



(11)

EP 4 269 925 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
01.11.2023 Bulletin 2023/44

(51) International Patent Classification (IPC):
F28D 9/00 (2006.01)

(21) Application number: **23170746.4**

(52) Cooperative Patent Classification (CPC):
F28D 9/005; F28F 3/046

(22) Date of filing: **28.04.2023**

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

(72) Inventors:
• **ZHANG, Xiaobin**
Zhejiang, 310018 (CN)
• **ZHANG, Ting**
Zhejiang, 310018 (CN)
• **ZHANG, Junjie**
Zhejiang, 310018 (CN)

(30) Priority: **28.04.2022 CN 202210456457**

(71) Applicant: **Hangzhou Sanhua Research Institute
Co., Ltd.**
Hangzhou, Zhejiang 310018 (CN)

(74) Representative: **dompatent von Kreisler Selting
Werner -
Partnerschaft von Patent- und Rechtsanwälten
mbB
Deichmannhaus am Dom
Bahnhofsvorplatz 1
50667 Köln (DE)**

(54) **PLATE HEAT EXCHANGER**

(57) A plate heat exchanger includes a number of first heat exchange plates and a number of second heat exchange plates. The first heat exchange plate includes a first wave crest and a first wave trough. The second heat exchange plate includes a second wave crest and a second wave trough. Along a thickness direction, a maximum distance between the first wave crest and the first wave trough is h . In a direction of a shortest line connecting tops of adjacent first wave crests, a minimum connecting width of the first wave trough and the second wave crest is W_1 , and a minimum connecting width of the first wave crest and the second wave trough is W_2 . At least one of a ratio of W_1/h and a ratio of W_2/h is within a range of 0.25 to 2.5 to ensure the connection strength between adjacent heat exchange plates.

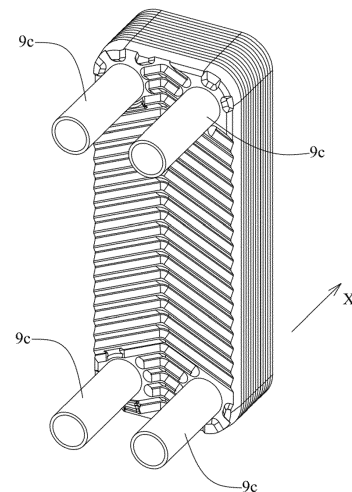


FIG. 1

EP 4 269 925 A1

Description

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This patent application claims priority of a Chinese Patent Application No. 202210456457.8, filed on April 28, 2022 and titled "PLATE HEAT EXCHANGER", the entire content of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention belongs to the field of heat exchangers, and in particular, relates to a plate heat exchanger.

BACKGROUND

[0003] Stainless steel plate heat exchangers are widely used in refrigeration and heating systems as evaporators, condensers, economizers, etc., due to their advantages of compact structure, high heat exchange coefficient, high reliability, and less refrigerant charge etc. The plate heat exchanger is composed of stacked plates with corrugations. After multi-layer plates are stacked, two fluid channels are formed, and heat exchange is performed through the corrugations of the plates.

[0004] The plate heat exchanger is welded after stacking heat exchange plates. Adjacent heat exchange plates form a network of multi contact points, and inter-plate channels are formed between adjacent heat exchange plates for medium fluid to flow for heat exchange. The connection strength of the contact point directly affects the working stability and service life of the plate heat exchanger. Therefore, it is necessary to propose a plate heat exchanger to ensure the connection strength of adjacent heat exchange plates.

SUMMARY

[0005] An object of the present invention is to provide a plate heat exchanger to ensure connection strength.

[0006] The present invention provides a plate heat exchanger, including:

a plurality of first heat exchange plates, the first heat exchange plate including a first corrugation, the first corrugation including a first wave crest and a first wave trough; and

a plurality of second heat exchange plates, the second heat exchange plate including a second corrugation, the second corrugation including a second wave crest and a second wave trough;

wherein the first heat exchange plate and the second heat exchange plate are stacked alternately along a stacking direction which is the same as a thickness

direction of the plate heat exchanger;

at least part of the second wave crest of the second heat exchange plate is in contact with a corresponding first wave trough of an adjacent first heat exchange plate which is located adjacent to the second heat exchange plate; at least part of the second wave trough of the second heat exchange plate is in contact with a corresponding first wave crest of another adjacent first heat exchange plate which is located adjacent to the second heat exchange plate;

along the thickness direction of the plate heat exchanger, a maximum distance between the first wave crest of the first heat exchange plate and the first wave trough of the first heat exchange plate is h ; and

in a direction of a shortest line connecting tops of adjacent first wave crests, in adjacent first heat exchange plate and second heat exchange plate, a minimum connecting width of the first wave trough and the second wave crest is W_1 , and a minimum connecting width of the first wave crest and the second wave trough is W_2 ; wherein at least one of a ratio of W_1/h and a ratio of W_2/h is within a range of 0.25 to 2.5.

[0007] For the plate heat exchanger provided in the present invention, the ratio of the minimum connecting width between the wave crest and the wave trough of the heat exchange plate to the height of the corrugation is designed to be within the range of 0.25 to 2.5, which ensures the connection strength between adjacent heat exchange plates of the plate heat exchanger.

BRIEF DESCRIPTION OF DRAWINGS

[0008] In order to more clearly illustrate the technical solutions in the embodiments of the present invention, the following will briefly introduce the drawings that need to be used in the description of the embodiments. Apparently, the drawings in the following description are only some embodiments of the present invention. For those skilled in the art, other drawings can also be obtained based on these drawings without any creative effort.

FIG. 1 is a structural view of a plate heat exchanger in accordance with a first embodiment of the present invention;

FIG. 2 is an exploded view of the plate heat exchanger in accordance with the first embodiment of the present invention;

FIG. 3a is a partial cross-sectional view of adjacent first heat exchange plate and second heat exchange plate in accordance with the first embodiment of the

present invention;

FIG. 3b is another partial cross-sectional view of the adjacent first heat exchange plate and second heat exchange plate in accordance with the first embodiment of the present invention;

FIG. 3c is a partially exploded view of the adjacent first heat exchange plate and second heat exchange plate in accordance with the first embodiment of the present invention;

FIG. 3d is a partial view of a front view of the plate heat exchanger in accordance with the first embodiment of the present invention;

FIG. 4a is an enlarged view of circle A in FIG. 2;

FIG. 4b is an enlarged view of circle B in FIG. 2;

FIG. 5 is a cross-sectional view of the plate heat exchanger in accordance with a second embodiment of the present invention;

FIG. 6 is a partial cross-sectional view of adjacent first heat exchange plate and second heat exchange plate in accordance with the second embodiment of the present invention;

FIG. 7 is an enlarged view of circle C in FIG. 5;

FIG. 8 is a view of an arrangement of second wave crests and convex ridges in a first implementation manner in accordance with the second embodiment of the present invention;

FIG. 9 is a view of the arrangement of the second wave crests and the convex ridges in a second implementation manner in accordance with the second embodiment of the present invention;

FIG. 10 is a view of the arrangement of the second wave crests and the convex ridges in a third implementation manner in accordance with the second embodiment of the present invention;

FIG. 11 is a partially exploded view of adjacent first heat exchange plate and second heat exchange plate in accordance with the second embodiment of the present invention;

FIG. 12 is a front view of the first heat exchange plate in accordance with a third embodiment of the present invention;

FIG. 13 is a front view of the second heat exchange plate in accordance with the third embodiment of the present invention;

FIG. 14 is a partial view of a first corrugation and a second corrugation forming a network contact in accordance with the third embodiment of the present invention;

FIG. 15 is a partial view of a first flow guiding section in a second implementation manner in accordance with the third embodiment of the present invention;

FIG. 16 is a partial view of a second flow guiding section in a second implementation manner in accordance with the third embodiment of the present invention;

FIG. 17 is a partial view of the first flow guiding section in a third implementation manner in accordance with the third embodiment of the present invention;

FIG. 18 is a partial view of the second flow guiding section in a third implementation manner in accordance with the third embodiment of the present invention;

FIG. 19 is a structural view of stacked adjacent first heat exchange plate and second heat exchange plate in accordance with an embodiment of the present invention;

FIG. 20 is a structural view of first ports and second ports with gaps in accordance with an embodiment of the present invention; and

FIG. 21 is an enlarged view of circle D in FIG. 5.

DETAILED DESCRIPTION

[0009] Exemplary embodiments will be described in detail here, examples of which are shown in drawings. When referring to the drawings below, unless otherwise indicated, same numerals in different drawings represent the same or similar elements. The examples described in the following exemplary embodiments do not represent all embodiments consistent with this application. Rather, they are merely examples of devices and methods consistent with some aspects of the application as detailed in the appended claims.

[0010] The terminology used in this application is only for the purpose of describing particular embodiments, and is not intended to limit this application. The singular forms "a", "said", and "the" used in this application and the appended claims are also intended to include plural forms unless the context clearly indicates other meanings.

[0011] It should be understood that the terms "first", "second" and similar words used in the specification and claims of this application do not represent any order, quantity or importance, but are only used to distinguish different components. Similarly, "an" or "a" and other sim-

ilar words do not mean a quantity limit, but mean that there is at least one; "multiple" or "a plurality of" means two or more than two. Unless otherwise noted, "front", "rear", "lower" and/or "upper" and similar words are for ease of description only and are not limited to one location or one spatial orientation. Similar words such as "include" or "comprise" mean that elements or objects appear before "include" or "comprise" cover elements or objects listed after "include" or "comprise" and their equivalents, and do not exclude other elements or objects. The term "a plurality of" mentioned in the present invention includes two or more.

[0012] Hereinafter, some embodiments of the present invention will be described in detail with reference to the accompanying drawings. In the case of no conflict, the following embodiments and features in the embodiments can be combined with each other.

First embodiment

[0013] As shown in FIG. 1, FIG. 2, FIG. 3a, FIG. 3b and FIG. 7, a plate heat exchanger provided in this embodiment includes a plurality of first heat exchange plates 10 and a plurality of second heat exchange plates 20. The first heat exchange plate 10 and the second heat exchange plate 20 are alternately stacked. A stacking direction of the first heat exchange plates 10 and the second heat exchange plates 20 is the same as a thickness direction of the plate heat exchanger. The stacked heat exchange plates are integrated by welding (such as brazing). The first heat exchange plate 10 has first corrugations 1. The second heat exchange plate 20 has second corrugations 2. The first corrugation 1 includes a first wave crest 1r and a first wave trough 1g. The second corrugation 2 includes a second wave crest 2r and a second wave trough 2g. At least part of the second wave crest 2r of the second heat exchange plate 20 is in contact with a corresponding first wave trough 1g of an adjacent first heat exchange plate 10. At least part of the second wave trough 2g of the second heat exchange plate 20 is in contact with a corresponding first wave crest 1r of another adjacent first heat exchange plate 10.

[0014] Along the thickness direction of the plate heat exchanger, a maximum distance between the first wave crest 1r and the first wave trough 1g of the first heat exchange plate 10 is h.

[0015] Specifically, at least part of a top surface of the first wave crest 1r of the first heat exchange plate 10 is located in a first plane P1. At least part of a bottom surface of the first wave trough 1g is located in a second plane P2. The first plane P1 is parallel to the second plane P2. A distance (i.e., a vertical distance) from the first plane P1 to the second plane P2 is the same as h. At least part of a top surface of the second wave crest 2r of the second heat exchange plate 20 is located in a third plane P3. At least part of a bottom surface of the second wave trough 2g is located in a fourth plane P4. The third plane P3 is parallel to the fourth plane P4. A distance (i.e., a vertical

distance) from the third plane P3 to the fourth plane P4 is the same as h. The third plane P3 of the second heat exchange plate 20 coincides with the second plane P2 of the adjacent first heat exchange plate 10. The fourth plane P4 of the second heat exchange plate 20 coincides with the first plane P1 of the another adjacent first heat exchange plate 10. In this embodiment, optionally, the top surfaces of the first wave crests 1r of the first heat exchange plates 10 are all located in the first plane P1, the bottom surfaces of the first wave trough 1g are all located in the second plane P2, the top surfaces of the second wave crests 2r of the second heat exchange plates 20 are all located in the third plane P3, and the bottom surfaces of the second wave troughs 2g are all located in the fourth plane P4.

[0016] In this embodiment, the stacking direction (an X direction shown in FIG. 1) of the first heat exchange plates 10 and the second heat exchange plates 20 is perpendicular to the first plane P1, that is, the thickness direction of the plate heat exchanger is perpendicular to the first plane P1. In this embodiment, the stacking order of the first heat exchange plates 10 and the second heat exchange plates 20 is not specifically limited, it may be that the first heat exchange plate 10-the second heat exchange plate 20-the first heat exchange plate 10 are stacked in sequence, or it may be the second heat exchange plate 20-the first heat exchange plate 10-the second heat exchange plate 20 are stacked in sequence.

[0017] The plate heat exchanger is connected by corresponding wave crests and wave troughs, forming a network of multi-point contacts. During the heat exchange process of the plate heat exchanger, the medium flows back and forth between these contacts. Moreover, the corrugation of the plate can make the medium form a turbulent flow at a lower Reynolds number to achieve better heat exchange performance. If the connection fastness between adjacent heat exchange plates is low, there will be problems of poor working stability and even failure. In order to ensure the connection strength between adjacent heat exchange plates and improve the stability of the plate heat exchanger, the present embodiment performs the following design on the connected wave crests and wave troughs: referring to FIG. 3a, FIG. 3b again in conjunction with FIG. 3d, in a direction of a shortest line connecting the tops of the adjacent first wave crests 1r (Y direction as shown in FIG. 3d), that is, a direction of the line connecting the tops of the first wave crests 1r perpendicular to the first heat exchange plate 10, a minimum width of the contact between the first wave trough 1g and the second wave crest 2r is W_1 , a minimum width of the contact between the first wave crest 1r and the second wave trough 2g is W_2 , wherein at least one of a ratio of W_1/h and a ratio of W_2/h is with a range of 0.25 to 2.5. By designing the ratio of W_1/h and/or W_2/h in the range of 0.25 to 2.5, the problems of false welding and insufficient welding caused by too little contact between the tops of the wave crests and the bottoms of the wave troughs are avoided. At the same time, the exces-

sive contact between the heat exchange plates caused by solder to occupy too many inter-plate channels, thereby affecting the heat exchange performance of the heat exchanger is avoided.

[0018] In order to ensure the connection width, in the direction of the shortest line connecting the tops of the adjacent first wave crests 1r, an outer width of the bottom of the first wave trough 1g that is connected to the second wave crest 2r is greater than or equal to W_1 , an outer width of the top of the second wave crest 2r that is connected to the first wave trough 1g is greater than or equal to W_1 , an outer width of the top of the first wave crest 1r that is connected to the second wave trough 2g is greater than or equal to W_2 , and an outer width of the bottom of the second wave trough 2g that is connected to the first wave crest 1r is greater than or equal to W_2 . In this embodiment, optionally, in the direction of the shortest line connecting the tops of the adjacent first wave crests 1r, the outer width of the bottom of the first wave trough 1g that is connected to the second wave crest 2r is W_1 , the outer width of the top of the second wave crest 2r that is connected to the first wave trough 1g is W_1 , the outer width of the top of the first wave crest 1r that is connected to the second wave trough 2g is W_2 , and the outer width of the bottom of the second wave trough 2g that is connected to the first wave crest 1r is W_2 .

[0019] In this embodiment, along the thickness direction of the plate heat exchanger, the maximum distance between the second wave crest 2r and the second wave trough 2g of the second heat exchange plate 20 is also h . It should be understood that due to the influence of machining accuracy, assembly accuracy and measurement errors, the distance from the first plane P1 to the second plane P2 is not absolutely equal to h , and a certain error is acceptable, for example, an error range is $\pm 0.1 h$. Similarly, an error range of $\pm 0.1 h$ is allowed for coincident planes. In this embodiment, W_1 is equal to W_2 . W_1 and W_2 here are not absolutely equal, and an error range of $\pm 0.3\text{mm}$ between the two is acceptable. Therefore, the ratio of W_1/h is approximately the same as that of W_2/h , and h is with a range of 1 mm to 2 mm in this embodiment. Of course, the ratios of W_1 and W_2 may also be different (not shown in the drawings), so the ratio of W_1/h is different from that of W_2/h . W_1 can be chosen to be greater than W_2 , or smaller than W_2 , or the same as W_2 , according to actual needs.

[0020] Specifically, referring to FIG. 3a, FIG. 3b again in conjunction with FIG. 5, the inter-plate channels of the plate heat exchanger include at least one first channel 6 and at least one second channel 7. The first channel 6 is located between the second heat exchange plate 20 and the adjacent first heat exchange plate 10. The second channel 7 is located between the second heat exchange plate 20 and the another adjacent first heat exchange plate 10. The first channels 6 communicate with each other. The second channels 7 communicate with each other. There is no communication between the first channels 6 and the second channels 7. In this embodi-

ment, the corrugation of the first heat exchange plate 10 and the corrugation of the second heat exchange plate 20 are distributed symmetrically, so the volume of the first channel 6 and the volume of the second channel 7 are approximately the same (as shown in FIG. 3a), or the volume of the first channel 6 and the volume of the second channel 7 have a relative big difference (as shown in FIG. 3b).

[0021] In this embodiment, wavelengths λ of the first wave crest 1r, the first wave trough 1g, the second wave crest 2r, and the second wave trough 2g are substantially the same. That is, a distance between adjacent first wave crests 1r, a distance between adjacent first wave troughs 1g, a distance between adjacent second wave crests 2r, and a distance between adjacent second wave troughs 2g are the same. Of course, the wavelengths λ of the first wave trough 1g and the second wave crest 2r, and the wavelengths λ of the first wave crest 1r and the second wave trough 2g may also be different.

[0022] In order to further improve the connection strength between adjacent heat exchange plates after welding, referring to FIG. 3c, in this embodiment, the top of the first wave crest 1r, the top of the second wave crest 2r, the bottom of the first wave trough 1g and the bottom of the second wave trough 2g are all straight portions 3a which are flat. A contact surface of the straight portion 3a is perpendicular to the stacking direction. In other words, the tops of the first wave crest 1r and the second wave crest 2r are the straight portions 3a, and the bottoms of the first wave trough 1g and the second wave trough 2g are the straight portions 3a. During the welding process, the solder can fully contact the surfaces of the tops of the wave crests and the bottoms of the wave troughs, and fill between the corresponding straight portions 3a, thereby increasing the contact area, reducing the problem of false welding, and further improving the welding strength.

[0023] In addition, in this embodiment, the first wave crest 1r, the second wave crest 2r, the first wave trough 1g and the second wave trough 2g further include a first side wall portion 3b and a second side wall portion 3c. In the direction of the shortest line connecting the tops of the adjacent first wave crests 1r, one side of the straight portion 3a is connected to the first side wall portion 3b, and the other side is connected to the second side wall portion 3c. An angle α is formed between the first side wall portion 3b and the second side wall portion 3c, where $120^\circ \leq \alpha \leq 135^\circ$. In this embodiment, the first side wall portion 3b and the second side wall portion 3c are symmetrical with respect to the straight portion 3a.

Second embodiment

[0024] In this embodiment, the parts that are the same as in the first embodiment are given the same reference numerals, and the same text descriptions are omitted.

[0025] Compared with the first embodiment, the plate heat exchanger provided in this embodiment has the fol-

lowing different designs.

[0026] Referring to FIG. 4a, FIG. 4b, and FIG. 5 to FIG. 7, in order to improve the heat exchange effect of the plate heat exchanger and prevent the heat exchange performance from being reduced due to excessive pressure loss during the heat exchange process, in this embodiment, the design of the second corrugation 2 is improved, and the first corrugation 1 is the same as that of the first embodiment. Specifically, the second corrugation 2 also includes at least one convex ridge 2a. The convex ridges 2a are distributed along a direction of a shortest line connecting the tops of adjacent second wave crests 2r of the second heat exchange plates 20. Along the stacking direction (i.e., along the thickness direction of the plate heat exchanger), a top of the convex ridge 2a is located between the top of the second wave crest 2r and the bottom of the second wave trough 2g. Along the stacking direction, the first channel 6 and the second channel 7 are provided on two sides of the same convex ridge 2a. The volume of the first channel 6 and the volume of the second channel 7 are different. In this embodiment, the convex ridge 2a are provided on the second heat exchange plate 20 so that the volumes of the inter-plate channels (along the stacking direction) on two sides of the convex ridge 2a of the plate heat exchanger are different. Of course, this embodiment can also adopt the design of disposing the convex ridge 2a on the first corrugation 1 so that the volumes of the inter-plate channels are different, which will not be described in detail here.

[0027] In this embodiment, only part of the corrugation of one of the adjacent heat exchange plates is changed, so that the corrugation height of this part is different from the overall corrugation height of the heat exchange plate. That is, one side of the inter-plate channel is a symmetrical heat exchange plate, and the other side is an asymmetrical heat exchange plate, so that the adjacent first channel 6 and the second channel 7 have different volumes. With this arrangement, the pressure loss is small, the heat exchange efficiency of the plate heat exchanger is improved, but the volume difference between the adjacent first channel 6 and the second channel 7 will not be too large to affect the heat exchange performance. During the heat exchange process of the plate heat exchanger, the medium flows through the first channel 6 and the second channel 7. The flow pressure drop of the medium in the inter-plate channel with a smaller volume increases, which increases the turbulence of the medium fluid, improves the heat exchange effect of the medium in the heat exchanger, and improves the heat exchange performance. On the other side, due to the increase in the volume of the inter-plate channel, the flow pressure drop of the medium is significantly reduced, and the turbulence is slowed down, which can be used to circulate high-pressure medium to reduce the pressure drop and improve the heat exchange performance. In this embodiment, by changing part of the corrugations, compared with forming several grooves on the corrugations to make the volumes of the inter-plate channels different, it is more

convenient to process.

[0028] Due to the arrangement of the convex ridge 2a, the network-shaped multi-point contact points between the heat exchange plates are reduced. In order to ensure the connection strength between the heat exchange plates, and the welding strength of the tops of the wave crests and the wave troughs which are in contact with the tops of the wave crests, at least one of the ratios of W_1/h and W_2/h is with a range of 0.3 to 1, for example, the ratio is 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 1, etc. The present invention not only improves the heat exchange performance and heat exchange efficiency of the heat exchanger, but also ensures high welding strength and improves the working stability of the plate heat exchanger. In this embodiment, the optional values of W_1/h and W_2/h are both within the range of 0.3 to 1.

[0029] Referring to FIG. 7 again, in this embodiment, the wavelength λ of the convex ridge 2a (that is, a distance between two wave troughs adjacent to the convex ridge 2a) is substantially the same as the wavelength λ of the first wave crest 1r, the first wave trough 1g, the second wave crest 2r and the second wave trough 2g. The tops of the convex ridges 2a of the same second heat exchange plate 20 are substantially located in a fifth plane P5. The fifth plane P5 is located between the third plane P3 and the fourth plane P4 of the same second heat exchange plate 20. The fifth plane P5 is substantially parallel to the third plane P3. A height d of the convex ridge 2a is a distance from the fifth plane P5 to the fourth plane P4 of the same second heat exchange plate 20, where $d=(0.4-0.75)*h$. The height d of the convex ridge 2a is limited in order to prevent the heat exchange performance of the heat exchanger from being too low or too high.

[0030] Since the convex ridge 2a is provided, the first side wall portion 3b and the second side wall portion 3c of the second wave trough 2g adjacent to the convex ridge 2a are asymmetrical with respect to the straight portion 3a, as shown in FIG. 11.

[0031] In this embodiment, at least one convex ridge 2a is provided on the second corrugation 2 at every interval of at least one second wave crest 2r. The convex ridge 2a is distributed along the direction of the shortest line connecting the tops of the adjacent second wave crests 2r of the second heat exchange plate 20. That is, at least one convex ridge 2a is provided between adjacent second wave crests 2r, and at least one second wave crest 2r is provided between adjacent convex ridges 2a. For the convenience of understanding, the following examples will illustrate different implementation manners:

[0032] First implementation manner: as shown in FIG. 8, the second corrugation 2 is provided with a convex ridge 2a at every interval of the second wave crest 2r. That is, the second wave crest 2r-the convex ridge 2a are arranged in sequence, and the second wave trough 2g is located between adjacent second wave crest 2r and

convex ridge 2a.

[0033] Second implementation manner: as shown in FIG. 9, the second corrugation 2 is provided with two convex ridges 2a at every interval of the second wave crest 2r. That is, the second wave crest 2r-the convex ridge 2a-the convex ridge 2a are arranged in sequence. The second wave troughs 2g are provided between adjacent second wave crest 2r and convex ridge 2a, and between adjacent convex ridges 2a.

[0034] Third implementation manner: as shown in FIG. 10, the second corrugation 2 is provided with a convex ridge 2a at every interval of two second wave crests 2r. That is, the second wave crest 2r-the second wave crest 2r-the convex ridge 2a are arranged in sequence. The second wave troughs 2g are provided between adjacent second wave crest 2r and the convex ridge 2a, and between adjacent second wave crests 2r.

[0035] The arrangements of the convex ridge 2a on the second corrugation 2 are merely examples, but not limited thereto. The present invention may also adopt that the second wave crest 2r-the second wave crest 2r-the convex ridge 2a-the convex ridge 2a are arranged in sequence. Other arrangements may also be adopted, and appropriate arrangements can be selected according to heat exchange requirements.

[0036] Of course, in this embodiment, the tops of the convex ridges 2a of the same second heat exchange plate 20 may not be in the same plane, that is, the convex ridges 2a have different heights d.

Third embodiment

[0037] In this embodiment, the parts that are the same as those in the first and the second embodiments are given the same reference numerals, and the same text descriptions are omitted.

[0038] Compared with the first embodiment and the second embodiment, the plate heat exchanger provided in this embodiment has the following designs:

[0039] Referring to FIG. 12 to FIG. 14, the first heat exchange plate 10 and the second heat exchange plate 20 are rectangular, including two short sides 3d and two long sides 3e. The first corrugation 1 includes a first flow guiding section 4. The second corrugation 2 includes a second flow guiding section 5. An opening angle β_1 of the first flow guiding section 4 is the same as an opening angle β_2 of the second flow guiding section 5. A direction of the opening angle β_1 of the first flow guiding section 4 is opposite to a direction of the opening angle β_2 of the second flow guiding section 5. Through the reverse combination of the first corrugation 1 of the first heat exchange plate 10 and the second corrugation 2 of the second heat exchange plate 20, a network-shaped multi-point contact is formed. Moreover, under the action of the corrugations, the fluid medium forms turbulent flow in the inter-plate channels at a lower Reynolds number, which improves the heat exchange effect and helps to reduce the fouling of the heat exchange plates.

[0040] In order to improve the heat exchange performance, in this embodiment, the first flow guiding section 4 and the second flow guiding section 5 may be distributed in a V-shape or a W-shape, etc., which will be described in detail below through different implementation manners.

[0041] First implementation manner: referring to FIG. 12 and FIG. 13 again, the first flow guiding section 4 includes a first flow guiding subsection 4a and a second flow guiding subsection 4b. The connection between the first flow guiding subsection 4a and the second flow guiding subsection 4b forms a V shape, and forms an opening angle β_1 . The first flow guiding section 4a and the second flow guiding section 4b are symmetrical with respect to a center line l . The center line l is perpendicular to the two short sides 3d. Correspondingly, the second corrugation 2 includes a second flow guiding section 5. The second flow guiding section 5 includes a third flow guiding subsection 5a and a fourth flow guiding subsection 5b. The third flow guiding subsection 5a and the fourth flow guiding subsection 5b are connected, and form an opening angle β_2 .

[0042] Second implementation manner: referring to FIG. 15 and FIG. 16, the first flow guiding section 4 includes two first flow guiding subsections 4a and one second flow guiding subsection 4b. The first flow guide subsections 4a and the second flow guide subsection 4b are alternately distributed along a direction of the short side of the heat exchange plate. Adjacent first flow guiding subsection 4a and second flow guiding subsection 4b are connected, and form an opening angle β_1 . The first flow guiding section 4a and the second flow guiding section 4b are symmetrical with respect to a center line l' . The center line l' is perpendicular to the two short sides. Correspondingly, the second corrugation 2 includes a second flow guiding section 5. The second flow guiding section 5 includes two third flow guiding subsections 5a and a fourth flow guiding subsection 5b. The third flow guide subsections 5a and the fourth flow guide subsection 5b are alternately distributed along the direction of the short side of the heat exchange plate. Adjacent third flow guiding subsection 5a and fourth flow guiding subsection 5b are connected, and form an opening angle β_2 .

[0043] Third implementation manner: referring to FIG. 17 and FIG. 18, on the basis of the second implementation manner, this embodiment adds a second flow guiding subsection 4b to the first flow guiding section 4, and adds a fourth flow guiding subsection 5b to the second flow guiding section 5, so that the first flow guiding section 4 is W-shaped and the second flow guiding section 5 is a reverse W shape.

[0044] The above is just examples of the distribution of some flow guiding sections, but it is not limited to this, and it can also be distributed in 3-fold V-shape or even more heavy-V-shape. Moreover, the opening angles on the same heat exchange plate can be the same or different.

[0045] Further, the opening angle of the corrugation is

selected to be large, for example $90^\circ \leq \beta_1 (\beta_2) \leq 135^\circ$, to increase the heat exchange coefficient so as to obtain more heat exchange.

[0046] Part of the technical implementations of the first to third embodiments above may be combined or replaced.

[0047] Referring to FIG. 12 and FIG. 13 again in conjunction with FIG. 19, in the above embodiment, the first heat exchange plate 10 is provided with four first ports 8a. Two first ports 8a are located in a same plane as the bottom of the first wave trough 1g of the first heat exchange plate 10. Another two first ports 8a are in a same plane as the top of the first wave crest 1r of the first heat exchange plate 10. The four first ports 8a are located at four corners of the first heat exchange plate 10, respectively. The second heat exchange plate 20 is provided with four second ports 8b. Two second ports 8b are located in a same plane as the top of the second wave crest 2r of the same second heat exchange plate 20. Another two second ports 8b are located in a same plane as the bottom of the second wave trough 2g of the same second heat exchange plate 20. The four second ports 8b are located at four corners of the second heat exchange plate 20, respectively. Positions of the second ports 8b of the second heat exchange plate 20 correspond to positions of the first ports 8a of the adjacent first heat exchange plate 10. In the adjacent first heat exchange plate 10 and second heat exchange plate 20, two pairs of corresponding first ports 8a and second ports 8b are fitted together, and another two pairs are spaced apart from each other with gaps to communicate with corresponding inter-panel channels. Further, the two pairs of first ports 8a and second ports 8b that fit together are distributed diagonally. In other words, the first port 8a and the second port 8b with gaps are also distributed diagonally. When the plate heat exchanger is configured for the heat exchange process, the medium flows into the corresponding inter-plate channel from a position between a pair of first port 8a and the second port 8b with the gap, and the medium flows out from a position between the first port 8a and the second port 8b with the gap diagonally across. Of course, in the above embodiment, the first port 8a and the second port 8b with gaps can also be distributed on the same side and close to the long sides.

[0048] Further, in order to improve the structural strength of the corners of the first port 8a and the second port 8b with gaps, in the paired and spaced first port 8a and the second port 8b with gaps, the first heat exchange plate 10 is provided with a first support portion 8c at the corner where the first port 8a is located, and the second heat exchange plate 20 is provided with a second support portion 8d at the corner where the second port 8b is located. Both the first support portion 8c and the second support portion 8d protrude toward the gap and abut against each other. By arranging the first support portion 8c and the second support portion 8d, a periphery of the first port 8a and the second port 8b with gaps form an

effective support, thereby improving the structural strength. Wherein, the first support portion 8c and the second support portion 8d are protrusions or grooves formed by pressing.

[0049] Further, referring to FIG. 21, in the above embodiment, an outer periphery of the first heat exchange plate 10 has a first skirt 9a, and an outer periphery of the second heat exchange plate 20 has a second skirt 9b. The first skirt 9a of the first heat exchange plate 10 is at least partially overlapped with the second skirt 9b of the adjacent second heat exchange plate 20 and surrounds a corresponding inter-plate channel. In addition, referring to FIG. 1 and FIG. 2 again, in the above embodiment, the plate heat exchanger further includes connecting pipes 9c and blocking elements 9d. The first port 8a or the second port 8b on one side of the plate heat exchanger along the stacking direction is connected to one connecting pipe 9c, and the first port 8a or the second port 8b on the other side is provided with one blocking element 9d. That is, each port of the first heat exchange plate of the plate heat exchanger is respectively connected with one connecting pipe 9c, and each port of the last heat exchange plate is provided with one blocking element 9d for blocking. The blocking element 9d may be a gasket. Of course, the last heat exchange plate can also not be provided with a port.

[0050] The above embodiments are only used to illustrate the present invention and not to limit the technical solutions described in the present invention. The understanding of this specification should be based on those skilled in the art. Descriptions of directions, although they have been described in detail in the above-mentioned embodiments of the present invention, those skilled in the art should understand that modifications or equivalent substitutions can still be made to the application, and all technical solutions and improvements that do not depart from the spirit and scope of the application should be covered by the claims of the application.

Claims

1. A plate heat exchanger, **characterized by** comprising:

a plurality of first heat exchange plates (10), the first heat exchange plate (10) comprising a first corrugation (1), the first corrugation (1) comprising a first wave crest (1r) and a first wave trough (1g); and

a plurality of second heat exchange plates (20), the second heat exchange plate (20) comprising a second corrugation (2), the second corrugation (2) comprising a second wave crest (2r) and a second wave trough (2g);

wherein the first heat exchange plate (10) and the second heat exchange plate (20) are stacked alternately along a stacking direction

which is the same as a thickness direction of the plate heat exchanger;

at least part of the second wave crest (2r) of the second heat exchange plate (20) is in contact with a corresponding first wave trough (1g) of an adjacent first heat exchange plate (10) which is located adjacent to the second heat exchange plate (20); at least part of the second wave trough (2g) of the second heat exchange plate (20) is in contact with a corresponding first wave crest (1r) of another adjacent first heat exchange plate (10) which is located adjacent to the second heat exchange plate (20);

along the thickness direction of the plate heat exchanger, a maximum distance between the first wave crest (1r) of the first heat exchange plate (10) and the first wave trough (1g) of the first heat exchange plate (10) is h ; and in a direction of a shortest line connecting tops of adjacent first wave crests (1r), in adjacent first heat exchange plate (10) and second heat exchange plate (20), a minimum connecting width of the first wave trough (1g) and the second wave crest (2r) is W_1 , and a minimum connecting width of the first wave crest (1r) and the second wave trough (2g) is W_2 ; wherein at least one of a ratio of W_1/h and a ratio of W_2/h is within a range of 0.25 to 2.5.

2. The plate heat exchanger according to claim 1, wherein along the thickness direction of the plate heat exchanger, a maximum distance between the second wave crest (2r) of the second heat exchange plate (20) and the second wave trough (2g) of the second heat exchange plate (20) is h ;

in the direction of the shortest line connecting the tops of the adjacent first wave crests (1r), an outer width of a bottom of the first wave trough (1g) connected to the second wave crest (2r) is greater than or equal to W_1 , an outer width of a top of the second wave crest (2r) connected to the first wave trough (1g) is greater than or equal to W_1 , an outer width of a top of the first wave crest (1r) connected to the second wave trough (2g) is greater than or equal to W_2 , and an outer width of a bottom of the second wave trough (2g) connected to the first wave crest (1r) is greater than or equal to W_2 ; wherein at least one of a ratio of W_1/h and a ratio of W_2/h is within a range of 0.3 to 1.

3. The plate heat exchanger according to claim 2, wherein in the direction of the shortest line connecting the tops of the adjacent first wave crests (1r), the outer width of the bottom of the first wave trough (1g) connected to the second wave crest (2r) is W_1 , the outer width of the top of the second wave crest (2r) connected to the first wave trough (1g) is W_1 , the outer width of the top of the first wave crest (1r) con-

nected to the second wave trough (2g) is W_2 , and the outer width of the bottom of the second wave trough (2g) connected to the first wave crest (1r) is W_2 ; and

wherein W_1 is the same as W_2 .

4. The plate heat exchanger according to claim 1, wherein at least part of a top surface of the first wave crest (1r) of the first heat exchange plate (10) is located in a first plane P1, at least part of a bottom surface of the first wave trough (1g) is located in a second plane P2, the first plane P1 is parallel to the second plane P2, and a distance from the first plane P1 to the second plane P2 is the same as h ;

at least part of a top surface of the second wave crest (2r) of the second heat exchange plate (20) is located in a third plane P3, at least part of a bottom surface of the second wave trough (2g) is located in a fourth plane P4, the third plane P3 is parallel to the fourth plane P4, and a distance from the third plane P3 to the fourth plane P4 is the same as h ;

the third plane P3 of the second heat exchange plate (20) coincides with the second plane P2 of the adjacent first heat exchange plate (10), and the fourth plane P4 of the second heat exchange plate (20) coincides with the first plane P1 of the another adjacent first heat exchange plate (10);

the thickness direction of the plate heat exchanger is perpendicular to the first plane P1.

5. The plate heat exchanger according to claim 1, wherein the top of the first wave crest (1r), a top of the second wave crest (2r), a bottom of the first wave trough (1g) and a bottom of the second wave trough (2g) are straight portions (3a); a contact surface of the straight portion is perpendicular to the thickness direction of the plate heat exchanger;

the first wave crest (1r), the second wave crest (2r), the first wave trough (1g) and the second wave trough (2g) further comprise a first side wall portion (3b) and a second side wall portion (3c); in the direction of the shortest line connecting the tops of the adjacent first wave crests (1r), one side of the straight portion (3a) is connected to the first side wall portion (3b), and another side of the straight portion (3a) is connected to the second side wall portion (3c); an included angle α is formed between the first side wall portion (3b) and the second side wall portion (3c), where $120^\circ \leq \alpha \leq 135^\circ$.

6. The plate heat exchanger according to claim 1, wherein the second corrugation (2) further comprises at least one convex ridge (2a) which is distributed along a direction of a shortest line connecting tops of adjacent second wave crests (2r) of the second

heat exchange plate (20);

along the thickness direction of the plate heat exchanger, a top of the convex ridge (2a) is located between the top of the second wave crest (2r) and a bottom of the second wave trough (2g); along the thickness direction of the plate heat exchanger, volumes of inter-plate channels on two sides of the convex ridge (2a) of the plate heat exchanger are different; the top of the convex ridge (2a) of the second heat exchange plate (20) is located in a fifth plane P5, the fifth plane P5 is located between a third plane P3 and a fourth plane P4 of the same second heat exchange plate (20); the fifth plane P5 is parallel to the third plane P3, a height d of the convex ridge (2a) is a distance from the fifth plane P5 to the fourth plane P4, where $d=(0.4-0.75)*h$; and wherein h is 1-2mm.

7. The plate heat exchanger according to claim 6, wherein at least one convex ridge (2a) is arranged between adjacent second wave crests (2r), at least one second wave crest (2r) is arranged between adjacent convex ridges (2a);

the inter-plate channels of the plate heat exchanger comprise at least one first channel (6) and at least one second channel (7); the first channel (6) is located between the second heat exchange plate (20) and the adjacent first heat exchange plate (10); the second channel (7) is located between the second heat exchange plate (20) and the another adjacent first heat exchange plate (10); the first channel (6) and the second channels (7) are located on two sides of a same convex ridge (2a), respectively, along the thickness direction of the plate heat exchanger; volumes of the first channel (6) and the second channel (7) are different; the first channels (6) communicate with each other, the second channels (7) communicate with each other, and the first channel (6) and the second channel (7) do not communicate with each other.

8. The plate heat exchanger according to claim 1, wherein both the first heat exchange plate (10) and the second heat exchange plate (20) comprise two short sides (3d) and two long sides (3e); the first corrugation (1) comprises a first flow guiding section (4); the first flow guiding section (4) comprises at least one first flow guiding subsection (4a) and at least one second flow guiding subsection (4b); adjacent first guiding subsection and second guiding subsection are connected to form an opening angle β_1 , where $90^\circ \leq \beta_1 \leq 135^\circ$;

the first flow guiding subsection (4a) and the second flow guiding subsection (4b) are symmetrical about a center line l, and the center line l is perpendicular to the two short sides (3d); the second corrugation (2) comprises a second flow guiding section (5); the second flow guiding section (5) comprises at least one third flow guiding subsection (5a) and at least one fourth flow guiding subsection (5b); adjacent third flow guiding subsection (5a) and fourth flow guiding subsection (5b) are connected to form an opening angle β_2 , where $90^\circ \leq \beta_2 \leq 135^\circ$; the opening angle β_1 of the first flow guiding section (4) is the same as the opening angle β_2 of the second flow guiding section (5); a direction of the opening angle β_1 of the first flow guiding section (4) is opposite to a direction of the opening angle β_2 of the second flow guiding section (5).

9. The plate heat exchanger according to claim 1, wherein the first heat exchange plate (10) is opened with four first ports (8a), in which two first ports (8a) are in a same plane as a bottom of the first wave trough (1g) of the same first heat exchange plate (10), and another two first ports (8a) are in a same plane as the top of the first wave crest (1r) of the same first heat exchange plate (10);

the four first ports (8a) are located at four corners of the first heat exchange plate (10), respectively; the second heat exchange plate (20) is opened with four second ports (8b), in which two second ports (8b) are in a same plane as a top of the second wave crest (2r) of the same second heat exchange plate (20), and another two second ports (8b) are in a same plane as a bottom of the second wave trough (2g) of the same second heat exchange plate (20); the four second ports (8b) are located at four corners of the second heat exchange plate (20), respectively; positions of the second ports (8b) of the second heat exchange plate (20) correspond to positions of the first ports (8a) of the adjacent first heat exchange plate (10); in adjacent first heat exchange plate (10) and second heat exchange plate (20), two pairs of corresponding first ports (8a) and second ports (8b) are fitted together, and another two pairs are arranged at intervals with gaps; the two pairs of fitted first ports (8a) and second ports (8b) are diagonally distributed.

10. The plate heat exchanger according to claim 9, wherein in the first port and the second port arranged at intervals with gaps, the first heat exchange plate

(10) is provided with a first support portion (8c) at a corner where the first ports (8a) are located, and the second heat exchange plate (20) is provided with a second support portion (8d) at a corner where the second ports (8b) are located; both the first support portion (8c) and the second support portion (8d) protrude toward the gap and abut against each other;

an outer periphery of the first heat exchange plate (10) is provided with a first skirt (9a), an outer periphery of the second heat exchange plate (20) is provided with a second skirt (9b), the first skirt (9a) of the first heat exchange plate (10) is at least partially overlapped with the second skirt (9b) of an adjacent second heat exchange plate (20) so as to surround a corresponding inter-plate channel;

the plate heat exchanger further comprises connecting pipes (9c) and blocking elements (9d), the first port (8a) or the second port (8b) on one side of the plate heat exchanger along the thickness direction of the plate heat exchanger is respectively connected with one connecting pipe (9c); the first port (8a) or the second port (8b) on another side is provided with one blocking element (9d).

30

35

40

45

50

55

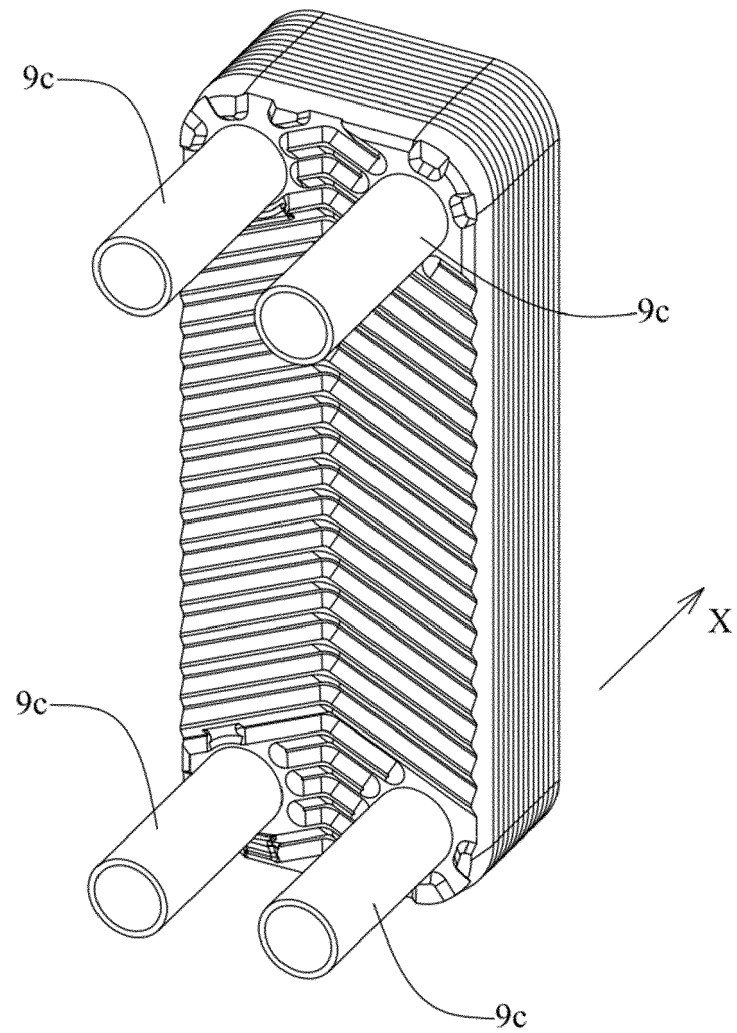


FIG. 1

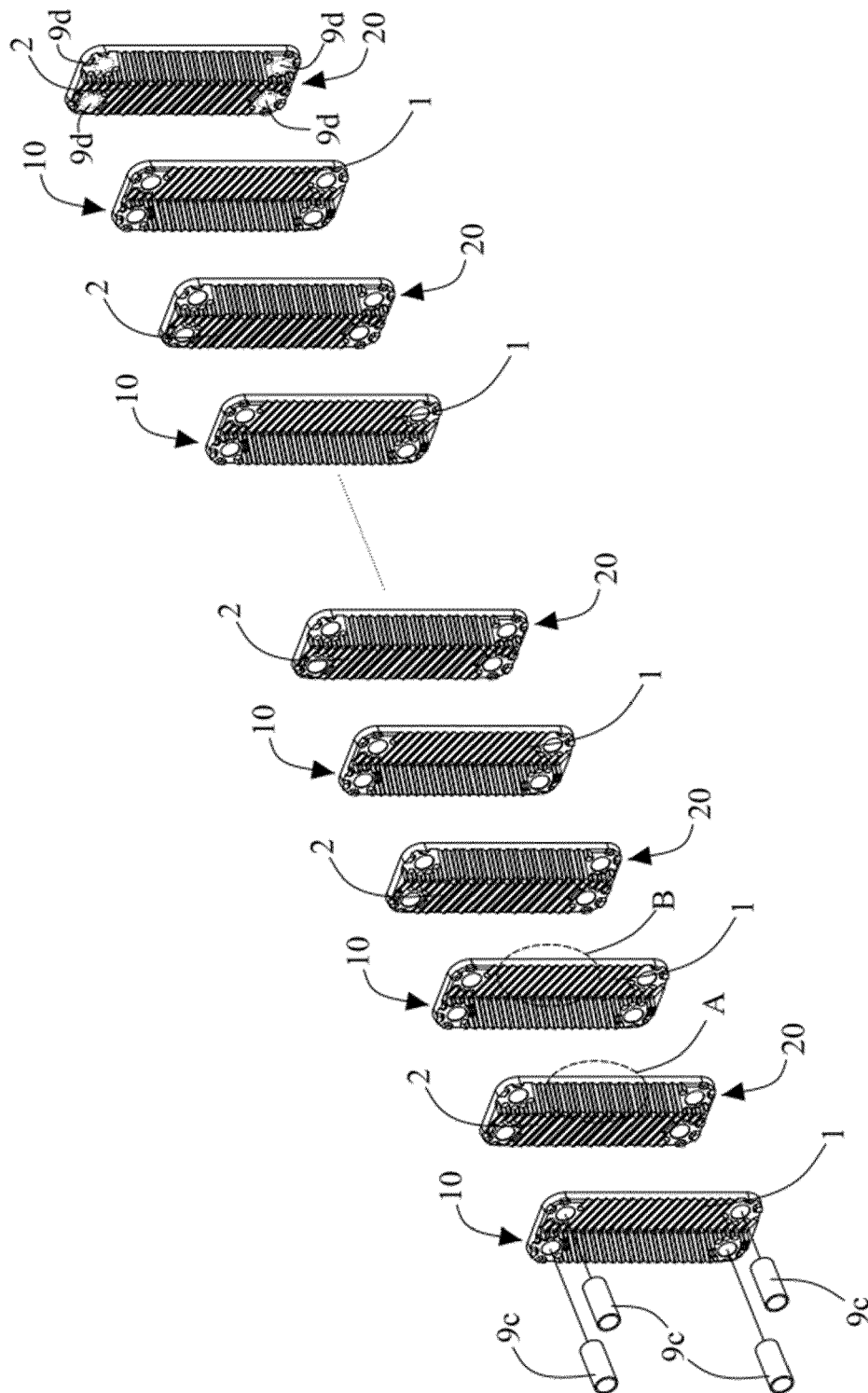


FIG. 2

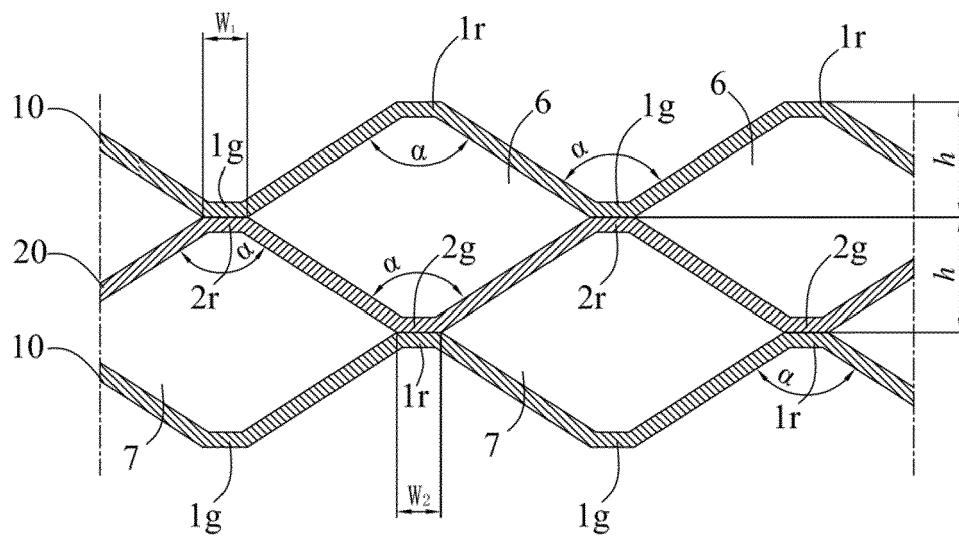


FIG. 3a

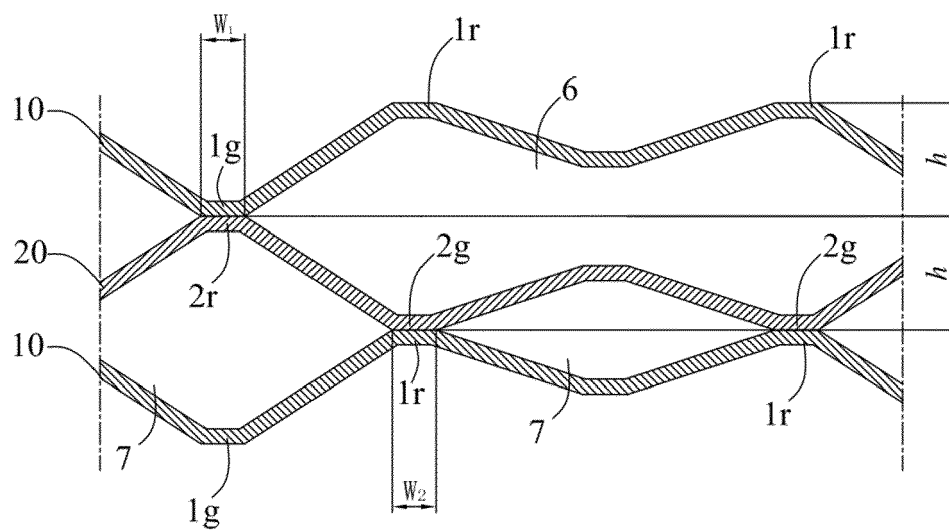


FIG. 3b

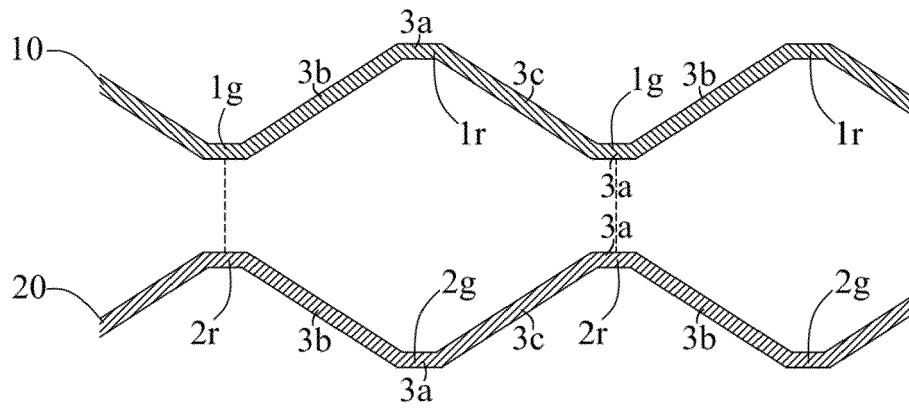


FIG. 3c

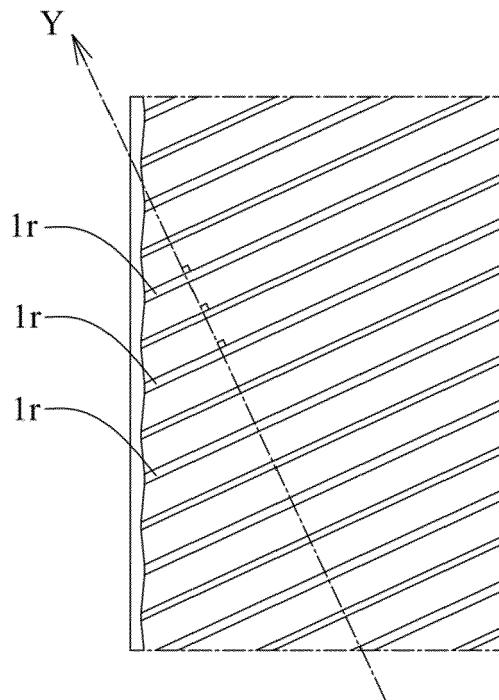


FIG. 3d

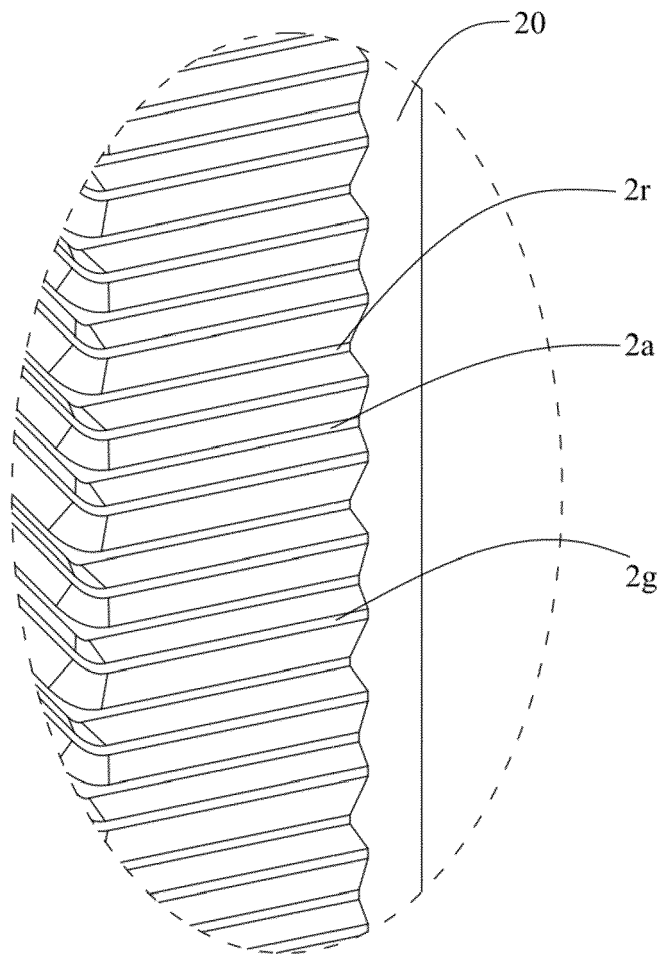


FIG. 4a

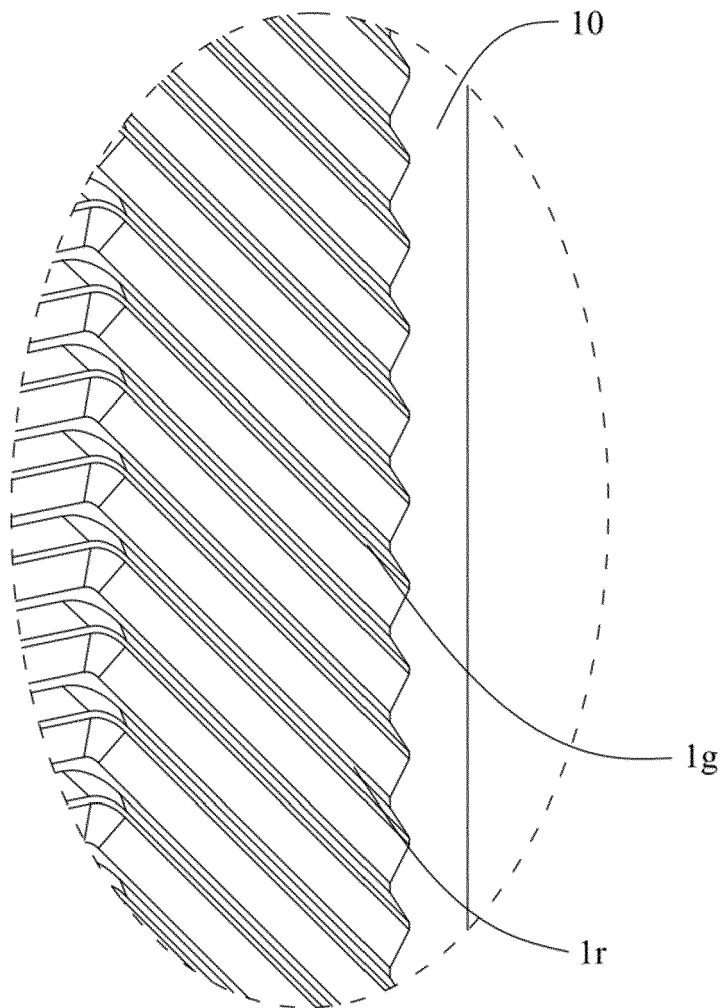


FIG. 4b

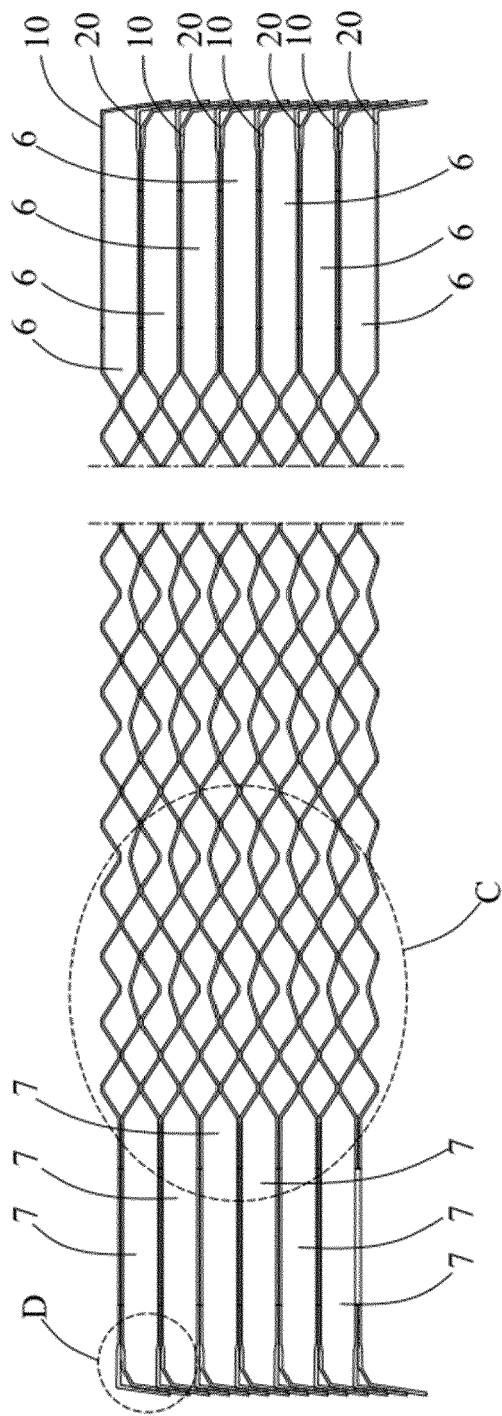


FIG. 5

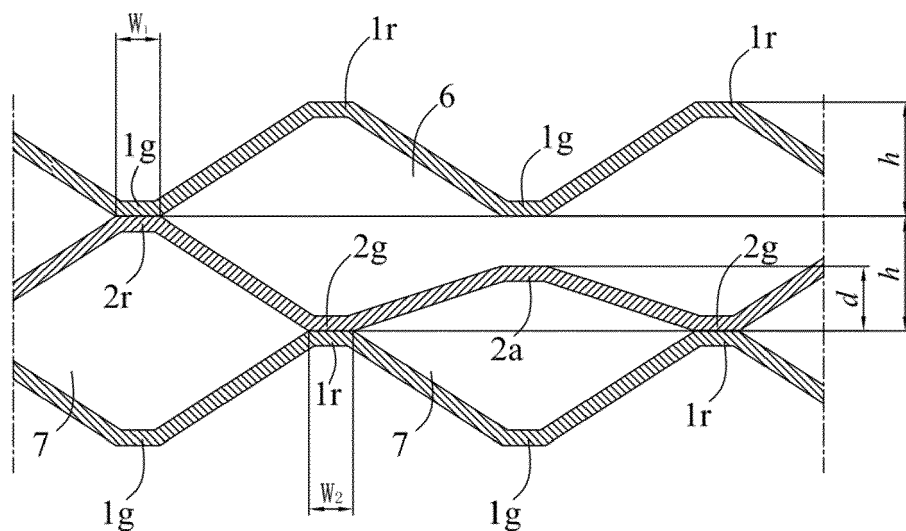


FIG. 6

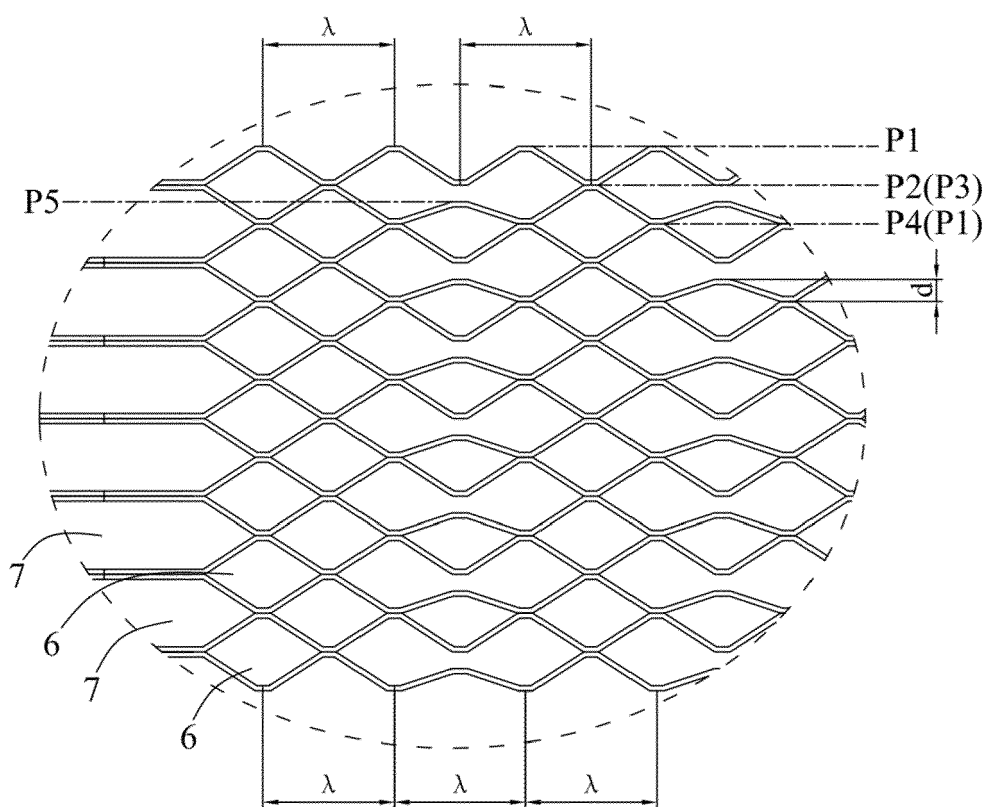


FIG. 7



FIG. 8



FIG. 9



FIG. 10

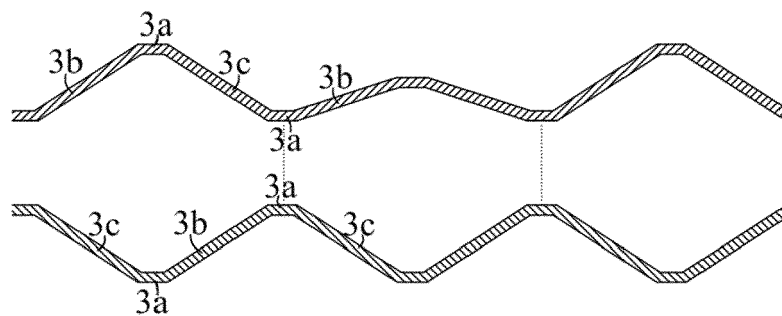


FIG. 11

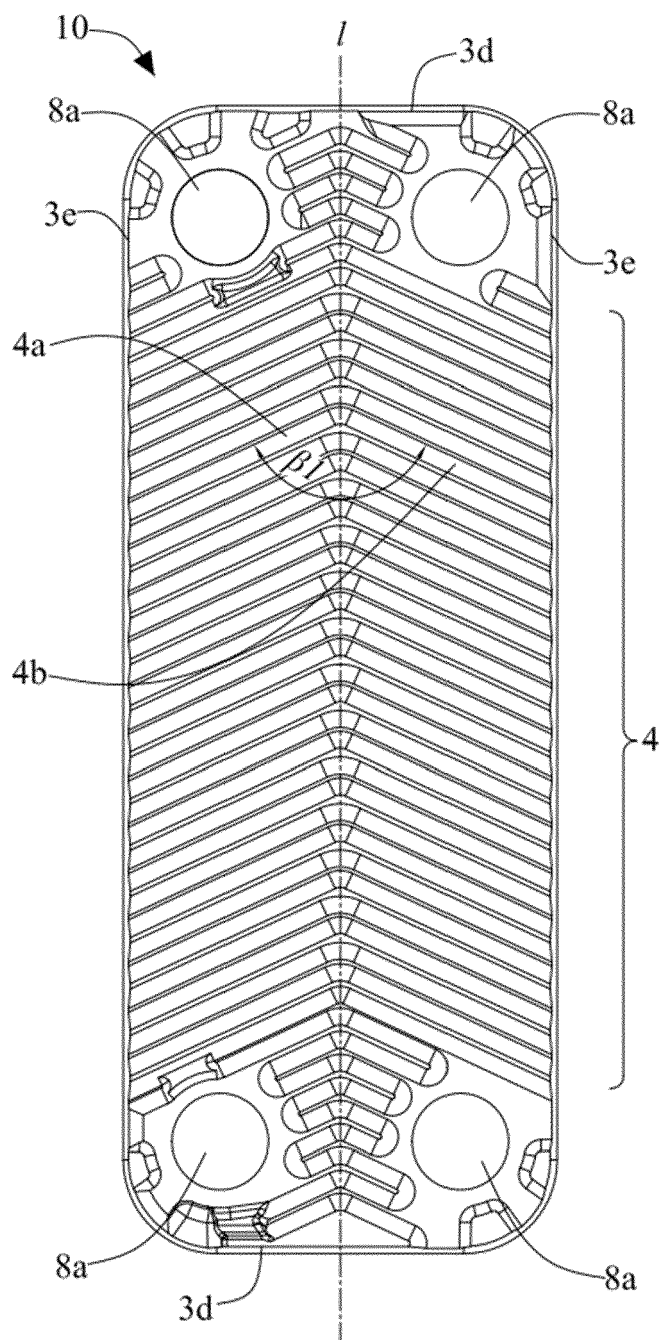


FIG. 12

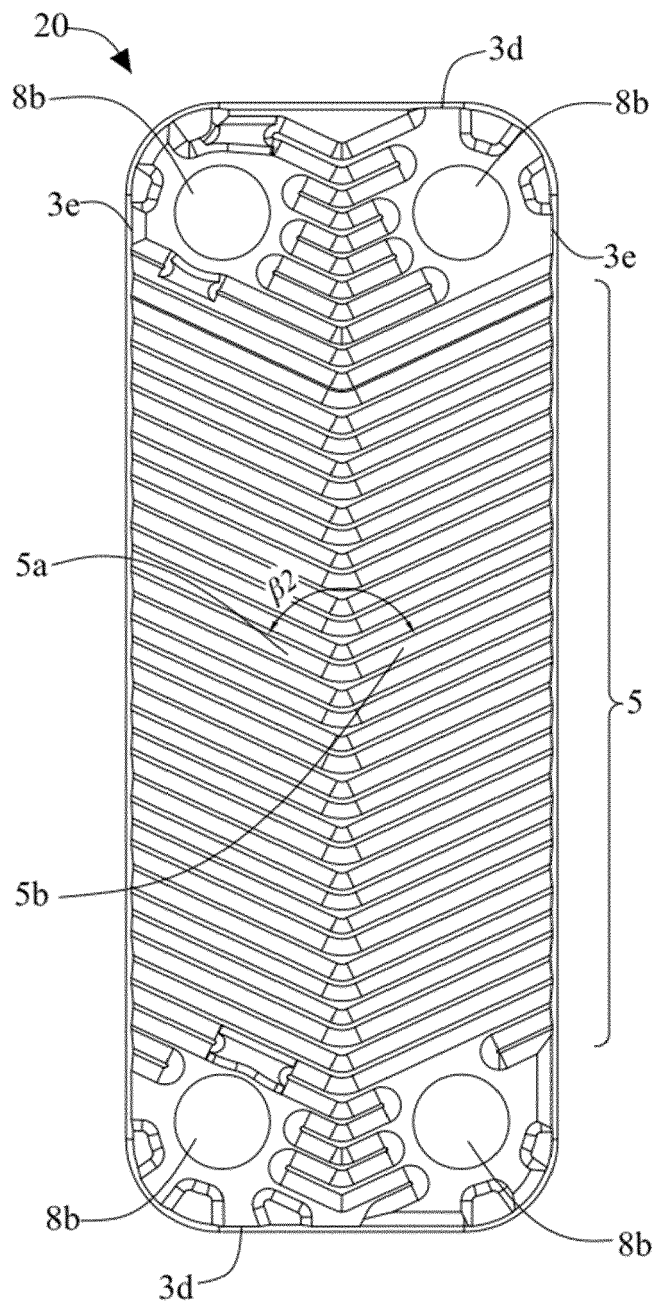


FIG. 13

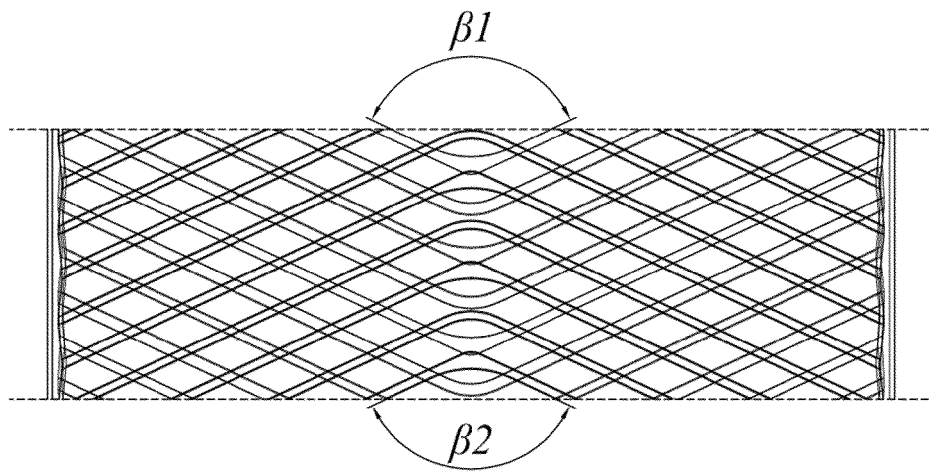


FIG. 14

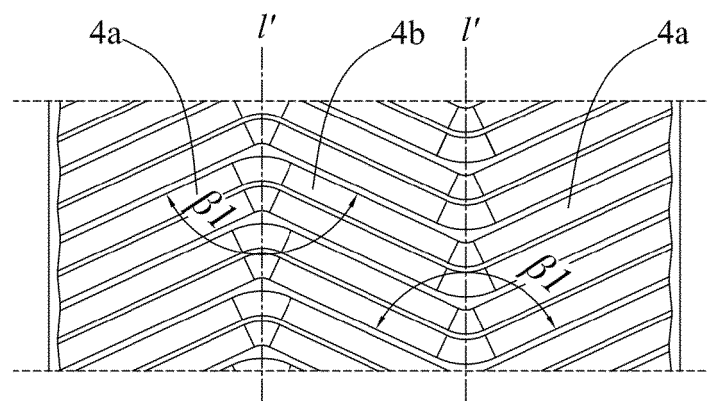


FIG. 15

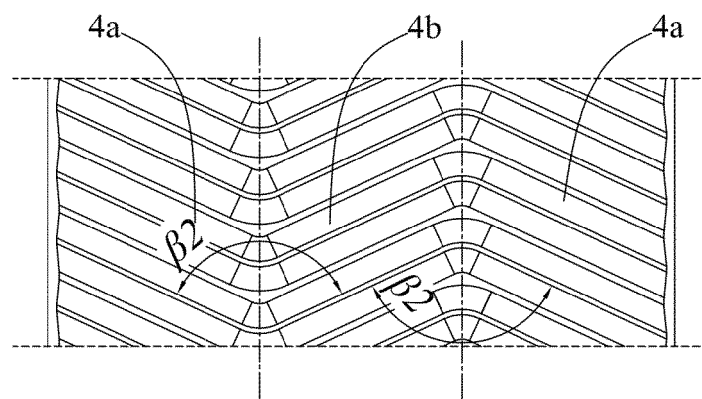


FIG. 16

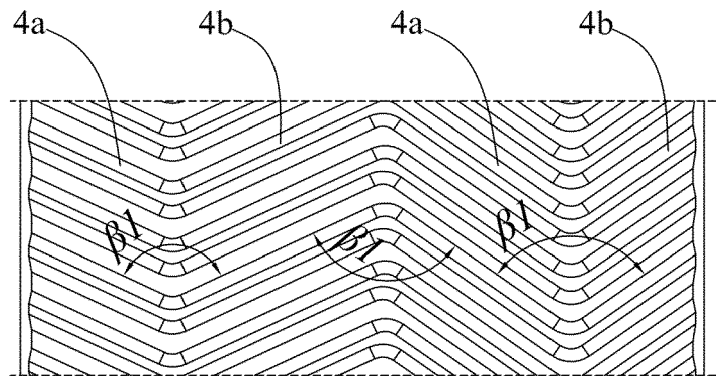


FIG. 17

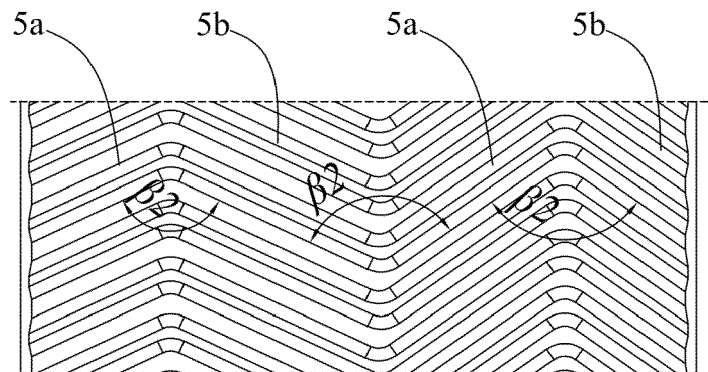


FIG. 18

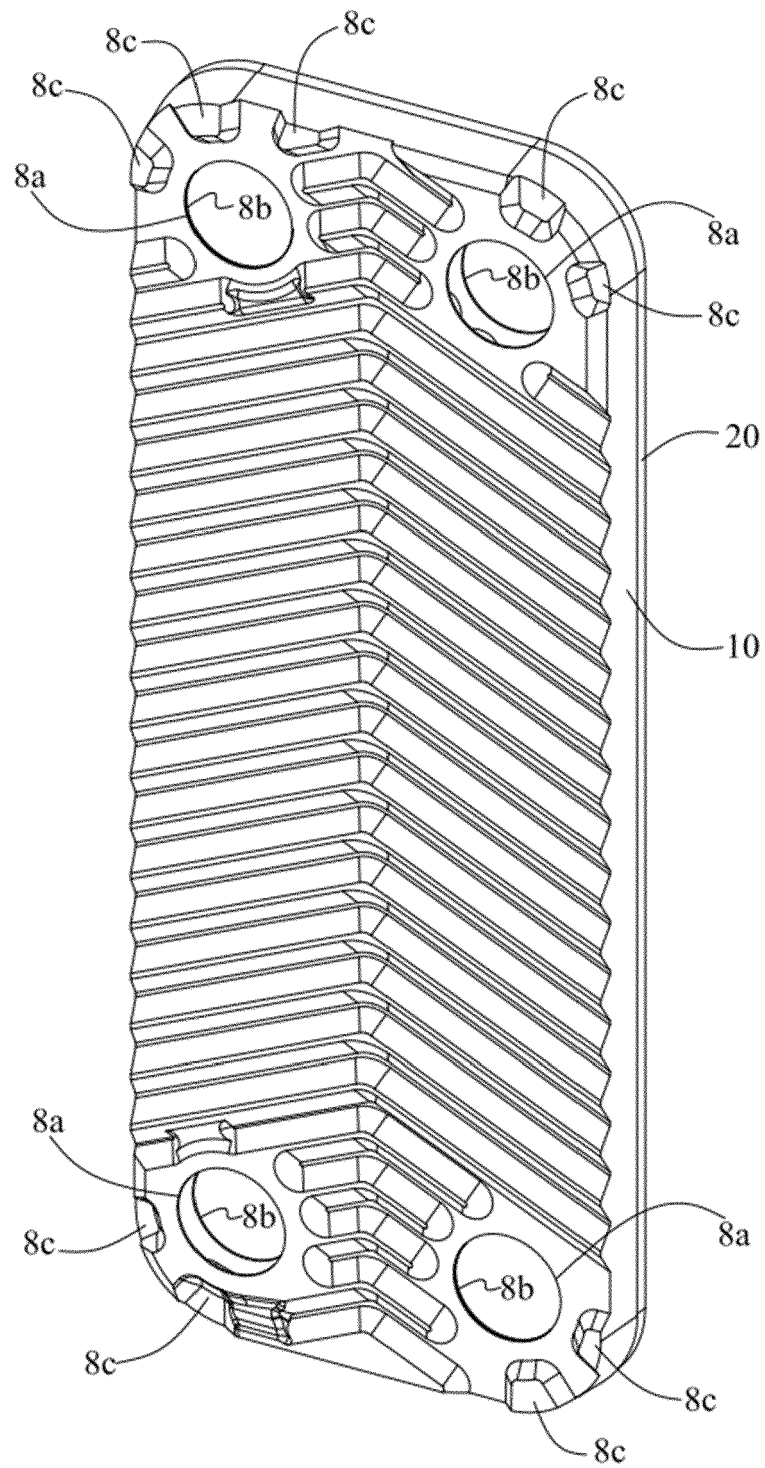


FIG. 19

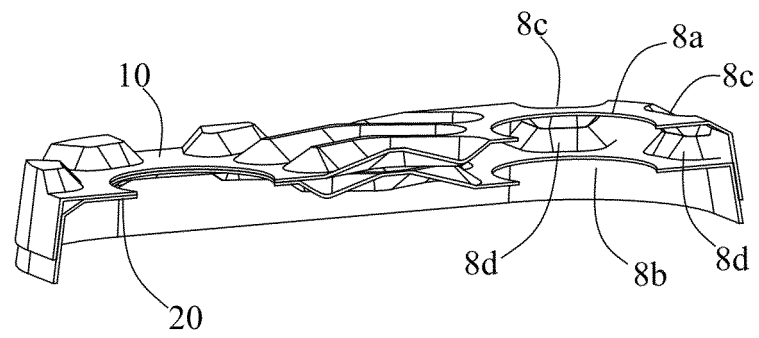


FIG. 20

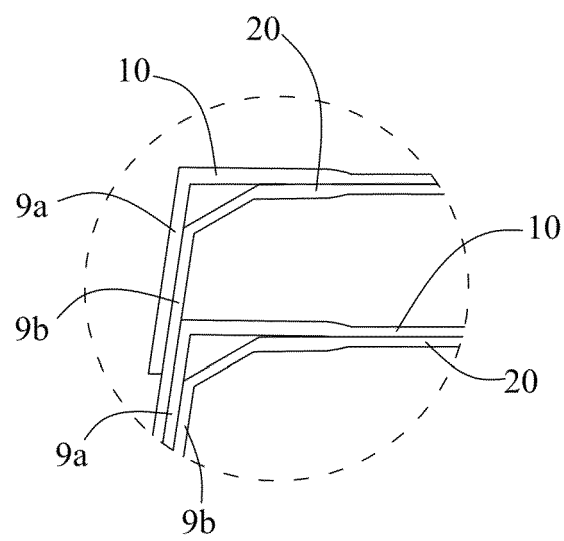


FIG. 21



EUROPEAN SEARCH REPORT

Application Number

EP 23 17 0746

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2021/063091 A1 (LEE SUKYOUNG [KR] ET AL) 4 March 2021 (2021-03-04)	1-5, 9, 10	INV. F28D9/00
Y	* paragraph [0113] - paragraph [0139]; claims 7, 10, 11, 12; figures 1, 3, 4, 6 *	6-8	
Y	WO 2021/154152 A1 (SWEP INT AB [SE]) 5 August 2021 (2021-08-05)	6-8	
A	* page 6, line 24 - page 10, line 5; figure 5, *	10	
A	* page 11, line 6 - line 26; figure 7a *		
A	EP 3 828 489 A1 (ALFA LAVAL CORP AB) 2 June 2021 (2021-06-02)	1-10	TECHNICAL FIELDS SEARCHED (IPC)
A	* paragraph [0040] - paragraph [0057]; figures 4-7b *		
A	EP 2 585 783 A1 (ALFA LAVAL CORP AB [SE]) 1 May 2013 (2013-05-01)	1-10	F28D F28F
	* paragraph [0031]; figures 5, 8; examples 1-6 *		
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		1 September 2023	Jessen, Flemming
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 23 17 0746

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

01-09-2023

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2021063091 A1	04-03-2021	KR 20210026216 A	10-03-2021
		US 2021063091 A1	04-03-2021
		WO 2021040228 A1	04-03-2021
WO 2021154152 A1	05-08-2021	CN 114945789 A	26-08-2022
		EP 4097413 A1	07-12-2022
		JP 2023512425 A	27-03-2023
		SE 2050094 A1	31-07-2021
		US 2023036224 A1	02-02-2023
		WO 2021154152 A1	05-08-2021
EP 3828489 A1	02-06-2021	AU 2020390520 B2	23-06-2022
		BR 112022008060 A2	12-07-2022
		CA 3159923 A1	03-06-2021
		CN 114729789 A	08-07-2022
		EP 3828489 A1	02-06-2021
		EP 4065915 A1	05-10-2022
		JP 7214923 B2	30-01-2023
		JP 2022547356 A	11-11-2022
		KR 20220097537 A	07-07-2022
		SA 522432757 B1	15-06-2023
		TW 202130965 A	16-08-2021
		US 2023160642 A1	25-05-2023
		WO 2021104815 A1	03-06-2021
EP 2585783 A1	01-05-2013	AU 2010356148 A1	10-01-2013
		BR 112012031888 A2	26-09-2017
		CA 2803776 A1	29-12-2011
		CN 102985780 A	20-03-2013
		DK 2585783 T3	26-01-2015
		EP 2585783 A1	01-05-2013
		ES 2526998 T3	19-01-2015
		JP 5612203 B2	22-10-2014
		JP 2013529770 A	22-07-2013
		KR 20130031848 A	29-03-2013
		MY 183356 A	18-02-2021
		PL 2585783 T3	31-03-2015
		PT 2585783 E	05-01-2015
		RU 2520767 C1	27-06-2014
		SE 1050690 A1	25-12-2011
		SI 2585783 T1	30-01-2015
		TW 201207351 A	16-02-2012
		US 2013126135 A1	23-05-2013
		WO 2011162659 A1	29-12-2011
		ZA 201208944 B	26-02-2014

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- CN 202210456457 [0001]