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(19) **United States**(12) **Patent Application Publication****Yoo et al.**(10) **Pub. No.: US 2010/0314088 A1**(43) **Pub. Date: Dec. 16, 2010**(54) **HEAT EXCHANGER HAVING
MICRO-CHANNELS**

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(52) **U.S. Cl.** **165/170**(57) **ABSTRACT**

Disclosed is a heat exchanger configured by laminating layers having micro-channels by adapting a micromachining, wherein the micro-channels having uniform length and cross section are constructed within a heat exchanger body in a curved outer shape, thereby minimizing deviation for each channel and improving heat transfer efficiency.

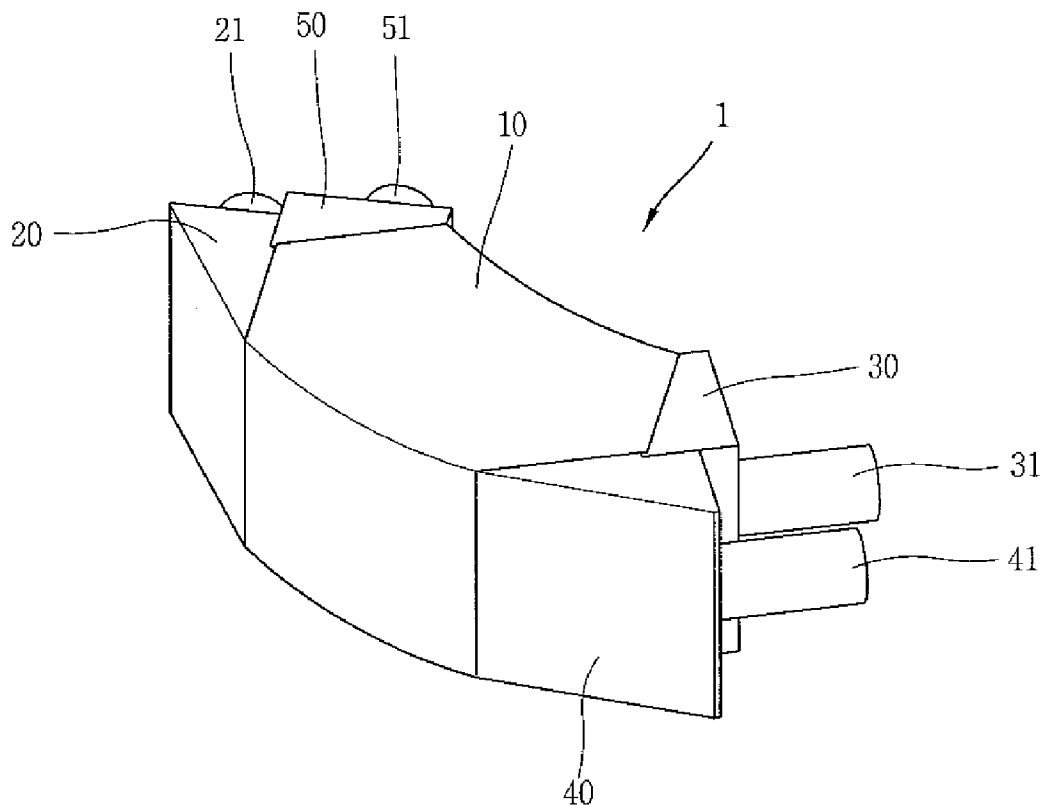


FIG. 1

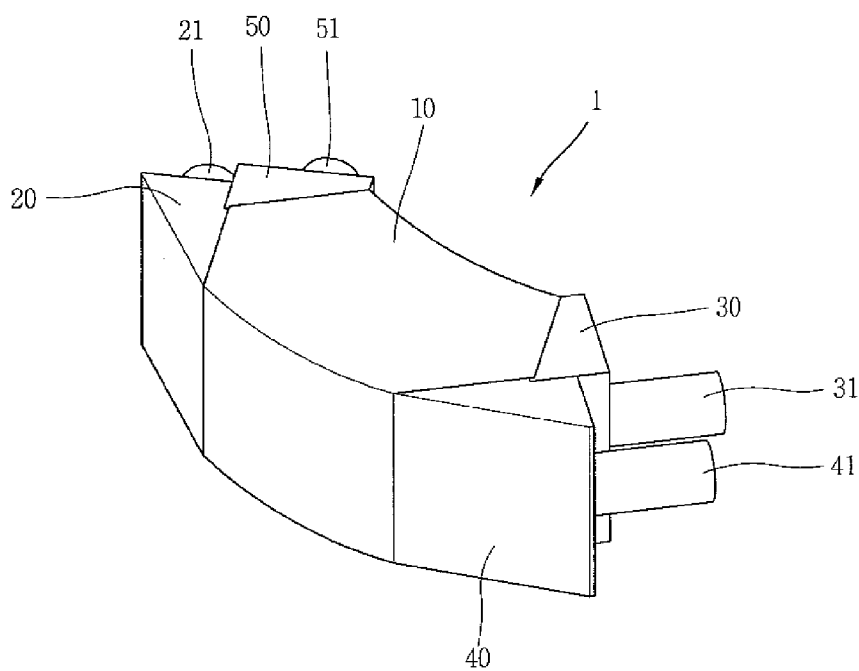


FIG. 2

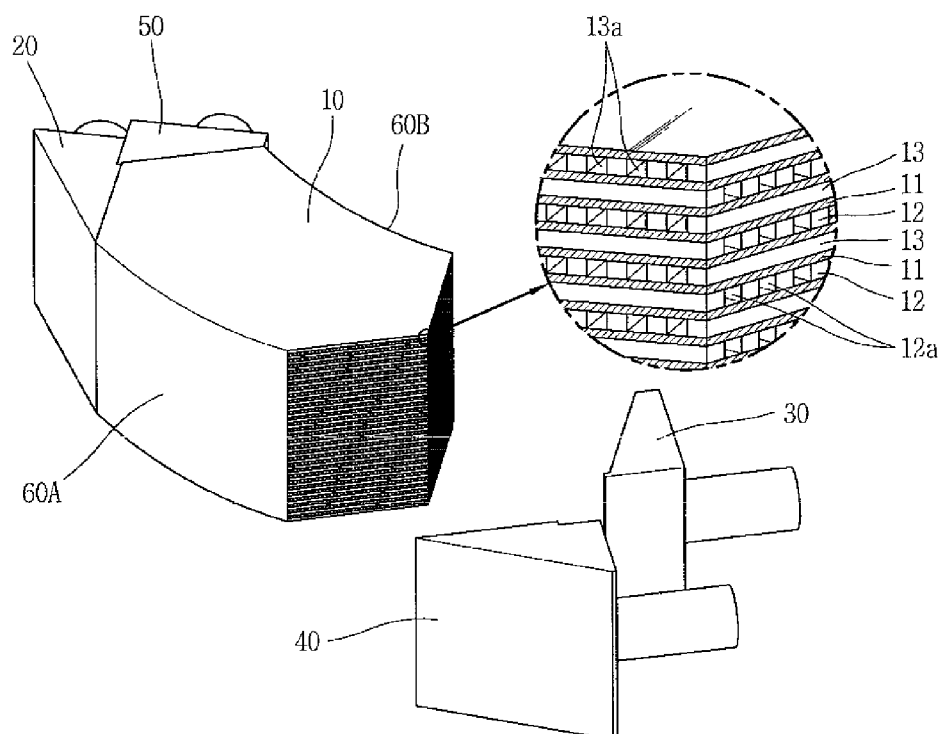


FIG. 3

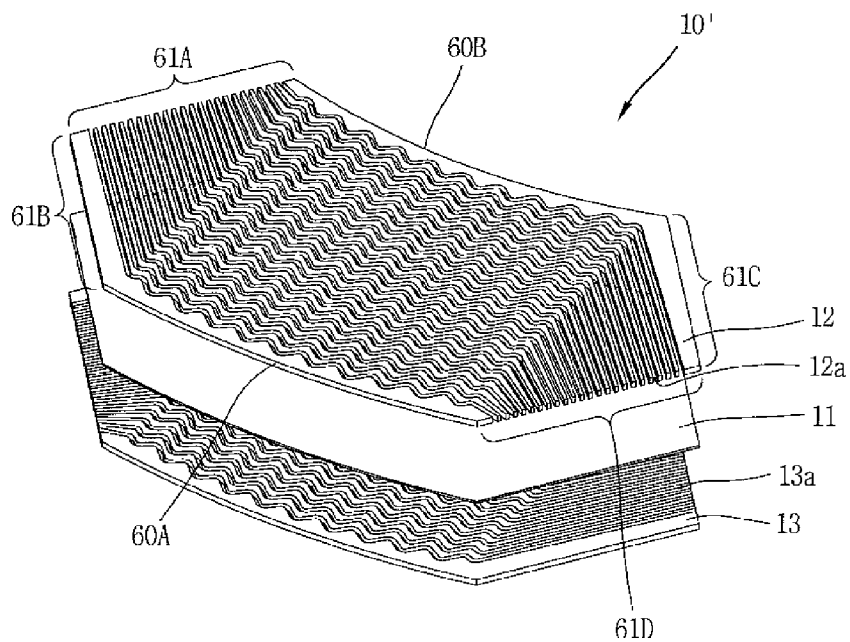


FIG. 4

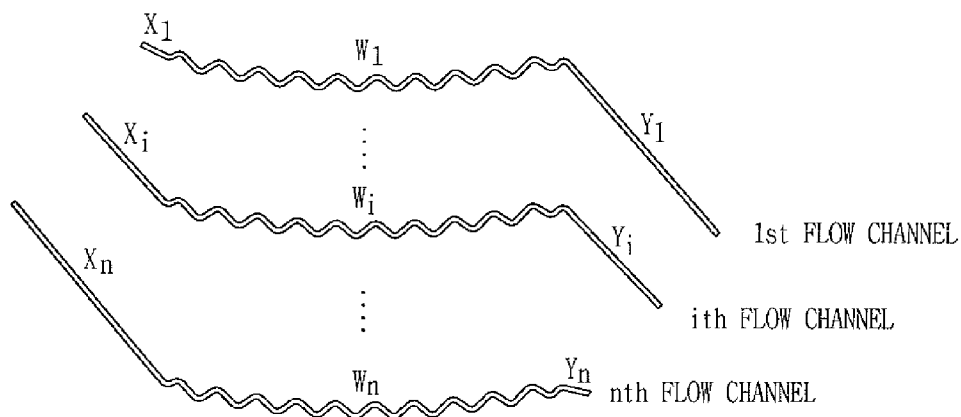


FIG. 5

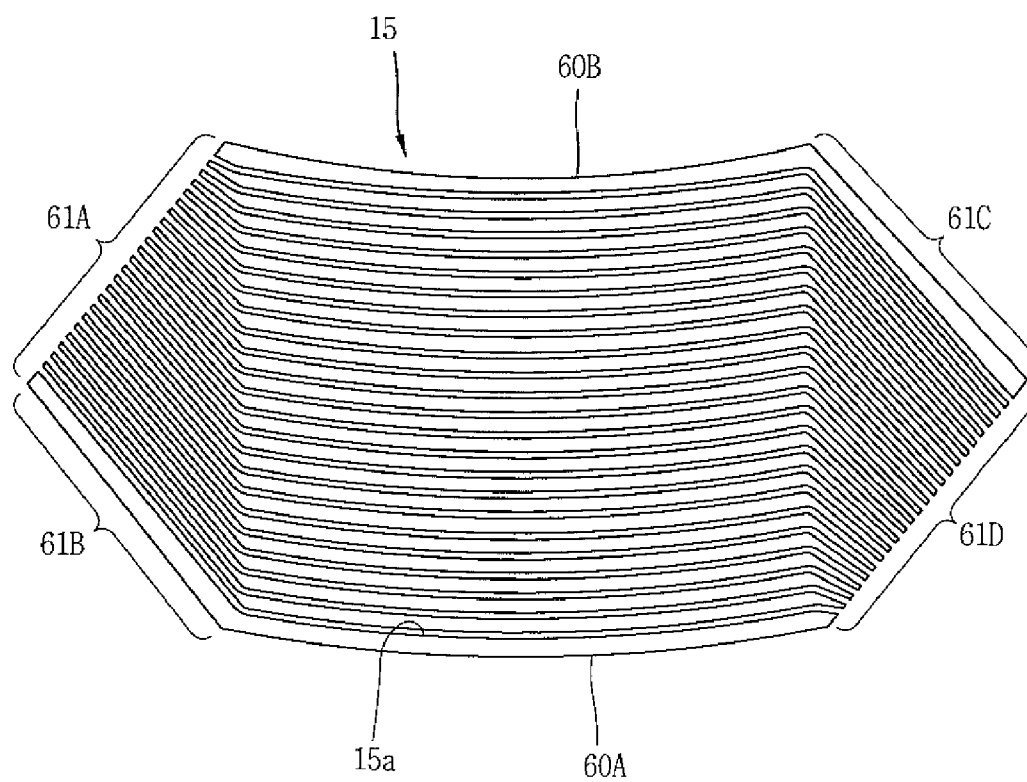


FIG. 6

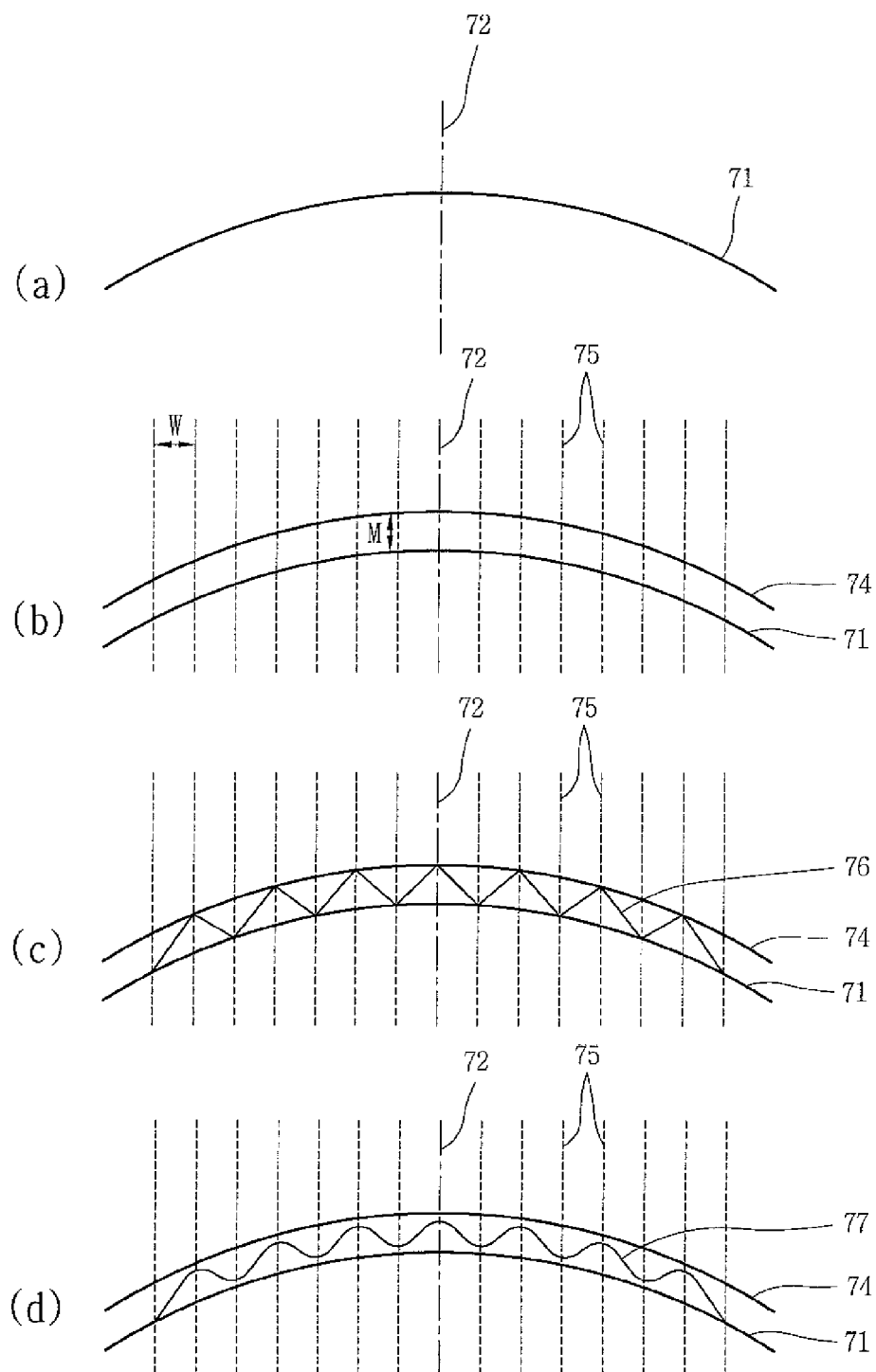
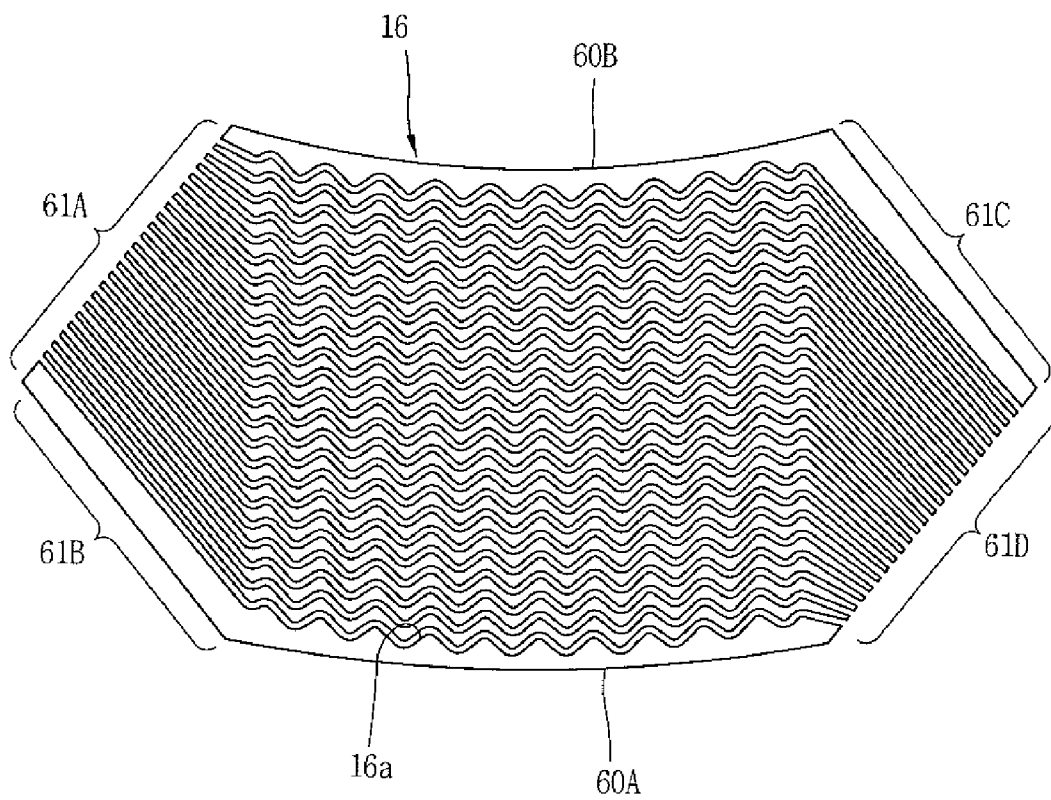


FIG. 7



HEAT EXCHANGER HAVING MICRO-CHANNELS

CROSS-REFERENCE TO A RELATED APPLICATION

[0001] This application claims the benefit of and right of priority to Korean Application No. 10-2009-0051898, filed on Jun. 11, 2009, the contents of which is incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to a heat exchanger having micro-channels formed by micromachining.

BACKGROUND OF THE INVENTION

[0003] Heat exchangers employed for special use are used in high temperature and high pressure environments, unlike typical heat exchangers, or required to be compact and durable in order to meet constraint conditions, such as weight, space and the like.

[0004] Gas-to-gas heat exchange needs a greater heat transfer area for the same heat exchange due to a low overall heat transfer coefficient, which causes difficulty in adapting the same to cases having constraint conditions of weight and space.

[0005] A printed circuit heat exchanger (PCHE), as a type of micro-channel heat exchanger, is made by alternately bonding different plates, having channels formed through etching, with interposing a separating plate therebetween. The PCHE has several advantages of forming millimeter-sized channels and having a large heat transfer area, compared to a usage space, by providing a large heat transfer area with allowing free flow of liquid as well as gas. Also, the PCHE has advantage of configuring a heat exchanger profitable for high temperature and high pressure usage environments. Improvement of a micro electro mechanical system (MEMS) field allows the PCHE to be fabricated in various forms by utilizing a variety of micromachining.

[0006] The PCHE having a compact size and high performance is applied to various fields, namely, energy technologies relating to energy-associated industries and the like as well information technologies relating to computers, semiconductors and the like. In addition, the PCHE has a great ripple effect not only on petrochemical plants needing micro-channel heat exchangers but also on other industries, such as fuel cell reactors, waste heat recovery facilities, refrigeration and air-conditioning industries of CO₂ heat pumps, water heaters and the like.

[0007] For a typical heat exchanger, when heat transfer is increased, pressure drop is simultaneously increased. However, by a design of the form of a micro-channel heat exchanger, the large amount of heat transfer can be generated with maintaining a small amount of pressure drop.

[0008] However, in case of a rectangular heat exchanger designed by the related art, since the shape and outline of flow channels are simple, it is relatively easy to design the shape of the flow channels, but usually difficult to meet a spatial condition within a device for mounting the heat exchanger

therein. In particular, if an overall outline has a curvature, the design of flow channels having the same flow length becomes more difficult.

SUMMARY OF THE INVENTION

[0009] Therefore, in order to obviate such problems of the related art, an object of the present invention is to provide a heat exchanger capable of implementing high performance by designing micro-channels having the same flow length when an outer appearance thereof has a curvature.

[0010] To achieve this and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described herein, there is provided a heat exchanger having micro-channels including a heat exchanger body having a plurality of layers laminated, each layer having a plurality of micro-channels, a high temperature fluid inlet body and a low temperature fluid outlet body detachably connected to one end portion of the heat exchanger body, and a low temperature fluid inlet body and a high temperature fluid outlet body detachable connected to another end portion of the heat exchanger body, wherein both side surfaces defining a width of the heat exchanger body have a first curvature profile and a second curvature profile in parallel to the first curvature profile.

[0011] As one example of the present invention, the heat exchanger body may include a hot side layer having a plurality of first micro-channels in parallel to one another, high temperature fluid flowing within the plurality of first micro-channels, and a cold side layer having a plurality of second micro-channels in parallel to one another, low temperature fluid flowing within the plurality of second micro-channels.

[0012] As one example of the present invention, the micro-channels may comprise n micro-channels ($n \geq 2$), and i th (i =natural number) channel of the channels may include an inlet portion having a length X_i , a curved portion having a length W_i and an outlet portion having a length Y_i , wherein X_i , Y_i and W_i may be constructed to meet the following equation.

$$X_i + Y_i + W_i = \text{Constant}$$

[0013] As one example of the present invention, a width between one curved portion and another curved portion adjacent thereto, among the curved portions, may be constantly maintained in a lengthwise direction.

[0014] As one example of the present invention, the curved portion may be configured in a wavy form.

[0015] According to the heat exchanger relating to the present invention, micro-channels can be formed in a heat exchanger body having a curved outer shape, thereby remarkably improving heat exchange efficiency as compared to a heat exchanger according to the related art.

[0016] According to one example of the present invention, wavy micro-channels may be employed in the heat exchanger body having the curved outer shape such that a total length and a cross section of each micro-channel are the same, thereby minimizing deviation for each channel.

[0017] Also, the heat exchanger having the curved outer shape and excellent heat transfer performance can be easily installed even at a place where it is difficult to install a linear type heat exchanger of the related art, thereby improving the installation.

[0018] The foregoing and other objects, features, aspects and advantages of the present invention will become more

apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention.

[0020] FIG. 1 is a perspective view showing one example of a micro-channel heat exchanger in accordance with the present invention.

[0021] FIG. 2 is a disassembled perspective view showing a low temperature fluid inlet body and a high temperature fluid outlet body being disassembled from the heat exchanger body of FIG. 1;

[0022] FIG. 3 is a disassembled perspective view showing a unit module configuring the heat exchanger body.

[0023] FIG. 4 is a planar view showing a schematic shape of each micro-channel.

[0024] FIG. 5 is a planar view of micro-channels having gently curved flow channels, as one example according to the present invention.

[0025] FIG. 6 is a diagram showing a process of constructing a wavy flow channel, as one example according to the present invention.

[0026] FIG. 7 is a planar view of micro-channels according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0027] Description will now be given in detail of the present invention, with reference to the accompanying drawings.

[0028] FIG. 1 is a perspective view showing one example of a micro-channel heat exchanger in accordance with the present invention. As shown in FIG. 1, a heat exchanger may include a heat exchanger body 10 having a curved shape, a high temperature fluid inlet body 20 and a low temperature fluid outlet body 50 detachably connected to one end portion of the heat exchanger body 10, and a low temperature fluid inlet body 40 and a high temperature fluid outlet body 30 attached onto another end portion of the heat exchanger body 10.

[0029] One side surface 60A of both side surfaces 60A and 60B (see FIG. 2), which define a width of the heat exchanger body 10 may have a first curvature profile, and another side surface 60B may have a second curvature profile in parallel to the first curvature profile. The first curvature profile and the second curvature profile may possibly be arcuately formed. Alternatively, they can be formed in a shape of an oval or a parabola or a combination thereof.

[0030] A high temperature fluid inlet pipe 21 may be disposed at an end of the high temperature fluid inlet body 20. High temperature fluid introduced into the singular high temperature fluid inlet pipe 21 is diffused into each micro-channel by the high temperature fluid inlet body 20 and flows within the heat exchanger body 10 so as to exchange heat with low temperature fluid. Such heat-exchanged fluid are all combined at the high temperature fluid outlet body 30 so as to be discharged via a high temperature fluid outlet pipe 31. Similar to this, a low temperature fluid inlet pipe 41 may be disposed at an end of the low temperature fluid inlet body 40. Low temperature fluid introduced into the singular low tempera-

ture fluid inlet pipe 41 is diffused into micro-channels, which are different from the high temperature side micro channels, by the low temperature fluid inlet body 40, and flows within the heat-exchanger body 10 so as to exchange heat with high temperature fluid. Such heat-exchanged fluid are all combined at the low temperature fluid outlet body 50 so as to be discharged via a low temperature fluid outlet pipe 51.

[0031] FIG. 2 is a disassembled perspective view showing a low temperature inlet body and a high temperature outlet body being disassembled from the heat exchanger body of FIG. 1, and FIG. 3 is a disassembled perspective view showing a unit module configuring the heat exchanger body.

[0032] Referring to FIGS. 2 and 3, the heat exchanger body 10 may have a structure in which a plurality of layers each having micro-channels are laminated.

[0033] A unit module 10' may include a hot side layer 12, a cold side layer 13 and a separating plate 11. The hot side layer 12 may be provided with a plurality of first micro-channels in which high temperature fluid flows, and the cold side layer 13 may be provided with a plurality of second micro-channels 13a in which low temperature fluid flows.

[0034] When viewed in a planar view, the hot side layer 12 and the cold side layer 13 forming the unit module 10' may commonly include end portion surfaces 61A, 61B, 61C and 61D in addition to the side surfaces 60A and 60B as aforesaid. The end portion surfaces 61A, 61B, 61C and 61D may be formed in a symmetrical shape with respect to a central arc so as to allow attachment of the high temperature fluid inlet body 20, the low temperature fluid inlet body 50, the high temperature fluid outlet body 30 and the low temperature fluid outlet body 40 all having the same size.

[0035] The hot side layer 12 and the cold side layer 13 may be bonded to each other by interposing the separating plate 11 therebetween, thereby sealing the first micro-channel 12a and the second micro-channel 13a, respectively. Thus, high temperature fluid flowing within the first micro-channels 12a can exchange heat with low temperature fluid of the second micro-channels 13a via the separating plate 11.

[0036] The micro-channel exchanger 1 employs a method for uniformly fixing an amount of pressure drop for distributing uniform fluid into each channel. That is, a flow channel length of the heat exchanger, which may be an important factor for determining efficiency of the heat exchanger is required to be equally set for all flow channels, in order to prevent decrease of the efficiency due to deviation of fluid introduced into each channel. If each micro-channel has a different length, fluid is excessively supplied into a short micro-channel, which may fatally affect the overall efficiency of the heat exchanger. Also, for fixing a constant amount of pressure drop, the flow channel within each micro-channel is fabricated to have the same flow length and shape. In the meantime, in case of employing wavy micro-channels other than linear micro-channels, heat transfer and the pressure drop can be increased. However, it has been known that heat transfer as compared to pressure drop is the most effective at an angle of approximately 30° based upon a proceeding direction of the micro-channel.

[0037] Therefore, the embodiment illustrates that, in order to obtain high efficiency of a heat exchanger having a curved outer shape, each micro-channel within the heat exchanger body 10 in the curved outer shape can be implemented in a wavy shape so as to constantly maintain the total length of each micro-channel.

[0038] FIG. 4 is a planar view showing a schematic shape of each micro-channel.

[0039] That is, as one approach for constantly maintaining the length of each micro-channel, the shape of each micro-channel of the heat exchanger body, the micro-channel being divided into an inlet portion, an outlet portion and an intermediate flow channel portion, may be formed such that the sum of the inlet portion length ($X_1, \dots, X_i, \dots, X_n$) and the outlet portion length ($Y_1, \dots, Y_i, \dots, Y_n$) is constant and the lengths ($W_1, \dots, W_i, \dots, W_n$) of the intermediate flow channels are the same, thereby constantly maintaining the entire length of the micro-channel.

$$X_i + Y_i + W_i = \text{Constant} \quad [\text{Equation 1}]$$

[0040] Here, if a cross section of the micro-channel is different for each micro-channel in a lengthwise direction, the heat transfer efficiency may be lowered in spite of the same flow length, accordingly, it is also preferable to equally maintain the cross section of each micro-channel.

[0041] In order to increase the efficiency of the heat exchanger, when designing the channels of the heat exchanger plates to have the wavy form by adapting a simple parallel option method, overlapping of the channels may be caused.

[0042] FIG. 5 is an example according to the present invention, which is a planar view of a micro-channel 15 having gently curved intermediate flow channels 15a. For the micro-channel 15 shown in FIG. 5, the overlap between the intermediate flow channels 15a may not occur, and the total length of each micro-channel 15 is constant.

[0043] FIG. 6 is an example according to the present invention, which shows a process of making a wavy intermediate flow channel.

[0044] As shown in FIG. 6(a), a curved shape to implement is determined and a first virtual line 71 for the shape is drawn.

[0045] As shown in FIG. 6(b), a second virtual line 74 having the same shape as that of the first virtual line 71 is drawn with a desired interval M based upon a centerline 72.

[0046] Then, vertical virtual lines 75 are drawn with a constant interval W based upon the centerline 72.

[0047] As shown in FIG. 6(c), intersections between the vertical virtual lines 75 drawn with the constant interval W and the first and second virtual lines 71 and 74 drawn with the interval M therebetween are connected.

[0048] As shown in FIG. 6(d), if the edges of the intersections are processed to be curved, a wavy centerline 77 in a wavy form is completed. Another centerline having the same shape as the first centerline 77 is drawn with an interval therebetween as far as a width of the wavy form, thus to complete one wavy intermediate flow channel.

[0049] The thusly-constructed micro-channels are shown in FIG. 7. That is, FIG. 7 is a planar view of the micro-channels according to the present invention, which shows that micro-channels 16a having the wavy curved intermediate flow channels can be obtained. As compared to the linear intermediate flow channel as the example of the related art, the wavy micro-channel 16a can remarkably improve the performance of the heat exchanger. In addition, as compared to the micro-channel having a gently curved portion shown in FIG. 5, the wavy micro-channel 16a can improve the performance of the heat exchanger.

[0050] As such, the wavy form ensuring excellent heat transfer as compared to pressure drop is applied to the heat exchanger body 10 having two curved edges (sides), thereby

reducing the sizes of the curvature profiles of the heat exchanger body 10 and varying proceeding angles of fluid within the wavy micro-channels according to positions.

[0051] The constructions and methods of the foregoing embodiments and advantages of the micro-channel are merely exemplary and are not to be construed as limiting the present disclosure. The present teachings can be readily applied to other types of apparatuses. This description is intended to be illustrative, and not to limit the scope of the claims. Many alternatives, modifications, and variations will be apparent to those skilled in the art. The features, structures, methods, and other characteristics of the exemplary embodiments described herein may be combined in various ways to obtain additional and/or alternative exemplary embodiments.

[0052] As the present features may be embodied in several forms without departing from the characteristics thereof, it should also be understood that the above-described embodiments are not limited by any of the details of the foregoing description, unless otherwise specified, but rather should be construed broadly within its scope as defined in the appended claims, and therefore all changes and modifications that fall within the metes and bounds of the claims, or equivalents of such metes and bounds are therefore intended to be embraced by the appended claims.

What is claimed is:

1. A heat exchanger having micro-channels comprising:
 - a heat exchanger body having a plurality of layers laminated, each layer having a plurality of micro-channels;
 - a high temperature fluid inlet body and a low temperature fluid outlet body detachably connected to one end portion of the heat exchanger body; and
 - a low temperature fluid inlet body and a high temperature fluid outlet body detachable connected to another end portion of the heat exchanger body,
 wherein both side surfaces defining a width of the heat exchanger body have a first curvature profile and a second curvature profile in parallel to the first curvature profile.
2. The heat exchanger of claim 1, wherein the heat exchanger body comprises:
 - a hot side layer having a plurality of first micro-channels in parallel to one another, high temperature fluid flowing within the plurality of first micro-channels; and
 - a cold side layer having a plurality of second micro-channels in parallel to one another, low temperature fluid flowing within the plurality of second micro-channels.
3. The heat exchanger of claim 2, wherein the first and second micro-channels respectively comprise n micro-channels, $n \geq 2$,
 - wherein i^{th} ($i = \text{natural number}$) channel of the channels may include an inlet portion having a length X_i , a curved portion having a length W_i and an outlet portion having a length Y_i ,
 - wherein X_i , Y_i and W_i are constructed to meet the following equation.
$$X_i + Y_i + W_i = \text{Constant}$$
4. The heat exchanger of claim 3, wherein a width between one curved portion and another curved portion adjacent thereto, among the curved portions, is constantly maintained in a lengthwise direction.
5. The heat exchanger of claim 4, wherein the curved portion is configured in a wavy form.

* * * * *