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(54) **MICRO-CHANNEL STRUCTURE FOR HEAT EXCHANGER, AND INTEGRATED TYPE MICRO-CHANNEL HEAT EXCHANGER**

(57) The present invention discloses a micro-channel structure for a heat exchanger, and an integrated type micro-channel heat exchanger. The micro-channel structure is formed between multiple layers of heat exchange plates (1) arranged in a stacked manner, with a plurality of fin units (2) formed on the heat exchange plate (1), the fin units (2) are arranged uniformly into a plurality of fin unit groups (9) in the direction perpendicular to a flow direction of fluid, and the fin unit groups (9) are arranged in a staggered manner and spaced from one another by a distance in the flow direction of the fluid; a rear end of the fin unit (2) at the upstream side is arranged in an intermediate position between two adjacent fin units (2) at the downstream side; the fin unit (2) comprises at least two fins (21), with the adjacent fins (21) spaced from each other by a distance; and the fluid channels between the adjacent fin units (2) and between the adjacent fins (21) form the micro-channel structure. The integrated type micro-channel heat exchanger comprises multiple layers of heat exchange plates (1) arranged in a stacked manner, with the aforementioned micro-channel structure formed between the heat exchange plates (1).

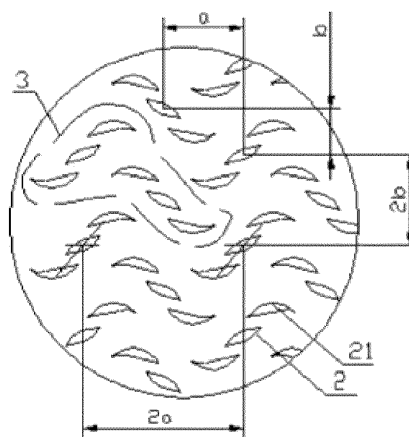


FIG. 2

Description

Technical Field

[0001] The present invention relates to a heat exchange apparatus for the purpose of heat exchange between two fluids, in particular, relates to a streamline type micro-channel structure and an integrated type micro-channel heat exchanger suitable for heat energy transfer between water and a cooling agent.

Background of the Invention

[0002] Currently, in the technical field of heat exchangers, micro-channel heat exchangers of small size, light weight and high compactness now render a new direction of research, development and application of heat exchangers

[0003] Almost all of the micro-channel heat exchangers for a heat pump system of prior arts are configured with flat aluminum tube section bars, in addition to inlets and outlets of cooling agents and working fluids, and thus are limited to branch-stream typed heat exchangers used for heat exchange between a cooling agent and the air. For instance, the micro-channel heat exchanger disclosed by Chinese Patent Literature CN102095285A is one of the aforementioned branch-stream type heat exchangers. The flat tubes for heat exchange are aluminum tube section bars, so they are of fixed dimensions. As there are constraints with respect to selection of hydraulic diameters of the micro-channels, it is difficult to get an aluminum tube section bar which is suitable for optimized heat design. Besides, limited by manufacture technology of aluminum tube section bars, the wall thickness between the micro-channels are unable to be made into a suitable dimension required for heat transfer (the wall is required to be very thin), thus, the micro-channel heat exchangers using flat tubes of aluminum tube section bars cannot be a development direction of the micro-channel heat exchanger technology.

[0004] With the development of micromachining technology, metal micro-channel heat exchangers machined by lithography, chemical or photoelectric etching, diamond cutting or wire-electrode cutting has become a new technology development direction of the present technical field. For instance, the micro-channel heat exchangers disclosed by Chinese Patent Literatures CN101509736A and CN201973962U are this type of heat exchangers. However, limited by machining and molding technology, this type of heat exchangers has disadvantages such as thick heat-exchange walls, inconvenience of assembly, monotonous connection means of inlets and outlets, etc. Wherein, the micro-channel heat exchanger disclosed by CN101509736A is formed by stacking heat-exchange units which comprise three layers including a cooling agent channel layer, a partition board layer and a working fluid channel layer, and it is required to machine three fluid channel layers of different

shapes and then to integrate them into a whole piece by atomic diffusion, which has complicated assembly processes and higher processing costs. In the micro-channel heat exchanger disclosed by CN201973962U, cooling agent channels and working fluid channels are formed between metal plates which have been stacked and bound together, at least one of the two opposed surfaces of adjacent metal plates is configured with alternately arranged cooling agent grooves and working fluid grooves, after the metal plates are stacked and bound together, the cooling agent grooves and working fluid grooves respectively form cooling agent channels and working fluid channels, and because the multiple layers of metal plates are bound together by atomic diffusion, each binding interface of the metal plates must have a width no less than 0.4mm in order to ensure overall binding strength of the heat exchanger, which leads to that the heat-exchange walls thereof are relatively thick and the heat-exchange capacity thereof is not able to meet the requirements. Most of micro-channel heat exchangers of prior arts, no matter whether it is a flat aluminum tube type or a compact type of micro-channel heat exchanger for heat exchange between water and a cooling agent, have internal channels that are basically straight channels with square-shaped or circular-shaped cross-sections. Although the micro-channels of this type of heat exchangers are able to enhance heat exchange, they cause increase of fluid pressure loss, and this type of micro-channel structure also does not take into consideration the influence of turbulence on heat transfer enhancement.

[0005] U.S. Patent Literature US7334631B2 and Japanese Patent Literature JP2006170549A both disclose a micro-channel heat exchanger, wherein, micro-channels of this micro-channel heat exchanger are alternately formed between multiple stacked layers of heat-exchange plates; a plurality of regularly arranged streamline type fins are provided on the heat-exchange plates; and the micro-channels are formed between the fins. Compared to heat exchangers with straight channels, this type of heat exchangers has an increased forced convection heat transfer coefficient as well as a reduced fluid pressure loss, however, for such a configuration, due to lack of micro structures which are able to facilitate phase transition of condensation or evaporation, the heat transfer performance still needs to be improved and the fluid flow resistance still needs to be reduced.

Summary of the Invention

[0006] Therefore, an objective of the present invention is to solve the problem that the micro-channel structure of the heat exchangers of prior arts is not optimally designed, causing relatively high fluid flow resistance and relatively poor heat exchange capacity, thus the present invention provides a micro-channel structure with a high forced convection heat transfer coefficient as well as low fluid flow resistance for a heat exchanger and an integrated type micro-channel heat exchanger comprising

the same.

[0007] In order to solve the above-mentioned technical problem, in accordance with a first aspect of the present invention, there is provided a micro-channel structure for a heat exchanger, wherein, the micro-channel structure is formed between multiple layers of heat exchange plates arranged in a stacked manner, with a plurality of fin units formed on the heat exchange plate, the fin units are arranged uniformly into a plurality of fin unit groups in the direction perpendicular to a flow direction of fluid, and the fin unit groups are arranged in a staggered manner and spaced from one another by a distance in the flow direction of the fluid; a rear end of a fin unit at the upstream side is arranged in an intermediate position between two adjacent fin units at the downstream side; the fin unit comprises at least two fins, with the adjacent fins spaced from each other by a distance; and the fluid channels between the adjacent fin units and between the adjacent fins form the micro-channel structure.

[0008] In an embodiment of the above-mentioned micro-channel structure, an external contour of the fin unit is rectilinear shaped or curvilinear shaped.

[0009] In an embodiment of the above-mentioned micro-channel structure, tilt directions of the adjacent fin unit groups relative to the flow direction of the fluid are opposite, and an intersection angle between each fin unit thereof and the flow direction of the fluid is $45^{\circ} \leq \alpha \leq 55^{\circ}$.

[0010] In an embodiment of the above-mentioned micro-channel structure, each two fin units adjacent along the flow direction of the fluid constitute a fin unit subgroup, with the two fin units thereof spaced from each other by a distance of $a \leq 2\text{mm}$ in the flow direction of the fluid and by a distance of $b \leq 2\text{mm}$ in the direction perpendicular to the flow direction of the fluid; two adjacent fin unit subgroups are spaced apart by a distance that is $\geq 2a$ in the flow direction of the fluid, and two adjacent fin unit subgroups are spaced apart by a distance that is $\geq 2b$ in the direction perpendicular to the flow direction of the fluid.

[0011] In an embodiment of the above-mentioned micro-channel structure, the fin unit has a length of $L \leq 2.5\text{mm}$ in the flow direction of the fluid and a width of $h \leq 1.5\text{mm}$ in the direction perpendicular to the flow direction of the fluid, and the fin has a thickness of $\delta \leq 0.5\text{mm}$.

[0012] In an embodiment of the above-mentioned micro-channel structure, the fins that form the fin unit include main edges which form an external contour of the fin unit and sub edges which adjoin the main edges, the sub edges of the adjacent fins are parallel to each other and spaced from each other by a distance of $0.05\text{mm} \leq t \leq 0.35\text{mm}$, and an intersection angle between each sub edge and the flow direction of the fluid is $0^{\circ} \leq \beta \leq 15^{\circ}$.

[0013] In an embodiment of the above-mentioned micro-channel structure, an external contour of the fin unit is an S-shaped curve with a straight middle segment, and the fin unit comprises a front fin, a rear fin and an intermediate fin which is parallelogram shaped and is arranged between the front fin and the rear fin.

[0014] In an embodiment of the above-mentioned micro-channel structure, an external contour of the fin unit is rectilinear shaped, and the fin unit comprises three parallelogram-shaped fins, with a circular arc transition segment at each obtuse angle of each of the parallelogram-shaped fins.

[0015] In an embodiment of the above-mentioned micro-channel structure, the micro-channel structure comprises a diversion segment, a heat exchange segment and a confluence segment arranged successively along the flow direction of the fluid, and the adjacent fin units of the diversion segment as well as those of the confluence segment are spaced apart by a larger distance in the flow direction of the fluid than the adjacent fin units of the heat exchange segment.

[0016] In an embodiment of the above-mentioned micro-channel structure, the fins on the heat exchange plate are preferably formed by light etching molding.

[0017] In accordance with a second aspect of the present invention, there is also provided an integrated type micro-channel heat exchanger, wherein, comprising multiple layers of heat exchange plates arranged in a stacked manner, with a plurality of fin units formed on the heat exchange plate, the fin units are arranged uniformly into a plurality of fin unit groups in the direction perpendicular to a flow direction of a fluid, and the fin unit groups are arranged in a staggered manner and spaced from one another by a distance in the flow direction of fluid; a rear end of a fin unit at the upstream side is arranged in an intermediate position between two adjacent fin units at the downstream side; the fin unit comprises at least two fins, with the adjacent fins spaced from each other by a distance; the fluid channels between the adjacent fin units and between the adjacent fins form a micro-channel structure; working fluid micro-channels and cooling agent micro-channels are alternately arranged in the direction perpendicular to a plate plane of the heat exchange plates, wherein a diversion segment and an inlet in communication with a fluid inflow pipeline are provided in the micro-channel structure at the upstream side of the flowing fluid, and a confluence segment and an outlet in communication with a fluid outflow pipeline are provided in the micro-channel structure at the downstream side of the flowing fluid; the inlets and the outlets of multiple layers of the working fluid micro-channels are intercommunicated; and the inlets and the outlets of multiple layers of the cooling agent micro-channels are intercommunicated.

[0018] In an embodiment of the above-mentioned integrated type micro-channel heat exchanger, the fins are formed on one side of each heat exchange plate, and the fin-side of a heat exchange plate and the plane-side of another adjacent heat exchange plate are combined to form the micro-channel structure.

[0019] In an embodiment of the above-mentioned integrated type micro-channel heat exchanger, the fins are formed on one side of each heat exchange plate, and the fin-sides of adjacent heat exchange plates are com-

bined to form the micro-channel structure.

[0020] In an embodiment of the above-mentioned integrated type micro-channel heat exchanger, the fins are formed on both sides of each heat exchange plate, with fins on one side forming the working fluid micro-channels and fins on the other side forming the cooling agent micro-channels.

[0021] In an embodiment of the above-mentioned integrated type micro-channel heat exchanger, an external contour of the fin unit is rectilinear shaped or curvilinear shaped, and an intersection angle between each fin unit and the flow direction of the fluid is $45^\circ \leq \alpha \leq 55^\circ$.

[0022] In an embodiment of the above-mentioned integrated type micro-channel heat exchanger, an external contour of the fin unit is an S-shaped curve with a straight middle segment, and the fin unit comprises two fins which are spaced from each other by a distance of $0.05\text{mm} \leq t \leq 0.35\text{mm}$; an intersection angle between each intermediate edge of the fins and the flow direction of the fluid is $0^\circ \leq \beta \leq 15^\circ$.

[0023] In an embodiment of the above-mentioned integrated type micro-channel heat exchanger, an external contour of the fin unit is rectilinear shaped, and the fin unit comprises three parallelogram-shaped fins, with a circular arc transition segment at each obtuse angle of each of the parallelogram-shaped fins.

[0024] In an embodiment of the above-mentioned integrated type micro-channel heat exchanger, the inlets are respectively arranged at opposite lateral sides relative to the diversion segment, and the outlets are respectively arranged at opposite lateral sides relative to the confluence segment.

[0025] In an embodiment of the above-mentioned integrated type micro-channel heat exchanger, the fins on the heat exchange plate are formed by light etching molding. In an embodiment of the above-mentioned integrated type micro-channel heat exchanger, the multiple layers of heat exchange plates are bound into a whole piece by atomic diffusion.

[0026] Compared to the prior art, the aforementioned technical solution of the present invention has the following advantages:

(1) In the micro-channel structure of the present invention, the fin unit comprises at least two fins, so that, for micro-channels with the same length and width, the micro-channels of the present invention has a heat exchange area which is increased by about 55% upon that of the straight channels and is increased by 4.8%-7.5% upon that of the streamline type micro-channels of prior arts; the configuration of multiple fins within a fin unit increases its contact area with the fluid, so as to form more evaporation nuclei, which is more favorable for phase change heat transfer of the cooling agent; besides, the configuration of each discontinuous fin unit is able to increase turbulence of the fluid, and for fluid condition of a low Reynolds number, such turbulence is

able to enhance heat exchange between the cooling agent and the working fluid with less increase of the fluid flow resistance. Therefore, for heat exchangers with this type of micro-channel structure, the forced convection heat transfer coefficient is greatly increased, and the heat exchange capacity is enhanced.

(2) In the present invention, the fins that compose a fin unit are spaced apart from each other, which facilitates dispersing as well as mixing of the fluid, avoids vortex caused by continuous angled fold lines as in the fluid micro-channels formed by gapless streamline type fins of prior arts, and thus reduces the fluid flow resistance.

(3) The fin unit of the present invention has an external contour which is rectilinear shaped or curvilinear shaped, and is formed by light etching molding, so that the heat-exchange walls between adjacent micro-channels can be machined to a thickness less than 0.12mm, and thus the heat passage capacity of the heat exchanger is further increased. Furthermore, the fin-side of a heat exchange plate and the plane-side of another adjacent heat exchange plate are combined or the fin-sides of adjacent heat exchange plates are combined to form the micro-channel structure, which further reduces the heat-exchange wall thickness under the condition of ensuring overall strength of the heat exchanger, and thus the heat transfer ability of the heat exchanger is further increased.

(4) In order to acquire the difference with fluid pressure loss between the micro-channel structure of the present invention and the micro-channel structure with gapless fins of prior arts, the applicant carried out a comparison experiment using the micro-channel structures of Embodiment 1 and 2 of the present invention as well as the micro-channel structure formed by gapless streamline type fins of prior arts, and it can be seen from the test results in FIG. 13 that, the fluid pressure loss ΔP of the micro-channel structure of the present invention is reduced, wherein, the configuration of micro-channel structure of Embodiment 1 has a fluid pressure loss ΔP which is reduced by 30.8% upon that of the micro-channel structure of prior arts, and the configuration of micro-channel structure of Embodiment 2 has a fluid pressure loss ΔP which is reduced by 40% upon that of the micro-channel structure of prior arts.

(5) The integrated type micro-channel heat exchanger of the present invention consists of heat exchange plates with working fluid micro-channels and heat exchange plates with cooling agent micro-channels, which only needs two types of heat exchange plates, thus compared to the configuration of heat-ex-

change units consisting of three layers of different plates, because the plates needed are less and the assembly process is simple, the manufacturing cost is reduced.

(6) The integrated type micro-channel heat exchanger of the present invention is provided with two inlets at opposite lateral sides relative to the diversion segment as well as two outlets at opposite lateral sides relative to the confluence segment, and by this configuration it is convenient for the user to select connecting pipelines according to different mounting positions.

Brief Description of the Drawings

[0027] The appended drawings constituting a part of the present application are used for facilitating further understanding of the present invention, and together with the exemplary embodiments and their descriptions which are used for explaining the present invention they do not constitute improper restriction to the present invention. In the appended drawings:

FIG. 1 shows an overall structural view of a micro-channel structure for a heat exchanger of the present invention;

FIG. 2 shows a structural view of relative positions between fin units of Embodiment 1 of the present invention;

FIG. 3 shows a structural view of a single fin unit of Embodiment 1 of the present invention;

FIG. 4 shows a structural view of relative positions between fin units of Embodiment 2 of the present invention;

FIG. 5 shows a structural view of a single fin unit of Embodiment 2 of the present invention;

FIG. 6 shows a stereogram of an integrated type micro-channel heat exchanger of the present invention;

FIG. 7 shows a structural view of a heat exchange plate forming the cooling agent channel layer of the integrated type micro-channel heat exchanger of the present invention;

FIG. 8 shows a structural view of a heat exchange plate forming the working fluid channel layer of the integrated type micro-channel heat exchanger of the present invention;

FIG. 9 shows a structural view of relative positions between fin units of Embodiment 4 of the present invention;

FIG. 10 shows a structural view of a single fin unit of Embodiment 4 of the present invention;

FIG. 11 shows a structural view of relative positions between fin units of Embodiment 5 of the present invention;

FIG. 12 shows a structural view of a single fin unit of Embodiment 5 of the present invention; and

FIG. 13 shows a comparison chart of performances of micro-channel structures of the present invention and of the prior art.

[0028] The marking numerals in the drawings are indicated as follows:

1-heat exchange plate, 2-fin unit, 21-fin, 211-front fin, 212-intermediate fin, 213-rear fin, 214-main edge, 215-sub edge, 3-fin unit subgroup, 4-diversion segment, 5-confluence segment, 6-heat exchange segment, 7-inlet, 8-outlet, 9-fin unit group

Detailed Description of Embodiments

[0029] The technical solution of the present invention is described in details below, in conjunction with specific embodiments of the present invention. The following specific embodiments are only to be considered as illustrative and not restrictive for the present invention, the embodiments of the present invention and the technical features therein may be combined with one another, and the present invention may be implemented in various ways that are limited and covered by the claims.

Embodiment 1

[0030] FIG. 1 shows a novel micro-channel structure for a heat exchanger of the present invention, wherein, the micro-channel structure is formed between multiple layers of heat exchange plates 1 arranged in a stacked manner, with a plurality of fin units 2 formed on the heat exchange plate 1, the fin units 2 are arranged uniformly into a plurality of fin unit groups 9 in the direction perpendicular to a flow direction of fluid, and the fin unit groups 9 are arranged in a staggered manner and spaced from one another by a distance in the flow direction of the fluid; and a rear end of a fin unit 2 at the upstream side is arranged in an intermediate position between two adjacent fin units 2 at the downstream side. The intermediate position mentioned in the present invention refers to any position between the two adjacent fin units 2 at the downstream side, including the case that the rear end of the fin unit 2 at the upstream side extends into an inside position between the two adjacent fin units 2 at the downstream side, as well as the case that the rear end of the fin unit 2 at the upstream side stays at an outside position between the two adjacent fin units 2 at the downstream side. The fin unit 2 comprises at least two fins 21, with the adjacent fins 21 spaced from each other by a distance; and the fluid channels between the adjacent fin units 2 and between the adjacent fins 21 form the micro-channel structure. Therefore, the heat exchange area of the micro-channel structure for a heat exchanger of the present invention is greatly increased upon the heat exchange area of micro-channel structures of prior arts.

[0031] The fluid flow direction is shown by Direction V in FIG. 1 which indicates a direction from the entrance

to the exit of the micro-channel structure.

[0032] An external contour of the fin unit 2 is curvilinear shaped, specifically in this embodiment, the external contour of the fin unit 2 is an S-shaped curve with a straight middle segment, as shown in FIG. 2 and FIG. 3, it comprises a front fin 211, a rear fin 213 and an intermediate fin 212 which is parallelogram shaped and is arranged between the front fin 211 and the rear fin 212. Tilt directions of the adjacent fin unit groups 9 relative to the flow direction of the fluid are opposite, and an intersection angle between each fin unit 2 thereof and the flow direction of the fluid is $\alpha=50^\circ$.

[0033] As shown in FIG. 2, each two fin units 2 adjacent along the flow direction of the fluid constitute a fin unit subgroup 3, wherein, the two fin units 2 thereof are spaced from each other by a distance of $a=2\text{mm}$ in the flow direction of the fluid and by a distance of $b=1\text{mm}$ in the direction perpendicular to the flow direction of the fluid; two adjacent fin unit subgroups 3 are spaced apart by a distance of 4mm in the flow direction of the fluid, and two adjacent fin unit subgroups 3 are spaced apart by a distance of 2mm in the direction perpendicular to the flow direction of the fluid.

[0034] As shown in FIG. 3, the fin unit 2 has a length of $L=2.5\text{mm}$ in the flow direction of the fluid and a width of $h=1.5\text{mm}$ in the direction perpendicular to the flow direction of the fluid, and the fin has a thickness of $\delta=0.35\text{mm}$.

[0035] Each of the fins 21 that form the fin unit 2 include main edges 214 which form an external contour of the fin unit and sub edges 215 which adjoin the main edges 214, the sub edges 215 of the adjacent fins 21 are parallel to each other and spaced from each other by a distance of $t=0.35\text{mm}$, and an intersection angle between each sub edge 215 and the flow direction of the fluid is $\beta=15^\circ$.

[0036] The micro-channel structure comprises a diversion segment 4, a heat exchange segment 6 and a confluence segment 5 arranged successively along the flow direction of the fluid, and the adjacent fin units 2 of the diversion segment 4 as well as those of the confluence segment 5 are spaced apart by a larger distance in the flow direction of the fluid than the adjacent fin units 2 of the heat exchange segment 6. The fluid flows into each single plate layer through the entrance segment, enters the diversion segment where it is dispersed uniformly, undergoes heat exchange in the heat exchange segment, enters the confluence segment to converge, and then flows out through the exit segment.

[0037] The fins 21 on the heat exchange plate 1 are formed by light etching molding.

Embodiment 2

[0038] FIG. 4 and FIG. 5 show another micro-channel structure of the present invention which is substantially consistent with the micro-channel structure of Embodiment 1, except for the difference with the shape of the fin unit.

[0039] An external contour of the fin unit 2 is rectilinear shaped, specifically in this embodiment, the shown fin unit 2 comprises three parallelogram-shaped fins 21, with a circular arc transition segment at each obtuse angle of each of the parallelogram-shaped fins 21. Such a micro-channel structure avoids vortex that is formed by continuous streamline, so as to reduce the fluid pressure loss caused by flow resistance. An intersection angle between the fin unit 2 and the flow direction of the fluid is $\alpha=45^\circ$.

[0040] Wherein, as shown in FIG. 4, two adjacent fin units 2 are spaced from each other by a distance of $a=1\text{mm}$ in the flow direction of the fluid and by a distance of $b=2\text{mm}$ in the direction perpendicular to the flow direction of the fluid; two adjacent fin unit subgroups 3 are spaced apart by a distance of 3mm in the flow direction of the fluid, and two adjacent fin unit subgroups 3 are spaced apart by a distance of 5mm in the direction perpendicular to the flow direction of the fluid.

[0041] As shown in FIG. 5, the fin unit 2 has a length of $L=2.3\text{mm}$ in the flow direction of the fluid and a width of $h=1.3\text{mm}$ in the direction perpendicular to the flow direction of the fluid, and the fin has a thickness of $\delta=0.5\text{mm}$.

[0042] The sub edges 215 of the adjacent fins 21 are spaced from each other by a distance of $t=0.2\text{mm}$, and an intersection angle between each sub edge 215 and the flow direction of the fluid is $\beta=10^\circ$.

Embodiment 3

[0043] The micro-channel structure of this embodiment is substantially consistent with Embodiment 2, except for the difference with the arranged positions and dimension parameters of the fins.

[0044] Wherein, as shown in FIG. 4, an intersection angle between the fin unit 2 and the flow direction of the fluid is $\alpha=55^\circ$. Two adjacent fin units 2 are spaced from each other by a distance of $a=1.5\text{mm}$ in the flow direction of the fluid and by a distance of $b=1.5\text{mm}$ in the direction perpendicular to the flow direction of the fluid; two adjacent fin unit subgroups 3 are spaced apart by a distance of 3mm in the flow direction of the fluid, and two adjacent fin unit subgroups 3 are spaced apart by a distance of 4mm in the direction perpendicular to the flow direction of the fluid.

[0045] As shown in FIG. 5, the fin unit 2 has a length of $L=2\text{mm}$ in the flow direction of the fluid and a width of $h=1\text{mm}$ in the direction perpendicular to the flow direction of the fluid, and the fin has a thickness of $\delta=0.25\text{mm}$.

[0046] The sub edges 215 of the adjacent fins 21 are spaced from each other by a distance of $t=0.05\text{mm}$, and an intersection angle between each sub edge 215 and the flow direction of the fluid is $\beta=0^\circ$.

[0047] In other embodiments, according to different design requirements, the fin unit 2 of the present invention might alternatively comprise two, four or more of the fins 21. Moreover, the curvilinear shape of the external contour of the fin unit might alternatively be a part of a

sinusoidal curve, a circle, an ellipse or a parabola curve.

Embodiment 4

[0048] FIG. 6 shows an integrated type micro-channel heat exchanger of the present invention which comprises multiple layers of heat exchange plates 1 arranged in a stacked manner, with a plurality of fin units 2 formed on the heat exchange plate 1, the fin units 2 are arranged uniformly into a plurality of fin unit groups 9 in the direction perpendicular to a flow direction of a fluid, and the fin unit groups 9 are arranged in a staggered manner and spaced from one another by a distance in the flow direction of fluid; a rear end of a fin unit 2 at the upstream side is arranged in an intermediate position between two adjacent fin units 2 at the downstream side. The intermediate position mentioned in the present invention refers to any position between the two adjacent fin units 2 at the downstream side, including the case that the rear end of the fin unit 2 at the upstream side extends into an inside position between the two adjacent fin units 2 at the downstream side, as well as the case that the rear end of the fin unit 2 at the upstream side stays at an outside position between the two adjacent fin units 2 at the downstream side. The fin unit 2 comprises at least two fins 21, with the adjacent fins 21 spaced from each other by a distance; the fluid channels between the adjacent fin units 2 and between the adjacent fins 21 form a micro-channel structure. Therefore, the heat exchange area of the micro-channel structure for the heat exchanger of the present invention is greatly increased upon the heat exchange area of micro-channel structures of prior arts. Working fluid (Fluid B in FIG. 6) micro-channels and cooling agent (Fluid A in FIG. 6) micro-channels are alternately arranged in the direction perpendicular to a plate plane of the heat exchange plates 1, wherein a diversion segment 4 and an inlet 7 in communication with a fluid inflow pipeline are provided in the micro-channel structure at the upstream side of the flowing fluid, and a confluence segment 5 and an outlet 8 in communication with a fluid outflow pipeline are provided in the micro-channel structure at the downstream side of the flowing fluid; the inlets 7 and the outlets 8 of multiple layers of the working fluid micro-channels are intercommunicated; and the inlets 7 and the outlets 8 of multiple layers of the cooling agent micro-channels are intercommunicated.

[0049] The fluid flow direction is shown by Direction V in FIG. 7 which indicates a direction from the entrance to the exit of the micro-channel structure.

[0050] In this embodiment, the fins 21 are formed on one side of each heat exchange plate 1, and the fin-side of a heat exchange plate 1 and the plane-side of another adjacent heat exchange plate 1 are combined to form the micro-channel structure. The heat exchange plate 1 are formed by light etching molding, and adjacent heat exchange plates 1 are bound into a whole piece by atomic diffusion. FIG. 7 shows the heat exchange plate 1 of a cooling agent channel layer thereof, and FIG. 8 shows

the heat exchange plate 1 of a working fluid channel layer thereof. Wherein, the inlets 7 of the working fluid channel layer are respectively arranged at opposite lateral sides relative to the diversion segment 4, and the outlets 8 of the working fluid channel layer are respectively arranged at opposite lateral sides relative to the confluence segment 5, so as to accommodate mounting location requirement of different pipelines.

[0051] An external contour of the fin unit 2 is curvilinear shaped, specifically in this embodiment, the external contour of the fin unit 2 is an S-shaped curve with a straight middle segment, as shown in FIG. 9 and FIG. 10, the fin unit 2 comprises two fins 21 which are spaced from each other by a distance of $t=0.35\text{mm}$, and an intersection angle between each intermediate edge of the fins 21 and the flow direction of the fluid is $\beta=15^\circ$.

[0052] Tilt directions of the adjacent fin unit groups 9 relative to the flow direction of the fluid are opposite, and an intersection angle between each fin unit 2 thereof and the flow direction of the fluid is $\alpha=55^\circ$.

[0053] As shown in FIG. 9, each two fin units 2 adjacent along the flow direction of the fluid constitute a fin unit subgroup 3, wherein, the two fin units 2 thereof are spaced from each other by a distance of $a=2\text{mm}$ in the flow direction of the fluid and by a distance of $b=1\text{mm}$ in the direction perpendicular to the flow direction of the fluid; two adjacent fin unit subgroups 3 are spaced apart by a distance of 4mm in the flow direction of the fluid, and two adjacent fin unit subgroups 3 are spaced apart by a distance of 2mm in the direction perpendicular to the flow direction of the fluid.

[0054] As shown in FIG. 10, the fin unit 2 has a length of $L=2.5\text{mm}$ in the flow direction of the fluid and a width of $h=1.5\text{mm}$ in the direction perpendicular to the flow direction of the fluid, and the fin has a thickness of $\delta=0.5\text{mm}$.

[0055] Each of the two fluids flowing through the integrated type micro-channel heat exchanger has a flow direction at the entrance segment or at the exit segment which is perpendicular to its flow direction in the heat exchange segment. The cooling agent fluid flows in through its inlet 7, undergoes dispersion in its diversion segment 4 and is then dispersed into the inner cavity of the heat exchange plate 1 with micro-channels for cooling agent fluid; the working fluid flows in through its inlet 7, undergoes dispersion in its diversion segment 4 and is then dispersed into the inner cavity of the heat exchange plate 1 with micro-channels for working fluid; these two fluids undergo heat exchange in the heat exchange segments 6, respectively converge in the confluence segments 5 for respective fluid and then flow out respectively through the outlet 8 for cooling agent fluid and the outlet 8 for working fluid. The inlet for working fluid and the outlet for working fluid on the other lateral side are reserved as spare, for adaption of different ways of connection.

Embodiment 5

[0056] The integrated type micro-channel heat exchanger of this embodiment is substantially consistent with Embodiment 4, except for the difference with the shape of the fin unit.

[0057] An external contour of the fin unit 2 of this embodiment is rectilinear shaped, and an intersection angle between each fin unit and the flow direction of the fluid is $\alpha=45^\circ$. Specifically in this embodiment, the fin unit 2 comprises three parallelogram-shaped fins 21, with a circular arc transition segment at each obtuse angle of each of the parallelogram-shaped fins 21. Such a micro-channel structure avoids vortex that is formed by continuous streamline, so as to reduce the fluid pressure loss caused by flow resistance.

[0058] Wherein, as shown in FIG. 11, two adjacent fin units 2 are spaced from each other by a distance of $a=1$ mm in the flow direction of the fluid and by a distance of $b=0.5$ mm in the direction perpendicular to the flow direction of the fluid; two adjacent fin unit subgroups 3 are spaced apart by a distance of 3 mm in the flow direction of the fluid, and two adjacent fin unit subgroups 3 are spaced apart by a distance of 2 mm in the direction perpendicular to the flow direction of the fluid.

[0059] As shown in FIG. 12, the fin unit 2 has a length of $L=2.3$ mm in the flow direction of the fluid and a width of $h=1.3$ mm in the direction perpendicular to the flow direction of the fluid, and the fin has a thickness of $\delta=0.5$ mm. The sub edges of the adjacent fins 21 are spaced from each other by a distance of $t=0.2$ mm, and an intersection angle between each sub edge and the flow direction of the fluid is $\beta=10^\circ$.

Embodiment 6

[0060] The integrated type micro-channel heat exchanger of this embodiment is substantially consistent with Embodiment 5, except for the difference with the arranged positions and dimension parameters of the fins.

[0061] Wherein, as shown in FIG. 11, an intersection angle between the fin unit 2 and the flow direction of the fluid is $\alpha=55^\circ$. Two adjacent fin units 2 are spaced from each other by a distance of $a=1.5$ mm in the flow direction of the fluid and by a distance of $b=1.5$ mm in the direction perpendicular to the flow direction of the fluid; two adjacent fin unit subgroups 3 are spaced apart by a distance of 3 mm in the flow direction of the fluid, and two adjacent fin unit subgroups 3 are spaced apart by a distance of 4 mm in the direction perpendicular to the flow direction of the fluid.

[0062] As shown in FIG. 12, the fin unit 2 has a length of $L=2$ mm in the flow direction of the fluid and a width of $h=1$ mm in the direction perpendicular to the flow direction of the fluid, and the fin has a thickness of $\delta=0.25$ mm. The sub edges of the adjacent fins 21 are spaced from each other by a distance of $t=0.05$ mm, and an intersection angle between each sub edge and the flow direction of the

fluid is $\beta=0^\circ$.

[0063] In other embodiments, according to different design requirements, a fin unit 2 of the present invention might alternatively comprise four or more of the fins 21. Moreover, the curvilinear shape of the external contour of the fin unit might alternatively be a part of a sinusoidal curve, a circle, an ellipse or a parabola curve.

[0064] In other embodiments, the fins 21 might alternatively be formed on one side of each heat exchange plate 1, the fin-sides of adjacent heat exchange plates 1 are combined to form the micro-channel structure for one fluid, and the micro-channel structure for the other fluid is also formed on the heat exchange plates at the combined fin-sides. The two kinds of fluid micro-channels are alternately arranged to form the heat exchanger.

[0065] In other embodiments, the fins 21 might alternatively be formed on both sides of each heat exchange plate 1, with fins 21 on one side forming the working fluid micro-channels and fins 21 on the other side forming the cooling agent micro-channels. Multiple layers of the heat exchange plates 1 are stacked to form the heat exchanger.

[0066] In other embodiments, for adaption of different ways of connection, the inlets 7 of the cooling agent channel layer are respectively arranged at opposite lateral sides relative to the diversion segment 4, and the outlets 8 of the cooling agent channel layer are respectively arranged at opposite lateral sides relative to the confluence segment 5.

[0067] The aforementioned embodiments are merely some preferred embodiments of the present invention which are not intended for restricting the present invention. For those skilled in the art, various changes and modifications can be made to the present invention. Within the spirit and scope of the present invention, any changes, equivalent alternatives, and modifications are intended to be embraced within the protection scope of the present invention.

Claims

1. A micro-channel structure for a heat exchanger, **characterized in that**, the micro-channel structure is formed between multiple layers of heat exchange plates (1) arranged in a stacked manner, with a plurality of fin units (2) formed on the heat exchange plate (1), the fin units (2) are arranged uniformly into a plurality of fin unit groups (9) in the direction perpendicular to a flow direction of fluid, and the fin unit groups (9) are arranged in a staggered manner and spaced from one another by a distance in the flow direction of the fluid; a rear end of a fin unit (2) at the upstream side is arranged in an intermediate position between two adjacent fin units (2) at the downstream side; the fin unit (2) comprises at least two fins (21), with the adjacent fins (21) spaced from each other by a distance; and the fluid channels between the

adjacent fin units (2) and between the adjacent fins (21) form the micro-channel structure.

2. The micro-channel structure of claim 1, **characterized in that**, an external contour of the fin unit (2) is rectilinear shaped or curvilinear shaped. 5
3. The micro-channel structure of claim 1 or 2, **characterized in that**, tilt directions of the adjacent fin unit groups (9) relative to the flow direction of the fluid are opposite, and an intersection angle between each fin unit (2) thereof and the flow direction of the fluid is $45^\circ \leq \alpha \leq 55^\circ$. 10
4. The micro-channel structure of any of claims 1-3, **characterized in that**, each two fin units (2) adjacent along the flow direction of the fluid constitute a fin unit subgroup (3), with the two fin units (2) thereof spaced from each other by a distance of $a \leq 2\text{mm}$ in the flow direction of the fluid and by a distance of $b \leq 2\text{mm}$ in the direction perpendicular to the flow direction of the fluid; two adjacent fin unit subgroups (3) are spaced apart by a distance that is $\geq 2a$ in the flow direction of the fluid, and two adjacent fin unit subgroups (3) are spaced apart by a distance that is $\geq 2b$ in the direction perpendicular to the flow direction of the fluid. 15 20 25
5. The micro-channel structure of any of claims 1-4, **characterized in that**, the fin unit (2) has a length of $L \leq 2.5\text{mm}$ in the flow direction of the fluid and a width of $h \leq 1.5\text{mm}$ in the direction perpendicular to the flow direction of the fluid, and the fin (21) has a thickness of $\delta \leq 0.5\text{mm}$. 30 35
6. The micro-channel structure of any of claims 1-5, **characterized in that**, the fins (21) that form the fin unit (2) include main edges (214) which form an external contour of the fin unit (2) and sub edges (215) which adjoin the main edges (214), the sub edges (215) of the adjacent fins (21) are parallel to each other and spaced from each other by a distance of $0.05\text{mm} \leq t \leq 0.35\text{mm}$, and an intersection angle between each sub edge (215) and the flow direction of the fluid is $0^\circ \leq \beta \leq 15^\circ$. 40 45
7. The micro-channel structure of any of claims 1-6, **characterized in that**, an external contour of the fin unit (2) is an S-shaped curve with a straight middle segment, and the fin unit (2) comprises a front fin (211), a rear fin (213) and an intermediate fin (212) which is parallelogram shaped and is arranged between the front fin (211) and the rear fin (213). 50
8. The micro-channel structure of any of claims 1-6, **characterized in that**, an external contour of the fin unit (2) is rectilinear shaped, and the fin unit (2) comprises three parallelogram-shaped fins (21), with a 55

circular arc transition segment at each obtuse angle of each of the parallelogram-shaped fins (21).

9. The micro-channel structure of any of claims 1-8, **characterized in that**, the micro-channel structure comprises a diversion segment (4), a heat exchange segment (6) and a confluence segment (5) arranged successively along the flow direction of the fluid, and the adjacent fin units (2) of the diversion segment (4) as well as those of the confluence segment (5) are spaced apart by a larger distance in the flow direction of the fluid than the adjacent fin units (2) of the heat exchange segment (6).
10. The micro-channel structure of any of claims 1-9, **characterized in that**, the fins (21) on the heat exchange plate (1) are formed by light etching molding.
11. An integrated type micro-channel heat exchanger, **characterized in that**, comprising multiple layers of heat exchange plates (1) arranged in a stacked manner, with a plurality of fin units (2) formed on the heat exchange plate (1), the fin units (2) are arranged uniformly into a plurality of fin unit groups (9) in the direction perpendicular to a flow direction of a fluid, and the fin unit groups (9) are arranged in a staggered manner and spaced from one another by a distance in the flow direction of fluid; a rear end of a fin unit (2) at the upstream side is arranged in an intermediate position between two adjacent fin units (2) at the downstream side; the fin unit (2) comprises at least two fins (21), with the adjacent fins (21) spaced from each other by a distance; the fluid channels between the adjacent fin units (2) and between the adjacent fins (21) form a micro-channel structure; working fluid micro-channels and cooling agent micro-channels are alternately arranged in the direction perpendicular to a plate plane of the heat exchange plates (1), wherein a diversion segment (4) and an inlet (7) in communication with a fluid inflow pipeline are provided in the micro-channel structure at the upstream side of the flowing fluid, and a confluence segment (5) and an outlet (8) in communication with a fluid outflow pipeline are provided in the micro-channel structure at the downstream side of the flowing fluid; the inlets (7) and the outlets (8) of multiple layers of the working fluid micro-channels are intercommunicated; and the inlets (7) and the outlets (8) of multiple layers of the cooling agent micro-channels are intercommunicated.
12. The integrated type micro-channel heat exchanger of claim 11, **characterized in that**, the fins (21) are formed on one side of each heat exchange plate (1), and the fin-side of a heat exchange plate (1) and the plane-side of another adjacent heat exchange plate (1) are combined to form the micro-channel structure.

13. The integrated type micro-channel heat exchanger of claim 11, **characterized in that**, the fins (21) are formed on one side of each heat exchange plate (1), and the fin-sides of adjacent heat exchange plates (1) are combined to form the micro-channel structure. 5

14. The integrated type micro-channel heat exchanger of claim 11, **characterized in that**, the fins (21) are formed on both sides of each heat exchange plate (1), with fins (21) on one side forming the working fluid micro-channels and fins (21) on the other side forming the cooling agent micro-channels. 10

15. The integrated type micro-channel heat exchanger of any of claims 11-14, **characterized in that**, an external contour of the fin unit (2) is rectilinear shaped or curvilinear shaped, and an intersection angle between each fin unit (2) and the flow direction of the fluid is $45^{\circ} \leq \alpha \leq 55^{\circ}$. 15
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16. The integrated type micro-channel heat exchanger of any of claims 11-15, **characterized in that**, an external contour of the fin unit (2) is an S-shaped curve with a straight middle segment, and the fin unit (2) comprises two fins (21) which are spaced from each other by a distance of $0.05\text{mm} \leq t \leq 0.35\text{mm}$; an intersection angle between each intermediate edge (215) of the fins (21) and the flow direction of the fluid is $0^{\circ} \leq \beta \leq 15^{\circ}$. 25
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17. The integrated type micro-channel heat exchanger of any of claims 11-15, **characterized in that**, an external contour of the fin unit (2) is rectilinear shaped, and the fin unit (2) comprises three parallelogram-shaped fins (21), with a circular arc transition segment at each obtuse angle of each of the parallelogram-shaped fins (21). 35

18. The integrated type micro-channel heat exchanger of any of claims 11-17, **characterized in that**, the inlets (7) are respectively arranged at opposite lateral sides relative to the diversion segment (4), and the outlets (8) are respectively arranged at opposite lateral sides relative to the confluence segment (5). 40
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19. The integrated type micro-channel heat exchanger of any of claims 11-18, **characterized in that**, the fins (21) on the heat exchange plate (1) are formed by light etching molding. 50

20. The integrated type micro-channel heat exchanger of any of claims 11-19, **characterized in that**, the multiple layers of heat exchange plates (1) are bound into a whole piece by atomic diffusion. 55

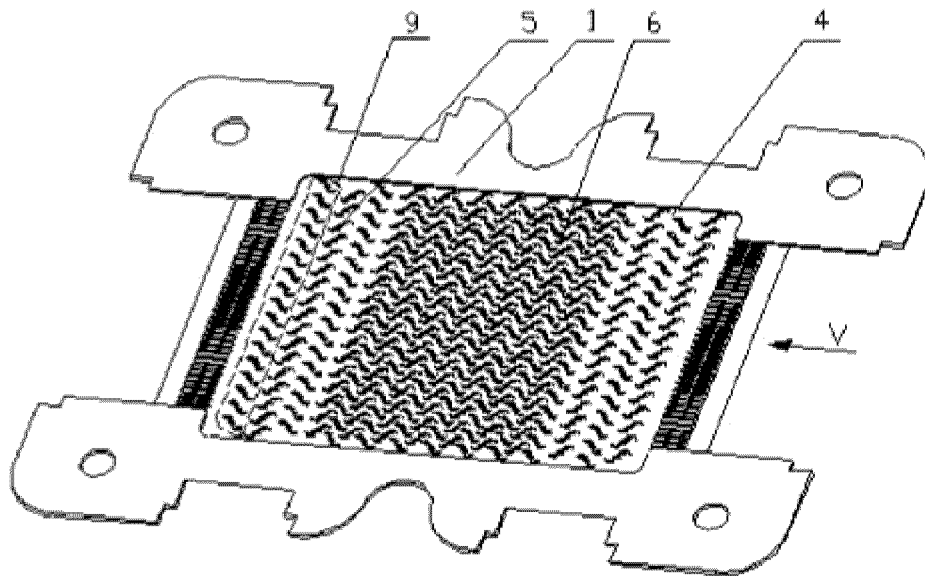


FIG. 1

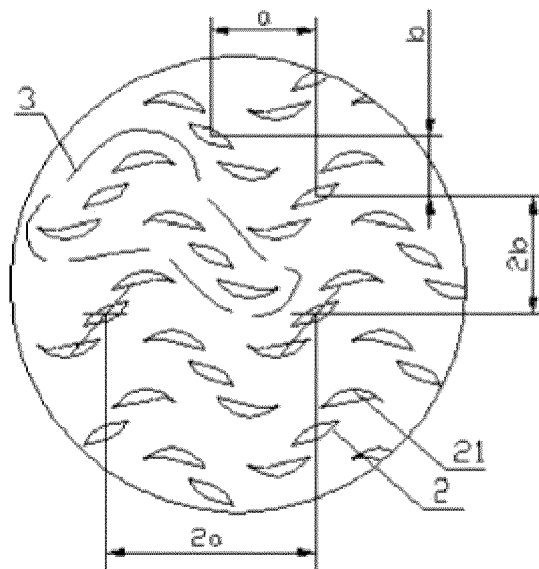


FIG. 2

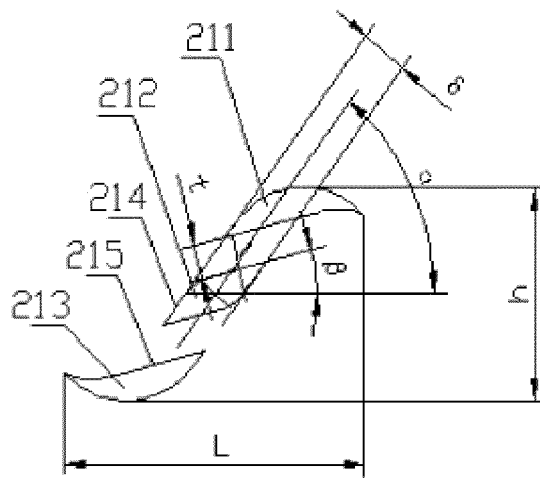


FIG. 3

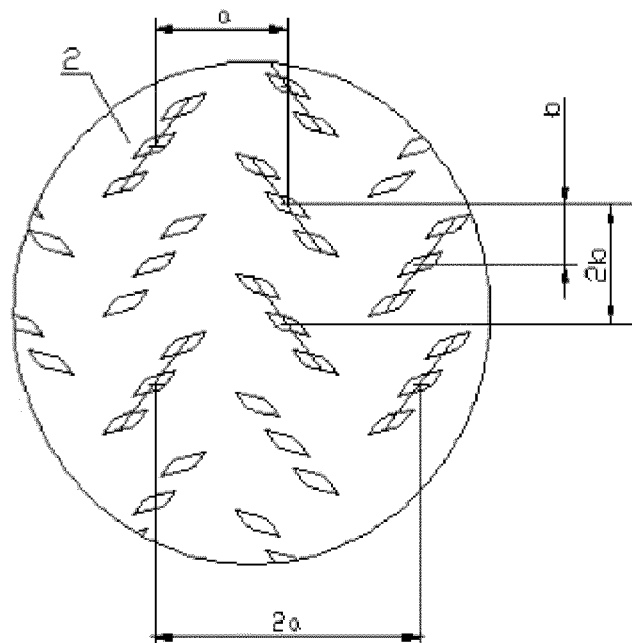


FIG. 4

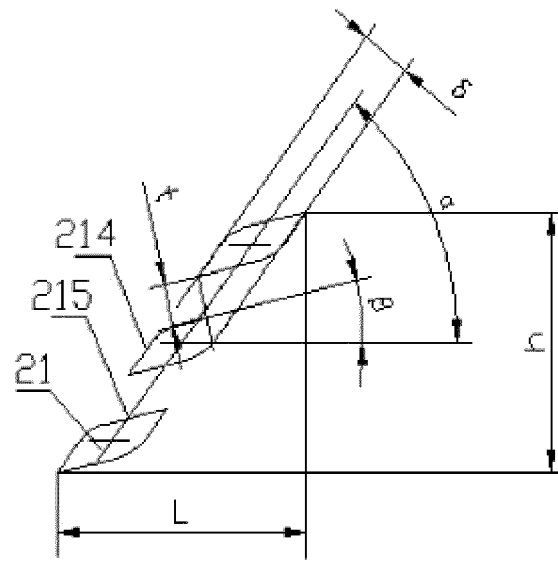


FIG. 5

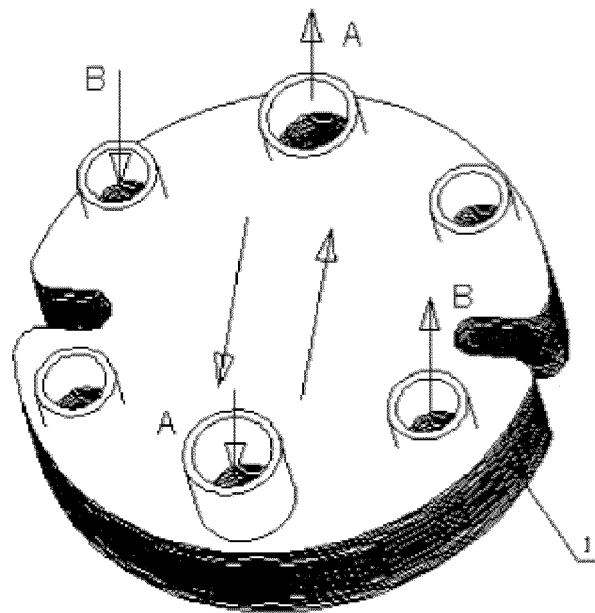


FIG. 6

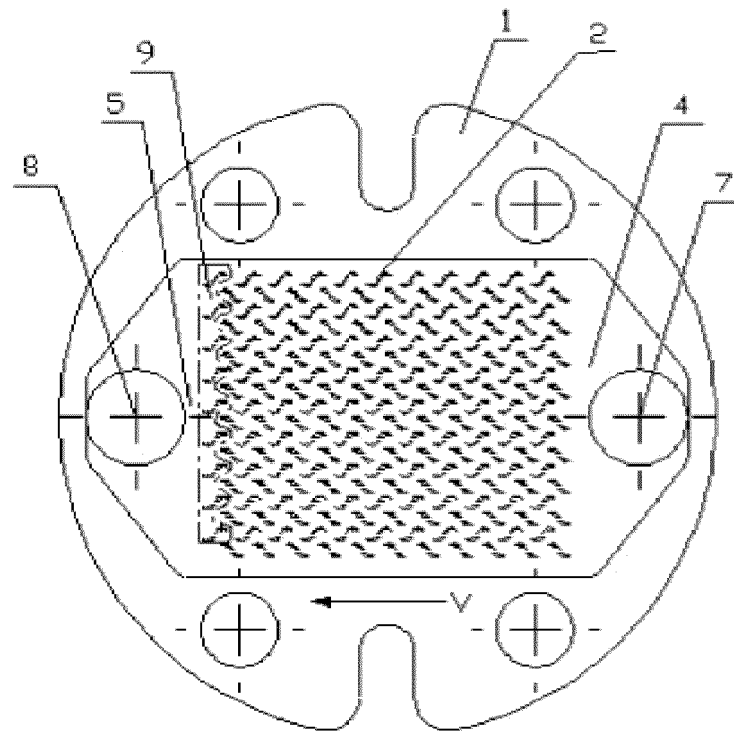


FIG. 7

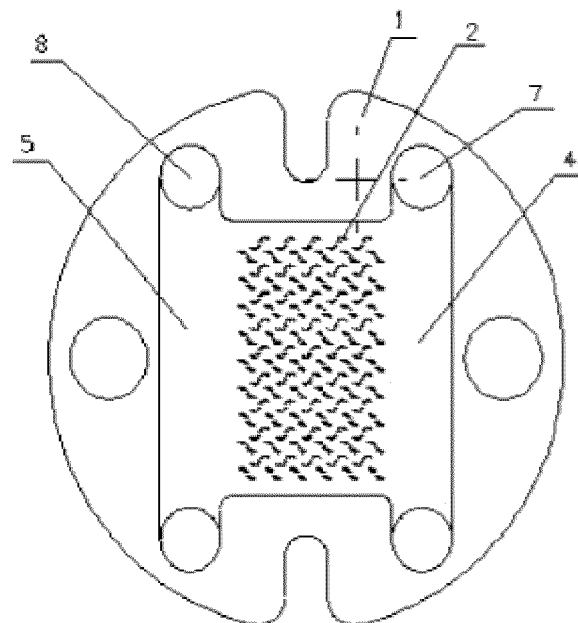


FIG. 8

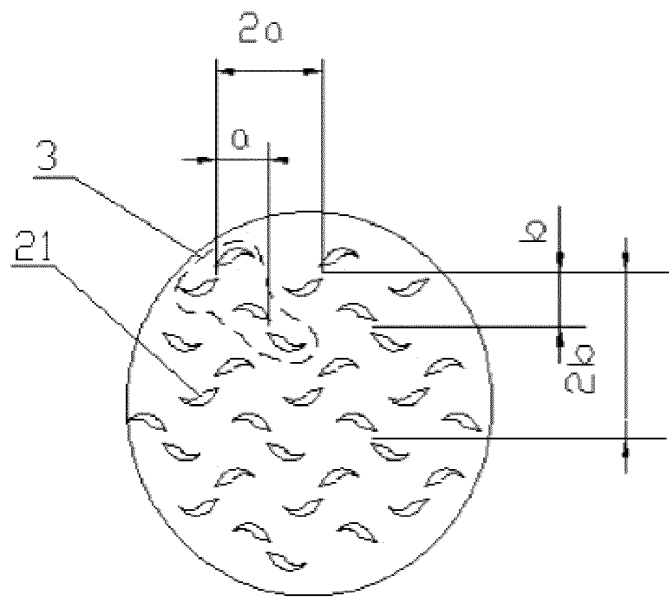


FIG. 9

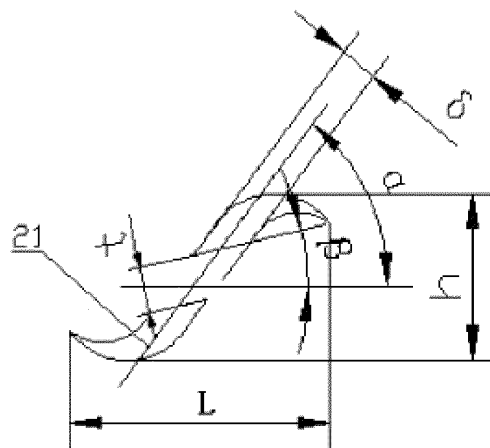


FIG. 10

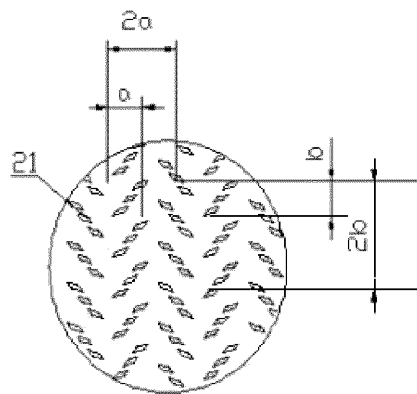


FIG. 11

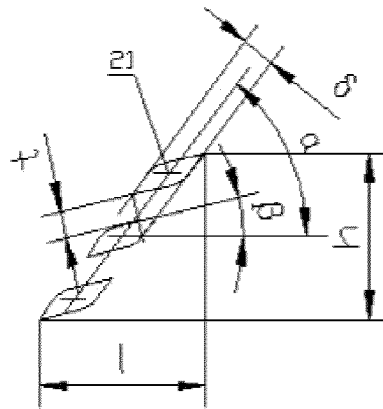


FIG. 12

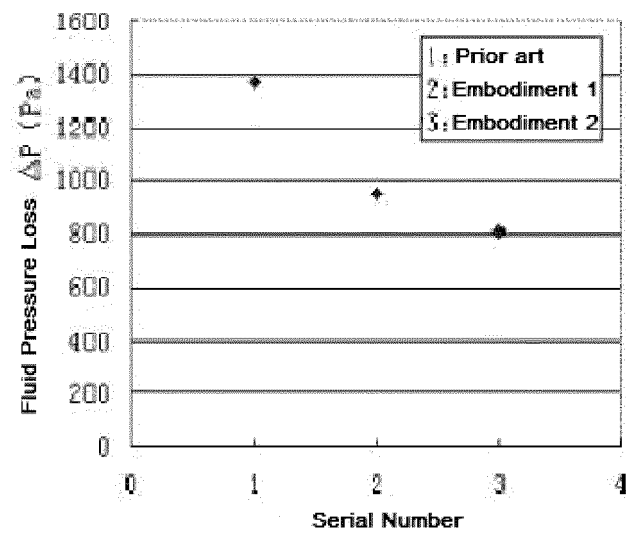


FIG. 13

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2013/076409

A. CLASSIFICATION OF SUBJECT MATTER

F28F 3/04 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F28F 3, F28F 13, F28F 1, F28D 9

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT, CNKI, WPI, EPODOC: heat w exchanger, plate, fin, fluid w channel, heat w sink, heat w transfer, surface, intervein

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 102706201 A (ZHEJIANG WEIZHIYUAN ENERGY TECHNOLOGY CO LTD et al.) 03 October 2012 (03.10.2012) claims 1 to 10, description, the whole document and figures 1 to 6	1-10
PX	CN 102706187 A (ZHEJIANG WEIZHIYUAN ENERGY TECHNOLOGY CO LTD et al.) 03 October 2012 (03.10.2012) claims 1 to 10, description, the whole document and figures 1 to 8	1-20
Y	US 7334631 B2 (TOKYO INST TECHNOLOGY et al.) 26 February 2008 (26.02.2008) description, column 5, line 9 to column 7, line 60, figures 1 to 5 and 7 to 9	1-20
Y	US 2008066888 A1 (DANAHER MOTION STOCKHOLM AB) 20 March 2008 (20.03.2008) description, paragraphs [0054] and [0055], figures 9, 11 and 12	1-20
Y	JP 2006170549 A (KATO Y) 29 June 2006 (29.06.2006) description, paragraphs [0020] to [0035] and figures 1 to 10	1-20

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☒ Further documents are listed in the continuation of Box C.
☒ See patent family annex.

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* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

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Date of the actual completion of the international search 11 July 2013 (11.07.2013)	Date of mailing of the international search report 01 August 2013 (01.08.2013)
Name and mailing address of the ISA/CN State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Facsimile No. (86-10) 62019451	Authorized officer WANG, Ying Telephone No. (86-10) 62084892

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2013/076409

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2013/076409

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Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
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CN 102706187 A	03.10.2012	None	
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		CA 2525081 C	06.04.2010
		EP 1653185 A2	03.05.2006
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Form PCT/ISA/210 (patent family annex) (July 2009)

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REFERENCES CITED IN THE DESCRIPTION

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- US 7334631 B2 [0005]
- JP 2006170549 A [0005]