell and tube type heat exchanger, the working fluid at an outlet of the evaporator is normally designed to be in a saturated vapor state or an over-heated vapor state. After the vapor working fluid is discharged off the evaporator, the vapor working fluid is guided to enter a power generation module to do work and generate power. In another embodiment, if the evaporator adopts a plate type heat exchanger, the working fluid, having a high flow velocity between the plates, may carry droplets when leaving the evaporator, so the working fluid at an outlet of the evaporator is preferably in a superheated vapor state.

[0021] In an exemplary example of this embodiment, two methods for detecting a pressure of the working fluid are provided. In one method, a pressure sensor to detect a pressure inside the evaporator. In the other method, a temperature sensor is used to detect a temperature inside the evaporator. When the working fluid inside the evaporator is in a vapor-liquid state, evaporation pressure and evaporation temperature are dependent on each other. Evaporation temperature refers to a saturated temperature (boiling point) at which the liquid working fluid is evaporated or boiled under a particular pressure, and the particular pressure is referred as evaporation pressure. When an evaporation pressure increases, a corresponding evaporation temperature will increase accordingly. Therefore, as long as the pressure or temperature inside the evaporator is controlled at a constant value, the evaporation pressure inside the evaporator will be maintained accordingly.

[0022] In an exemplary example of the present embodiment, the vapor-liquid separator is used for separating the vapor-liquid working fluid into a vapor working fluid and a liquid working fluid and guiding the vapor working fluid to enter the power generation module in the downstream of the separator. The liquid working fluid can be guided to enter the inlet of the evaporator and directly mix with the low-temperature working fluid at an outlet of the pump, and the temperature of the mixed working fluid is boosted and then the mixed working fluid is guided to enter the evaporator. Therefore, before entering the evaporator, the proportion of the sub-cooled liquid working fluid heat loading can be reduced so that the required heat transfer area inside the evaporator can be reduced accordingly. In another embodiment, the liquid working fluid can also be guided to enter an inlet of a condenser.

[0023] A number of embodiments are disclosed below for elaborating the disclosure. However, the embodiments of the disclosure are for detailed descriptions only, not for limiting the scope of protection of the disclosure.

[0024] Referring to FIG. **1**, a heat exchanger **101** having a mechanism for controlling the vapor quality of a working fluid according to an embodiment of the disclosure is shown. The heat exchanger **101** comprises an evaporator **110**, a vapor-liquid separator **120**, a liquid level sensor **130** and a controller **140**. The evaporator **110** is for heating a working fluid F up to a vapor state. One or more than one hot stream pipe is disposed inside the evaporator **110** for connecting the inlet In to an outlet Out, such that the hot stream H coming from the heat source can transfer the heat to the working fluid F through the hot stream pipe. The evaporator **110** has a working fluid inlet pipe **112** and a working fluid outlet pipe **114**. After entering the evaporator **110** through the working fluid inlet pipe **112**, the working fluid F, having been evaporated, vaporized and converted into a vapor-liquid state from a liquid state inside the evaporator **110**, is then discharged off the evaporator **110** through the working fluid outlet pipe **114**.

[0025] In an embodiment, the evaporator **110** can be realized by a shell and tube type heat exchanger or a plate type heat exchanger. The hot stream pipe disclosed above can be realized by a heat transfer pipe of the shell and tube type heat exchanger or a heat transfer plate of the plate type heat exchanger. The working fluid used in the OCR system can be organic substances having low boiling point under an atmospheric pressure (such as refrigerants or hydrocarbons), and can be heated by a diversity of middle and low temperature heat sources such as industrial waste heat, geothermal, hot springs or solar energy. Therefore, the working fluid, having been evaporated and vaporized inside the evaporator **110**, is guided to the power generation module **150** (referring to FIG. **3**) to do work and generate power.

[0026] In a super low temperature ORC power generating system, room temperature water (or surface seawater) can be used as a heat source to heat the working fluid which uses liquid gas, liquid nitrogen or liquid oxygen as a cooling fluid, such that the working fluid, having been evaporated and vaporized inside the evaporator **110**, is guided to the power generation module **150** (referring to FIG. **3**) to do work and generate power.

[0027] In an embodiment, the vapor quality (i.e., dryness) of the working fluid inside the evaporator **110** indicates the vaporization ratio of the liquid working fluid, and the higher the vapor quality, the higher the vaporization ratio. Therefore, after the vapor-liquid separator **120** separates the vapor-liquid working fluid into a vapor working fluid Fp and a liquid working fluid Fq, the vapor quality of the working fluid can be obtained from the level of the liquid working fluid Fq inside the vapor-liquid separator **120**. An increase in the level indicates a decrease in the vapor quality, and a decrease in the level indicates an increase in the vapor quality. The level of the working fluid is inversely proportional to the vapor quality.

[0028] The liquid level sensor **130**, disposed inside the vapor-liquid separator **120** or on the liquid working fluid reflow pipe **126**, detects a level of the liquid working fluid Fq inside the vapor-liquid separator **120** and outputs a liquid level signal to the controller **140** so as to control the vapor quality.

[0029] Please refer to FIG. **2**. Normally, the heat transfer coefficient of the working fluid reaches the peak when the vapor quality is between 60-80%, and experiences a steep fall as the vapor quality increases. After the working fluid is superheated (the vapor quality>1), the heat transfer mechanism thereof belongs to single phase heat transfer, and has a poor heat transfer coefficient. According to a conventional evaporator, after the working fluid absorbs heat and is evaporated inside the evaporator, the working fluid is in a superheated state when leaving the evaporator. The conventional evaporator whose vapor quality is greater than 0.8 and coefficient of heat transfer experiences a steep fall (referring to FIG. **2**) requires a larger heat transfer area, hence incurring more cost.

[0030] In general, the vapor-liquid separator **120** can be categorized as plate type separator, cyclone separator and centrifugal separator. In the vapor-liquid separator **120**, the density of the vapor working fluid is not equivalent to the density of the liquid working fluid. When the two types of working fluids flow together, the liquid working fluid will be affected by the gravity and generate a downward velocity while the vapor working fluid still flows towards the original direction. That is, the vapor working fluid and the liquid working fluid tend to be separated in a gravity field, and the liquid flowing downward will be attached on the wall and discharged off the vapor-liquid separator **120** through the working fluid outlet pipe **126**.

[0031] The controller **140** can be a programmable logic controller for adjusting the capacity of the liquid working fluid inside the evaporator **110** and receiving the liquid level signal from the liquid level sensor **130** so as to determine whether the vapor quality of the working fluid inside the evaporator **110** is greater than a predetermined value. For instance, the vaporization ratio of the working fluid is greater than 0.8 being the vapor quality corresponding to a steep fall of the heat transfer coefficient. If yes, the controller **140** can adjust the flow rate and pressure of the pump **170** (referring to FIG. **3**) by using a frequency variation control method. That is, the controller **140** can adjust the flow velocity of the working fluid and increase the flow rate of the working fluid at an inlet, so that the working fluid maintains at a vapor-liquid state with quality around 0.8 inside the evaporator **110**. Meanwhile, the working fluid at the vapor-liquid state has better heat transfer coefficient and lower heat resistance. Moreover, when the vapor quality of the working fluid inside the evaporator **110** is less than a predetermined value (for instance, the vaporization ratio of the working fluid is below 0.2), the controller **140** can adjust the flow velocity of the working fluid and decrease the flow rate of the working fluid at the inlet by using the frequency variation control method.

[0032] In an embodiment, the pressure sensor **124**, disposed on the vapor working fluid outlet pipe **122** of the vapor-liquid separator **120**, detects an evaporation pressure of the working fluid and outputs an evaporation pressure signal to the controller **140** to assure that the working fluid is in a saturated vapor state. In another embodiment, the pressure sensor **124** can be replaced by a temperature sensor or can be used together with the temperature sensor. The temperature sensor detects an evaporation temperature of the working fluid inside the vapor-liquid separator **120** and outputs an evaporation temperature signal to the controller **140** to assure that the working fluid is in a saturated vapor state.

[0033] Referring to FIG. **3**, a heat engine cycling system having the vapor quality control mechanism according to an embodiment of the disclosure is shown. The heat engine cycling system **100** comprises an evaporator **110**, a vapor-liquid separator **120**, a liquid level sensor **130**, a controller **140**, a power generation module **150**, a condenser **160** and a pump **170**. The evaporator **110** is for heating the working fluid F up to a vapor state. The condenser **160** cools a working fluid F to a liquid state. The power generation module **150** is connected to an outlet of the vapor-liquid separator **120** through a first pipe **131** and is connected to an inlet of the condenser **160** through a second pipe **132**. Besides, the pump **170** is connected to an outlet of the condenser **160** through a third pipe **133** and connected to an inlet of the evaporator **110** through a fourth pipe **134** to form a closed loop. Therefore, the heat engine cycling system can be a closed heat engine cycling system.

[0034] The disclosed power generation module **150** can be composed of an expander (such as turbine, screw expander, scroll expander) and a power generator. Please refer to FIG. **2**. In an embodiment, the heat and pressure of the working fluid F in a high-temperature vapor state can be converted into a shaft power of the expander **151**. Then, the mechanic energy generated from the expansion of the working fluid is inputted to the power generator **152** for generating power. In addition, after the work is done, the working fluid F flows through the condenser **160**, and the cooling fluid C in the heat transfer medium absorbs the heat of the working fluid F and thus the working fluid in vapor state becomes a liquid working fluid. Then, the pump **170** boosts the pressure of the liquid working fluid and pumps the working fluid to be heated in the evaporator **110** to form a heat engine cycling system.

[0035] Principles of operation of the evaporator **110**, the vapor-liquid separator **120**, the liquid level sensor **130** and the controller **140** are disclosed with reference to FIG. **1** and relevant descriptions. Descriptions of the vapor quality control method are disclosed below. Referring to FIG. **4**, a flowchart of a vapor quality control method according to an embodiment is shown. Firstly, in step **401**, an evaporator **110** is provided and a working fluid F is introduced to the evaporator **110** for heating the working fluid F up to a vapor-liquid state. In step **402**, the vapor-liquid working fluid is introduced to the vapor-liquid separator **120** for separating the vapor-liquid working fluid into a vapor working fluid Fp and a liquid working fluid Fq. In step **403**, a level of the liquid working fluid Fq is detected and a liquid level signal is outputted. The liquid level signal is outputted to a controller **140** in the form of an electric signal. In step **404**, the liquid working fluid Fq is reflowed to an inlet of the evaporator **110** to mix with a low-temperature working fluid at an outlet of the pump **170**, and the temperature of the mixed working fluid is boosted and the mixed working fluid guided to enter the evaporator **110**. In step **405**, the controller **140** is used to receive the liquid level signal and adjust the flow rate and pressure of the pump **170** so as to adjust the flow rate of the working fluid F at the inlet, and as long as the working fluid F inside the evaporator **110** maintains in a vapor-liquid state, the vapor quality of the working fluid inside the evaporator **110** can be controlled to be within a particular range such as between 0.4-0.8. Preferable, the vapor quality of the working fluid inside the evaporator **110** is between 0.6-0.8, but the disclosure is not limited thereto.

[0036] It can be known from the control method of the vapor quality disclosed above, the heat transfer performance of the working fluid can be improved by controlling the vapor quality of the working fluid and the overall heat efficiency of the ORC system can be improved accordingly.

[0037] Referring to FIG. **5**, a temperature-entropy diagram of an organic Rankine cycle (ORC) system is shown. The dotted line as indicated in FIG. **5** is a heat transfer path through which the liquid working fluid Fq inside the vapor-liquid separator **120** is reflowed to the evaporator **110**. The high-temperature liquid working fluid mixes with the low-temperature working fluid at an outlet of the pump **170**, so that the temperature of the mixed working fluid is boosted and then the mixed working fluid is guided to enter the evaporator **110**. Therefore, before entering the evaporator **110**, the proportion of the sub-cooled liquid working fluid heat loading can be reduced so that the required heat transfer area inside the evaporator **110** can be reduced accordingly.

[0038] A heat exchanger, a heat engine cycling system and a vapor quality control method using the same are disclosed in above embodiments of the disclosure. The heat exchanger has a mechanism for controlling the vapor quality of a working fluid. Since the working fluid in a vapor-liquid state has high performance in heat transfer, the vapor quality of the working fluid at an outlet of the evaporator can be controlled to achieve following effects: (1) The working fluid inside the evaporator has better performance in heat transfer, largely reducing the heat transfer area required inside the evaporator and decreasing the cost. (2) After the working fluid enters the vapor-liquid separator, a saturated vapor working fluid is provided to the power generation module to increase the overall heat efficiency of the ORC system. (3) The liquid working fluid separated from the vapor-liquid separator directly mixes with the low-temperature working fluid before entering the evaporator, so that the proportion of the sub-cooled liquid working fluid heat loading can be reduced to decrease the heat transfer area required inside the evaporator.

[0039] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed embodiments. It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the following claims and their equivalents.

What is claimed is:

1. A heat exchanger, comprising:

an evaporator for heating a working fluid up to a vapor-liquid state, wherein the evaporator has a working fluid inlet pipe and a working fluid outlet pipe;

a vapor-liquid separator connected to the working fluid outlet pipe for separating the working fluid into a vapor working fluid and a liquid working fluid;

a liquid level sensor for detecting a level of the liquid working fluid inside the vapor-liquid separator and outputting a liquid level signal; and

a controller for receiving the liquid level signal to control a vapor quality of the working fluid inside the evaporator.

2. The heat exchanger according to claim **1**, wherein the vapor quality of the working fluid inside the evaporator is between 0.6-0.8.

3. The heat exchanger according to claim **1**, wherein the level of the liquid working fluid inside the vapor-liquid separator is inversely proportional to the vapor quality of the working fluid inside the evaporator.

4. The heat exchanger according to claim **1**, wherein the controller determines whether the vapor quality of the working fluid inside the evaporator is greater than a predetermined value to obtain a state of the working fluid, the predetermined value is settled when a vaporization ratio of the working fluid is greater than 0.8.

5. The heat exchanger according to claim **4**, wherein when the vapor quality of the working fluid is greater than the predetermined value, the controller adjusts the flow velocity of the working fluid to increase a flow rate of the working fluid at an inlet of the evaporator.

6. The heat exchanger according to claim **1**, wherein the vapor-liquid separator has a vapor working fluid outlet pipe and a liquid working fluid reflow pipe, the liquid working fluid reflow pipe is connected to the working fluid inlet pipe of the evaporator for reflowing the liquid working fluid into the evaporator.

7. A heat engine cycling system, comprising:

an evaporator for heating a working fluid up to a vapor-liquid state, wherein the evaporator has a working fluid inlet pipe and a working fluid outlet pipe;

a vapor-liquid separator connected to the working fluid outlet pipe for separating the working fluid into a vapor working fluid and a liquid working fluid, wherein the vapor-liquid separator has a vapor working fluid outlet pipe and a liquid working fluid reflow pipe, the liquid working fluid reflow pipe is connected to the working fluid inlet pipe for reflowing the liquid working fluid into the evaporator;

a liquid level sensor for detecting a level of the liquid working fluid and outputting a liquid level signal;

a controller for receiving the liquid level signal and controlling a vapor quality of the working fluid inside the evaporator;

a condenser for cooling the working fluid to a liquid state;

a power generation module connected to an outlet of the vapor-liquid separator through a first pipe and connected to an inlet of the condenser through a second pipe; and

a pump connected to an outlet of the condenser through a third pipe and connected to an inlet of the evaporator through a fourth pipe.

8. The heat engine cycling system according to claim **7**, wherein the vapor quality of the working fluid inside the evaporator is between 0.6-0.8.

9. The heat engine cycling system according to claim **7**, wherein the level of the liquid working fluid inside the vapor-liquid separator is inversely proportional to the vapor quality of the working fluid inside the evaporator.

10. The heat engine cycling system according to claim **7**, wherein the controller determines whether the vapor quality of the working fluid inside the evaporator is greater than a predetermined value to obtain a state of the working fluid, and the predetermined value is settled when a vaporization ratio of the working fluid is greater than 0.8.

11. The heat engine cycling system according to claim **10**, wherein when the vapor quality of the working fluid is greater than the predetermined value, the controller adjusts the flow velocity of the working fluid to increase the flow of the working fluid at the inlet of the evaporator.

12. The heat engine cycling system according to claim **7**, wherein the vapor-liquid separator has a vapor working fluid outlet pipe and a liquid working fluid reflow pipe, and the liquid working fluid reflow pipe is connected to the working fluid inlet pipe of the evaporator for reflowing the liquid working fluid into the evaporator.

13. A control method, comprising:

providing an evaporator and introducing a working fluid to the evaporator to heat the working fluid up to a vapor-liquid state;

introducing a vapor-liquid working fluid to a vapor-liquid separator for separating the working liquid into a vapor working liquid and a liquid working liquid;

detecting a level of the liquid working fluid and outputting a liquid level signal; and

using a controller to receive the liquid level signal and control a vapor quality of the working fluid inside the evaporator.

14. The control method according to claim **13**, wherein the vapor quality of the working fluid inside the evaporator is between 0.6-0.8.

15. The control method according to claim **13**, wherein the level of the liquid working fluid inside the vapor-liquid separator is inversely proportional to the vapor quality of the working fluid inside the evaporator.

16. The control method according to claim **13**, wherein the controller determines whether the vapor quality of the working fluid inside the evaporator is greater than a predetermined value to confirm whether the working fluid is overheated, and the predetermined value is settled when a vaporization ratio of the working fluid is greater than 0.8.

17. The control method according to claim **16**, wherein when the vapor quality of the working fluid is greater than the predetermined value, the controller adjusts the flow velocity of the working fluid to increase a flow rate of the working fluid at an inlet of the evaporator.

18. The control method according to claim **13**, further comprising reflowing the liquid working fluid into an inlet of the evaporator.

* * * * *