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(54) **HEAT EXCHANGER**

(57) Wave-like concaves/ convexes 34 and 36 are formed on respective flat surfaces 33 and 35 of a heat exchange tube 30, such that crest lines 34a and 36a of continuing V shapes in a horizontal direction and trough lines 34b and 36b of continuing V shapes in the horizontal direction are alternately arranged and that bends of the V shapes form curve lines. This configuration reduces the stress concentration at the bends in a press-forming process, compared with a configuration that crest lines and trough lines have bends formed in a shape of continuing sharply-angled V shapes in the horizontal direction. As a result, this configuration increases the yield in the press-forming process at a fixed amplitude of the wave-like concaves/ convexes 34 and 36 and increases the amplitude of the wave-like concaves/ convexes 34 and 36 at a fixed yield in the press-forming process.

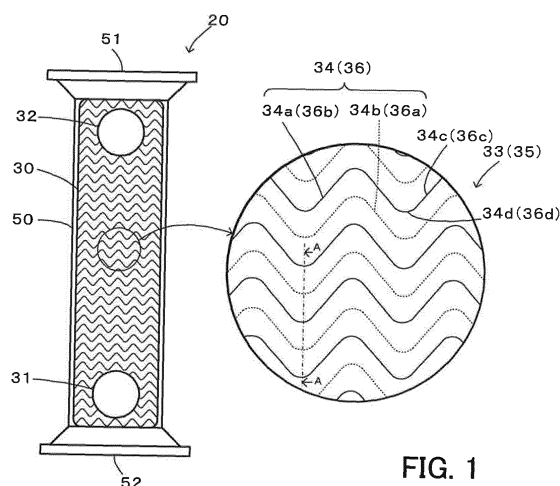


FIG. 1

Description

[0001] This is a national phase application of PCT/JP2015/086562 filed December 28, 2015, the contents of which are incorporated herein by reference.

Technical Field

[0002] The present disclosure relates to a heat exchanger and more specifically to a heat exchanger configured to perform heat exchange by flowing a fluid on the surface of a heat transfer member.

Background

[0003] In a proposed configuration of a heat exchanger, wave-like concaves/convexes are provided on a flat surface of a flat tubular heat exchange tube, such that the wave-like concaves/convexes have a predetermined angle in a range of 10 degrees to 60 degrees to the main flow of the air and that the wave-like concaves/convexes have crests and troughs to be symmetrically folded back on folding lines at predetermined intervals along the main flow of the air (as described in, for example, Patent Literature 1). The wave-like concaves/convexes of this heat exchanger include crests (convexes) of continuing V shapes (or W shapes) and troughs (concaves) of continuing V shapes (or W shapes). Forming such wave-like concaves/convexes causes a secondary flow along the surfaces of the wave-like concaves/convexes to be generated, in addition to the main flow of the air and improves the heat exchange efficiency of the heat exchanger.

Citation List

Patent Literature

[0004] PTL 1: JP 2008-232592A

Summary

[0005] In the heat exchanger described above, it is desired to increase the amplitude (height difference between the crest and the trough) of the wave-like concaves/convexes, with a view to improving the heat exchange efficiency. Increasing the amplitude of the wave-like concaves/convexes, however, causes damages due to stress concentration at bends of the continuing V shapes (or W shapes) of the crests (convexes) and the troughs (concaves) of the wave-like concaves/convexes in the process of press-forming the heat exchange tube. This reduces the yield of the heat exchange tube.

[0006] A heat exchanger of the present disclosure mainly aims to increase the yield of a heat transfer member at a fixed amplitude of wave-like concaves/convexes formed on the heat transfer member and to increase the amplitude of the wave-like concaves/convexes of the heat transfer member at a fixed yield of the heat transfer

member.

[0007] In order to achieve the above primary object, the heat exchanger of the present disclosure employs the following configuration.

[0008] The present disclosure is directed to a heat exchanger configured to perform heat exchange by flowing a fluid on a surface of a heat transfer member. The heat transfer member includes wave-like concaves/convexes of smooth curve lines provided on the surface exposed to the fluid. The wave-like concaves/convexes are formed such that crest lines of continuing crests of wave and trough lines of continuing troughs of wave are formed in a shape of continuing V shapes in a horizontal direction, that bends of the V shapes form curve lines, and that a main flow of the fluid flows in a direction perpendicular to the V shapes.

[0009] In the heat exchanger of this aspect, the wave-like concaves/convexes of smooth curve lines are formed on the surface of the heat transfer member exposed to the fluid, such that the crest lines of continuing the crests of wave and the trough lines of continuing the troughs of wave are formed in the shape of continuing the V shapes in the horizontal direction and that the bends of the V shapes form curve lines, i.e., in a shape of continuing two V shapes in the horizontal direction to form a W shape and further continuing the W shapes. The wave-like concaves/convexes are also formed such that the main flow of the fluid flows in the direction perpendicular to the V shapes (i.e., in the vertical direction). Forming the crest lines and the trough lines to have curved V-shaped bends (i.e., curved W-shaped bends) reduces the stress concentration at the bends. As a result, this configuration increases the yield of the heat transfer member at a fixed amplitude of the wave-like concaves/convexes of the heat transfer member and increases the amplitude of the wave-like concaves/convexes of the heat transfer member at a fixed yield of the heat transfer member. In the heat exchanger of this aspect, the wave-like concaves/convexes of smooth curve lines are formed in the shape of continuing V shapes on the surface of the heat transfer member exposed to the fluid. This configuration enables a secondary flow along the surfaces of the wave-like concaves/convexes of the heat transfer member to be generated, in addition to the main flow of the fluid and thereby improves the heat transfer efficiency of the heat exchanger.

[0010] In the heat exchanger of this aspect, the crest line and the trough line may be formed by alternately arranging linear portions and arc portions in a continuous manner. This configuration increases the minimum radius of the bends, compared with a configuration that crest lines and trough lines are formed by sinusoidal curves. As a result, this configuration increases the yield of the heat transfer member at a fixed amplitude of the wave-like concaves/convexes of the heat transfer member and increases the amplitude of the wave-like concaves/convexes of the heat transfer member at a fixed yield of the heat transfer member, compared with the configuration

that the crest lines and the trough lines are formed by sinusoidal curves. In this case, the arc portion may have a radius that is equal to or larger than one fifth a length of the linear portion.

[0011] In the heat exchanger of another aspect, the wave-like concaves/convexes may be formed by alternately arranging straight lines and arcs in a continuous manner in cross section. This configuration increases the amplitude of the wave-like concaves/convexes, compared with a configuration that the wave-like concaves/convexes are formed by sinusoidal curves in cross section, and thereby further improves the heat transfer efficiency of the heat exchanger.

[0012] In the heat exchanger of another aspect, the heat transfer member may be a heat exchange tube formed as a flat hollow pipe, and the wave-like concaves/convexes may be formed on a flat surface of the heat exchange tube. Accordingly, the present disclosure may be applied to a fin-less heat exchanger. In the heat exchanger of still another aspect, the heat transfer member may be a fin coupled with a heat exchange tube. Accordingly, the present disclosure may be applied to a corrugated fin heat exchanger or the like.

Brief Description of Drawings

[0013]

Fig. 1 is a diagram illustrating the schematic configuration of a heat exchanger according to one embodiment of the present disclosure;

Fig. 2 is a side view illustrating the side view appearance of a plurality of heat exchange tubes used for the heat exchanger according to the embodiment;

Fig. 3 is a sectional view illustrating a cross section taken on a line A-A shown in Fig. 1, and

Fig. 4 is a diagram illustrating the schematic configuration of a heat exchanger according to a comparative example.

Description of Embodiments

[0014] The following describes some aspects of the disclosure with reference to embodiments.

[0015] Fig. 1 is a diagram illustrating the schematic configuration of a heat exchanger 20 according to one embodiment of the present disclosure. Fig. 2 is a side view illustrating the side view appearance of a plurality of heat exchange tubes 30 used for the heat exchanger 20 according to the embodiment. Fig. 3 is a sectional view illustrating a cross section taken on a line A-A shown in Fig. 1. Fig. 4 is a diagram illustrating the schematic configuration of a heat exchanger 920 according to a comparative example. As shown in Fig. 1, the heat exchanger 20 of the embodiment includes a plurality of heat exchange tubes 30 arranged in parallel such that their longitudinal directions correspond to a vertical direction, and a shell 50 configured to place the plurality of heat

exchange tubes 30 therein.

[0016] Each of the heat exchange tubes 30 is formed by press-forming a plate member made of a metal material (for example, stainless steel or aluminum) to be a flat hollow pipe in an approximately rectangular shape as a whole. The respective heat exchange tubes 30 are stacked such that their longitudinal directions correspond to the vertical direction and are joined with one another at respective contact points by brazing. An inflow port 31 formed at a vertically lower position near to a lower end of each heat exchange tube 30 is joined with an inflow port 31 of another heat exchange tube 30 adjacent thereto in the stack of the respective heat exchange tubes 30. This forms a connecting pipe 31a to make the respective inflow ports 31 communicate with one another. Like the inflow ports 31, an outflow port 32 formed at a vertically upper position near to an upper end of each heat exchange tube 30 is joined with an outflow port 32 of another heat exchange tube 30 adjacent thereto in the stack of the respective heat exchange tubes 30. This forms a connecting pipe 32a to make the respective outflow ports 32 communicate with one another. This configuration enables a first heat exchange medium such as water or oil to flow in from the inflow ports 31 of the respective heat exchange tubes 31, to flow vertically upward, and to flow out from the outflow ports 32 of the respective heat exchange tubes 30.

[0017] The shell 50 is formed from a plate member made of a metal material (for example, stainless steel or aluminum) like the respective heat exchange tubes 30 and is configured as a case in an approximately rectangular parallelepiped shape to place therein the plurality of heat exchange tubes 30 that are coupled with one another by means of the connecting pipes 31a and 32a. A flow inlet 51 is formed in an upper portion of the shell 50, and a flow outlet 52 is formed in a lower portion of the shell 50. This configuration enables a second heat exchange medium such as the air or exhaust gas to flow in from the flow inlet 51 formed in the upper portion of the shell 50, to pass through between the plurality of heat exchange tubes 30 and to flow out from the flow outlet 52 formed in the lower portion of the shell 50.

[0018] A plurality of wave-like concaves/convexes 34 and 36 are formed by smooth curved surfaces on respective flat surfaces 33 and 35 of each of the heat exchange tubes 30. Fig. 1 illustrates the wave-like concaves/convexes 34 provided on one flat surface 33 out of the respective flat surfaces 33 and 35 of the heat exchange tube 30, and wave-like concaves/convexes 36 provided on the other flat surface 35 (flat surface on a rear side in Fig. 1) are shown in parentheses. The wave-like concaves/convexes 34 and 36 are formed such that crest lines 34a and 36a of continuing crests of waves shown by a plurality of solid lines and trough lines 34b and 36b of continuing troughs of waves shown by a plurality of broken lines are arranged alternately in a shape of continuing V shapes (or W shapes) in a horizontal direction and that respective bends of the V shapes (or the W

shapes) form curved lines. The crest of wave herein means the position of 90 degrees in a sinusoidal waveform of upward waves and downward waves, i.e., the position of a maximum value (crest of the upward wave). The trough of wave here means the position of 270 degrees in the sinusoidal waveform of upward waves and downward waves, i.e., the position of a minimum value (trough of the downward wave). As described above, the second heat exchange medium passing through between the plurality of heat exchange tubes 30 flows in from the flow inlet 51 formed in the upper portion of the shell 50 and flows out from the flow outlet 52 formed in the lower portion of the shell 50. Accordingly, the main flow of the second heat exchange medium intersects with slant line portions of the V shapes (or the W shapes) of the crest lines 34a or 36a and the trough lines 34b or 36b at angles of the slant line portions (angles in a range of 30 degrees to 60 degrees). As described above, each heat exchange tube 30 is configured such that the crest lines 34a and 36a and the trough lines 34b and 36b are formed in the shape of continuing V shapes (or W shapes) in the horizontal direction on the respective flat surfaces 33 and 35. This configuration enables a secondary flow effective for heat exchange to be generated, in addition to the main flow of the second heat exchange medium. The secondary flow herein means a flow along the surfaces of the wave-like concaves/convexes 34 and 36 that is effective for heat exchange and is different from vortex flow and stirring flow.

[0019] According to the embodiment, the crest lines 34a and 36a and the trough lines 34b and 36b are formed such that linear portions 34c and 36c formed by straight lines and arc portions 34d and 36d formed by arcs are arranged alternately in a continuous manner. According to the embodiment, the radius of the arc portions 34d and 36d is equal to or larger than one fifth the length of the linear portions 34c and 36c. Such configuration of forming the bends of the V shapes (or the W shapes) by arcs (curve lines) reduces the stress concentration at the bends in the press-forming process, compared with the heat exchanger 920 of the comparative example of Fig. 4 configured such that wave-like concaves/convexes 934 and 936 provided on respective flat surfaces 933 and 935 of each heat exchange tube 930 have crest lines 934a and 936a and trough lines 934b and 936b with bends formed in a shape of continuing sharply-angled V shapes (or W shapes) in the horizontal direction. The stress concentration at the bends in the press-forming process increases with a decrease in minimum radius of the bends and also increases with an increase in amplitude of the wave-like concaves/convexes 34 and 36. An increase in the stress concentration increases the possibility of cracking. As a result, the heat exchange tubes 30 of the embodiment have the higher yield in the press-forming process at a fixed amplitude of the wave-like concaves/convexes 34 and 36 and have the larger amplitude of the wave-like concaves/convexes 34 and 36 at a fixed yield in the press-forming process, compared with the

heat exchange tubes 930 of the heat exchanger 920 of the comparative example.

[0020] The wave-like concaves/convexes 34 and 36 of the embodiment are formed such that straight lines and arcs are alternately arranged in a continuous manner in cross section as shown in Fig. 3. Tops and bottoms of the arcs respectively form the crest lines 34a and 36a and the trough lines 34b and 36b. The configuration of the wave-like concaves/convexes 34 and 36 by alternately arranging the straight lines and the arcs in a continuous manner in cross section increases the minimum radius of the crest and the trough of wave and accordingly increases the amplitude, compared with a configuration of sinusoidal curves in cross section.

[0021] In the heat exchange tube 30 of the embodiment, the wave-like concaves/convexes 34 provided on one flat surface 33 and the wave-like concaves/convexes 36 provided on the other flat surface 35 are arranged parallel to each other, such that the crest lines 34a of the wave-like concaves/convexes 34 on one flat surface 33 are aligned with the trough lines 36b of the wave-like concaves/convexes 36 on the other flat surface 35 and that the trough lines 34b of the wave-like concaves/convexes 34 on one flat surface 33 are aligned with the crest lines 36a of the wave-like concaves/convexes 36 on the other flat surface 35.

[0022] In the heat exchanger 20 of the embodiment described above, the wave-like concaves/convexes 34 and 36 provided on the respective flat surfaces 33 and 35 of each of the heat exchange tubes 30 are formed such that the crest lines 34a and 36a and the trough lines 34b and 36b are arranged alternately in the shape of continuing V shapes (or W shapes) in the horizontal direction and that the respective bends of the V shapes (or the W shapes) form the curved lines. This configuration increases the yield in the press-forming process at the fixed amplitude of the wave-like concaves/convexes 34 and 36 and increases the amplitude of the wave-like concaves/convexes 34 and 36 at the fixed yield in the press-forming process, compared with the heat exchange tubes 930 of the heat exchanger 920 of the comparative example configured such that the crest lines 934a and 936a and the trough lines 934b and 936b have the bends formed in the shape of continuing sharply-angled V shapes (or W shapes) in the horizontal direction. Additionally, the crest lines 34a and 36a and the trough lines 34b and 36b are formed by alternately arranging the linear portions 34c and 36c and arc portions 34d and 36d in a continuous manner. This configuration increases the minimum radius of the bends and reduces the stress concentration at the bends in the press-forming process, compared with the configuration that the crest lines and the trough lines are formed by sinusoidal curves. Accordingly, this configuration further increases the yield in the press-forming process at the fixed amplitude of the wave-like concaves/convexes 34 and 36 and further increases the amplitude of the wave-like concaves/convexes 34 and 36 at the fixed yield in the press-forming process.

[0023] The configuration that the crest lines 34a and 36a and the trough lines 34b and 36b are formed in the shape of continuing V shapes (or W shapes) in the horizontal direction on the respective flat surfaces 33 and 35 of the heat exchange tube 30. This configuration enables the secondary flow effective for heat exchange to be generated, in addition to the main flow of the second heat exchange medium, on the surfaces of the wave-like concaves/ convexes 34 and 36 and provides the heat exchange having a high heat exchange efficiency. Furthermore, the configuration of the wave-like concaves/ convexes 34 and 36 by alternately arranging the straight lines and the arcs in a continuous manner in cross section increases the minimum radius of the crest and the trough of wave and accordingly increases the amplitude, compared with the configuration of sinusoidal curves in cross section. This configuration provides the heat exchanger having the higher heat exchange efficiency.

[0024] In the heat exchanger 20 of the embodiment, the wave-like concaves/ convexes 34 and 36 have the crest lines 34a and 36a and the trough lines 34b and 36b formed by alternately arranging the linear portions 34c and 36c and the arc portions 34d and 36d in a continuous manner. The requirement is that the crest lines and the trough lines have curved V-shaped (or W-shaped) bends. According to a modification, the crest lines and the trough lines may be formed by alternately arranging S-shaped curves and arcs in a continuous manner, or the crest lines and the trough lines may be formed by continuing sinusoidal curves.

[0025] In the heat exchanger 20 of the embodiment, the wave-like concaves/ convexes 34 and 36 are formed by alternately arranging the straight lines and the arcs in a continuous manner in cross section. According to a modification, the wave-like concaves/ convexes 34 and 36 may be formed by alternately arranging S-shaped curves and arcs in a continuous manner in cross section or may be formed by continuing sinusoidal curves in cross section.

[0026] In the heat exchanger 20 of the embodiment, the first heat exchange medium and the second heat exchange medium form opposed flows. According to a modification, the first heat exchange medium and the second heat exchange medium may form cross flows, or one or both of the first heat exchange medium and the second heat exchange medium may form a bypass flow.

[0027] The embodiment describes the application of the present disclosure to the heat exchange tubes in the fin-less heat exchanger 20. The present disclosure may, however, be applied to a fin in a corrugated fin heat exchanger. In this modification, the fin may be configured such that wave-like concaves/ convexes of smooth curve lines are formed by alternately arranging crest lines of continuing V shapes (or W shapes) in the horizontal direction and trough lines of continuing V shapes (or W shapes) in the horizontal direction, that bends of the V shapes (or W shapes) form curved lines, and that the main flow of a fluid flows in the fin in an perpendicular

direction of the V shapes.

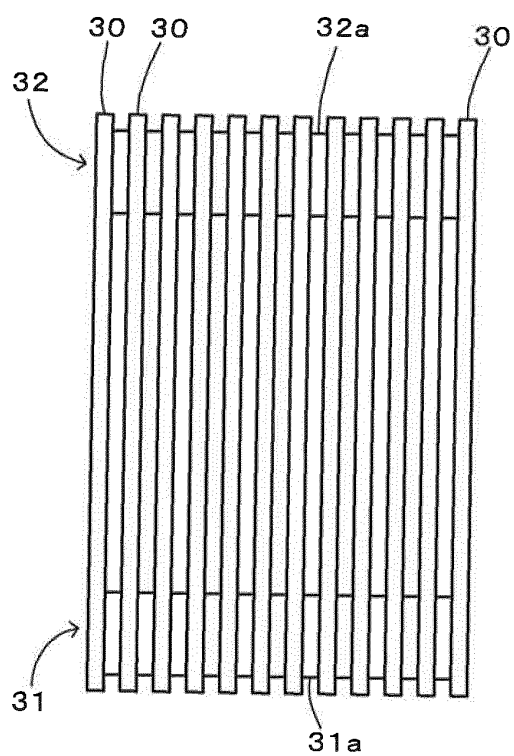
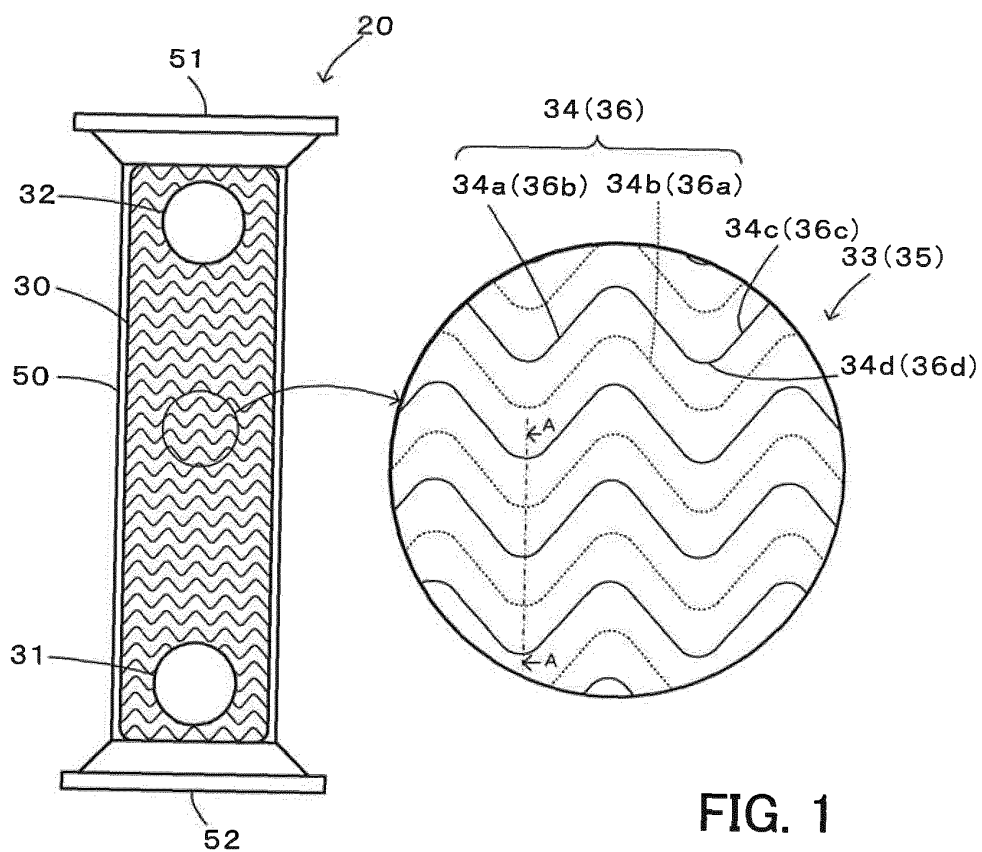
[0028] The aspect of the disclosure is described above with reference to the embodiment. The disclosure is, however, not limited to the above embodiment but various modifications and variations may be made to the embodiment without departing from the scope of the disclosure.

Industrial Applicability

[0029] The technique of the disclosure is preferably applicable to the manufacturing industries of the heat exchanger and so on.

Claims

1. A heat exchanger configured to perform heat exchange by flowing a fluid on a surface of a heat transfer member, the heat transfer member comprising wave-like concaves/ convexes of smooth curve lines provided on the surface exposed to the fluid, wherein the wave-like concaves/ convexes are formed such that crest lines of continuing crests of wave and trough lines of continuing troughs of wave are formed in a shape of continuing V shapes in a horizontal direction, that bends of the V shapes form curve lines, and that a main flow of the fluid flows in a direction perpendicular to the V shapes.
2. The heat exchanger according to claim 1, wherein the crest line and the trough line are formed by alternately arranging linear portions and arc portions in a continuous manner.
3. The heat exchanger according to claim 2, wherein the arc portion has a radius that is equal to or larger than one fifth a length of the linear portion.
4. The heat exchanger according to any one of claims 1 to 3, wherein the wave-like concaves/ convexes are formed by alternately arranging straight lines and arcs in a continuous manner in cross section.
5. The heat exchanger according to any one of claims 1 to 4, wherein the heat transfer member is a heat exchange tube formed as a flat hollow pipe, and the wave-like concaves/ convexes are formed on a flat surface of the heat exchange tube.
6. The heat exchanger according to any one of claims 1 to 4, wherein the heat transfer member is a fin coupled with a heat exchange tube.



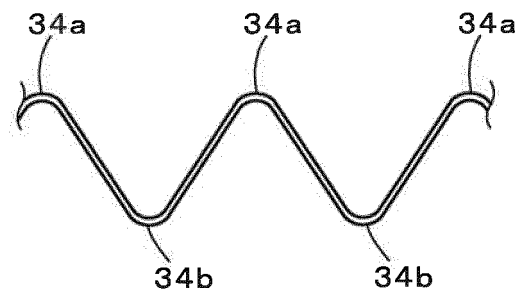


FIG. 3

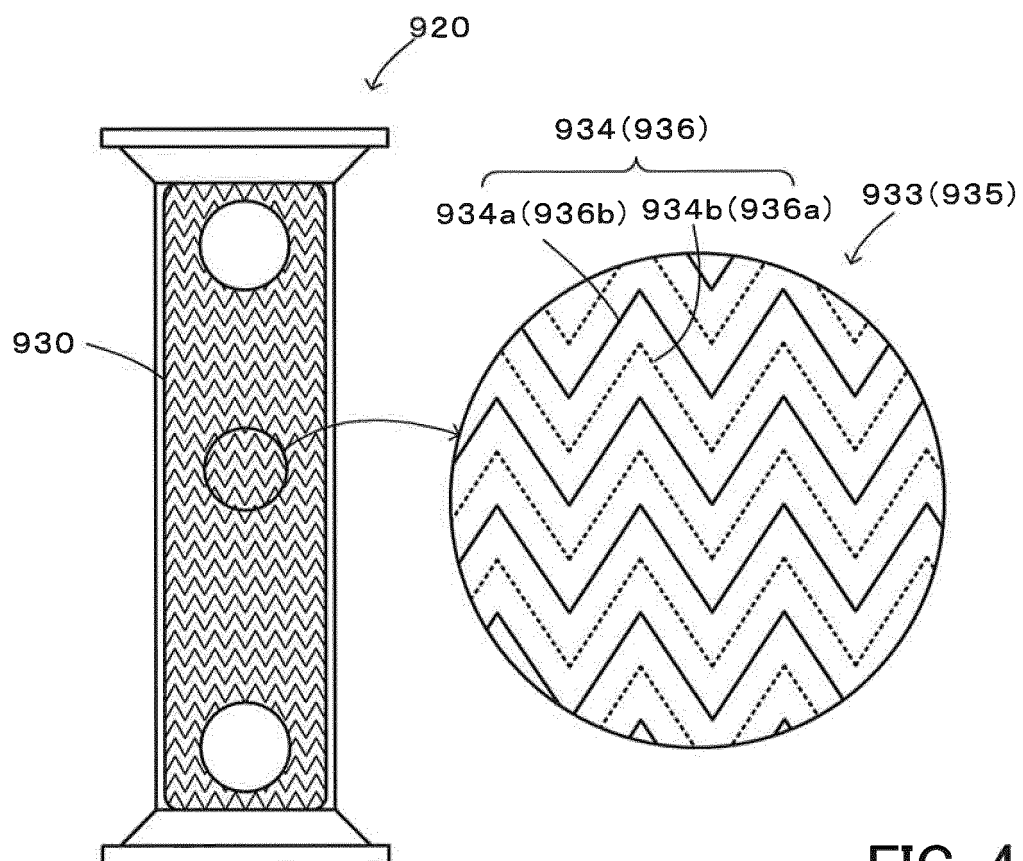


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/086562

A. CLASSIFICATION OF SUBJECT MATTER

F28D1/053(2006.01)i, F28F1/06(2006.01)i, F28F3/04(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F28D1/053, F28F1/06, F28F3/04

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016

Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2008-232592 A (The University of Tokyo), 02 October 2008 (02.10.2008), paragraphs [0020] to [0044]; fig. 2 & US 2010/0089560 A1 paragraphs [0005] to [0018]	1-6
Y	JP 2003-251500 A (Kawasaki Thermal Engineering Co., Ltd.), 09 September 2003 (09.09.2003), paragraphs [0003] to [0006], [0034]; fig. 3 (Family: none)	1-6
Y	WO 2014/069175 A1 (Calsonic Kansei Corp.), 08 May 2014 (08.05.2014), paragraph [0027]; fig. 1 & US 2015/0300755 A1 paragraph [0055]	6

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

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Date of the actual completion of the international search
03 March 2016 (03.03.16)Date of mailing of the international search report
22 March 2016 (22.03.16)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

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Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/086562

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 10-281677 A (Ishikawajima-Harima Heavy Industries Co., Ltd.), 23 October 1998 (23.10.1998), paragraph [0005]; fig. 6 (Family: none)	1-6
A	JP 9-280764 A (Hitachi, Ltd.), 31 October 1997 (31.10.1997), paragraphs [0012] to [0020]; fig. 1 (Family: none)	1-6

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2015086562 W [0001]
- JP 2008232592 A [0004]