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(54) **Heat exchange plate**

(57) A heat exchange plate (10) has protrusions (11) and recesses (12). The protrusion (11) having a curved outer peripheral surface is surrounded by adjacent protrusions placed at regular intervals on a circle around the protrusion (11) with the same central angle relative to the center of the protrusion (11). The recess (12) having a curved inner peripheral surface that partially extends to the curved outer peripheral surface of the protrusion (11)

is placed in a predetermined arrangement that is deviated by the same pitch from the predetermined arrangement of the protrusions (11). The recesses (12) provide on the other surface of the plate with the same configuration as the protrusions (11). The protrusions (11) provide on the surface of the plate with the same configuration as the recesses (12), so as to provide on the opposite surfaces of the metallic plate with the same pattern of irregularity.

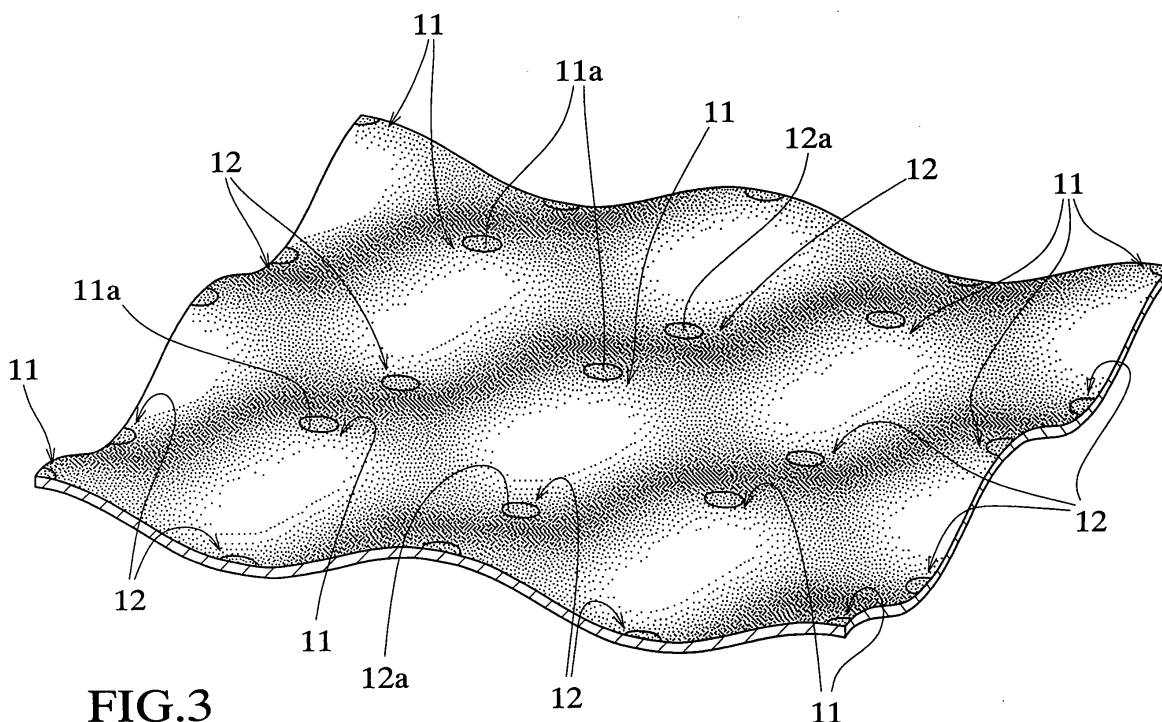


FIG. 3

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates a heat exchange plate, which is formed of a metallic plate and to be used in combination with the other heat exchange plates having the same structure so that they are combined in parallel and integrally with each other to form a heat exchanger, and especially to such a heat exchange plate that permits to provide an integrally combined state for the heat exchanger in which an appropriate heat exchange can be made between heat exchange fluids under the same heat transfer conditions between them, while causing the heat exchange fluids to flow smoothly along the opposite surfaces of the heat exchange plate, respectively, thus enhancing heat exchange efficiency.

Description of the Related Art

[0002] If there is a demand that heat transfer coefficient is increased to enhance heat exchange efficiency, utilizing a heat exchanger by which transfer of heat (i.e., 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 heat transfer plates are placed parallelly one upon another at prescribed intervals so as to form passages, which are separated by means of the respective heat transfer plates. A high temperature fluid and a low temperature fluid flow alternately in the above-mentioned passages to make heat exchange through the respective heat transfer plates. Japanese Patent Provisional Publication No. H3-91695 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, without using any gasket members, at their ends by welding to assemble the plates into a single unit so as to form 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 heat transfer plates formed of 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] A pattern of irregularity of herringbone type has conventionally and widely applied to the heat transfer plates of the plate-type heat exchanger. However, such a pattern of irregularity could not achieve a balance of decrease in pressure loss and assured resistance to pressure. Accordingly, various kinds of different pattern of irregularities have been proposed. Japanese Patent Provisional Publication No. 2000-257488 describes an example of such different pattern of irregularities.

[0006] The plates for the above-mentioned conventional heat exchanger has a structure in which the plate includes a plurality of heat transfer sections each of which has a mound configuration provided at its top with a flat portion in a thickness direction of the plate (i.e., a cross section thereof) and a rectangular shape in a plan view of the plate. These plates are combined to each other so as to be placed one upon another to form a single heat exchanger.

[0007] The conventional heat exchangers (i.e., heat exchange units) have structures as described in Japanese Patent Provisional Publication Nos. H3-91695, 2003-194490 and 2000-257488. With respect to the conventional plates described in Japanese Patent Provisional Publication No. 2000-257488, which have a pattern of irregularity that is applicable also to the plates described in Japanese Patent Provisional Publication Nos. H3-91695 and 2003-194490, the plates are placed one upon another to form a heat exchanger so that alternating plates are turned upside down and upper end portions of heat transfer sections of the plate faces flowing passage-intersections of the adjacent plate. The plates are combined to each other so that the heat transfer sections protrude the same direction, with the result that the flowing passages formed between the adjacent two plates have the same pattern, although the alternating plates are turned by 180 degrees, leading to a reverse positional relationship in a direction perpendicular to the combining direction of the plates.

[0008] When the conventional heat exchange plates are placed one upon another with the same orientation, there is provided the similar configuration of flow passages. However, the plate is provided on the lower surface side with the reverse pattern of irregularity to the upper surface side, leading to symmetrical configuration on the opposite surfaces of the plate. Therefore, the same heat transfer conditions cannot be given to fluids on the opposite surfaces of the heat exchange plate, thus making it impossible to cope appropriately with a case in which the heat transfer states between the opposite sur-

faces of the plate and the respective fluids are kept identical to ensure sufficient heat transfer efficiency between heat exchange fluids.

[0009] Even when the opposite surfaces of the plate are different from each other in configuration, the matching of such a configuration with characteristic property of the respective heat exchange fluids which are brought into contact with the respective surfaces of the plate, or with flowing state thereof makes it possible to enhance independently the heat transfer efficiency between the plate and the respective fluids, so as to improve a general heat exchange efficiency between the fluids, even in case where the heat transfer states on the opposites surfaces of the plate are different from each other. However, the configuration of the respective plates is specialized for a certain flowing state of each fluid. In case where an intended use as the heat exchanger or a positional relationship between the plates of the heat exchanger causes variation in flowing conditions of the heat exchange fluids passing through gaps between the plates, or replacement of the fluids itself, the heat transfer performance may deviate from the optimum point, thus leading to a severe deterioration in performance and being inferior in general versatility.

SUMMARY OF THE INVENTION

[0010] An object of the present invention, which was made to solve the above-mentioned problems, is therefore to provide a heat exchange plate, which permits optimization of a pattern of irregularity of heat transfer sections on the opposite surfaces of the plate, an appropriate combination with the other kinds of plates for a combined unit, coincidence of a pattern of irregularity on the opposite surfaces of the plate and of heat transfer conditions of the respective fluids, so as to ensure heat transfer performance for the fluids on the opposite surfaces of the plate, thus obtaining a high heat exchange efficiency.

[0011] In order to attain the aforementioned object, a heat exchange plate of the first aspect of the present invention, which is formed of a metallic plate and has a predetermined pattern of irregularity, the heat exchange plate being placed on another heat exchange plate having a same structure so as to come into contact with each other on a same side of the heat exchange plate to provide a pair of heat exchange plates, the pair of heat exchange plates being combined to one or more other pair of heat exchange plates integrally with each other to form a heat exchanger in which heat exchange is to be made between first and second heat exchange fluids that come into contact with opposite surfaces of the heat exchange plate, respectively, the heat exchange plate comprises: a plurality of protrusions that are placed in a predetermined arrangement on a surface of the metallic plate; and a plurality of recesses each of which is placed between two or more protrusions of said plurality of protrusions on said surface of the metallic plate so as to dent in an opposite direction to a protruding direction of said

protrusions, said plurality of protrusions and said plurality of recesses providing said predetermined pattern of irregularity; wherein: each of said protrusions has a curved outer peripheral surface, one protrusion of said plurality of protrusions is surrounded by adjacent protrusions of other protrusions, said adjacent protrusions being placed at regular intervals on a circle around said one protrusion and with a same central angle relative to a center of said one protrusion; each of said recesses has a curved inner peripheral surface that partially extends to the curved outer peripheral surface of said protrusions, said recesses being placed in a predetermined arrangement that is deviated by a same pitch from the predetermined arrangement of said protrusions; and said recesses provide on another surface of said metallic plate with a same configuration as said plurality of protrusions and said protrusions provide on said surface of said metallic plate with a same configuration as said recesses, so as to provide on the opposite surfaces of the metallic plate with a same pattern of irregularity.

[0012] According to the first aspect of the present invention, the plate is provided on the lower surface side with the reverse pattern of irregularity to the upper surface side so that the protrusions on the upper surface of the plate correspond to the recesses on the lower surface of the plate on the basis of the same pattern of irregularity. When the plate is placed on the other plate on the same side so that the tops of the protrusions of the former plate come into contact with the tops of the protrusions of the latter plate, and such combination is repeated to form a combined unit, the configuration of the plate, in which the protrusions on the upper surface of the plate correspond to the recesses on the lower surface of the plate, provides a passage having the corresponding configuration, between the plates. It is therefore possible to impart the same heat transfer environment on the opposite surfaces of the plate to the heat transfer fluids passing through gaps between the plates. Accordingly, proper heat transfer between the fluids through the plates can progress, without being affected by flowing state of the fluids and characteristic property thereof, thus permitting effective heat exchange between the heat exchange fluids. In addition, gaps between the plates extend linearly on straight lines along which the protrusions and recesses are aligned, while expanding and reducing in a repeated manner, to form passage sections so that the passage section intersects the other passage section so as to communicate therewith, thus providing a braided passage structure. Even when a flowing relationship of the heat exchange fluids is based on any one of a parallel flowing system, a counter-flowing system and a cross flowing system, it is therefore possible to cause the heat exchange fluids to behave in flow in substantially the same manner to provide substantially the same heat transfer performance. In addition, even when the heat exchange fluids flow on the basis of any combination of the flowing directions, it is possible to make smoothly heat exchange with low pressure-loss and enhance de-

gree of freedom in design of a heat exchanger, thus providing excellent versatility.

[0013] In the second aspect of the heat exchange plate of the present invention, there may be adopted a structure in which the protrusions are placed on a basis of a matrix arrangement in which the protrusions are aligned at regular intervals on lines extending in two directions that are perpendicular to each other, and the recesses are placed on a basis of a similar matrix arrangement to the matrix arrangement of the protrusions, in which one recess of the plurality of recesses is placed in a center of a square defined by four protrusions that are adjacent to each other by a shortest distance; the protrusions and recesses that respectively continue in diagonal lines of the metallic plate in the matrix arrangement in which the protrusions and recesses are alternated at the regular intervals have a sine wave shape in a cross section of the metallic plate; and a central portion between closest adjacent two protrusions and a central portion between closest adjacent two recesses are level with an intermediate height between a bottom of the recess and a top of the protrusion.

[0014] According to the second aspect of the present invention, the protrusions are placed on the basis of the matrix arrangement in which the protrusions are aligned at regular intervals on lines extending in two directions that are perpendicular to each other, and the recesses are placed on the basis of the similar matrix arrangement, and the protrusions and recesses that respectively continue in diagonal lines of the metallic plate in the matrix arrangement in which the protrusions and recesses are alternated at the regular intervals have a sine wave shape in a cross section of the metallic plate, so as to determine the outer peripheral surface of the protrusion and the inner peripheral surface of the recess. This can provide formation of the curved structure in which regular cyclic variation of the protrusions and recesses is caused in the predetermined direction on the opposite surfaces of the plate. It is therefore possible to reduce pressure loss between the plates, even when the plates are used with any orientation, and achieve smooth flow of the heat exchange fluids and smooth heat transfer, thus improving heat exchange efficiency. In addition, such a curved structure permits dispersion of force applied to the plate, thus enhancing strength to cope with a fluid having a high pressure and improving formability. When seawater is used as one of the heat exchange fluids, which is introduced into the passage between the plates, such a curved structure prevents fouling from attaching thereto, thus avoiding deterioration of performance for a long period of time.

[0015] In the third aspect of the heat exchange plate of the present invention, the protrusions and recesses may be alternated to form parallel rows that are in parallel with or perpendicular to sides of the metallic plate having a rectangular or square shape, thus providing the predetermined pattern of irregularity.

[0016] According to the third aspect of the present invention, the protrusions and recesses are be alternated

to form the parallel rows that are in parallel with or perpendicular to sides of the metallic plate having the rectangular or square shape. When the plate is supported so that the side of the plate is placed in the horizontal or vertical direction, linearly extending passage sections that are defined as main passages between the combined plates by the recesses and valley areas held between the adjacent projections and are provided in an inclined state relative to the vertical direction. As a result, the heat exchange fluids flowing along the plates flow in the oblique direction, while repeating divergence and confluence to spread smoothly over every area of the plate. The heat exchange efficiency is therefore improved.

[0017] In the fourth aspect of the heat exchange plate of the present invention, each of the protrusions may be provided at a top thereof with a flat surface having a predetermined area.

[0018] According to the fourth aspect of the present invention, the protrusion is provided at the top thereof with the flat surface. When the plates are placed one upon another so that the flat surfaces of the tops come into contact with each other, the protrusions of the plates as combined are subjected to a surface contact to provide stability. It is therefore possible to bring reliably the protrusions into contact with each other without causing deviation in a lateral direction, thus keeping a constant direction between the plates and enhancing strength against fluid pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

FIG. 1 is a schematic structural view of a heat exchange plate according to the first embodiment of the present invention;

FIG. 2 is a partial enlarged view of the heat exchange plate as shown in FIG. 1;

FIGS. 3 is a partial enlarged perspective view of the heat exchange plate as shown in FIG. 1;

FIGS. 4 is a cross-sectional view cut along the line IV-IV in FIG. 2;

FIGS. 5 is a cross-sectional view cut along the line V-V in FIG. 2;

FIGS. 6 is a cross-sectional view cut along the line VI-VI in FIG. 2;

FIGS. 7 is a cross-sectional view cut along the line VII-VII in FIG. 2;

FIGS. 8 is a cross-sectional view cut along the line VIII-VIII in FIG. 2; and

FIGS. 9 and 10 are structural views of gaps provided above and below the heat exchange plate, respectively, according to the first embodiment of the present invention in a state in which the heat exchange plates are combined in parallel with each other.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] Now, an embodiment of the present invention will be described in detail below with reference to FIGS. 1 to 10. FIG. 1 is a schematic structural view of a heat exchange plate according to the first embodiment of the present invention; FIG. 2 is a partial enlarged view of the heat exchange plate as shown in FIG. 1; FIGS. 3 is a partial enlarged perspective view of the heat exchange plate as shown in FIG. 1; FIGS. 4 is a cross-sectional view cut along the line IV-IV in FIG. 2; FIGS. 5 is a cross-sectional view cut along the line V-V in FIG. 2; FIGS. 6 is a cross-sectional view cut along the line VI-VI in FIG. 2; FIGS. 7 is a cross-sectional view cut along the line VII-VII in FIG. 2; FIGS. 8 is a cross-sectional view cut along the line VIII-VIII in FIG. 2; and FIGS. 9 and 10 are structural views of gaps provided above and below the heat exchange plate, respectively, according to the first embodiment of the present invention in a state in which the heat exchange plates are combined in parallel with each other.

[0021] As shown in the above-mentioned figures, the heat exchange plate 10 according to the embodiment of the present invention is formed of a metallic plate having a rectangular shape. The metallic plate has a pattern of irregularity press-formed thereon, which includes a plurality of protrusions 11 formed on the upper surface of the plate and a plurality of recesses 12. The protrusions 11 have a predetermined bulge shape and placed on the basis of a matrix arrangement in which these protrusions are aligned at regular intervals. Each of the recesses 12 is placed between the adjacent protrusions 11 so as to dent in the opposite direction to the protruding direction of the protrusions 11.

[0022] The protrusions 11 for the pattern of irregularity are aligned at the predetermined intervals in two directions that are perpendicular to each other on the basis of the matrix arrangement on the upper surface of the plate. Each of the protrusions 11 has the same shape with a curved outer peripheral surface, which is a rotational symmetry. Each of the protrusions 11 continues to the other four adjacent protrusions with which the former protrusion 11 is surrounded. The protrusion 11 has a top 11a in the form of a flat circle area and the remaining outer peripheral surface other than the top 11a. The outer peripheral surface has a truncated conical shape expanding downward from the top 11a.

[0023] The recesses 12 are placed on the basis of the similar matrix arrangement to the protrusions 11, in which one recess 12 of the plurality of recesses is placed in a center of a square defined by four protrusions 11 that are adjacent to each other by a shortest distance on the upper surface of the plate. Each recess 12 has a bottom 12a and a curved inner peripheral surface continuing to the outer peripheral surfaces of the above-mentioned four protrusions 11.

[0024] The outer peripheral surfaces of the protrusions

11 and the inner peripheral surfaces of the recesses 12 that respectively continue in diagonal lines of the metallic plate in the matrix arrangement in which the protrusions 11 and recesses 12 are alternated at the regular intervals have a sine wave shape in a cross section of the metallic plate. Each protrusion 11 has a curved surface that is formed by smoothly connecting the adjacent recess 12 to the other adjacent protrusion 11. The inner peripheral surface of each recess 12 has the same shaped portion continuing to the outer peripheral surfaces of the adjacent protrusions 11. In addition, the recess 12 smoothly continues at the inner peripheral surface thereof to the four adjacent recesses 12. The recess 12 has such a continuing surface to provide a rotational symmetrical shape.

[0025] A central portion between closest adjacent two protrusions 11 and a central portion between closest adjacent two recesses 12 are transition curved portions 13 for smoothly connecting the adjacent curved surfaces. Such transition curved portions 13 are level with an intermediate height between a bottom of the recess 12 and a top of the protrusion 11. The outer peripheral surface of the protrusion 11 smoothly continues directly to the inner peripheral surface of the recess 12. The protrusion 11 and recess 12 continue to the other closest adjacent protrusions 11 and recesses 12 through the transition curved portions 13, respectively. Such a curved structure permits dispersion of force applied to the plate, thus enhancing strength to cope with a fluid having a high pressure and improving formability.

[0026] In the heat exchange plate 10 of the present invention, the recesses 12 provide on the other (i.e., lower) surface of the metallic plate with the same configuration as the protrusions 11 and the protrusions 11 provide on the surface of the metallic plate with the same configuration as the recesses 12, so as to provide on the opposite surfaces of the metallic plate with the same pattern of irregularity.

[0027] Straight lines along which the protrusions 11 and the recesses 12 are aligned, respectively, on the basis of the matrix arrangement on the heat exchange plate 10 are inclined at an angle of 45 degrees relative to the respective sides of the plate having the rectangular shape, with the result that the diagonal lines along which the protrusions 11 and the recesses 12 are alternated, are just in parallel to or perpendicular to the respective sides of the plate.

[0028] The above-described heat exchange plate 10 is placed on the other heat exchange plate having the same structure so that they face each other on the same side and the tops 11a of the protrusions 11 of the former plate come into contact with the corresponding tops of the protrusions of the latter plate, to form a combined unit, and then the thus formed combined unit is combined to the other combined units in the same manner, to form a heat exchanger that has gaps, i.e., passages. The heat exchange fluids flow in these passages to make heat exchange between one of these fluids coming into contact with the upper surface of the plate and the other of

these fluids coming into contact with the lower surface of thereof. The plates are combined integrally with each other in this manner so that the protrusions come into contact with each other, thus enhancing strength. As a result, even when a high pressure is applied between the plates, the heat exchanger cannot be easily deformed. Variation in distance between the plates can be prevented, thus permitting to cope with a case in which there is a large difference in pressure between the heat exchange fluids.

[0029] In the gap 14 formed between the two adjacent plates of the thus combined plates in which the tops 11a of the protrusions 11 of the plate come into contact with the tops 11a of the protrusions 11 of the other plate, the corresponding outer peripheral surfaces of the protrusions 11 of these plates 10, excluding the contacting tops 11a face each other with a predetermined distance kept therebetween, the corresponding transition curved portions 13 of these plates 10 face each other with a predetermined distance kept therebetween, and the corresponding recesses 12 having a smaller height than the transition curved portions 13 face each other with a predetermined distance kept therebetween. Gaps formed between the corresponding outer peripheral surfaces of the protrusions 12 communicate with gaps formed between the corresponding recesses 12 to form a straight passage. In such a passage, the flow passage area between the corresponding recesses 12 is larger than the flow passage area between the corresponding protrusions 12 so that the passage extends linearly, while expanding and reducing in a repeated manner. Such a passage intersects the other passages so as to communicate therewith, thus providing a braided passage structure (see FIG. 9).

[0030] On the other hand, in the gap 15 formed on the opposite side relative to the plate, the same pattern of irregularity provides the same structure with the result that the passage extends linearly, while expanding and reducing in a repeated manner, and such a passage intersects the other passages so as to communicate therewith, thus providing a braided passage structure (see FIG. 10) in the same manner as described above. When a heat exchanger composed of the plates as combined in a manner as described above is placed in use so that one of the both sides of each plate is placed horizontally or vertically, the main passages, i.e., the gaps each of which is defined by the alternating corresponding recesses 12 and transition curved portions 13, are kept in an inclined state. The plate is provided on the lower surface side with the reverse pattern of irregularity to the upper surface side so that the protrusions on the upper surface of the plate correspond to the recesses on the lower surface of the plate on the basis of the same pattern of irregularity. These plates are placed one upon another on the same side, resulting in deviation of position of the protrusions and recesses by a half length of the distance between them. Except for this matter, the same conditions are kept for each of the gaps between the plates.

[0031] Now, description will be given below of operation of the heat exchanger that is composed of the heat exchange plates 10 according to the embodiment of the present invention. Heat exchange is made between the two kinds of heat exchange fluids by introducing one of these fluids into the gaps 14 formed between the two adjacent plates of the unit in which the plates are placed parallelly one upon another and combined together, and discharging it therefrom, on the one hand, and by introducing the other of these fluids into the gaps 15 formed between the two adjacent plates of the unit and discharging it therefrom, on the other hand.

[0032] The gaps 14, 15 that are defined between the plates by configurations of the protrusions 11 extend continuously and linearly on the straight lines along which the protrusions 11 are aligned, to form passage sections so that the passage section intersects the other passage section so as to communicate therewith, thus providing a braided passage structure. Even when a flowing relationship of the heat exchange fluids, which flow in the gaps 14, 15, respectively, is based on any one of a parallel flowing system, a counter-flowing system and a cross flowing system, it is therefore possible to cause the heat exchange fluids to behave in flow in substantially the same manner to provide substantially the same heat transfer performance. In addition, even when the heat exchange fluids flow on the basis of any combination of the flowing directions, it is possible to reduce pressure loss in the passages so as to ensure smooth flow in the gaps 14, 15, thus making effective heat exchange.

[0033] In an example case in which heat exchange fluids flow in accordance with the counter-flowing system, there is formed, in the gap 14 formed between the two adjacent plates of the combined plates, a flow braided passage mainly including passage sections that extend obliquely along the straight lines on which the protrusions 11 and the recesses 12 are aligned, between the corresponding recesses 12 having the lowest projection height and between the corresponding transition curved portions 13 having the intermediate projection height so that the heat exchange fluid flows in this flow braided passage. On the other hand, in the other gap 15 formed between the two adjacent plates of the combined plates, a flow braided passage mainly including passage sections that extend obliquely along the straight lines, between the corresponding recesses 12, which are provided on the back side of the protrusions 11, and between the corresponding transition curved portions 13 so that the other heat exchange fluid flows in this flow braided passage. As a result, the heat exchange fluids introduced into the combined plates flows in the oblique direction on the opposite surfaces of the heat transfer plate 10, respectively, while repeating divergence and confluence to spread smoothly over every area of the plate.

[0034] 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. In addition,

the heat transfer fluids respectively flow in the flow braided passages that have specific configurations enabling the heat exchange fluids to flow, while repeating divergence and confluence and have heat transfer performance as set in contemplation of the characteristic properties of the heat exchange fluids on the opposite surfaces of the plate. As a result, heat transfer between the heat exchange fluids, which pass through the similar gaps 14, 15 based on the pattern of irregularity in view of the above-mentioned characteristic properties, through the heat transfer plate 10 effectively progresses, thus remarkably enhancing heat exchange efficiency between the fluids.

[0035] In the heat exchange plate according to the embodiment of the present invention, the heat exchange plate 10 is provided on the lower surface side with the reverse pattern of irregularity to the upper surface side so that the protrusions on the upper surface of the plate correspond to the recesses on the lower surface of the plate on the basis of the same pattern of irregularity. When the plate is placed on the other plate on the same side so that the tops 11a of the protrusions 11 of the former plate come into contact with the tops 11a of the protrusions 11 of the latter plate, and such combination is repeated to form a combined unit, the configuration of the plate, in which the protrusions 11 on the upper surface of the plate correspond to the recesses 12 on the lower surface of the plate, provides a passage having the corresponding configuration, between the plates. It is therefore possible to impart the same heat transfer environment on the opposite surfaces of the plate to the heat transfer fluids passing through the gaps 14, 15 between the plates. Accordingly, proper heat transfer between the fluids through the plates can progress, without being affected by flowing state of the fluids and characteristic property thereof, thus permitting effective heat exchange between the heat exchange fluids. In addition, the gaps between the plates extend linearly on straight lines along which the protrusions and recesses are aligned, while expanding and reducing in a repeated manner, to form passage sections so that the passage section intersects the other passage section so as to communicate therewith, thus providing the braided passage structure. Even when a flowing relationship of the heat exchange fluids is based on any one of a parallel flowing system, a counter-flowing system and a cross flowing system, it is therefore possible to cause the heat exchange fluids to behave in flow in substantially the same manner to provide substantially the same heat transfer performance. In addition, even when the heat exchange fluids flow on the basis of any combination of the flowing directions, it is possible to make smoothly heat exchange with low pressure-loss and enhance degree of freedom in design of a heat exchanger, thus providing excellent versatility.

[0036] The heat exchange plate according to the embodiment of the present invention may have any desired structure, except for the heat transfer sections having the pattern of irregularity. More specifically, the heat ex-

change plate may be used as a heat exchange plate having a desired edge shape or a desired opening, for a plate-type heat exchanger in which the plates are welded together at their edges or for a plate-type heat exchanger in which the plates are combined together through gasket members provided between the adjacent two plates.

[0037] With respect to arrangement of the protrusions 11 and the recesses for defining the pattern of irregularity, in the heat exchange plate according to the embodiment of the present invention, the plate has a structure based on the matrix arrangement in which there are provided around one protrusion 11 or recess 12 four protrusions 11 or recesses 12 so as to be placed at regular intervals on the periphery through the transition curved portions 13. The present invention is not limited only to such an arrangement, and the plate may have, for example, a structure in which, on the assumption that one of the protrusions is surrounded by adjacent protrusions of the other protrusions and the adjacent protrusions are placed at regular intervals on a circle around the one protrusion and with the same central angle relative to the center of the one protrusion, three recesses are placed around one protrusion at regular intervals with the same central angle relative to the center of the one protrusion, and in addition, six protrusions are placed on the outer side of the three recesses at regular intervals with the same central angle relative thereto so that the recess is placed in the center of a triangle defined by the closest three protrusions, so as to form a staggered arrangement in the protrusions or recesses. The plate may have any desired type of structure with arrangement in which each of the main protrusions is combined with a predetermined number of adjacent protrusions in this manner. It is therefore possible to make precise adjustment so that the flow braided passages defined by the adjacent two plates have suitable heat transfer performance for the characteristic properties of the heat transfer fluids introduced into the passages.

[0038] In the heat exchange plate according to the above-described embodiment of the present invention, there is applied the pattern of irregularity in which the straight line along which the protrusions 31 are aligned is inclined at an angle of 45 degrees relative to the respective sides of the plate having the rectangular shape. However, the present invention is not limited only to such an embodiment, there may be applied the pattern of irregularity in which the straight line along which the protrusions 11 are aligned is in parallel with or perpendicular to the respective sides of the plate having the rectangular shape, or inclined at a predetermined angle relative thereto.

Claims

1. A heat exchange plate (10), which is formed of a metallic plate and has a predetermined pattern of irregularity, the heat exchange plate being placed on

another heat exchange plate having a same structure so as to come into contact with each other on a same side of the heat exchange plate to provide a pair of heat exchange plates, the pair of heat exchange plates being combined to one or more other pair of heat exchange plates integrally with each other to form a heat exchanger in which heat exchange is to be made between first and second heat exchange fluids that come into contact with opposite surfaces of the heat exchange plate, respectively, the heat exchange plate comprising:

a plurality of protrusions (11) that are placed in a predetermined arrangement on a surface of the metallic plate; and
a plurality of recesses (12) each of which is placed between two or more protrusions of said plurality of protrusions (11) on said surface of the metallic plate so as to dent in an opposite direction to a protruding direction of said protrusions (11), said plurality of protrusions (11) and said plurality of recesses (12) providing said predetermined pattern of irregularity;

wherein:

each of said protrusions (11) has a curved outer peripheral surface, one protrusion of said plurality of protrusions (11) is surrounded by adjacent protrusions of other protrusions, said adjacent protrusions being placed at regular intervals on a circle around said one protrusion and with a same central angle relative to a center of said one protrusion;
each of said recesses (12) has a curved inner peripheral surface that partially extends to the curved outer peripheral surface of said protrusions (11), said recesses (12) being placed in a predetermined arrangement that is deviated by a same pitch from the predetermined arrangement of said protrusions (11); and
said recesses provide on another surface of said metallic plate with a same configuration as said plurality of protrusions (11) and said protrusions provide on said surface of said metallic plate with a same configuration as said recesses (12), so as to provide on the opposite surfaces of the metallic plate with a same pattern of irregularity.

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

said protrusions (11) are placed on a basis of a matrix arrangement in which said protrusions are aligned at regular intervals on lines extending in two directions that are perpendicular to each other, and said recesses (12) are placed on a basis of a similar matrix arrangement to

said matrix arrangement of the protrusions (11), in which on recess of said plurality of recesses (12) is placed in a center of a square defined by four protrusions (11) that are adjacent to each other by a shortest distance;

said protrusions (11) and recesses (12) that respectively continue in diagonal lines of the metallic plate in the matrix arrangement in which the protrusions (11) and recesses (12) are alternated at the regular intervals have a sine wave shape in a cross section of the metallic plate; and a central portion between closest adjacent two protrusions (11) and a central portion between closest adjacent two recesses (12) are level with an intermediate height between a bottom (12a) of said recess (12) and a top (11a) of said protrusion (11).

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

said protrusions (11) and recesses (12) are alternated to form parallel rows that are in parallel with or perpendicular to sides of the metallic plate having a rectangular or square shape, thus providing the predetermined pattern of irregularity.

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

each of said protrusions (11) is provided at a top (11a) thereof with a flat surface having a predetermined area.

10

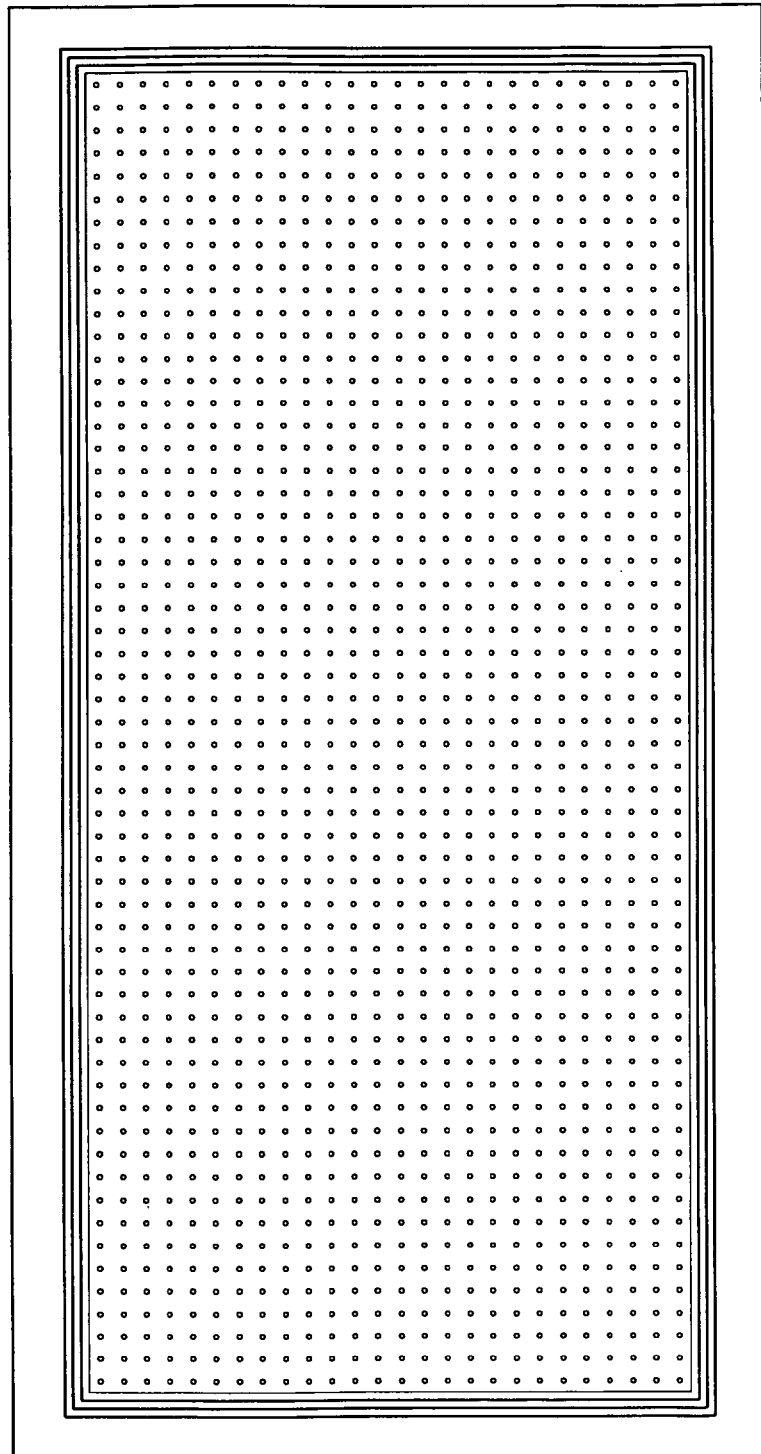


FIG.1

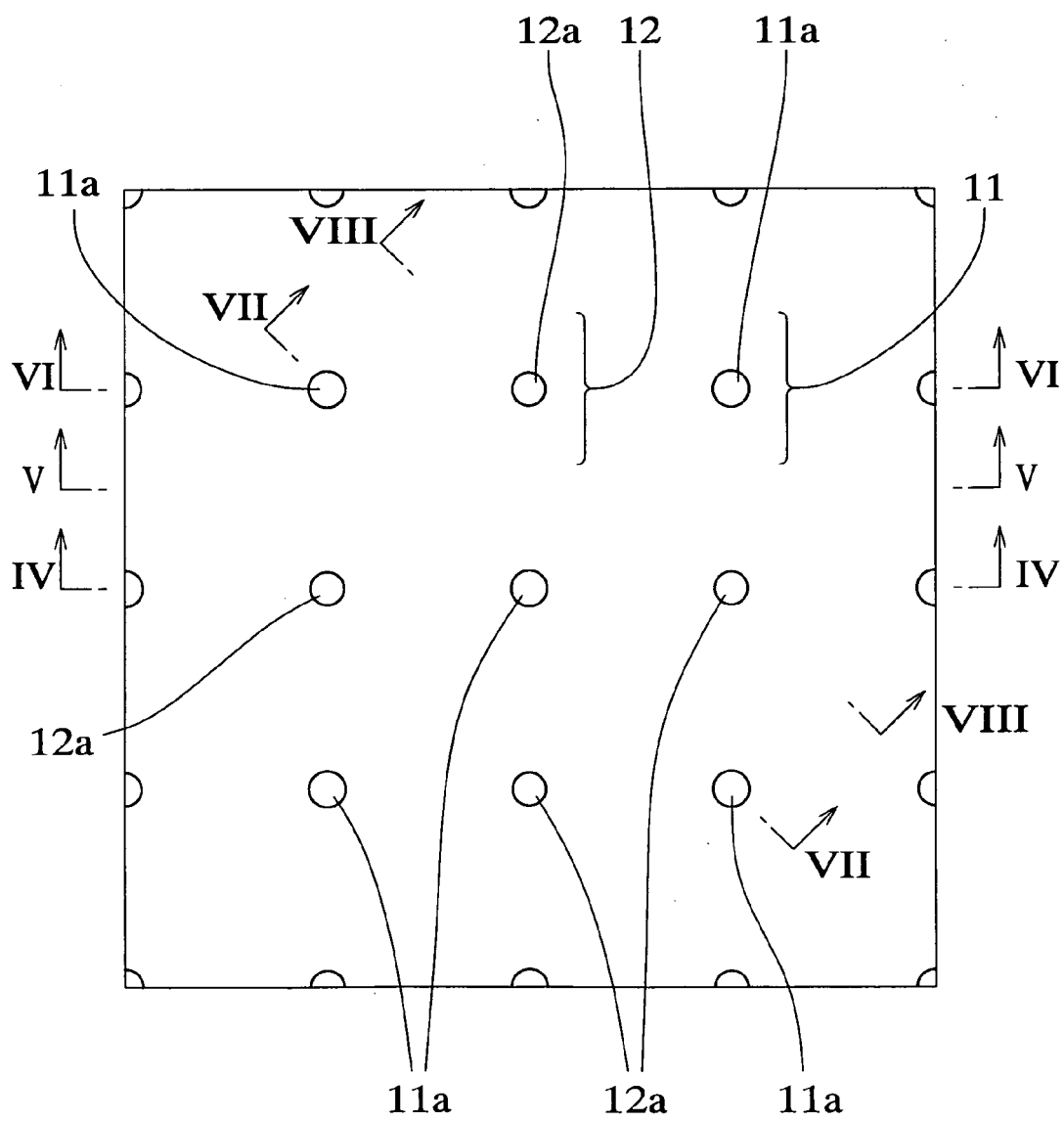


FIG.2

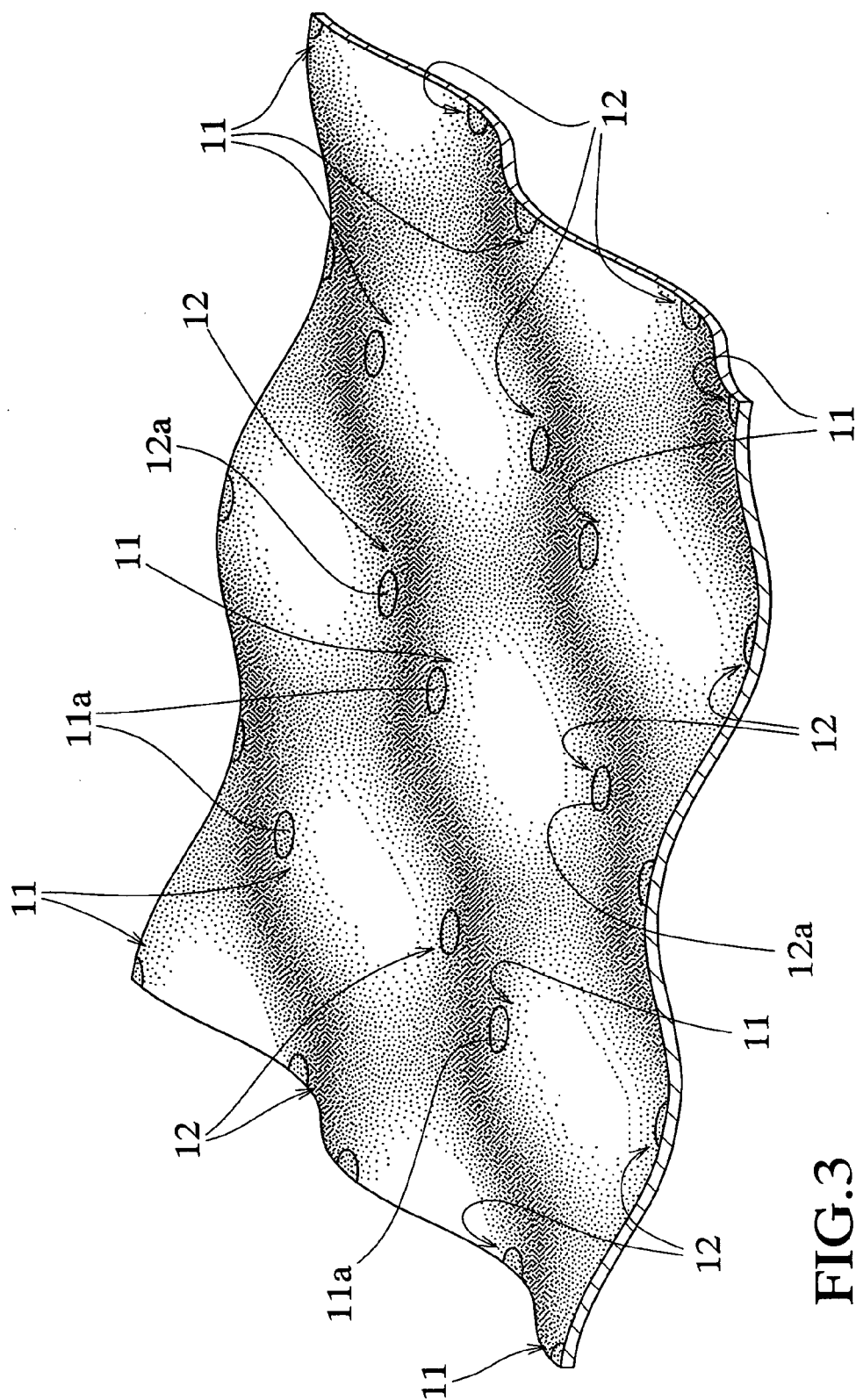


FIG.3

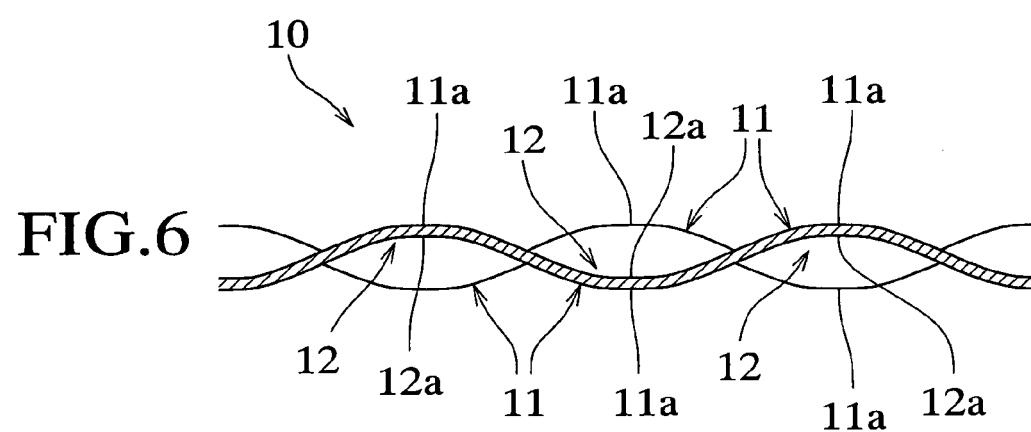
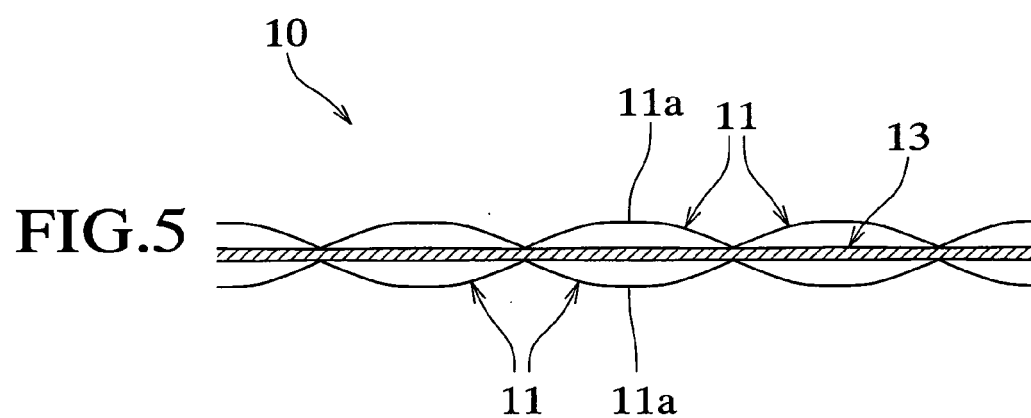
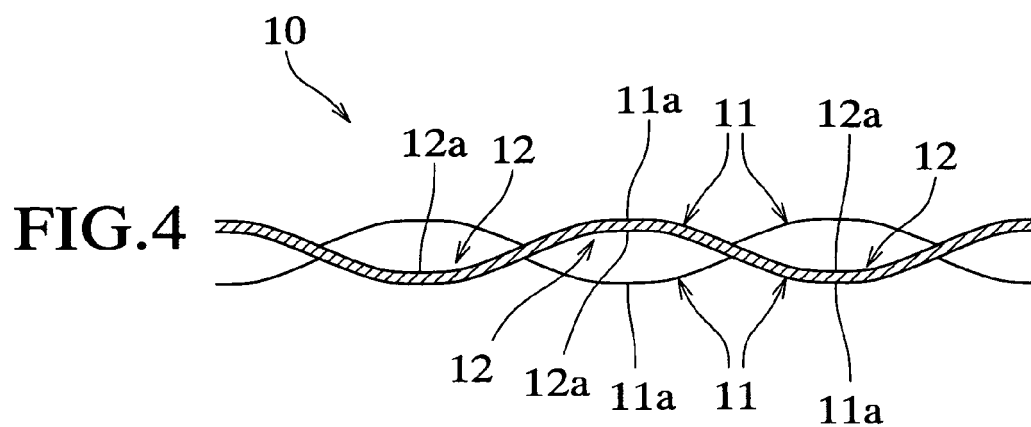


FIG.7

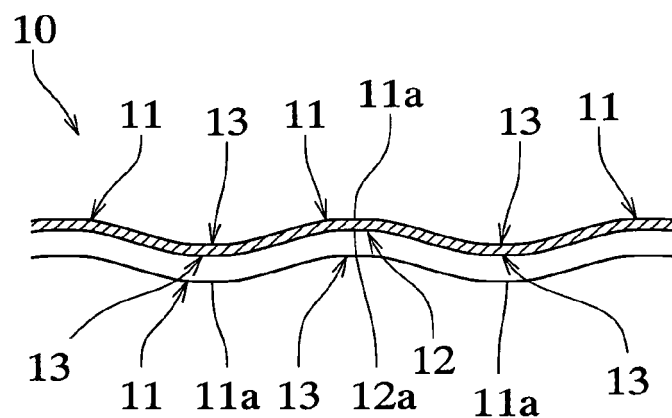


FIG.8

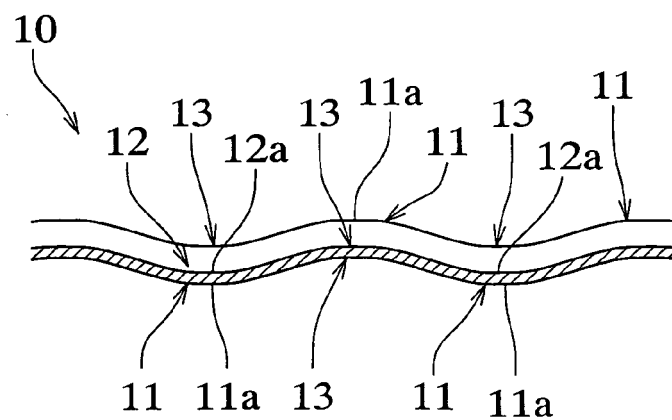


FIG.9

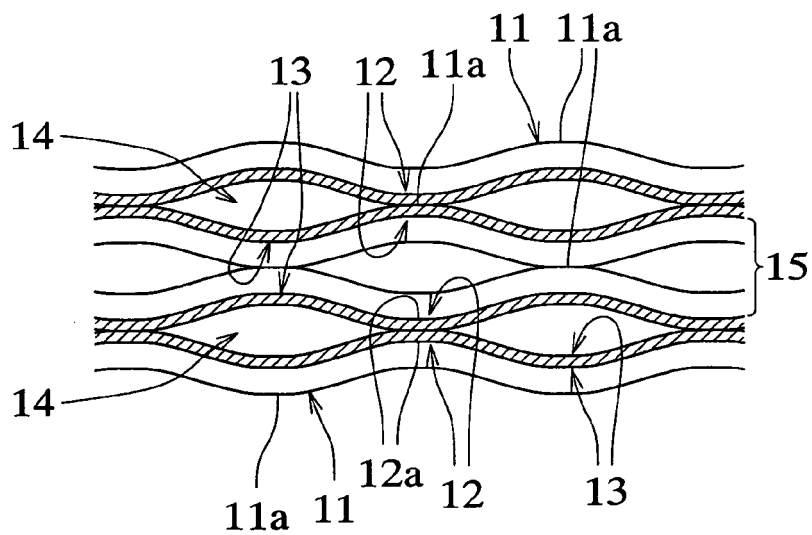


FIG.10

