

(19)



(11)

EP 3 225 925 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
04.10.2017 Bulletin 2017/40

(51) Int Cl.:
F24F 1/00 (2011.01)

(21) Application number: **16163305.2**

(22) Date of filing: **31.03.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

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AL AT BE BG CH CY CZ DE DK EE ES FI FR GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
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Designated Contracting States:
GB

(54) **HEAT EXCHANGER UNIT WITH SYNTHETIC JET FLOW DEVICE**

(57) The invention relates to a heat exchanger unit comprising at least one heat exchanger and at least one synthetic jet flow device having an expelling direction, the expelling direction being a direction in which gas is expelled by the synthetic jet flow device in operation, the at least one heat exchanger being arranged in the expelling direction with respect to the at least one synthetic jet flow device at such a distance that gas being expelled by the at least one synthetic jet flow device flows towards the heat exchanger.

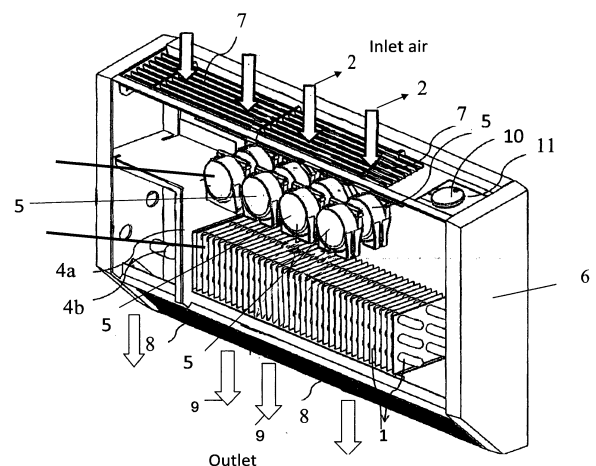


Fig. 1

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Description

[0001] The present invention relates to a heat exchanger unit comprising at least one synthetic jet flow device expelling air in the direction of at least one heat exchanger.

[0002] Radiators and fan coils are commonly used in domestic heating and cooling in the EU market. Traditional radiators need high temperature water supply to achieve a certain amount of heat output and comfort by radiation from the front panel. Fan coils are becoming popular to work with heat pumps due to the low water temperature requirement. In current fan coil units fans are commonly used as the driver for the heat coils. The fan drives air for achieving a high heat transfer coefficient.

[0003] A problem of conventional fan coil units is that the fan usually produces noise due to mechanical vibration and aerodynamic turbulence. Furthermore, the mechanically rotating movement of the fan rotor will wear out the bearing and this will cause more vibration and increased noise after a while. Furthermore, the reliability is reduced over time. In addition, fans consume quite a high amount of electrical power for running.

[0004] It is an object of the present invention to overcome above mentioned disadvantages of conventional fan coil units.

[0005] The object is solved by the heat exchanger unit according to claim 1. The dependent claims describe advantageous embodiments of the heat exchanger unit according to claim 1.

[0006] The present invention relates to a heat exchanger unit. A heat exchanger unit usually causes a transfer of heat from a heat transport medium, as for example water, to air.

[0007] The heat exchanger unit according to the present invention comprises at least one heat exchanger and at least one synthetic jet flow device. A synthetic jet flow device is a device producing a jet flow. A jet flow is a fluid flow in which a stream of one fluid mixes with a surrounding medium. Synthetic jets may optionally be formed by a flow moving back and forth through a small opening. Such flow back and forth may for example be produced by periodic ejection and suction of fluid from an orifice induced by movement of a diaphragm inside a cavity among other ways.

[0008] The at least one synthetic jet flow device according to the invention has an expelling direction which is a direction in which gas is expelled by the synthetic jet flow device in operation. Preferably the gas can be air in many common heat exchanger units. The expelling direction may for example be a direction perpendicular to a plane in which said orifice extends.

[0009] In the heat exchanger unit according to the present invention the at least one heat exchanger is arranged in an expelling direction with respect to the at least one synthetic jet flow device. That is, the at least one synthetic jet flow device expels the gas in the direction of the at least one heat exchanger.

[0010] According to the present invention the at least one heat exchanger is located at such a distance from the at least one synthetic jet flow device that air being expelled by the at least one synthetic jet flow device flows towards the heat exchanger and reaches the heat exchanger. Thus, the at least one heat exchanger is arranged at such a distance from the at least one synthetic jet flow device that the synthetic jet flow device effects a flow of the gas through the heat exchanger with a non-vanishing velocity.

[0011] In a preferred embodiment the synthetic jet flow device may be a piezoelectric synthetic jet or a plasma synthetic jet. Also a combination of both types of synthetic jets is possible.

[0012] A piezoelectric synthetic jet may for example comprise a chamber which one end is sealed off by a membrane, which the other end is left partially open. The opening is referred to as the nozzles of the synthetic jet. When the membrane vibrates periodically it also changes the volumes of the chamber, which in turn induces a flow into and out of the nozzle. The fluctuating velocity at the nozzles exit can be used to actively influence a surrounding fluid system. Similar to piezoelectric synthetic jet a plasma synthetic jet may mainly comprise two electrodes embedded in the end of a chamber, and a small opening may be located on the other end. By applying a voltage difference greater than the disruptive voltage of the air, an electric arc can be created between the two electrodes, leading to an increase in the internal energy. Since the air is confined, the temperature and pressure increase quickly inside the chamber. Air will be released through the opening and it will create a pulsed air jet same as a piezoelectric synthetic jet.

[0013] In a preferred embodiment the heat exchanger may comprise at least one heat coil. A heat coil may for example be a pipe or tube in which the heat transfer medium can flow. Preferably the tube or pipe may comprise means to increase the heat transfer between the heat transport medium and the surrounding gas. The tube or pipe may for example be wound in one or more bends, for example extending in a plane.

[0014] In a preferred embodiment the heat exchanger may comprise a plurality of fins extending in parallel planes. The expelling direction of the synthetic jet flow devices may then be directed towards the plurality of fins. Preferably the expelling direction may be parallel to planes in which the fins extend. In a preferred embodiment the fins may for example be louvered fins and/or pin fins.

[0015] In an advantageous embodiment the heat exchanger may comprise metallic foam. The heat exchanger may furthermore comprise at least one pipe which is arranged in heat conducting contact with the metallic foam. The pipe may allow heat transport medium to flow within the pipe. Preferably the pipe may run through the foam so that in at least a part of its length the pipe is surrounded by the metallic foam. Preferably the pipe has one or more bends within the foam. For example, the

foam may be shaped as a flat cuboid and the pipe may run within the cuboid in at least one bend in a plane parallel to the largest surface of the cuboid.

[0016] In an advantageous embodiment the heat exchanger unit may comprise at least one fan having a blowing direction which is parallel to the expelling direction of the at least one synthetic jet flow device. The blowing direction may for example be perpendicular to a plane in which the fan rotates.

[0017] In a preferred embodiment the heat exchanger unit may comprise a temperature sensor and a control unit. The control unit may preferably be adapted to control the operation of the synthetic jet flow devices to expel air based on a temperature measured by the temperature sensor. The temperature sensor may preferably take the measurement of air temperature at an inlet of the heat exchanger unit and the control unit may use the measured temperature for controlling actuators to control a speed of vibration or a plasma intensity of the synthetic jet flow devices. The control unit may for example use a PI control structure. A manipulated variable may for example be the vibration frequency of an electromagnetical or piezo synthetic jet or a voltage for plasma generation in a plasma synthetic jet.

[0018] The heat exchanger unit according to the present invention allows better control, reduced weight, reduced space and cost savings compared to the prior art.

[0019] The heat exchanger unit according to the present invention can preferably be employed in an air conditioner or heat pump. For example the heat exchanger unit may be an outdoor unit or an indoor unit. Depending on the purpose the indoor unit or the outdoor unit may comprise an evaporator or a condenser. Said heat exchanger may be part of the evaporator or the condenser or may be in heat conducting contact with the evaporator or condenser.

[0020] In the following the invention shall be explained by way of example with reference to figures.

Figure 1 shows a heat exchanger unit according to the present invention,

Figure 2 shows a control structure of a heat exchanger unit according to the present invention, and

Figure 3 shows an example of a heat exchanger 10 that can be employed in the invention.

[0021] Figure 1 shows an example of a heat exchanger unit according to the present invention. The heat exchanger unit comprises a heat exchanger 1 which allows heat exchange between inlet air 2 and a heat transport medium 3 (not shown), in this example water 3. The heat exchanger 1 is shaped as a grid of water pipes. It comprises an inlet 4a for water and an outlet 4b for water. The heat transport medium 3 flows into the inlet 4a, then through the heat exchanger 1 and out of the heat ex-

changer through outlet 4b.

[0022] The heat exchanger unit of Figure 1 comprises a plurality of synthetic jet flow devices 5. In Figure 1 the expelling direction of the synthetic jet flow devices 5 is directed in the direction of the heat exchanger 1 at a distance such that air being expelled by the synthetic jet flow devices 5 flows towards the heat exchanger 1 so that a movement of air at a non-vanishing velocity is affected in the heat exchanger 1.

[0023] The flow of air affected by the synthetic jet flow devices 5 results in an air flow through the heat exchanger unit. To allow for this airflow the heat exchanger unit comprises a housing 6 comprising plurality of inlet openings 7 through which inlet air 2 can enter. On its opposite surface the housing 6 comprises a plurality of outlet openings 8 through which outlet air 9 can be expelled. The outlet openings 8 are on an opposite side of the heat exchanger 1 in relation to the synthetic jet flow devices 5.

[0024] The array of synthetic jets 5 is installed in a space between the inlet openings 7 and the heat exchanger 1. The outlet of nozzles of the synthetic jet flow devices 5 is directed towards fins of the heat exchanger 1. The fins may be highly dense fins, for example of louvered type or made of metallic foam or other similar ones which may show heat transfer enhancement for a better heat dissipating capacity. One or more fans may optionally be provided which have blowing directions parallel to the blowing directions of the synthetic jet flow devices. However, such fans are not necessary and only advantageous in certain specific circumstances.

[0025] In the example shown in Figure 1 the heat exchanger unit comprises a temperature sensor 10 which is connected to a control unit 11. The control unit can be adapted to control the operation of the synthetic jet flow devices 5 to expel air based on a temperature measured by the temperature sensor 10.

[0026] Figure 2 shows an example flow diagram of a control of the heat exchanger unit according to the present invention. The measured temperature at the inlet 2 is the process variable (PV) and used as the important measurement for controlling the actuators of the synthetic jet flow devices 5, and the desired temperature is defined the setpoint (SP). The input to the process (the vibration frequency of electromechanical synthetic jets or the voltage for plasma generation) is the output from the PI controller. It is called the manipulated variable (MV) or the control variable (CV). The difference between the measured temperature and the setpoint is the error (e), which quantifies whether the frequency or voltage is too low or too high and by how much. By measuring the temperature (PV), and subtracting it from the setpoint (SP), the error (e) is found, and from it the controller calculates how much frequency or voltage to supply to the synthetic jets (MV). One method may be proportional control: the frequency or voltage is set in proportion to the existing error. Integral action adds a second term, using the accumulated temperature error in the past to detect whether the frequency or voltage of the synthetic jet is settling out

too low or too high and to set the electrical voltage in relation not only to the error but also to the time for which it has persisted. The proportional term produces an output value that is proportional to the temperature error value. The proportional response can be adjusted by multiplying the error by a constant K_p , called the proportional gain constant. The contribution from the integral term is proportional to both the magnitude of the error and the duration of the error. The integral in a PI controller is the sum of the instantaneous error over time and gives the accumulated offset that should have been corrected previously. The accumulated error is then multiplied by the integral gain (K_i) and added to the controller output.

[0027] Figure 3 shows an example of a heat exchanger 1 that can be employed in the invention. The heat exchanger 1 shown in Figure 3 is in this example identical to that shown in Figure 1.

[0028] The heat exchanger of Figure 3 comprises a plurality of fins 12 which in this example are rectangular plates 12 which are arranged parallel to each other. Most of the fins 12 have equal distances to their respective neighbouring fins 12. The corresponding corners of the fins are arranged in a straight line.

[0029] A system 13 of tubes 14 and 15 runs through the fins, wherein each tube 14 and 15 passes through each fin 12 such that its longitudinal direction is perpendicular to the plane of the respective fin 12. The system 13 of tubes 14 and 15 in the example of figure 3 comprises two the tubes 14 and 15 which branch off each other behind the entry 4a and come together before the exit 4b. Each of the tubes 14 and 15 in the shown example after branching off the entry 4a runs through the fins in three bows before entering the exit tube 4b. The bows of each tube 14 and 15 may run parallel to each other. Of course other numbers of bows are possible.

Claims

1. Heat exchanger unit comprising at least one heat exchanger and at least one synthetic jet flow device having an expelling direction, the expelling direction being a direction in which gas is expelled by the synthetic jet flow device in operation, the at least one heat exchanger being arranged in the expelling direction with respect to the at least one synthetic jet flow device at such a distance that gas being expelled by the at least one synthetic jet flow device flows towards the heat exchanger.
2. Heat exchanger unit according to the preceding claim, wherein the synthetic jet flow device is a piezoelectric synthetic jet or a plasma synthetic jet.
3. Heat exchanger unit according to one of the preceding claims, wherein the heat exchanger comprises

at least one heat coil.

4. Heat exchanger unit according to one of the preceding claims, wherein the heat exchanger comprises a plurality of fins extending in parallel planes, the expelling direction is directed towards the plurality of fins and wherein the expelling direction is parallel to the planes in which the fins extend.
5. Heat exchanger unit according to one of the preceding claims wherein the fins are louvered fins and/or pin fins.
6. Heat exchanger unit according to one of the preceding claims wherein the heat exchanger comprises metallic foam, and at least one pipe which is arranged in heat conducting contact with the metallic foam and through which pipe a heat transport medium can flow.
7. Heat exchanger unit according to one of the preceding claims, further comprising at least one fan, the blowing direction of which is directed parallel to the expelling direction of the at least one synthetic jet flow device.
8. Heat exchanger unit according to one of the preceding claims wherein the heat exchanger unit is an outdoor unit comprising an evaporator.
9. Heat exchanger unit according to one of the preceding claims, further comprising a temperature sensor and a control unit, the control unit being adapted to control the operation of the synthetic jet flow devices to expel gas based on a temperature measured by the temperature sensor.

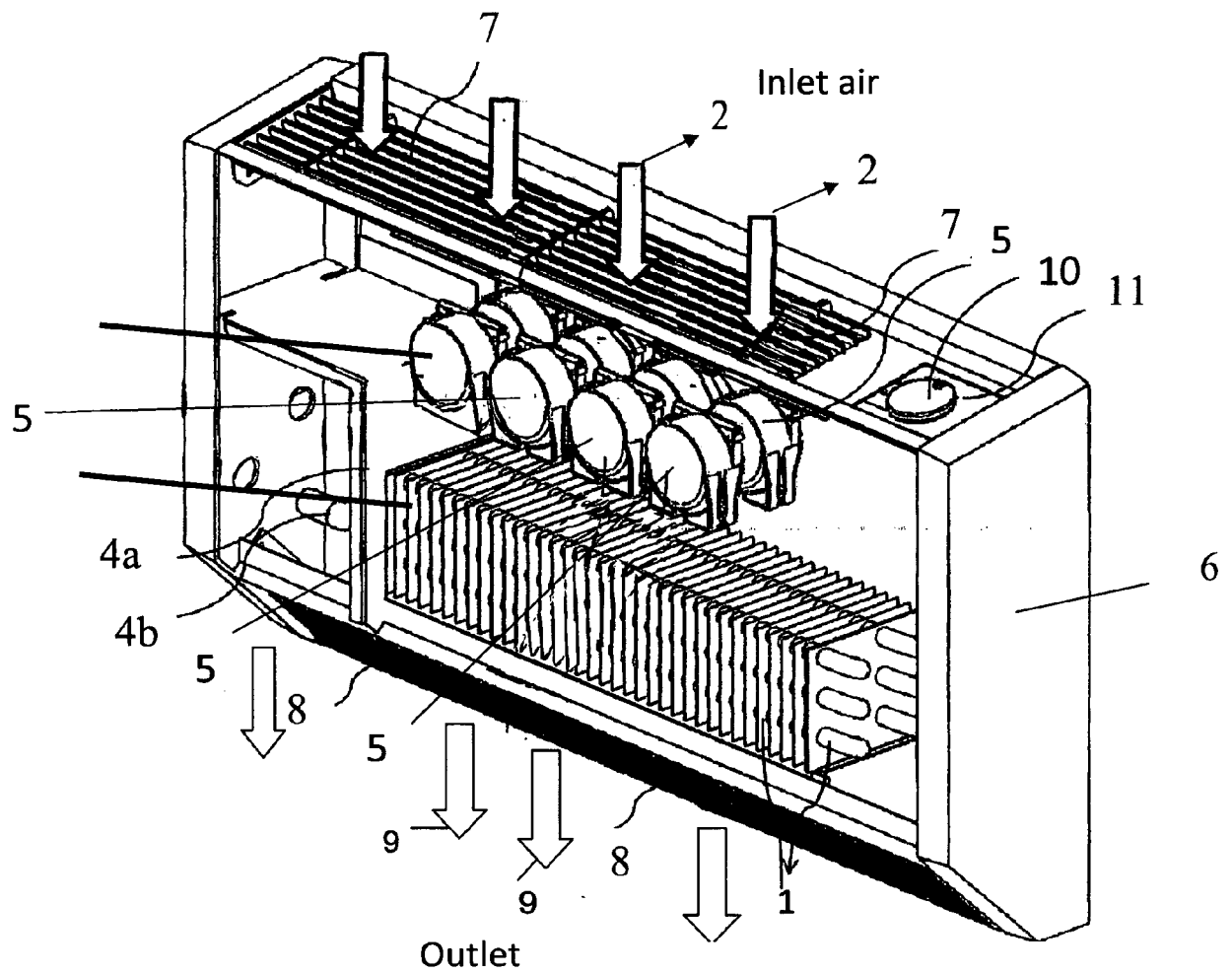
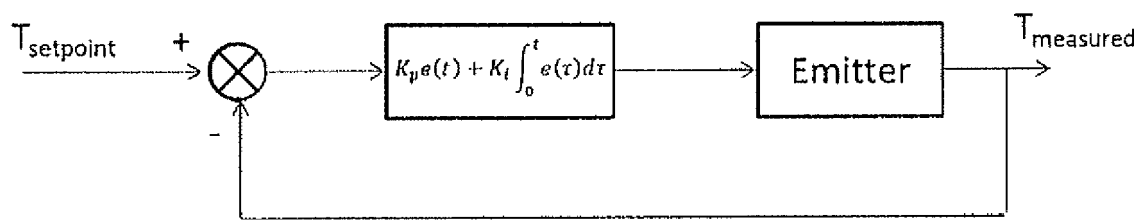


Fig. 1

Fig. 2*Fig. 1 The control structure of synthetic jet heat emitter.*

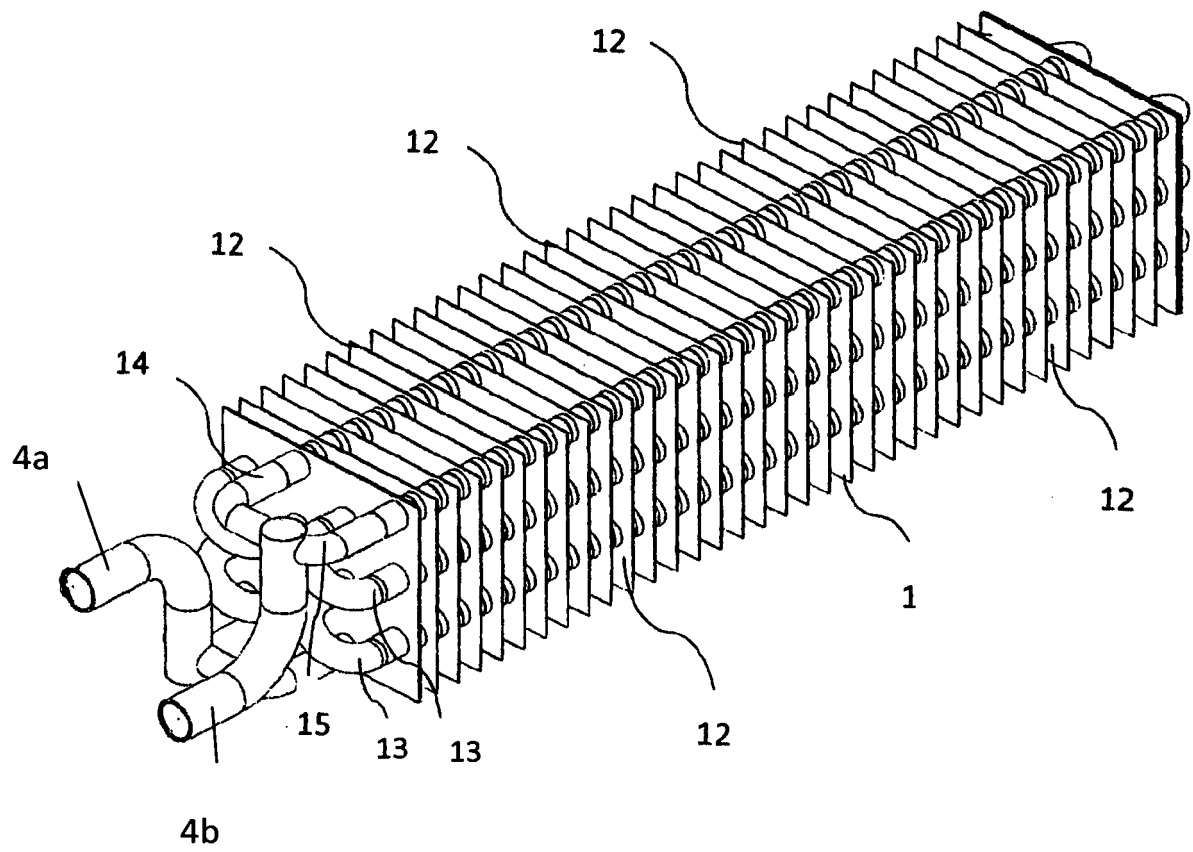


Fig. 3



EUROPEAN SEARCH REPORT

Application Number
EP 16 16 3305

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CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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