DESCRIPTION

TITLE OF INVENTION

Microchannel Heat Exchanger Apparatus

Technical Field of the Invention

Chemical engineering and mechanical engineering relating to a microchannel heat exchanger apparatus.

Background Art

Heat exchange is an important process in industrial plants because device and machines involved in the production process must operate at different specific temperatures. When one device discharges heat, the obtained heat can be used by other devices or machines. A heat exchanger assists in managing the energy used for heating or cooling with high efficiency. There are various types of heat exchangers such as plate heat exchangers, shell and tube heat exchangers, and the heat exchangers mentioned above usually have large sizes in order to maximize the amount of heat exchange.

However, an important method for improving the efficiency of heat exchange is to increase the surface area for heat exchange, which may result in the heat exchanger being smaller in size while still maintaining high efficiency by using a microchannel heat exchanger, which is designed such that the fluid flow channel comprises a large number of micron-scale flow channels, resulting in a greater contact surface area for heat exchange than conventional heat exchangers. This is discussed in patent applications both in Thailand and abroad, for example, U.S. Patent Application Publication No. US20210278139A1, which seeks protection for a heat exchange device comprising microchannels in a symmetric wave-shaped form, formed by assembling heat exchange plates in layered arrangement to cause heat exchange between a high-temperature fluid and a low-temperature fluid in alternately layered heat exchange plates, with wavy flow channels.

Chinese Utility Model Patent No. CN218296859U protects a heat exchanger and the welding assembly of heat exchange plates, wherein the heat exchange plate (channel sheet) has a straight-line flow characteristic at the microchannel level, and the heat exchange plate of the second type of fluid is arranged such that the microchannel flow path is perpendicular to the heat exchange plate of the first type of fluid.

Indian Patent No. IN431810B discloses a heat exchanger apparatus comprising alternately layered heat exchange plates, with flat plates interposed between each layer, by designing the microchannel to be selectable from straight, zigzag, or various curved types, and is alternately stacked to assemble into a heat exchanger by connecting to a flow channel allowing the fluid to enter and exit.

The invention of the heat exchange device mentioned above helps increase the efficiency of heat exchange through the use of microchannels. However, using microchannels for fluids containing particles or these waste gases may cause clogging of flow passages, including an increase in pressure drop. Therefore, it is necessary to choose the form of heat exchange plate suitable for each type of fluid.

In addition, the form of microchannel used for heat exchange still requires the invention of an apparatus having a heat exchanger inside, where such apparatus must have characteristics that allow the fluid to enter and exit the heat exchanger well. There are patents protecting the embodiment of such apparatus, for example, European Patent Application Publication No. EP4067800A4 proposed a heat exchanger between water and fluid, where both flow through small flow channels alternately stacked so that the fluid enters and exits from the side of the heat exchanger apparatus, while water flows in from below and exits at the top of the heat exchanger apparatus, with the flow paths of water and fluid arranged perpendicularly. The flow channels have a zigzag characteristic. Chinese Utility Model No. CN218686470U has claimed protection over a shell and tube heat exchanger, which externally is a tube with passages for fluid to flow into the shell, causing the gas intended to be condensed to be inside the tubes to exchange heat with cold water in the shell. Thai Patent Application No. 1801007286 has protected a heat exchanger apparatus using microchannel plates with curved symmetrical wave form for two types of fluids to exchange heat, where the design of the wave form of the curved channels together with the contact surface area of metal and fluid enables effective heat exchange. In addition, it shows one embodiment of the external appearance having passages for fluid to flow into the heat exchanger from the corner of the heat exchanger. However, using such heat exchangers with contaminated fluids may not be suitable for the invention claimed.

Therefore, in the invention created here, a heat exchanger apparatus has been provided for exchanging heat with gases which may contain impurities or may be waste gases containing a large number of small particles. Therefore, the use of heat exchange plates for such fluids focuses on open passages allowing fluid to flow through conveniently, reducing the accumulation of particles that cause high pressure drop. In addition, the invention of the apparatus having an internal microchannel heat exchanger provided is suitable for use in industrial plants for installation as a heat exchange system.

Summary of the Invention

A microchannel heat exchanger apparatus comprises main components, namely, a microchannel heat exchanger, a fluid inlet or outlet device on the top of the heat exchanger, and a fluid inlet or outlet device on the bottom of the heat exchanger. The microchannel heat exchanger is arranged to have flat heat exchange plates and microchannel heat exchange plates stacked alternately in the same orientation, forming

microchannel-sized passages along the length of the microchannel heat exchange plate to serve as passages for the fluid or gas intended for heat exchange to pass through.

The top end of the microchannel heat exchanger is fixedly attached to a fluid inlet or outlet device at the top of the heat exchanger, comprising a top connecting chamber and a top connecting plate joined together, allowing the fluid to flow in or out to the top inlet pipe. The bottom end of the microchannel heat exchanger is fixedly attached to a fluid inlet or outlet device on the bottom of the heat exchanger, comprising a bottom connecting chamber and a bottom connecting plate joined together, allowing fluid to flow through. For the top connecting chamber and bottom connecting chamber, there are top and bottom guide connecting passages for guiding fluid or gas, functioning to allow fluid or gas to flow through the passages to enter or exit from the top or bottom of the microchannel-sized channels.

The present invention aims to provide a heat exchanger apparatus designed so that fluid exchanges heat for reuse by using microchannel heat exchange plates, which help increase the contact surface area to enable good heat transfer, and, as another part, flat open-channel heat exchange plates, which allow gas to flow in and out easily. Both types of heat exchange plates are alternately positioned to achieve highly efficient heat exchange, suitable for use in industrial plants to exchange heat with gases that may contain impurities or may be waste gases containing a large number of small particles, and to reduce the accumulation of particles that cause high pressure drop.

Brief Description of the Drawings

FIG. 1: Microchannel heat exchanger apparatus

FIG. 2: Microchannel heat exchanger apparatus

FIG. 3: Component for assembling the microchannel heat exchanger apparatus

FIG. 4: Component for assembling the microchannel heat exchanger apparatus

FIG. 5: Microchannel heat exchanger (7)

FIG. 6: Flat surface heat exchange plate (100)

FIG. 7: Arrangement order of heat exchange plates of the flat surface heat exchange plate (100) and the microchannel heat exchange plate (200)

FIG. 8: Top view of the microchannel heat exchanger (7)

FIG. 9: Microchannel heat exchange plate (200) having a straight corrugation (201)

FIG. 10: Microchannel heat exchange plate (200) having a wave-shaped curved corrugation (202)

FIG. 11: Fluid inlet or outlet device on the top of the heat exchanger (8)

FIG. 12: Enlarged view of the fluid inlet or outlet device on the top of the heat exchanger (8)

FIG. 13: Fluid inlet or outlet device on the bottom of the heat exchanger (11)

FIG. 14: Enlarged view of the fluid inlet or outlet device on the bottom of the heat exchanger (11)

FIG. 15: Microchannel heat exchanger apparatus connected to a cylindrical pipe for gas inlet or outlet at the top side (1) and a cylindrical pipe for gas inlet or outlet at the bottom side (5)

Detailed Description of the Invention

A heat exchanger apparatus, which is designed such that a part of fluid to be reused for heat, inside said heat exchanger apparatus comprising a heat exchanger which has a part allowing the fluid which is liquid or gas to flow through, having a characteristic of a microchannel heat exchange plate that has micron-scale small channels to increase the contact surface area for enhancing heat transfer efficiency; and another part being a flat open-channel heat exchange plate to allow gas to flow in and out easily, wherein both types of heat exchange plates are alternately arranged so as to achieve high-efficiency heat exchange. The embodiment of the invention is shown as the following information.

A microchannel heat exchanger apparatus, as shown in FIG. 1, comprising a microchannel heat exchanger (7), wherein both ends of the microchannel heat exchanger (7) are connected to devices used for exchanging heat between gas and fluid, wherein:

the top end of the microchannel heat exchanger (7) is fixed to a fluid inlet or outlet device on the top of the heat exchanger (8), wherein said device comprises a top inlet pipe (9), which is in a cylindrical shape, and a top connection chamber (10), wherein said top connection chamber (10) is in a cylindrical shape having a thickness of 1.00–1.05 times the diameter of the top inlet pipe (9), and one end of the top inlet pipe (9) further comprises a top pipe flange (33), which is a flange for connection with a flange of another apparatus (34),

the bottom end of the microchannel heat exchanger (7) is fixed to a fluid inlet or outlet device on the bottom of the heat exchanger (11), wherein said device comprises a bottom inlet pipe (12), which is in a cylindrical shape, and a bottom connection chamber (13), wherein said bottom connection chamber (13) is in a cylindrical shape having a thickness of 1.00–1.05 times the diameter of the bottom inlet pipe (12), and one end of the bottom inlet pipe (12) further comprises a bottom pipe flange (43), which is a flange for connection with a flange of another apparatus (44),

in addition, the microchannel heat exchanger apparatus, wherein the top of the fluid inlet or outlet device on the top of the heat exchanger (8) further comprises a top flange support plate (60), which is circular with an open center, and an edge of said circle has a thickness of 30% to 60% of the thickness of the top connection chamber (10), wherein it fits snugly into the top connection chamber (10); and further comprises a top flange (61), which is stacked on the top of the top flange support plate (60) on a side opposite to the fluid inlet or outlet device on the top of the heat exchanger (8),

and the bottom of the fluid inlet or outlet device on the bottom of the heat exchanger (11) further comprises a bottom flange support plate (70), which is circular with an open center, and an edge of said circle has a thickness of 30% to 60% of a thickness of the bottom connection chamber (13), wherein it fits snugly into the bottom connection chamber (13); and further comprises a bottom flange (71), which is stacked below the bottom flange support plate (70) on a side opposite to the fluid inlet or outlet device on the bottom of the heat exchanger (11),

the periphery of the microchannel heat exchanger (7) further comprises a first cover (3) and a second cover (4), both covers being semi-cylindrical tube in the longitudinal direction, which can be joined together snugly, wherein the first cover (3) and the second cover (4) are installed in a covering manner over a part of the microchannel heat exchanger (7), and can be fitted snugly to the top flange support plate (60) and the bottom flange support plate (70).

In another aspect, either or both of the first cover (3), or the second cover (4) has a recessed portion at an edge adjacent to either or both of the top inlet pipe (9) or the bottom inlet pipe (12), wherein said recessed portion is provided such that the first cover (3) and the second cover (4) can fit snugly with either or both of the top inlet pipe (9) or the bottom inlet pipe (12).

FIG. 2 shows an aspect of the microchannel heat exchanger apparatus, having main components similar to FIG. 1, and the first cover (3) and the second cover (4) are in a state of being joined together.

FIGS. 3–4 show an aspect of the fluid movement, wherein the fluid flows into the microchannel heat exchanger (7) in a top-down direction, through the fluid inlet or outlet device on the top of the heat exchanger (8), and exits the microchannel heat exchanger (7) to the fluid inlet or outlet device on the bottom of the heat exchanger (11); or the fluid enters the microchannel heat exchanger (7) in a bottom-up direction through the fluid inlet or outlet device on the bottom of the heat exchanger (11), and exits to the fluid inlet or outlet device on the top of the heat exchanger (8), either one.

FIG. 5 shows an aspect of the microchannel heat exchanger (7), comprising: a flat surface heat exchange plate (100) (FIG. 6), which is a rectangular plate that is flat on both top and bottom, wherein the top of said plate has raised edges on the left and right sides along the longitudinal direction of the plate; and a microchannel heat exchange plate (200) (FIGS. 9–10), which is a rectangular plate, wherein the top of said plate is corrugated along the longitudinal direction of the plate, wherein each corrugation is of micron-scale size, and the bottom surface of the microchannel heat exchange plate (200) is flat.

The microchannel heat exchanger (7) is configured to install the flat surface heat exchange plate (100) and the microchannel heat exchange plate (200) stacked alternately in the same direction, wherein the top of the microchannel heat exchange plate (200) is joined to the bottom of the flat surface heat exchange

plate (100), and the bottom of the microchannel heat exchange plate (200) is joined to the top of the flat surface heat exchange plate (100), alternately (FIG. 7), wherein the microchannel heat exchanger (7) comprises 10 to 200 plates each of the flat surface heat exchange plate (100) and the microchannel heat exchange plate (200) stacked alternately.

When the top of the microchannel heat exchange plate (200) is joined to the bottom surface of the flat surface heat exchange plate (100), it results in a microchannel (210) being formed along the longitudinal direction of the microchannel heat exchange plate (200), through which the fluid to be heat-exchanged flows; and the bottom surface of the microchannel heat exchange plate (200), joined to the top of the flat surface heat exchange plate (100), is configured as an open channel (110), allowing the gas to be heat-exchanged to flow through said channel. Therefore, the top and bottom ends of the microchannel heat exchanger (7), which comprises the flat surface heat exchange plates (100) and the microchannel heat exchange plates (200) stacked alternately in the same direction, have passages for fluid to flow through the microchannel (210) and passages for gas to flow through the open channel (110) (FIG. 8).

Wherein characteristics as shown in FIGS. 9–10 are: the microchannel heat exchange plate (200) is corrugated, wherein each corrugation is of micron-scale size along the longitudinal direction of the plate, and each corrugation is either a straight corrugation (201), a wave-shaped curved corrugation (202), or a zigzag corrugation. In addition, a corrugation having a wave-shaped curved corrugation (202) preferably has a symmetric shape, wherein the axis of symmetry is a center line of each flow channel, and the width of each corrugation of the microchannel heat exchange plate (200) is in a range of 3,000 to 5,000 μm.

In another aspect, FIGS. 11–12 show the top end of the microchannel heat exchanger (7) attached to a fluid inlet or outlet device on the top of the heat exchanger (8), wherein said fluid inlet or outlet device on the top of the heat exchanger (8) comprises: a top inlet pipe (9), which is cylindrical in shape, and a top connection chamber (10), wherein said top connection chamber (10) is a cylinder having a thickness of 1.00–1.05 times the diameter of the top inlet pipe (9), wherein one end of the top inlet pipe (9) is connected to a top connection plate (32) to allow the fluid to flow through, and the other end of the top connection plate (32) is integrally joined with the top connection chamber (10), in such a manner that the top connection chamber (10) and the top connection plate (32) have a hollow interior to allow the fluid to flow into or out of the top inlet pipe (9).

The center of the top connection chamber (10) is provided with a top fluid guiding channel (30) in an alternating arrangement with a top gas guiding channel (31), wherein the top fluid guiding channel (30) functions to allow the fluid to flow through said channel to enter or exit from the top of the microchannel (210), wherein the width, length, including area of the top fluid guiding channel (30) are equal to the size

of the microchannel (210). In a case where the fluid flows in from the top inlet pipe (9), said fluid flows through the top connection plate (32) and into the top connection chamber (10), then the fluid flows into the top fluid guiding channel (30) to allow the fluid to enter the top of the microchannel (210); or in a case where the fluid flows out from the top of the microchannel (210), the fluid flows into the top fluid guiding channel (30), then into the top connection chamber (10), through the top connection plate (32), and out to the top inlet pipe (9).

As for the top gas guiding channel (31), it is provided as a through hole in a top-down direction, wherein said channel functions to allow the gas to flow through said channel to enter or exit from the top of the open channel (110), wherein the width, length, including area of the top gas guiding channel (31) are equal to the size of the open channel (110). In a case where the gas flows in from the top side of the top gas guiding channel (31), the gas penetrates into the top of the open channel (110); or, in a case where the gas flows out from the top of the open channel (110), the gas penetrates out through the top side of the top gas guiding channel (31).

In another aspect, FIGS. 13–14 illustrate the bottom end of the microchannel heat exchanger (7), wherein the bottom end of the microchannel heat exchanger (7) is fixedly attached to the fluid inlet or outlet device on the bottom of the heat exchanger (11). Said device comprises: a bottom inlet pipe (12), which has a cylindrical form, and a bottom connection chamber (13), wherein the bottom connection chamber (13) has a cylindrical form having a thickness of 1.00 to 1.05 times the diameter of the bottom inlet pipe (12), wherein one end of the bottom inlet pipe (12) is connected to a bottom connection plate (42) such that fluid can flow through, and the other end of the bottom connection plate (42) is welded integrally to the bottom connection chamber (13), in such a manner that the bottom connection chamber (13) and the bottom connection plate (42) have a hollow interior such that the fluid can flow into or out to the bottom inlet pipe (12).

At the center of the bottom connection chamber (13), it is provided a bottom fluid guiding channel (40), in such a manner that it alternates with a bottom gas guiding channel (41), wherein the bottom fluid guiding channel (40) functions to allow fluid to flow through said channel to enter or exit the bottom of the microchannel (210), wherein the width, length, including area of the bottom fluid guiding channel (40) are equal to the microchannel (210). In a case where the fluid flows from the bottom inlet pipe (12), said fluid will flow through the bottom connection plate (42) and into the bottom connection chamber (13), then the fluid flows into the bottom fluid guiding channel (40) such that said fluid enters the bottom of the microchannel (210); or in a case where the fluid flows out from the top of the microchannel (210), the fluid enters the bottom fluid guiding channel (40), and exits to the bottom connection chamber (13) through the bottom connection plate (42), then exits to the bottom inlet pipe (12).

In addition, the bottom gas guiding channel (41) is a through-hole extending vertically from top to bottom, wherein said channel functions to allow gas to flow through said channel to enter or exit the top of the open channel (110), wherein the width, length, including area of the bottom gas guiding channel (41) are equal to the open channel (110). In a case where gas flows into the bottom side of the bottom gas guiding channel (41), the gas penetrates into the bottom of the open channel (110); or in a case where gas flows out from the bottom of the open channel (110), it penetrates out from the bottom side of the bottom gas guiding channel (41).

In another aspect, the top connection plate (32) is configured to fit snugly with the top inlet pipe (9) and the top connection chamber (10), wherein the top connection plate (32) has a shape selected from either a semicircle or a rectangle, preferably a semicircle; and the bottom connection plate (42) is configured to fit snugly with the bottom inlet pipe (12) and the bottom connection chamber (13), wherein the bottom connection plate (42) has a shape selected from either a semicircle or a rectangle, preferably a semicircle.

In another aspect, the attachment of each part of the microchannel heat exchanger apparatus is selected from: metal welding, adhesive bonding, threaded bolt fastening, flange clamping, either one or a combination thereof; and the suitable attachment of each part is flange clamping.

FIG. 15 shows the microchannel heat exchanger apparatus connected to the cylindrical pipe for gas inlet or outlet at the top side (1) and the cylindrical pipe for gas inlet or outlet at the bottom side (5), wherein the top of the fluid inlet or outlet device on the top of the heat exchanger (8) further comprises the top flange support plate (60), which features a circle with a hollow center, and an edge of said circle has a thickness of 30–60% of the thickness of the top connection chamber (10), and is fitted snugly into the top connection chamber (10), and further comprises the top flange (61), which is stacked on the top of the top flange support plate (60), on the side opposite to the fluid inlet or outlet device on the top of the heat exchanger (8).

The bottom of the fluid inlet or outlet device on the bottom of the heat exchanger (11) further comprises the bottom flange support plate (70), which features a circle with a hollow center, and an edge of said circle has a thickness of 30–60% of the thickness of the bottom connection chamber (13), and is fitted snugly into the bottom connection chamber (13), and further comprises the bottom flange (71), which is stacked below the bottom flange support plate (70), on the side opposite to the fluid inlet or outlet device on the bottom of the heat exchanger (11).

In another aspect, the top flange (61), which is stacked on the top of the top flange support plate (60), on the side opposite to the fluid inlet or outlet device on the top of the heat exchanger (8), is connected to the top gas connecting flange (62), which is used for connecting with a gas inlet or outlet channel. In

order to allow gas to travel conveniently, the top gas connecting flange (62) is attached to the downward conical pipe (2) at the wide end of the downward conical pipe (2); the narrow end of the downward conical pipe (2) is attached to the cylindrical pipe for gas inlet or outlet at the top side (1), which are joined together by the flange (63) at the narrow end of the downward conical pipe (2) and the flange (64) at the end of the cylindrical pipe for gas inlet or outlet at the top side (1).

In another aspect, the bottom flange (71), which is stacked on the top of the bottom flange support plate (70) on the side opposite to the fluid inlet or outlet device on the bottom of the heat exchanger (11), is connected to the bottom gas connecting flange (72), which is used for connecting with a gas inlet or outlet channel. In order to allow gas to travel conveniently, the bottom gas connecting flange (72) is attached to the upward conical pipe (6) at the wide end of the upward conical pipe (6); and the narrow end of the upward conical pipe (6) is attached to the cylindrical pipe for gas inlet or outlet at the bottom side (5), which are joined together by the flange (73) at the narrow end of the upward conical pipe (6) and the flange (74) at the end of the cylindrical pipe for gas inlet or outlet at the bottom side (5).

In addition, the microchannel heat exchanger apparatus can be installed or used in either a vertical, horizontal, or inclined orientation.

Next, an inventive example of a microchannel heat exchanger apparatus will be shown. However, the scope of the invention is not limited by the example, which is only one embodiment of the invention.

Inventive Example

To compare the efficiency of the microchannel heat exchanger apparatus, by considering different types of the microchannel heat exchanger (7), including the flat surface heat exchange plate (100) and the microchannel heat exchange plate (200), a computational fluid dynamics simulation model was constructed and tested using ANSYS version 2023 R2 software with the following details:

Microchannel heat exchanger apparatus having heat exchanger according to the invention

Heat exchanger A

The heat exchanger (7), having a width of 40.8 cm, a length of 59.2 cm, and a height of 32.1 cm, comprises layers of flat surface heat exchange plates (100), which are flat open-channel heat exchange plates, each plate having a thickness of 6000 μm, in a number of 40 plates, alternately stacked with microchannel heat exchange plates (200), which have straight corrugations (201), in a number of 40 plates. The microchannel heat exchange plates (200) having the straight corrugations (201) each have a thickness of 2000 μm and a flow channel width of 4000 μm.

Wherein, when the top of the microchannel heat exchange plate (200) is attached to the bottom of the flat surface heat exchange plate (100), microchannel (210) are formed along the longitudinal direction of the microchannel heat exchange plate (200); and when the bottom of the microchannel heat exchange plate (200) is attached to the top of the flat surface heat exchange plate (100), an open channel (110) is formed. The fluid flows through the microchannel (210), and gas flows through the open channel (110).

Heat Exchanger B

The heat exchanger (7), having a width of 40.8 cm, a length of 59.2 cm, and a height of 32.1 cm, comprises: a plurality of flat surface heat exchange plates (100), which are flat open-channel heat exchange plates, each plate having a thickness of 6000 μm, in a number of 40 plates, alternately stacked with a plurality of microchannel heat exchange plates (200), which have wave-shaped curved corrugations (202), wherein said wave-shaped curved corrugations are symmetric, wherein the axis of symmetry is the center line of each flow channel, in a number of 40 plates; wherein the microchannel heat exchange plate (200) having the wave-shaped curved corrugations (202) has a thickness of each plate of 2000 μm, a depth of 1000 μm, a curve radius of 4000 μm, a narrowest width of 3420 μm, and a widest width of 4580 μm; wherein the structure of said heat exchanger (7) is identical to that described in the heat exchanger A.

Heat Exchanger Apparatus Having Comparative Heat Exchanger

Heat Exchanger C

The heat exchanger, having a width of 40.8 cm, a length of 59.2 cm, and a height of 32.1 cm, comprises: a plurality of microchannel heat exchange plates (200), which have straight corrugations (201), stacked such that fluid and gas flow through microchannel passages formed by the layered arrangement of said plates, wherein the flow is alternated between layers through which fluid flows and layers through which gas flows; wherein the fluid-flowing layers comprise 40 microchannel heat exchange plates having straight corrugations (201), each plate having a thickness of 2000 μm and each flow channel having a width of 4000 μm; and the gas-flowing layers comprise 40 microchannel heat exchange plates having straight corrugations (201), each plate having a thickness of 6000 μm and each flow channel having a width of 4000 μm.

Heat Exchanger D

The heat exchanger, having a width of 40.8 cm, a length of 59.2 cm, and a height of 32.1 cm, comprises: a plurality of flat surface heat exchange plates (100), stacked such that fluid and gas flow through open channels formed by said layered arrangement, wherein the flow is alternated between layers through which fluid flows and layers through which gas flows; wherein the fluid-flowing layers comprise 40 flat surface heat exchange plates (100), each plate having a thickness of 2000 μm and each flow channel having

a width of 3880 μm; and the gas-flowing layers comprise 40 flat surface heat exchange plates (100), each plate having a thickness of 6000 μm and each flow channel having a width of 3880 μm.

Performance Test Results of the Microchannel Heat Exchanger Apparatus

From the data of the heat exchangers in various aspects as described above, the summary can be shown in Table 1. Said data were used for testing the performance of the heat exchanger by the software ANSYS version 2023 R2. The testing was conducted in two forms: Form 1 – heat exchange between water and flue gas; and Form 2 – heat exchange between air and flue gas.

Table 1: Forms of the heat exchangers used for testing

Heat Exchanger	Gas Flow	Fluid Flow
A	Flat surface heat exchange plate (100), wherein gas flows through the open channel (110)	Microchannel heat exchange plate (200) having straight corrugation (201), wherein the fluid flows through the microchannel (210)
B	Flat surface heat exchange plate (100), wherein gas flows through the open channel (110)	Microchannel heat exchange plate (200) having wave-shaped curved corrugation (202), wherein the fluid flows through the microchannel (210)
C	Microchannel heat exchange plate (200) having straight corrugation (201), wherein gas flows through the microchannel (210)	Microchannel heat exchange plate (200) having straight corrugation (201), wherein gas flows through the microchannel (210)
D	Flat surface heat exchange plate (100), wherein gas flows through the open channel (110)	Flat surface heat exchange plate (100), wherein the fluid flows through the open channel (110)

Form 1: Heat exchange between water and flue gas

A heat exchange between water (fluid) and flue gas (gas) was tested by setting the inlet temperature of water at 105°C and the inlet temperature of flue gas at 242°C. The test results of heat exchange efficiency are shown in Table 2. From the table, it was found that, when comparing the power obtained from heat exchanger A in Data No. 1, in which flue gas flows through the open channel (110) and water flows through the microchannel (210) having straight corrugation (201), with heat exchanger C, in which both water and flue gas flow through the microchannel (210) having straight corrugation (201), in Data No. 4, the power

value of the heat exchanger C is higher than that of A, which indicates that the efficiency of the heat exchanger C is better than that of A. This is because heat exchanger C has a greater contact surface area between the substance and the heat exchange plate, resulting from both water and flue gas flowing through the microchannel, which causes better heat transfer than that of heat exchanger A. However, the flue gas discharged into the atmosphere may contain small particles, soot, or other contaminants. Therefore, allowing flue gas to flow through the microchannel (210) may easily cause blockage, which results in increased pressure drop accordingly.

In addition, when comparing heat exchanger C under the condition that the pressure drop of flue gas is reduced (Data No. 5) to be close to heat exchanger A, it is found that the power value substantially decreases. This shows that, although allowing flue gas to flow through the microchannel improves the heat transfer efficiency, it also results in a higher pressure drop.

For heat exchanger B, which uses the microchannel heat exchange plate (200) having wave-shaped curved corrugation (202), wherein the fluid flows through the microchannel (210), it increases the contact of the fluid with the heat exchange plate more effectively. From Data No. 2, it is found that heat exchange by allowing water to flow through such a heat exchange plate results in an increased power value compared to Data No. 1. However, although the test results do not show such clear improvement, if a liquid other than water having higher viscosity is used, it tends to result in better heat exchange. Furthermore, when testing with increased pressure drop of flue gas in the system from heat exchanger B in Data No. 3, it was found that the power value is 36% higher than that of heat exchanger C in Data No. 4.

Table 2: Table Comparing Heat Exchange Efficiency Between Water and Flue Gas

No.	Heat Exchanger	Pressure Drop (bar)		Power (kW)	Water Temperature (°C)		Flue Gas Temperature (°C)	
		Water	Flue Gas		Outlet	Temperature Change	Outlet	Temperature Change
1	A	0.005	0.011	212.9	135.1	30.1	132.4	109.6
2	B	0.007	0.011	213.3	135.2	30.2	132.2	109.8
3	B	0.007	0.043	378.5	158.6	53.6	169.8	72.2
4	C	0.005	0.043	241.5	139.2	34.2	117.6	124.4
5	C	0.005	0.013	98.3	118.9	13.9	105.4	136.6

Therefore, it is shown that the heat exchanger that allows water to flow through the microchannel (210) and allows flue gas to flow through the open channel (110) has better efficiency than using a heat exchanger that allows both water and flue gas to flow through the microchannel (210).

Form 2: Heat exchange between air and flue gas

Heat exchange between air (fluid) and flue gas (gas) was tested by setting the inlet temperature of the air to 25°C and the inlet temperature of the flue gas to 242°C. The result of the heat exchange efficiency test is shown in Table 3. From the table, it was found that, when comparing the power obtained from heat exchanger A, which is the invention constructed in Data No. 6, wherein the flue gas flows through the open channel (110) and the air flows through the microchannel (210) having straight corrugation (201), with heat exchanger C, wherein both air and flue gas flow through the microchannel (210) having straight corrugation (201), in Data No. 9, it was found that the power value of heat exchanger C is higher than that of A, which shows that the efficiency of heat exchanger C is better than that of A, because heat exchanger C has more contact surface area of the substance and the heat exchange plates due to air and flue gas flowing through the microchannel (210) having straight corrugation (201), resulting in better heat transfer than heat exchanger A. However, flue gas discharged into the atmosphere may contain small particles, soot, or other impurities, and therefore, the use of heat exchange plates having microchannel for flue gas may cause clogging easily, which results in increased pressure drop accordingly.

Table 3: Table Comparing Heat Exchange Efficiency Between Water and Flue Gas

No.	Heat Exchanger	Pressure Drop (bar)		Power (kW)	Water Temperature (°C)		Flue Gas Temperature (°C)	
		Water	Flue Gas		Outlet	Temperature Change	Outlet	Temperature Change
6	A	0.39	0.011	161.6	217.8	192.8	158.7	83.3
7	B	0.61	0.011	163.2	219.6	194.6	157.9	84.1
8	B	0.61	0.043	176.3	235.3	210.3	208.3	33.7
9	C	0.39	0.043	170.4	228.3	203.3	154.2	87.8
10	D	0.15	0.011	158.9	214.6	189.6	160.1	81.9

For the heat exchanger B, which uses the microchannel heat exchange plate (200) having wave-shaped curved corrugation (202), wherein the fluid flows through the microchannel (210), the improvement of the microchannel heat exchange plate by forming the corrugation as wave-shaped curved corrugation (202) enhances the contact between the fluid and the heat exchange plate. As shown in Data No. 7, it was

found that the heat exchange by allowing air to pass through the said heat exchanger results in increased power when compared with Data No. 6. In addition, when the pressure drop of the flue gas in the system was increased in heat exchanger B of Data No. 8, it was found that the power is higher than that of heat exchanger C in Data No. 9.

Furthermore, when Data No. 6, which is heat exchanger A, was compared with Data No. 10, which is heat exchanger D that uses the flat surface heat exchange plate (100), wherein the flue gas and the air flow through the open channel (110), it was found that the efficiency of heat exchanger A is better, because the contact surface of the air is higher due to the flow through the microchannel (210).

Therefore, from the above-mentioned performance examples, it was found that using the microchannel heat exchanger apparatus comprising the microchannel heat exchange plate (200) together with the flat surface heat exchange plate (100) to form the microchannel (210) for fluid to flow through and the open channel (110) for gas to flow through results in good efficiency, suitable for application in systems where the fluid is gas with low impurities or liquid flowing through the microchannel (210), and gas which may contain high impurities flows through the open channel (110).

Best Mode for Carrying Out the Invention

As already described in the section of complete disclosure of the invention.

CLAIMS

Claim 1

A microchannel heat exchanger apparatus, comprising: a microchannel heat exchanger (7); a fluid inlet or outlet device on the top of the heat exchanger (8); and a fluid inlet or outlet device on the bottom of the heat exchanger (11); wherein said apparatus is used to exchange heat between gas and fluid; wherein the fluid flows into the microchannel heat exchanger (7) in a top-down direction through the fluid inlet or outlet device on the top of the heat exchanger (8) and exits from the microchannel heat exchanger (7) to the fluid inlet or outlet device on the bottom of the heat exchanger (11); or the fluid flows into the microchannel heat exchanger (7) in a bottom-up direction through the fluid inlet or outlet device on the bottom of the heat exchanger (11) and exits to the fluid inlet or outlet device on the top of the heat exchanger (8), either one;

characterized in that

the microchannel heat exchanger (7) comprises: a flat surface heat exchange plate (100), which is a rectangular plate having flat surfaces on both top and bottom, wherein the top of the plate has raised edges on the left and right sides along a longitudinal direction of said plate; and a microchannel heat exchange plate (200), which is a rectangular plate having a corrugated top surface along the longitudinal direction of the plate, wherein each corrugation is of micron-scale size, and the bottom surface of the microchannel heat exchange plate (200) is flat;

wherein the microchannel heat exchanger (7) is configured to have the flat surface heat exchange plates (100) and the microchannel heat exchange plates (200) stacked alternately in the same direction, such that the top of the microchannel heat exchange plate (200) is attached to the bottom of the flat surface heat exchange plate (100), and the bottom of the microchannel heat exchange plate (200) is attached to the top of the flat surface heat exchange plate (100), alternately; wherein the microchannel heat exchanger (7) comprises 10 to 200 plates each of the flat surface heat exchange plates (100) and the microchannel heat exchange plates (200) arranged alternately;

wherein, when the top of the microchannel heat exchange plate (200) is attached to the bottom of the flat surface heat exchange plate (100), a microchannel (210) is formed along the longitudinal direction of the microchannel heat exchange plate (200), through which the fluid to be heat-exchanged flows; and the bottom of the microchannel heat exchange plate (200) attached to the top of the flat surface heat exchange plate (100) is formed as an open channel (110), allowing gas to be heat exchanged flow through; wherein the top and bottom ends of the microchannel heat exchanger (7), which comprises the flat surface heat exchange plates (100) and the microchannel heat exchange plates (200) alternately stacked in the same

direction have channels for the fluid to flow through the microchannel (210), and channels for the gas to flow through the open channel (110);

wherein the top end of the microchannel heat exchanger (7) is fixed to the fluid inlet or outlet device on the top of the heat exchanger (8), said device comprising: a top inlet pipe (9), which is cylindrical, and a top connection chamber (10), which is cylindrical and has a thickness of 1.00–1.05 times the diameter of the top inlet pipe (9); wherein one end of the top inlet pipe (9) is connected to a top connection plate (32), allowing fluid to pass through; and the other end of the top connection plate (32) is integrally joined to the top connection chamber (10), wherein the top connection chamber (10) and the top connection plate (32) are hollow inside, allowing fluid to enter or exit through the top inlet pipe (9);

wherein the center of the top connection chamber (10) is provided with a top fluid guiding channel (30) alternating with a top gas guiding channel (31); wherein the top fluid guiding channel (30) functions to allow fluid to flow in or out from the top of the microchannel (210), and the width, length, including area of the top fluid guiding channel (30) are equal to the size of the microchannel (210); wherein when fluid enters through the top inlet pipe (9), said fluid flows through the top connection plate (32), into the top connection chamber (10), then into the top fluid guiding channel (30), and to the top of the microchannel (210); or when fluid exits from the top of the microchannel (210), said fluid flows into the top fluid guiding channel (30), exits to the top connection chamber (10), through the top connection plate (32), and out to the top inlet pipe (9);

wherein the top gas guiding channel (31) is an open-through channel extending top to bottom, allowing gas to flow in or out from the top of the open channel (110); the width, length, including area of the top gas guiding channel (31) are equal to the size of the open channel (110); wherein when gas enters from the top side of the top gas guiding channel (31), it passes through to the top of the open channel (110); or when gas exits from the top of the open channel (110), it passes out through the top side of the top gas guiding channel (31);

wherein the bottom end of the microchannel heat exchanger (7) is fixed to the fluid inlet or outlet device on the bottom of the heat exchanger (11), said device comprising: a bottom inlet pipe (12), which is cylindrical, and a bottom connection chamber (13), which is cylindrical and has a thickness of 1.00–1.05 times the diameter of the bottom inlet pipe (12); one end of the bottom inlet pipe (12) is connected to a bottom connection plate (42), allowing fluid to pass through; and the other end of the bottom connection plate (42) is integrally joined to the bottom connection chamber (13), wherein the bottom connection chamber (13) and the bottom connection plate (42) are hollow inside, allowing fluid to enter or exit through the bottom inlet pipe (12);

wherein the center of the bottom connection chamber (13) is provided with a bottom fluid guiding channel (40) alternating with a bottom gas guiding channel (41); wherein the bottom fluid guiding channel (40) functions to allow fluid to flow in or out from the bottom of the microchannel (210), and the width, length, including area of the bottom fluid guiding channel (40) are equal to the size of the microchannel (210); wherein when fluid enters from the bottom inlet pipe (12), said fluid flows through the bottom connection plate (42), into the bottom connection chamber (13), into the bottom fluid guiding channel (40), and to the bottom of the microchannel (210); or when fluid exits from the top of the microchannel (210), said fluid flows into the bottom fluid guiding channel (40), exits to the bottom connection chamber (13), through the bottom connection plate (42), and out to the bottom inlet pipe (12);

wherein the bottom gas guiding channel (41) is an open-through channel extending top to bottom, allowing gas to flow in or out from the bottom of the open channel (110); and the width, length, including area of the bottom gas guiding channel (41) are equal to the size of the open channel (110); wherein when gas enters from the bottom side of the bottom gas guiding channel (41), it passes through to the bottom of the open channel (110); or when gas exits from the bottom of the open channel (110), it passes out through the bottom side of the bottom gas guiding channel (41).

Claim 2

The microchannel heat exchanger apparatus according to claim 1, wherein the microchannel heat exchange plate (200) which has a corrugated surface, wherein each corrugation is of micron-scale size along a longitudinal direction of the plate, and has a corrugation shape selected from a straight corrugation (201), a wave-shaped curved corrugation (202), or a zigzag corrugation, either one.

Claim 3

The microchannel heat exchanger apparatus according to claim 1 or 2, wherein the microchannel heat exchange plate (200) which surface having a wave-shaped curved corrugation (202) is appropriately configured to have a symmetrical shape.

Claim 4

The microchannel heat exchanger apparatus according to any one of claims 1 to 3, wherein the microchannel heat exchange plate (200) which surface having a wave-shaped curved corrugation (202) that is symmetrical is appropriately configured such that a symmetrical axis is a center line of each said flow channel.

Claim 5

The microchannel heat exchanger apparatus according to any one of claims 1 to 4, wherein the width size of each corrugation of the microchannel heat exchange plate (200) is in a range of 3,000 to 5,000 μm.

Claim 6

The microchannel heat exchanger apparatus according to any one of claims 1 to 5, wherein the fluid is configured to be either a liquid or a gas.

Claim 7

The microchannel heat exchanger apparatus according to claim 1, wherein the attachment of each apparatus component is selected from: metal welding, adhesive bonding, threaded bolt fastening, flange clamping, either one or a combination thereof.

Claim 8

The microchannel heat exchanger apparatus according to claim 1 or 7, wherein the attachment of each apparatus component is preferably the flange clamping.

Claim 9

The microchannel heat exchanger apparatus according to any one of claims 1 to 8, wherein the top of the fluid inlet or outlet device on the top of the heat exchanger (8) further comprises a top flange support plate (60), which is circular with an open center, and an edge of said circle has a thickness of 30–60% of a thickness of the top connection chamber (10), and fits snugly into the top connection chamber (10), and further comprises a top flange (61), which is stacked on the top of the top flange support plate (60), on an opposite side from the fluid inlet or outlet device on the top of the heat exchanger (8).

Claim 10

The microchannel heat exchanger apparatus according to any one of claims 1 to 9, wherein the bottom of the fluid inlet or outlet device on the bottom of the heat exchanger (11) further comprises a bottom flange support plate (70), which is circular with an open center, and an edge of said circle has a thickness of 30–60 percent of a thickness of the bottom connection chamber (13), and fits snugly into the bottom connection chamber (13), and further comprises a bottom flange (71) which is stacked below the bottom flange support plate (70), on an opposite side from the fluid inlet or outlet device on the bottom of the heat exchanger (11).

Claim 11

The microchannel heat exchanger apparatus according to any one of claims 1 to 10, wherein the periphery surrounding of the microchannel heat exchanger (7) is provided with a first cover (3) and a second

cover (4), both covers being semi-cylindrical tubes in the longitudinal direction, which fit together perfectly, and the first cover (3) and the second cover (4) are tightly attached to the top flange support plate (60) and the bottom flange support plate (70);

and the first cover (3) or the second cover (4), either one or both, has a recessed portion at an edge adjoining either the top inlet pipe (9) or the bottom inlet pipe (12), either one or both, wherein said recessed portion allows the first cover (3) and the second cover (4) to fit snugly with the top inlet pipe (9) or the bottom inlet pipe (12), either one or both.

Claim 12

The microchannel heat exchanger apparatus according to any one of claims 1 to 11, wherein the top connection plate (32) is configured to fit snugly with the top inlet pipe (9) and the top connection chamber (10), wherein the top connection plate (32) has a shape selected from either a semicircle or a rectangle.

Claim 13

The microchannel heat exchanger apparatus according to any one of claims 1 to 12, wherein the top connection plate (32) is configured to fit snugly with the top inlet pipe (9) and the top connection chamber (10), wherein the top connection plate (32) appropriately has a semicircle shape.

Claim 14

The microchannel heat exchanger apparatus according to any one of claims 1 to 13, wherein the bottom connection plate (42) is configured to fit snugly with the bottom inlet pipe (12) and the bottom connection chamber (13), wherein the bottom connection plate (42) has a shape selected from either a semicircle or a rectangle.

Claim 15

The microchannel heat exchanger apparatus according to any one of claims 1 to 14, wherein the bottom connection plate (42) is configured to fit snugly with the bottom inlet pipe (12) and the bottom connection chamber (13), wherein the bottom connection plate (42) appropriately has a semicircle shape.

Claim 16

The microchannel heat exchanger apparatus according to any one of claims 1 to 15, wherein the end of the top inlet pipe (9) has a top pipe flange (33) which is a flange used for connecting to a flange of another apparatus (34).

Claim 17

The microchannel heat exchanger apparatus according to any one of claims 1 to 16, wherein the end of the bottom inlet pipe (12) has a bottom pipe flange (43), which is a flange used for connecting to a flange of another apparatus (44).

Claim 18

The microchannel heat exchanger apparatus according to any one of claims 1 to 17, wherein the top flange (61) which is stacked on the top of the top flange support plate (60), on the side opposite to the fluid inlet or outlet device on the top of the heat exchanger (8) is connected to the top gas connecting flange (62), which is used to connect to a gas flow inlet or outlet channel.

Claim 19

The microchannel heat exchanger apparatus according to any one of claims 1 to 18, wherein the top gas connecting flange (62) is arranged to be fastened to the downward conical pipe (2) at the wide end of the downward conical pipe (2), and the narrow end of the downward conical pipe (2) is fastened to the cylindrical pipe for gas inlet or outlet at the top side (1), which are fastened together by the flange (63) located at the narrow end of the downward conical pipe (2), to the flange (64) located at the end of the cylindrical pipe for gas inlet or outlet at the top side (1), for assisting smooth gas transfer.

Claim 20

The microchannel heat exchanger apparatus according to any one of claims 1 to 19, wherein the bottom flange (71) which is stacked on the top of the bottom flange support plate (70), on the side opposite to the fluid inlet or outlet device on the bottom of the heat exchanger (11) is arranged to be connected to the bottom gas connecting flange (72), which is used to connect to a gas flow inlet or outlet channel.

Claim 21

The microchannel heat exchanger apparatus according to any one of claims 1 to 18, wherein the bottom gas connecting flange (72) is arranged to be fastened to the upward conical pipe (6) at the wide end of the upward conical pipe (6), and the narrow end of the upward conical pipe (6) is fastened to the cylindrical pipe for gas inlet or outlet at the bottom side (5), which are fastened together by the flange (73) located at the narrow end of the upward conical pipe (6), to the flange (74) located at the end of the cylindrical pipe for gas inlet or outlet at the bottom side (5), for assisting smooth gas transfer.

Claim 22

The microchannel heat exchanger apparatus according to any one of claims 1 to 21, wherein the installation or use of the microchannel heat exchanger apparatus can be in either a vertical, horizontal, or inclined orientation.