Plate for heat exchange and heat exchange unit

A heat exchange plate (1) having a pattern of irregularity is combined with the other plates to constitute a heat exchanger. The plate has main (2) and intermediate (3) protrusions. The main protrusions (2) have a quadrangular pyramid shape with a top, first and second pairs of side surfaces. The first and second pairs of side surfaces face each other in the first and second directions. The main protrusions (2) are aligned in these directions so that these pairs of surfaces of the main protrusion face the corresponding surfaces of adjacent protrusions. The intermediate protrusion (3) is placed between adjacent main protrusions (2) and has opposite foot portions and a head ridge placed between them. The foot portion is placed in a lowermost position at which ridgelines of the adjacent two main protrusions intersect. The head ridge is placed in a level higher than the foot portions, but lower than the top of the main protrusion.
Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a plate for heat exchange, which is formed from a metallic thin plate and combined with the other plates in an aligned state into a heat exchanger, and especially to the heat exchange plate, which enables, in use in combination with the other plates, heat exchange fluids to slow smoothly along the opposite surfaces of the heat exchange plate to make an effective heat exchange, irrespective of a flowing system such as a parallel flowing system in which the heat exchange fluids flow in parallel with each other, a counter-flowing system in which the heat exchange fluids flow in the opposite directions to each other, and a cross flowing system in which the heat exchange fluids flow in perpendicular directions to each other, and relates to a heat exchange unit in which such a heat exchange plate and the other plates are combined.

Description of the Related Art

[0002] If there is a request that heat transfer coefficient is increased to enhance heat exchange effectiveness, utilizing a heat exchanger by which heat exchange is made between a high temperature fluid and a low temperature fluid, a plate-type heat exchanger has conventionally been used widely. The plate-type heat exchanger has a structure in which a plurality of plates, i.e., heat transfer members having a plate-shape are placed parallelly one upon another at prescribed intervals so as to form passages, which are separated by means of the respective plates. A high temperature fluid and a low temperature fluid flow alternately in the above-mentioned passages to make heat exchange through the respective plates. Japanese Patent Provisional Publication No. S53-56748 describes an example of such a conventional plate-type heat exchanger. [0003] In the conventional plate-type heat exchanger, gasket members formed of elastic material are placed between the adjacent two plates to make the distance between them constant and define passages for fluid. However, a high pressure of the heat exchange fluid flowing between the plates may cause deformation of the gasket member, thus disabling an appropriate separation of the fluids from being ensured or leading to an unfavorable variation in distance between the plates. In such a case, an effective heat exchange may not be carried out, thus causing a problem. In view of these facts, the conventional heat exchanger involves a problem that the heat exchange fluids can be utilized only in a pressure range in which the gasket member withstands. [0004] There has recently been proposed a heat exchanger having a structure in which metallic thin plates, which are placed at predetermined intervals, are joined together at their ends by welding to assemble the plates into a single unit so as to form gaps, which serve as passages for heat exchange fluids, on the opposite sides of the respective plates. Japanese Patent Provisional Publication No. 2003-194490 describes, as an example of an invention made by the present inventor, a heat exchange unit in which metallic thin plates are aligned in parallel with each other so as to be apart from each other, these plates are welded at their periphery excepting one side into a united body having an opening, and the opening is closed by an end plate. [0005] The above-described conventional heat exchanger (i.e., the heat exchange unit) has a structure, as described in the above-mentioned publication, that each of the plates has a pattern of irregularity with a shape and arrangement, by which the most preferable heat transfer performance in the flowing direction of the respective heat exchange fluids. In most cases, fluids for heat exchange used in the heat exchanger utilizing the plates have a relationship based on a parallel flowing system, a counter-flowing system or a cross flowing system. The plate of the conventional heat exchanger has an optimized pattern of irregularity exclusively for any one of the parallel flowing system, the counter-flowing system and the cross flowing system. When the plates having the pattern of irregularity, which has been optimized exclusively for the flowing system to be applied originally, are applied to the different flowing system, variation in flowing conditions may occur to deteriorate the heat transfer performance, thus leading to a lower heat exchange efficiency and increase in pressure loss. Accordingly, there is a need to use plates having a pattern of irregularity, which has been optimized for the flowing system to be applied originally, exclusively for such a flowing system. [0006] In addition, in the conventional plate-type heat exchanger, the heat exchange fluid enters the heat exchanger from a narrow inlet, divergently extends over the wide plane of the plate to flow and then converges into a narrow outlet. Each of the plates has three kinds of patterns of irregularity, i.e., an inflow divergent area, a main heat transfer area and an outflow condensation area, in order to introduce the fluid over every area of the plate. However, the inflow divergent area and the outflow condensation area having patterns of irregularity, in which importance is placed generally on the guiding performance for the fluids, do not provide a sufficient heat transfer performance. The excellent heat transfer performance cannot be provided by these areas, with the result that an effective area utilized for heat transfer is relatively small to the total area of the plate, thus causing waste in space of occupancy and cost.

SUMMARY OF THE INVENTION

[0007] An object of the present invention, which was made to solve the above-mentioned problems, is therefore to provide a heat exchange plate, which is provided
on it surface with a pattern of irregularity properly formed, has flexibility in use in the flowing system, and permits to ensure a sufficient heat transfer performance relative to fluids, thus providing an excellent heat transfer property, as well as a heat exchange unit in which such a heat exchange plate and the other plates are combined to provide a determined heat transfer property.

[0008] In order to attain the aforementioned object, a plate for heat exchange of the first aspect of the present invention comprises a metallic plate member having a predetermined pattern of irregularity, said plate member being combined with at least one other plate member so as to be in parallel with each other to constitute a heat exchanger, which makes a heat exchange between a heat exchange fluid coming into contact with a surface of said metallic plate member and another heat exchange fluid coming into contact with another surface thereof, said metallic plate member comprising:

- a plurality of main protrusions formed on one surface of said plate member, each of said main protrusions having a shape of any one of a quadrangular pyramid and a quadrangular truncated pyramid with a top, a first pair of opposite side surfaces and a second pair of opposite side surfaces, said first pair of opposite side surfaces facing each other in a first direction and said second pair of opposite side surfaces facing each other in a second direction perpendicular to said first direction, said main protrusions being aligned in the first direction and the second direction by a predetermined distance so that the first pair of opposite surfaces and the second pair of opposite surfaces of one of the main protrusions face corresponding opposite surfaces of adjacent protrusions; and
- a plurality of intermediate protrusions formed between adjacent two main protrusions on said plate member, each of said intermediate protrusions having opposite foot portions and a head ridge placed between said foot portions, each of said foot portions being placed in a lowest position at which ridgelines of the adjacent two main protrusions intersect each other, and said head ridge being placed in a level that is higher than said foot portions and lower than said top of each main protrusion, so as to provide a bent roof shape, said intermediate protrusions and said main protrusions forming said predetermined pattern of irregularity.

[0009] According to the first aspect of the present invention, the heat exchange plate is formed of the metallic plate member having the pattern of irregularity that includes the main protrusions and the intermediate protrusions provided on the plate member. Combining such a heat exchange plate with the other heat exchange plates so that these plates face each other at the same side and the tops of the main protrusions of the plate come into contact with the corresponding tops of the main protrusions of the other plate, or so that these plates face each other at the same other side and projections between the adjacent two intermediate protrusions of the plate come into contact with corresponding projections of the other plate, provides a gap between the adjacent two plates. The above-mentioned gap has a dimension corresponding to the pattern of irregularity of the plates, in which a unit of the similar pattern of irregularity is repeated in two directions that are perpendicular to each other, thus providing linear passages extending in the above-mentioned two directions so as to cross each other at right angles. More specifically, each of the linear passages extending in the direction includes expanded areas and throat areas that are placed alternately in the same direction, on the one hand, and the linear passage extending in the perpendicular direction to the above-mentioned direction includes expanded areas and throat areas that are placed alternately in the same perpendicular direction, in the similar manner. Using the thus assembled plates so that the flowing direction of the heat exchange fluid coincides with the linear passage or is perpendicular thereto can impart substantially the same behavior to the heat exchange fluid, irrespective the flowing system of the heat exchange fluid, i.e., any one of the parallel flowing system, the counter-flowing system and the cross flowing system. As a result, it is possible to perform a smooth heat transfer at a low pressure loss to make an effective heat exchange, even when the heat exchange fluids are combined in any manner in their flowing directions, thus providing a high degree of freedom in design of the heat exchanger and becoming excellent in general purpose use. In addition, the heat exchange fluid can flow freely in the above-mentioned two directions along the plate, and the constant heat transfer property can be obtained, irrespective of the flowing direction of the heat exchange fluid. It is therefore possible to cause the heat exchange fluid to spread over the entire area of the plate so that such an entire area can serve as an effective heat transfer section, thus increasing remarkably an amount of heat transfer per area and achieving a high performance. Further, the strength of the assembled plates can be improved remarkably by bringing the protrusions of the plate into contact with the corresponding protrusions of the other plate, and it is therefore possible to keep the distance between the adjacent two plates constant, even when there exists a large difference in pressure between the heat exchange fluids, thus enhancing a pressure-resistant property.

[0010] In the second aspect of the present invention, the plate member may have a shape of any one of a rectangle and a square with side edges, along which said ridgelines of said main protrusions extend in parallel with or perpendicular to said side edges of said plate member.

[0011] According to the second aspect of the present invention, the plate member has the pattern of irregular-
ity in which the ridgelines of the main protrusions extend in parallel with or perpendicular to the side edges of the plate member. Placing the plates having such a pattern of irregularity so that the side edge of the plate coincides with a horizontal direction or vertical direction provides areas between the intermediate protrusions and the foot portions, each of which areas extends obliquely relative to the horizontal or vertical direction. As a result, the heat exchange fluids introduced into the combined plates flows in the oblique direction, and repeats divergence and confluence to spread over every area of the plate. It is therefore possible to cause the heat exchange fluid to spread over the entire area of the plate to facilitate the heat transfer between the heat exchange fluids and improving the heat exchange rate.

[0012] In order to attain the aforementioned object, a plate for heat exchange of the third aspect of the present invention comprises a metallic plate member having a predetermined pattern of irregularity, said plate member being combined with at least one other plate member so as to be in parallel with each other to constitute a heat exchanger, which makes a heat exchange between a heat exchange fluid coming into contact with a surface of said metallic plate member and another heat exchange fluid coming into contact with another surface thereof, said metallic plate member comprising:

- a plurality of protrusions formed on one surface of said plate member, each of said main protrusions having a shape of any one of a quadrangular pyramid and a quadrangular truncated pyramid with ridgelines, said protrusion being aligned by a predetermined distance so that parallel planes include said ridgelines of said protrusions; and
- a plurality of recess portions formed between adjacent two protrusions on said plate member, each of said recess portions having substantially the same shape as said protrusions by deforming said plate member in an opposite direction to a protruding direction of said protrusions, said protrusions and said recess portions on the surface of said plate member forming said predetermined pattern of irregularity so that a similar pattern of irregularity to said predetermined pattern of irregularity is provided on another surface of said plate member.

[0013] According to the third aspect of the present invention, the heat exchange plate is formed of the metallic plate member having the pattern of irregularity that includes the protrusions and the recess portions provided on the plate member. Combining such a heat exchange plate with the other heat exchange plates so that these plates face each other at the same side and the tops of the protrusions of the plate come into contact with the corresponding tops of the protrusions of the other plate. The above-mentioned gap has a dimension corresponding to the pattern of irregularity of the plates, in which a unit of the similar pattern of irregularity is repeated in two directions that are perpendicular to each other, thus providing linear passages extending in the above-mentioned two directions so as to cross each other at right angles. More specifically, each of the linear passages extending in the direction includes expanded areas and throat areas that are placed alternately in the same direction, on the one hand, and the linear passage extending in the perpendicular direction to the above-mentioned direction includes expanded areas and throat areas that are placed alternately in the same perpendicular direction, in the similar manner. Using the thus assembled plates so that the flowing direction of the heat exchange fluid coincides with the linear passage or is perpendicular thereto can impart substantially the same behavior to the heat exchange fluid, irrespective of the flowing system of the heat exchange fluid, i.e., any one of the parallel flowing system, the counter-flowing system and the cross flowing system. As a result, it is possible to perform a smooth heat transfer at a low pressure loss to make an effective heat exchange, even when the heat exchange fluids are combined in any manner in their flowing directions, thus providing a high degree of freedom in design of the heat exchanger and becoming excellent in general purpose use. In addition, the heat exchange fluid can flow freely in the above-mentioned two directions along the plate, and the constant heat transfer property can be obtained, irrespective of the flowing direction of the heat exchange fluid. It is therefore possible to cause the heat exchange fluid to spread over the entire area of the plate so that such an entire area can serve as an effective heat transfer section, thus increasing remarkably an amount of heat transfer per area and achieving a high performance. Further, the strength of the assembled plates can be improved remarkably by bringing the protrusions of the plate into contact with the corresponding protrusions of the other plate, and it is therefore possible to keep the distance between the adjacent two plates constant, even when there exists a large difference in pressure between the heat exchange fluids, thus enhancing a pressure-resistant property.

[0014] In order to attain the aforementioned object, a heat exchange unit of the fourth aspect of the present invention comprises a first set of plates for heat exchange according to any one of the above-mentioned first to third aspects of the present invention, the plate member of each of said plates having a shape of any one of a rectangle and a square with side edges, along which the ridgelines of the main protrusions or the protrusions extend in parallel with or perpendicular to the side edges of the plate member, thus providing the predetermined pattern of irregularity; and a second set of plates having a different predetermined pattern of irregularity, said different predetermined pattern of irregularity being substantially same as said predetermined pattern of irregularity of said first set of plates, but turning at an angle of about 45 degrees relative thereto, said first set of plates and said second set of plates being
assembled in variation in combination into a unit.

According to the fourth aspect of the present invention, two kinds of plates, i.e., the first set of plates and the second set of plates having the ridgelines extending in the different direction from the extending direction of the ridgelines of the first set of plates are assembled in an appropriate combination into a unit, so as to provide combined properties of the different heat exchange properties of the two kinds of plates, for a general structure of the unit. It is therefore possible to adjust the heat exchange properties for the general structure of the unit by combining the two kinds of plates in a different manner, thus providing relatively easily the desired heat exchange properties. Consequently, there can be provided a heat exchanger, which has optimum properties and an excellent heat exchange efficiency in accordance with a kind, state and amount of the heat exchange fluid, as well as an actual use of the heat exchanger.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic structural view of a heat exchange plate according to the first embodiment of the present invention;
FIG. 2 is an enlarged plan view of an essential structure of the heat exchange plate according to the first embodiment of the present invention;
FIG. 3(A) is a cross-sectional view cut along the line A-A in FIG. 2, FIG. 3(B) is a cross-sectional view cut along the line B-B in FIG. 2 and FIG. 3(C) is a cross-sectional view cut along the line C-C in FIG. 2;
FIG. 4(A) is a cross-sectional view cut along the line D-D in FIG. 2 and FIG. 4(B) is a cross-sectional view cut along the line E-E in FIG. 2;
FIGS. 5(A) and 5(B) are descriptive views illustrating gaps formed between a pair of combined heat exchange plates according to the first embodiment of the present invention; FIG. 6 is a schematic structural view of a heat exchange plate according to the second embodiment of the present invention;
FIG. 7 is a descriptive view illustrating a flow of a heat exchange fluid in the combined heat exchange plates according to the second embodiment of the present invention;
FIG. 8 is an enlarged plan view of an essential structure of the heat exchange plate according to the other embodiment of the present invention;
FIG. 9(A) is a cross-sectional view cut along the line F-F in FIG. 8 and FIG. 9(B) is a cross-sectional view cut along the line G-G in FIG. 8;
FIG. 10(A) is a cross-sectional view cut along the line H-H in FIG. 8, FIG. 10(B) is a cross-sectional view cut along the line I-I in FIG. 8 and FIG. 10(C) is a descriptive view illustrating a state in which the heat exchange plates according to the other embodiment of the present invention are combined with each other; and
FIG. 11 is a schematic structural view of a heat exchange unit according to the third embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[First Embodiment of the Present Invention]

Now, the first embodiment of the present invention will be described in detail below with reference to FIGS. 1 to 5(B). FIG. 1 is a schematic structural view of a heat exchange plate according to the first embodiment of the present invention. FIG. 2 is an enlarged plan view of an essential structure of the heat exchange plate according to the first embodiment of the present invention. FIG. 3(A) is a cross-sectional view cut along the line A-A in FIG. 2, FIG. 3(B) is a cross-sectional view cut along the line B-B in FIG. 2 and FIG. 3(C) is a cross-sectional view cut along the line C-C in FIG. 2. FIG. 4(A) is a cross-sectional view cut along the line D-D in FIG. 2 and FIG. 4(B) is a cross-sectional view cut along the line E-E in FIG. 2. FIGS. 5(A) and 5(B) are descriptive views illustrating gaps formed between a pair of combined heat exchange plates according to the first embodiment of the present invention and the other gaps formed between the other pair of combined heat exchange plates according to the first embodiment of the present invention.

As shown in FIGS. 1 to 5(B), the heat exchange plate 1 according to the first embodiment of the present invention includes a metallic plate member having a rectangular shape. The plate member, which has a pattern of irregularity formed through a press forming, includes a plurality of main protrusions 2 formed on one surface of the plate member and a plurality of intermediate protrusions 3 formed between adjacent two main protrusions 2 on the plate member. Each of the main protrusions 2 has a shape of a quadrangular pyramid with a top, the first pair of opposite side surfaces and the second pair of opposite side surfaces. The first pair of opposite side surfaces faces each other in the first direction. The second pair of opposite side surfaces faces each other in the second direction perpendicular to the first direction. The main protrusions are aligned in the first direction and the second direction by a predetermined distance so that the first pair of opposite surfaces and the second pair of opposite surfaces of one of the main protrusions face corresponding opposite surfaces of adjacent protrusions. Each of the intermediate protrusions 3 has an opposed foot portions 3a and a head ridge 3b placed between the foot portions 3a. Each of the foot
portions 3a is placed in a lowermost position at which ridgelines 2b of the adjacent two main protrusions 2b intersect each other. The head ridge 3b is placed in a level that is higher than the foot portions 3a and lower than the top 2a of each main protrusion 2, so as to provide a bent roof shape. The main protrusions 2 and the intermediate protrusions 3 form the predetermined pattern of irregularity.

[0019] The above-mentioned heat exchange plate 1 has a structure in which the direction along which any one of the ridgelines 2b of the main protrusion 2 having the quadrangular pyramid extends, intersects any one of the sides of the plate having the rectangular shape at an angle of 45 degrees. The present invention is not limited only to such a structure, but the direction along which the ridgeline 2b of the main protrusion 2 may intersect the side of the plate at a desired angle to provide a desired pattern of irregularity.

[0020] The above-mentioned heat exchange plate 1 is combined with the other plate having the same structure so that these plates face each other at the same side and the tops 2a of the main protrusions 2 of the plate 1 come into contact with the corresponding tops 2a of the main protrusions 2 of the other plate, or so that these plates face each other at the same other side and projections between the adjacent two intermediate protrusions 3 of the plate come into contact with corresponding projections of the other plate. Such a combination forms a gap 4, in which a heat exchange fluid can flow, between the adjacent two plates 1, excepting contacting portions thereof, thus providing a heat exchanger in which a heat exchange can be made between the heat exchange fluid coming into contact with the upper surface of the plate 1 and the other heat exchange fluid coming into contact with the lower surface of the plate 1.

[0021] When the plates are combined with each other as described above, the main protrusions 2 and the intermediate protrusions 3 project in the gap, the intermediate protrusions 3 of the plate 1, which have the lower height than the main protrusions 2, face the corresponding intermediate protrusions 3 of the other plate 1 so as to apart from each other by a predetermined distance, and the foot portions 3a of the plate 1, which are placed the lowest level, face the corresponding foot portions 3a of the other plate 1 so as to apart from each other by a predetermined larger distance. Areas formed between the intermediate protrusions 3 and areas formed between the foot portions 3a alternately communicate with each other to form linear passages in a reticulation shape. In such linear passages, the areas between the foot portions 3a provide orifices, which are larger than orifices provided by the areas between the intermediate protrusions 3, with the result that the respective passage includes expansion zones and reduction zones, which are repeated alternately, to extend linearly, and intersects the other passages so as to communicate therewith (see FIG. 5(A)).

[0022] On the opposite side to the projecting direction of the protrusions 2, 3 of the plate, spatial areas are provided between the opposing intermediate protrusions 3, which are the smaller height than the main protrusions 2, so as to communicate the adjacent areas formed between the opposing main protrusions 3 with each other, thus forming linear passages. In such linear passages, the areas between the main protrusions 3 provide orifices, which are larger than orifices provided by the areas between the intermediate protrusions 3, with the result that the respective passage includes expansion zones and reduction zones, which are repeated alternately, to extend linearly in the alignment direction of the main protrusions 2, and intersects the other passages so as to communicate therewith (see FIG. 5(B)).

[0023] Now, description will be given below of operation of the heat exchanger to which the heat exchange plates according to the first embodiment of the present invention are applied. In the assembled state in which the heat exchange plates 1 are combined in parallel with each other, a heat exchange fluid is introduced into and discharged from the gap 4 in which the respective protrusions 2, 3 project, while the other heat exchange fluid is introduced through the gap 5, which is placed on the opposite side to the projecting side of the protrusions 2, 3, through the heat exchange plate 1 separating the gap 5 from the gap 4, so as to make heat exchange between the two kinds of heat exchange fluids.

[0024] The gaps 4, 5, which are formed between the plates, extend linearly in the aligning directions of the protrusions 2, 3 in correspondence with the respective shapes of the protrusions 2, 3. Even when the two kinds of heat exchange fluids are introduced into the gaps 4, 5, respectively, in accordance with any one of the flowing systems of the parallel flowing system, the countercflowing system and the cross flowing system, the heat exchange fluids can be subjected to substantially the same conditions. Accordingly, it is possible to cause the heat exchange fluids to pass smoothly through the gaps 4, 5, respectively, to make an effective heat exchange. In addition, the heat exchange fluids pass through the passages having the specific shape in which expanded areas and throat areas are placed alternately to make an effective heat exchange relative to the plates, thus improving the heat exchange efficiency between the fluids and eliminating pressure loss in the passages.

[0025] Further, the strength of the assembled plates can be improved remarkably by bringing the protrusions of the plate into contact with the corresponding protrusions of the other plate, and it is therefore possible to keep the distance between the adjacent two plates constant, thus coping with a case where there exists a large difference in pressure between the heat exchange fluids.

[0026] According to the heat exchange plate according to the first embodiment of the present invention, the heat exchange plate 1 is formed of the metallic rectangular plate member having the pattern of irregularity that includes the main protrusions 2 and the intermediate
protrusions 3 provided on the plate member. Combining such a heat exchange plate 1 with the other heat exchange plates so that these plates face each other at the same side and the tops 2α of the main protrusions 2 of the plate come into contact with the corresponding tops of the main protrusions of the other plate, or so that these plates face each other at the same other side and projections between the adjacent two intermediate protrusions of the plate come into contact with corresponding projections of the other plate, provides a gap 4 between the adjacent two plates. A further additional plate is combined with one of these plates in the same manner to provide the other gap 5 between them. Each of the above-mentioned gaps 4, 5 has a dimension corresponding to the pattern of irregularity of the plates, in which a unit of the similar pattern of irregularity is repeated in two directions that are perpendicular to each other, thus providing linear passages extending in the above-mentioned two directions so as to cross each other at right angles. More specifically, each of the linear passages extending in the direction includes expanded areas and throat areas that are placed alternately in the same direction, on the one hand, and the linear passage extending in the perpendicular direction to the above-mentioned direction includes expanded areas and throat areas that are placed alternately in the same perpendicular direction, in the similar manner. Using the thus assembled plates can impart substantially the same behavior to the heat exchange fluid, irrespective the flowing system of the heat exchange fluid, i.e., any one of the parallel flowing system, the counter-flowing system and the cross flowing system. As a result, it is possible to perform a smooth heat transfer at a low pressure loss to make an effective heat exchange, even when the heat exchange fluids are combined in any manner in their flowing directions, thus providing a high degree of freedom in design of the heat exchanger and becoming excellent in general purpose use.

[0027] The present invention is not limited only to the above-described first embodiment of the present invention in which the heat exchange plates are connected directly to each other by welding, to constitute the heat exchanger. The present invention may be applied to the conventional plate-type heat exchanger in which the plates are assembled into a unit in a state that gasket members formed of elastic material are placed between the plates.

[Second Embodiment of the Present Invention]

[0028] Now, the second embodiment of the present invention will be described in detail below with reference to FIGS. 6 and 7. FIG. 6 is a schematic structural view of a heat exchange plate according to the second embodiment of the present invention. FIG. 7 is a descriptive view illustrating a flow of a heat exchange fluid in the combined heat exchange plates according to the second embodiment of the present invention.

[0029] As shown in FIGS. 6 and 7, the heat exchange plate 10 according to the second embodiment of the present invention has the pattern of irregularities with the main protrusions 11 and the intermediate protrusions 12 in the same manner as the above-described first embodiment of the present invention. However, the heat exchange plate 10 according to the second embodiment differs from the first embodiment in that the ridgelines 14 of the main protrusions 11 extend in parallel with or perpendicular to the side edges of the heat exchange plate 10.

[0030] Concerning the pattern of irregularities of the heat exchange plate, the main protrusions 11 and the intermediate protrusions 12 project in the gap, the intermediate protrusions 12 of the plate, which have the lower height than the main protrusions 11, face the corresponding intermediate protrusions 12 of the other plate so as to apart from each other by a predetermined distance, and the foot portions 15 of the plate, which are placed the lowest level, face the corresponding foot portions 15 of the other plate so as to apart from each other by a predetermined larger distance, in the same manner as the above-described first embodiment of the present invention.

[0031] Now, description will be given below of behavior of the heat exchange fluids flowing on the respective surfaces of the heat exchange plate according to the second embodiment of the present invention. In a state in which the heat exchange plates 10 are assembled into a unit so as to be placed in parallel with each other, the different kinds of heat exchange fluids flows on the opposite surfaces of the heat exchange plate 10, respectively, so as to provide the counter-flowing system in the same manner as the first embodiment of the present invention. However, on the side of the upper surface of the plate, from which the protrusions 11, 12 project, fluid passages are provided to extend obliquely in two directions along which the main protrusions 11 and the intermediate protrusions 12 are aligned alternately. In each of the fluid passages, the intermediate protrusions 12 having the intermediate height and the foot portions 15 having the lowest level are repeated alternately. The heat exchange fluid flows downward in the above-mentioned fluid passages (as shown in FIG. 7 by hollow arrows in solid lines). On the side of the lower surface of the plate, which is opposite to the projecting direction of the protrusions 11, 12, other fluid passages extending obliquely are provided by recess portions, which are formed directly below the main protrusions 11, and other recess portions, which are formed directly below the intermediate protrusions 12, in combination. The other heat exchange fluid flows upward in these fluid passages (as shown in FIG. 7 by hollow arrows in dotted lines). Each of the heat exchange fluids flows obliquely, while repeating divergence and confluence, to spread smoothly over every area of the heat exchange plate 10. As a result, an effective heat transfer can be made between the different kinds of heat exchange fluids.
through the heat exchange plates 10.

[0032] According to the heat exchange plate according to the second aspect of the present invention, the plate member has the pattern of irregularity in which the ridgelines of the main protrusions 11 extend in parallel with or perpendicular to the side edges of the plate 10. Placing the plates 10 having such a pattern of irregularity so that the side edge of the plate coincides with the horizontal direction or vertical direction provides areas between the intermediate protrusions 12 and the foot portions 15, each of which areas extends obliquely relative to the horizontal or vertical direction. As a result, the heat exchange fluids introduced into the combined plates flows in the oblique direction, and repeats divergence and convergence to spread over every area of the plate 10. It is therefore possible to cause the heat exchange fluid to spread over the entire area of the heat exchange plate 10 to facilitate the heat transfer between the heat exchange fluids and improving the heat exchange rate.

[0033] The heat exchange plate according to the first and second embodiments of the present invention has a structure in which there is used the pattern of irregularities having the combination of the main protrusions 2, 11, which have the quadrangular pyramid, and the intermediate protrusions 3, 12, which have the bent roof shape having the lower height than the main protrusions 2, 11. The present invention is not limited only to such a structure, but there may be adopted a structure as shown in FIGS. 8 to 10(C), in which the pattern of irregularities is formed by a plurality of protrusions 6 and a plurality of recess portions 7. The protrusions 6, each of which projects in the form of a quadrangular pyramid or a quadrangular truncated pyramid having four ridgelines, are aligned in the two directions, which are perpendicular to each other, so that the protrusions 6 are apart from each other by a predetermined distance and the ridgelines of the protrusions 6 are placed on straight lines corresponding to the above-mentioned two directions. Each of the recess portions 7 is formed, in the form of a quadrangular pyramid or a quadrangular truncated pyramid, between four protrusions so as to be surrounded by the four protrusions 6. Consequently, the plate is provided on the opposite surfaces with the patterns of irregularities having the inverse projection relationship, in which the plate is provided, on respective areas of its upper surface, with the protrusions 6, and on the corresponding areas of its lower surface, with the recess portions 7. When the heat exchange plate is combined with the other plate having the same structure so that the protrusions 6 of the former come into contact with the protrusions of the latter, the ridgelines 6a of the protrusions of the plate face those of the corresponding protrusions of the other plate by a predetermined distance, and the recess portions 7 of the plate face the corresponding portions of the other plate by a predetermined distance within the gap 8. Spaces formed between the adjacent protrusions 6 communicate alterna-

tively with spaces defined by the recess portions 7 to form linear passages. Accordingly, each of the linear passages extending in the direction includes expanded areas and throat areas that are placed alternately in the same direction, on the one hand, and the linear passage extending in the perpendicular direction to the above-mentioned direction includes expanded areas and throat areas that are placed alternately in the same perpendicular direction, in the similar manner (see FIG. 10 (c)). Even when the two kinds of heat exchange fluids are introduced into the gaps 8, respectively, in accordance with any one of the flowing systems of the parallel flowing system, the counter-flowing system and the cross flowing system, the heat exchange fluids can be subjected to substantially the same conditions in the same manner as the first embodiment of the present invention. Accordingly, it is possible to cause the heat exchange fluids to pass smoothly through the gaps 8, respectively, to make an effective heat exchange.

[0034] In the heat exchange plate according to the first and second embodiments of the present invention, there is no limitations in the introducing and discharging directions of the two kinds of heat exchange fluids, which flow on the opposite surfaces of the heat exchange plate, respectively, to make heat exchange between these fluids, and in the flowing system for them. These limitations may be given in accordance with the use of the heat exchanger. More specifically, there may be adopted a structure in which inlet and outlet for the first fluid are provided on the opposite edges of the heat exchange plate in its longitudinal direction, respectively, and inlet and outlet for the second fluid are provided on the opposite edges of the heat exchange plate in its transverse direction, respectively, and the first fluid flows in the longitudinal direction and the second fluid flows in the transverse direction in accordance with the cross flowing system. Alternatively, there may be adopted a structure in which inlet and outlet for the first fluid are provided on the opposite edges of the longitudinal side of the heat exchange plate, respectively, inlet and outlet for the second fluid are provided on the opposite edges of the remaining longitudinal side of the heat exchange plate, respectively, and the first fluid flows in the longitudinal direction and the second fluid flows in the longitudinal direction in accordance with the parallel flowing system or the counter-flowing system. Further, there may be adopted a structure in which inlet and outlet for the first fluid are provided on the opposite edges of the longitudinal side of the heat exchange plate, respectively, inlet and outlet for the second fluid are provided on the same opposite edges, respectively, and the first fluid flows in the longitudinal direction and the second fluid flows in the opposite longitudinal direction in accordance with the counter-flowing system.

[Third Embodiment of the Present Invention]

[0035] Now, the third embodiment of the present in-
vention will be described in detail below with reference to FIG. 11. The third embodiment describes a heat exchange unit into which the above-described heat exchange plates of the present invention are assembled so as to be placed in parallel with each other. FIG. 11 is a schematic structural view of the heat exchange unit according to the third embodiment of the present invention.

[0036] As shown in FIG. 11, the heat exchange unit 50 has a structure in which a predetermined number of the first heat exchange plates according to the first embodiment and a predetermined number of the second heat exchange plates according to the second embodiment are combined with each other. More specifically, the first heat exchange plates each having the pattern of irregularities in which the ridgelines 14 of the main protrusions 2 intersects any one of the sides of the plate having the rectangular shape at an angle of 45 degrees, and the second heat exchange plates each having the pattern of irregularities in which the ridgelines 14 of the main protrusions 11 are in parallel with or perpendicular to any one of the sides of the plate having the rectangular shape are assembled in the unit in an appropriate combination.

[0037] The heat exchange plates used in the heat exchange unit 50 are classified into the first group of the heat exchange plates 1, which have the same pattern of irregularities and are placed one upon another, and the second group of the heat exchange plates 10, which have the pattern of irregularities that are the same as each other but different from the first series of the heat exchange plates 1, and are placed one upon another in the same manner. Using the two groups of the heat exchange plates having the different heat exchanging properties due to the different pattern of irregularities, so as to be placed in parallel with each other provides an intermediate property between the first property according to the unit in which only the first group of heat exchange plates is utilized and the second property according to the unit in which only the second group of heat exchange plates is utilized. When such a unit is applied to the heat exchange fluids, which are suitable to such an intermediate property, heat exchange can be made in an appropriate manner, thus improving the heat exchange efficiency.

[0038] According to the heat exchange unit according to the third embodiment of the present invention, two kinds of plates, i.e., the first set of plates 1 and the second set of plates 10 having the ridgelines extending in the different direction from the extending direction of the ridgelines of the first set of plates are assembled in an appropriate combination into a unit, so as to provide combined properties of the different heat exchange properties of the two kinds of plates. It is therefore possible to provide the heat exchanger having the effective heat exchanging properties as desired, which cannot be obtained by combination of the single kind of plates.

[0039] In the heat exchange unit according to third embodiment of the present invention, the two kinds of heat exchange plates 1, 10 are assembled into the unit so that the first group of plates having the same pattern of irregularities and the second group of plates having the same pattern of irregularities are combined in parallel with each other. The present invention is not limited only to such a structure. A plurality of kinds of plates having the different pattern of irregularities, for example, two kinds of plates, i.e., the heat exchange plates 1 having the pattern of irregularities as shown in FIG. 1 and the heat exchange plates 10 having the pattern of irregularities as shown in FIG. 6 may be placed alternately one upon another. Alternatively, there may be placed, between a plurality of groups of plate having the same pattern of irregularities, one or more plate having the different pattern of irregularities. Combination of the plates can be varied strictly in number of the plates in the respective group in this manner. It is therefore possible to adjust appropriately the arrangement of the various kinds of plates having the different heat exchanging properties due to the different pattern of irregularities, to obtain a desired heat exchange properties for the general structure of the unit, thus providing a heat exchanger, which has optimum properties and an excellent heat exchange efficiency in accordance with a kind, state and amount of the heat exchange fluid, as well as an actual use of the heat exchanger.

Claims

1. A plate for heat exchange, comprising a metallic plate member having a predetermined pattern of irregularity, said plate member being combined with at least one other plate member so as to be in parallel with each other to constitute a heat exchanger, which makes a heat exchange between a heat exchange fluid coming into contact with a surface of said metallic plate member and another heat exchange fluid coming into contact with another surface thereof, said metallic plate member comprising:

   a plurality of main protrusions formed on one surface of said plate member, each of said main protrusions having a shape of any one of a quadrangular pyramid and a quadrangular truncated pyramid with a top, a first pair of opposite side surfaces and a second pair of opposite side surfaces, said first pair of opposite side surfaces facing each other in a first direction and said second pair of opposite side surfaces facing each other in a second direction perpendicular to said first direction, said main protrusions being aligned in the first direction and the second direction by a predetermined distance so that the first pair of opposite surfaces and the second pair of opposite surfaces of
one of the main protrusions face corresponding opposite surfaces of adjacent protrusions; and a plurality of intermediate protrusions formed between adjacent two main protrusions on said plate member, each of said intermediate protrusions having opposite foot portions and a head ridge placed between said foot portions, each of said foot portions being placed in a lowermost position at which ridgelines of the adjacent two main protrusions intersect each other, and said head ridge being placed in a level that is higher than said foot portions and lower than said top of each main protrusion, so as to provide a bent roof shape, said intermediate protrusions and said main protrusions forming said predetermined pattern of irregularity.

2. The plate for heat exchange as claimed in Claim 1, wherein:

said plate member has a shape of any one of a rectangle and a square with side edges, along which said ridgelines of said main protrusions extend in parallel with or perpendicular to said side edges of said plate member.

3. A plate for heat exchange, comprising a metallic plate member having a predetermined pattern of irregularity, said plate member being combined with at least one other plate member so as to be in parallel with each other to constitute a heat exchanger, which makes a heat exchange between a heat exchange fluid coming into contact with a surface of said metallic plate member and another heat exchange fluid coming into contact with another surface thereof, said metallic plate member comprising:

a plurality of protrusions formed on one surface of said plate member, each of said main protrusions having a shape of any one of a quadrangular pyramid and a quadrangular truncated pyramid with ridgelines, said protrusion being aligned by a predetermined distance so that parallel planes include said ridgelines of said protrusions; and

a plurality of recess portions formed between adjacent two protrusions on said plate member, each of said recess portions having substantially the same shape as said protrusions by deforming said plate member in an opposite direction to a protruding direction of said protrusions, said protrusions and said recess portions on the surface of said plate member forming said predetermined pattern of irregularity so that a similar pattern of irregularity to said predetermined pattern of irregularity is provided on another surface of said plate member.

4. A heat exchange unit comprising:

a first set of plates for heat exchange as claimed in any one of Claims 1 to 3, the plate member of each of said plates having a shape of any one of a rectangle and a square with side edges, along which the ridgelines of the main protrusions or the protrusions extend in parallel with or perpendicular to the side edges of the plate member, thus providing the predetermined pattern of irregularity; and a second set of plates having a different predetermined pattern of irregularity, said different predetermined pattern of irregularity being substantially same as said predetermined pattern of irregularity of said first set of plates, but turning at an angle of about 45 degrees relative thereto, said first set of plates and said second set of plates being assembled in variation in combination into a unit.
Fig. 6

10

11

14
Fig. 11