US 20240255233A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2024/0255233 A1
(43) Pub. Date: Aug. 1, 2024
TAKAGI et al.

(54) **HEAT EXCHANGER, POWER CONVERSION DEVICE INCLUDING HEAT EXCHANGER, AND METHOD FOR MANUFACTURING INNER FIN FOR HEAT EXCHANGER**

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(21) Appl. No.: **18/564,148**

(22) PCT Filed: **Jul. 21, 2021**

(86) PCT No.: **PCT/JP2021/027394**

§ 371 (c)(1),
(2) Date: **Nov. 27, 2023**

Publication Classification

(51) **Int. Cl.**

F28F 1/40	(2006.01)
F28F 3/02	(2006.01)
F28F 3/12	(2006.01)
H02M 7/00	(2006.01)

(52) **U.S. Cl.**
CPC ***F28F 1/40*** (2013.01); ***F28F 3/025*** (2013.01); ***F28F 3/12*** (2013.01); ***H02M 7/003*** (2013.01)

(57) **ABSTRACT**

In a heat exchanger, an inner fin having heat transference is disposed in a flat passage, the inner fin is formed by a plurality of fin portions having a convex shape formed by a top surface portion and a side surface portion and having a hollow inside the convex shape; when a direction in which the plurality of fin portions are formed and lined to be continuous via a coupling portion is defined as a first direction and a direction in which slits are formed between the plurality of fin portions and lined is defined as a second direction, the plurality of fin portions are arranged at a predetermined interval in the second direction; and the inner fin is arranged such that the first direction and the second direction respectively forms an acute angle with respect to a flow of a refrigerant flowing in the flat passage.

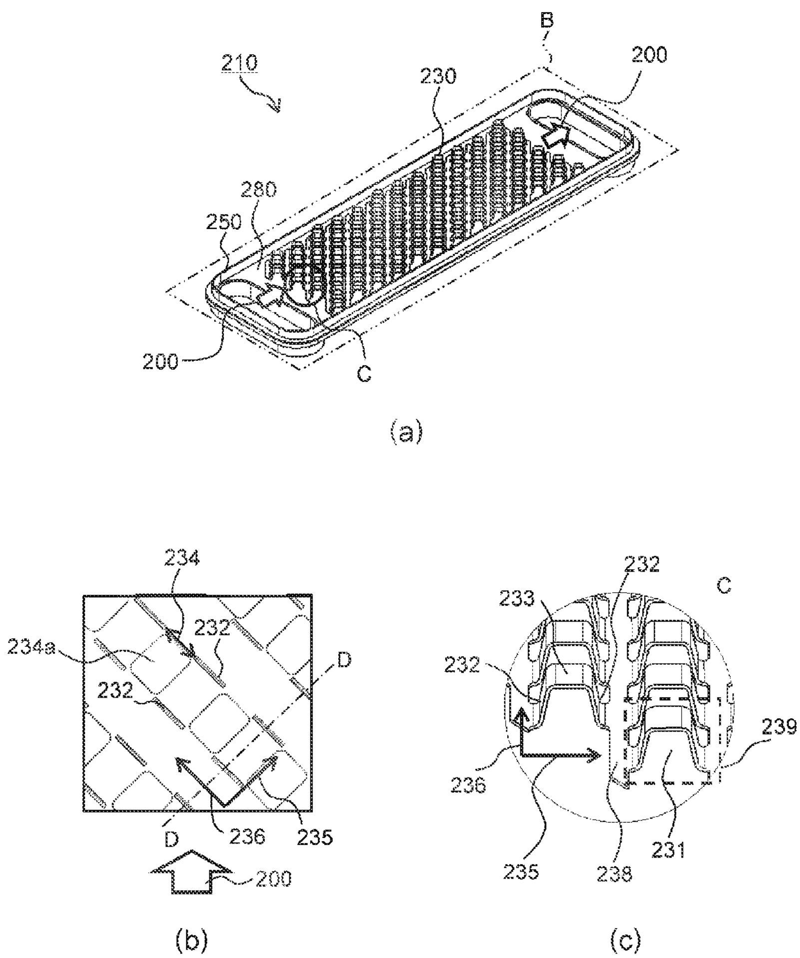


FIG. 1

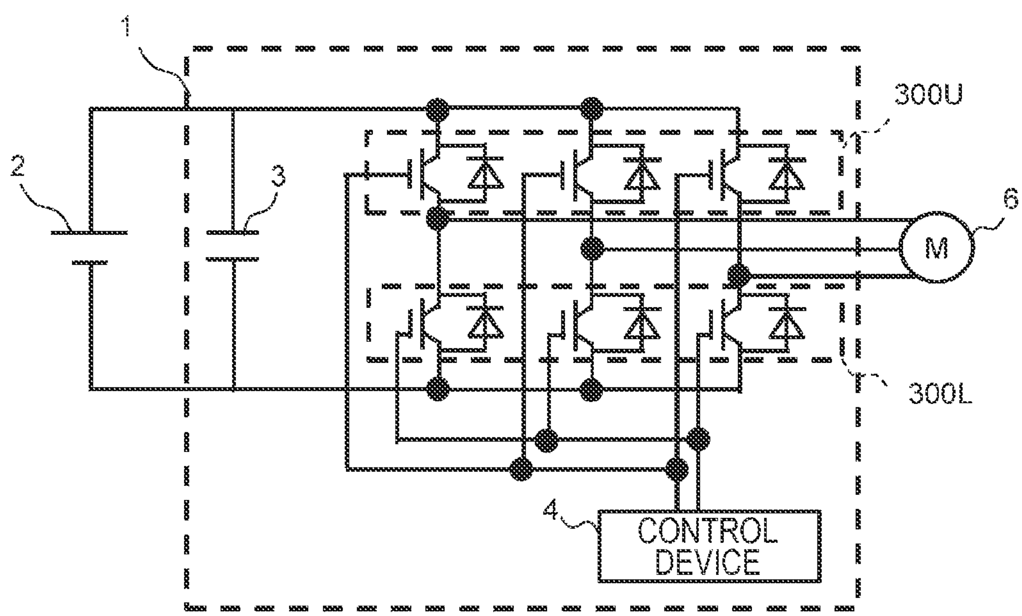


FIG. 2

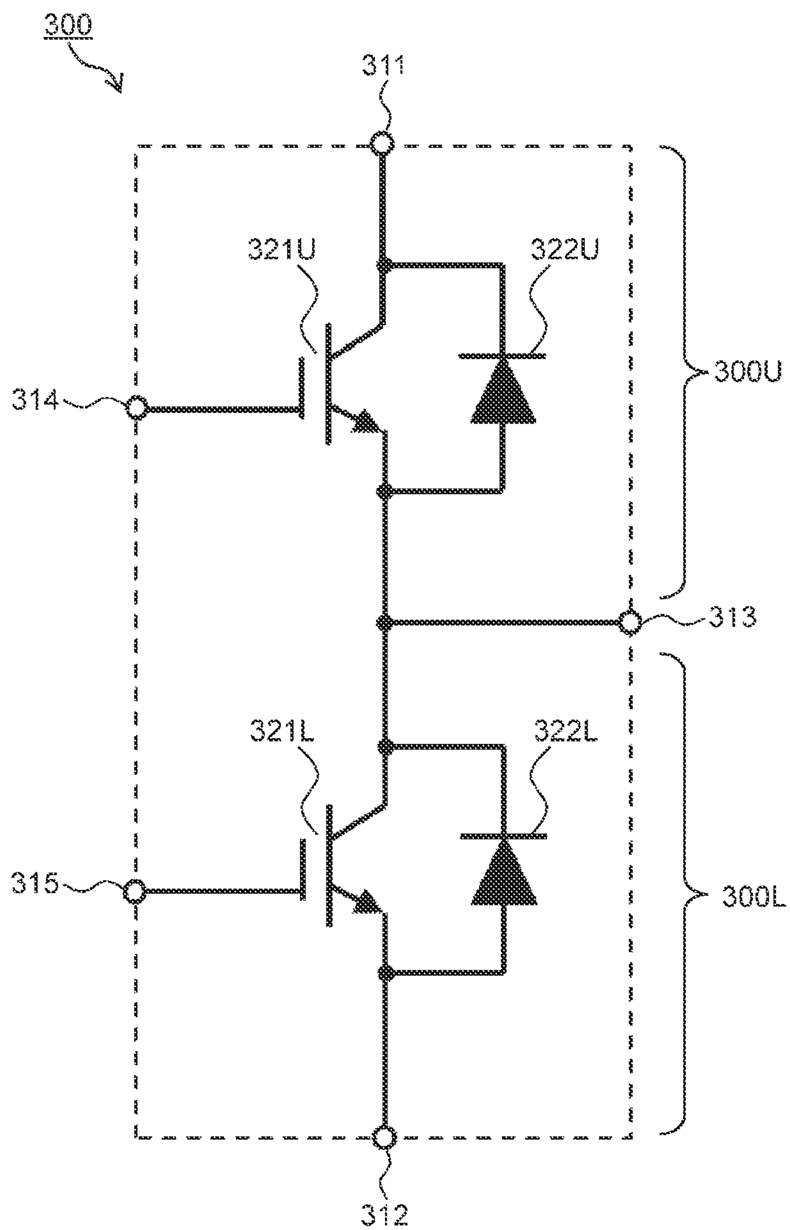


FIG. 3

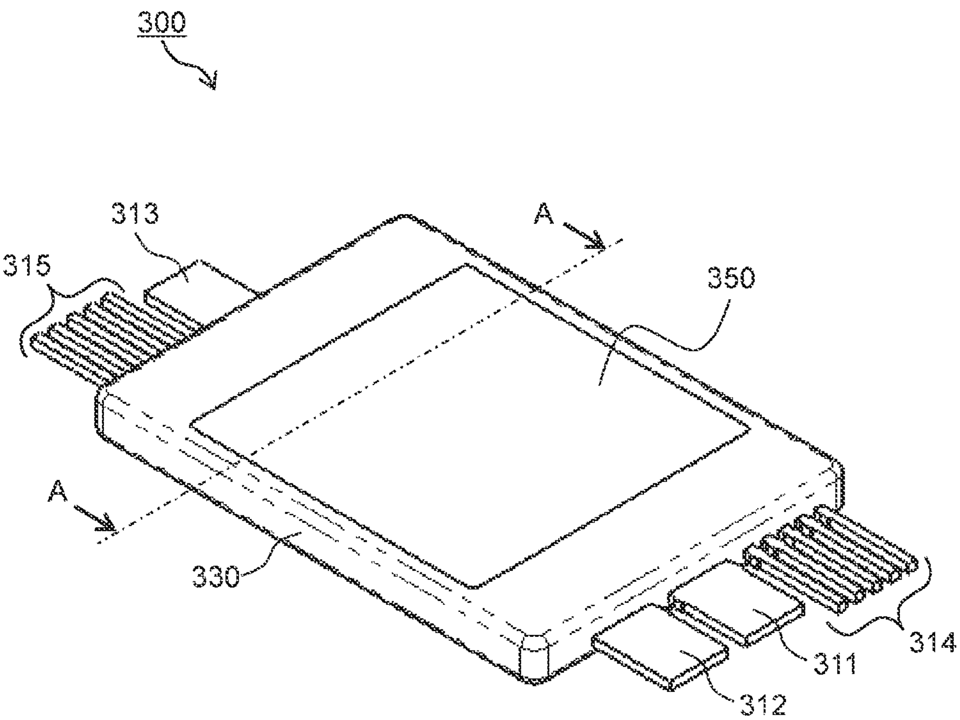


FIG. 4

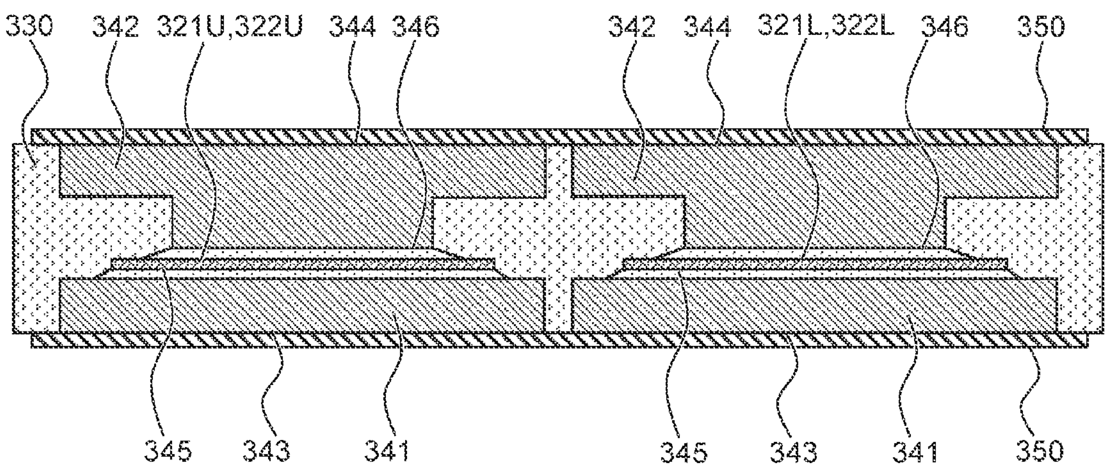

330
342
321U,322U
344
346
342
344
321L,322L
346
350
345
343
341
345
343
341
350

FIG. 5

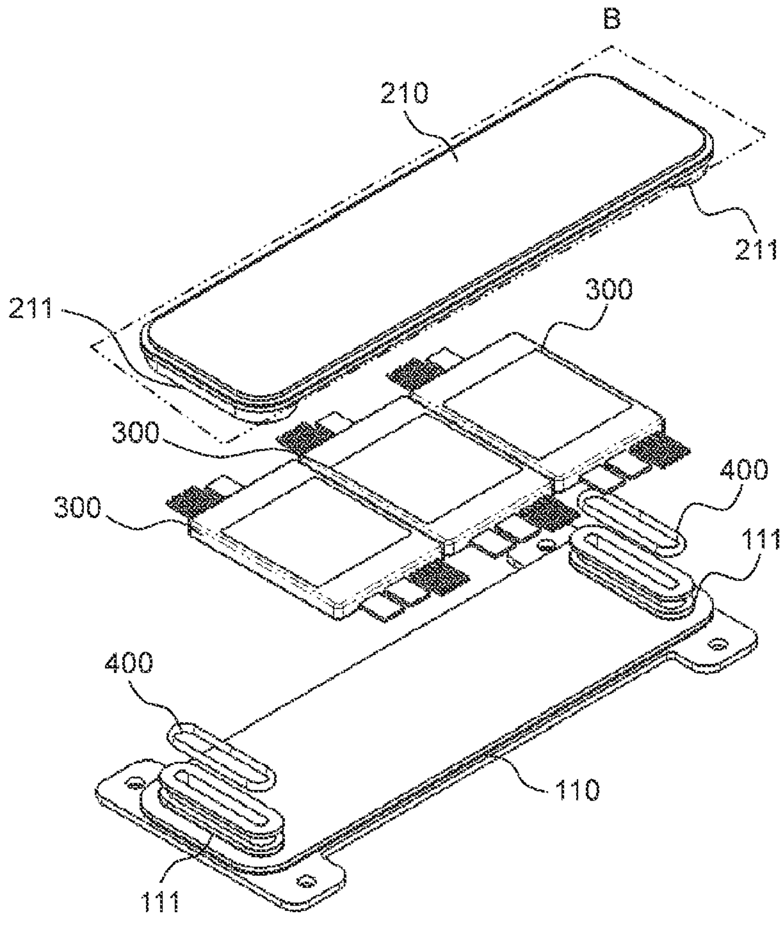


FIG. 6

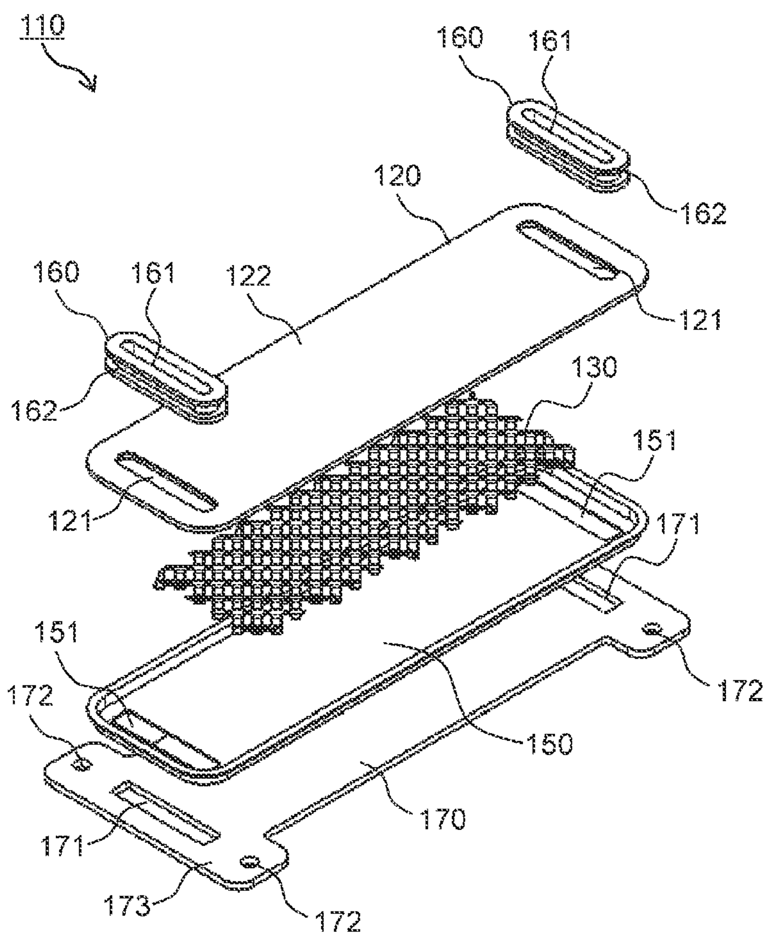

110
160
161
162
120
160
161
122
121
162
130
121
151
171
151
172
172
150
170
171
173
172

FIG. 7

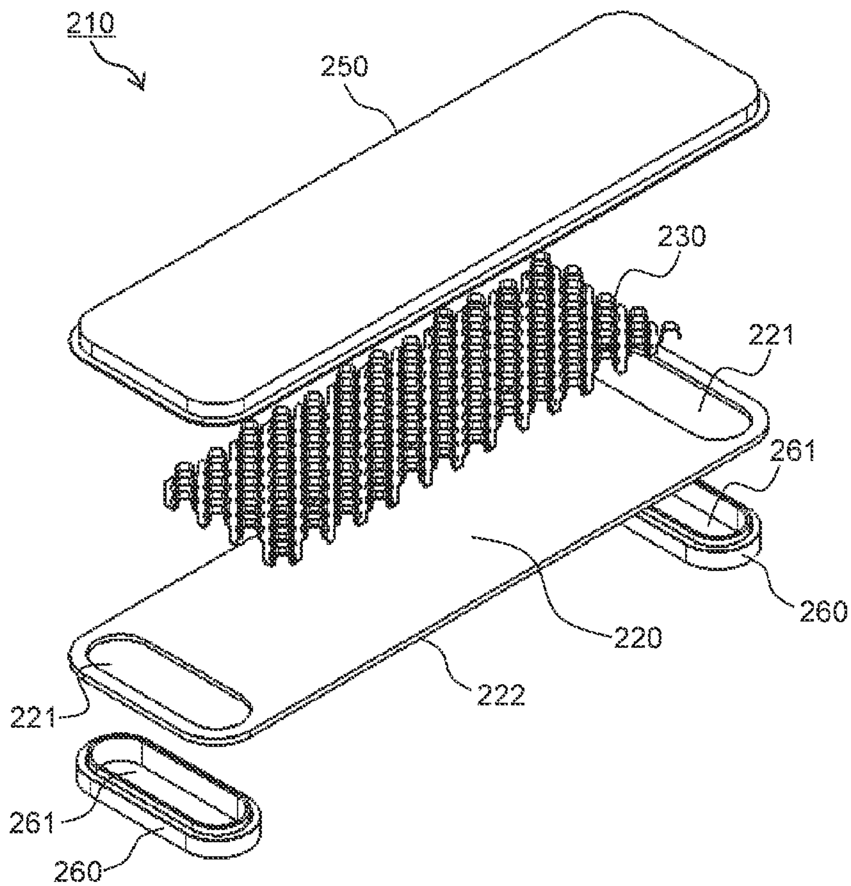
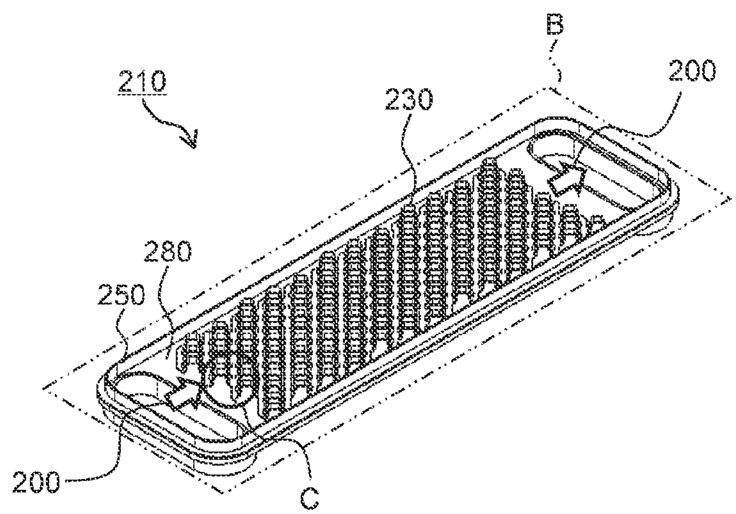
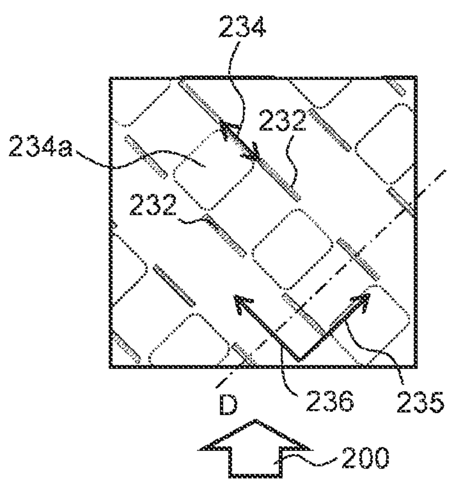


FIG. 8



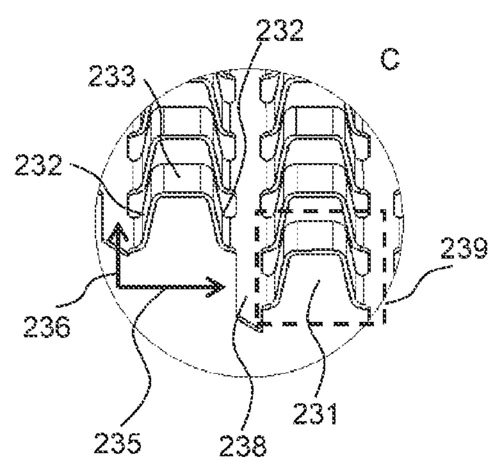
B
210
230
200
280
250
200
C

(a)



234
234a
232
232
D
D
236
235
200

(b)



232
C
233
232
239
236
235
238
231

(c)

FIG. 9

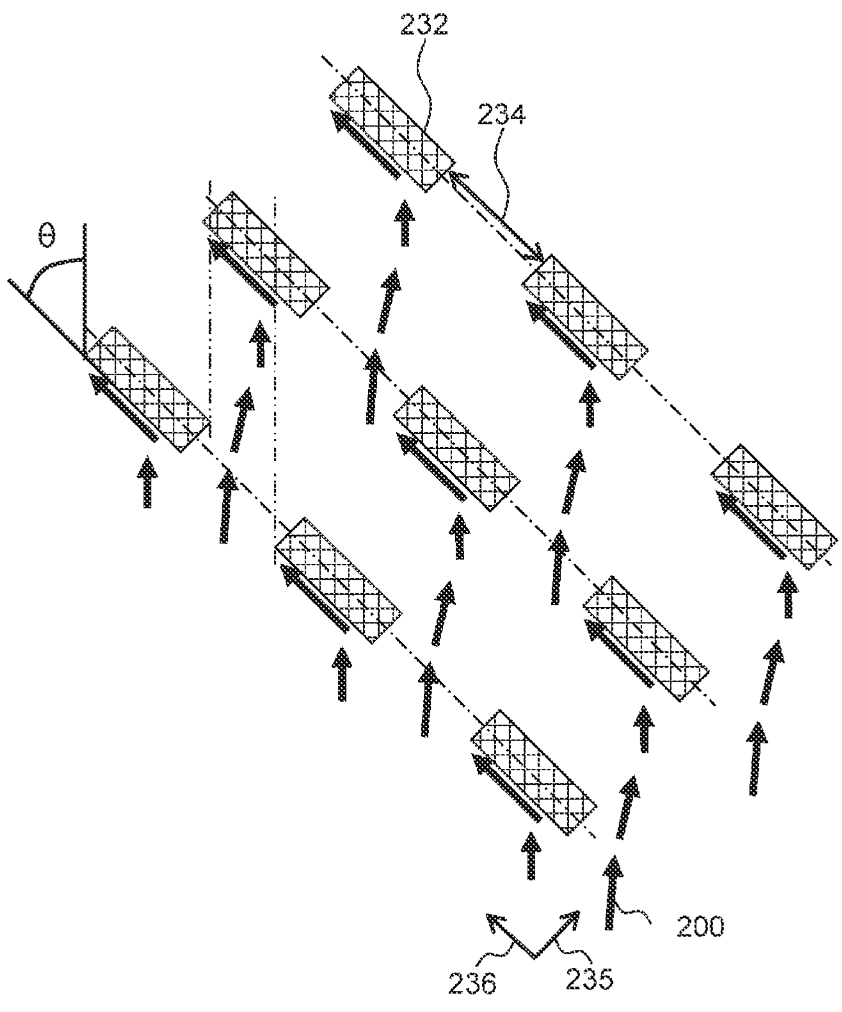


FIG. 10

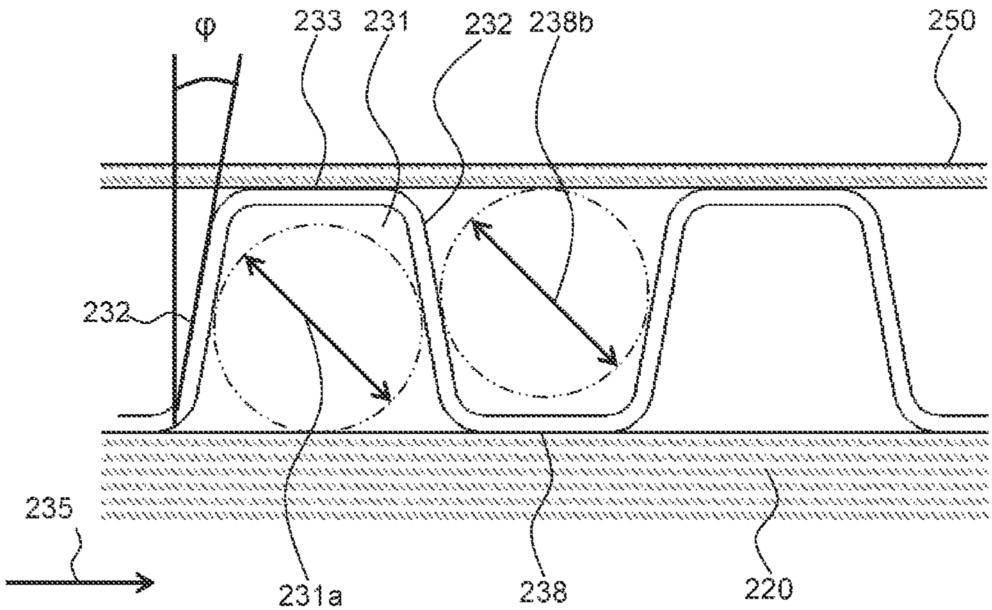
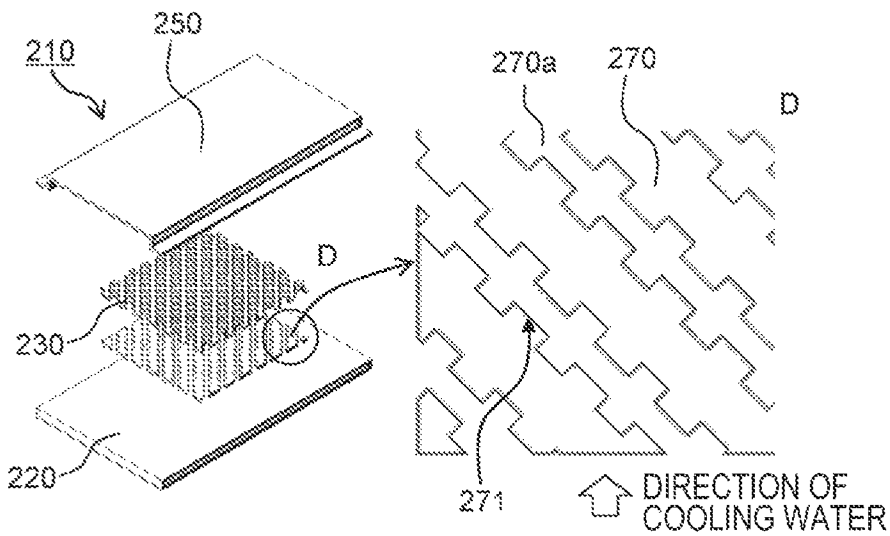
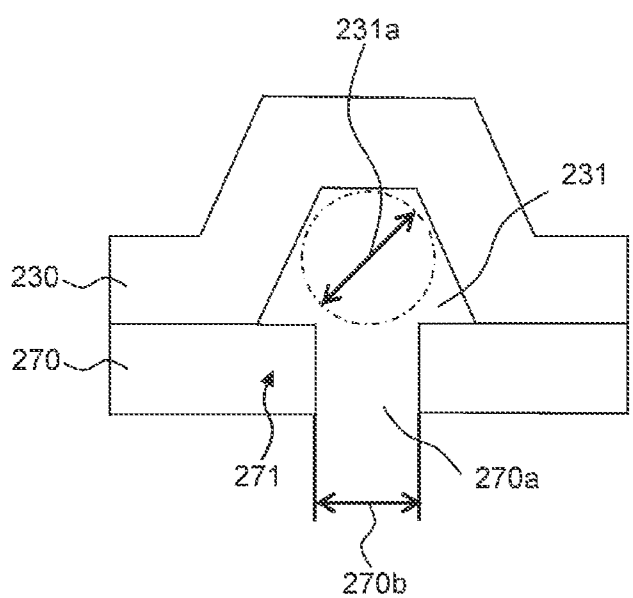


FIG. 11

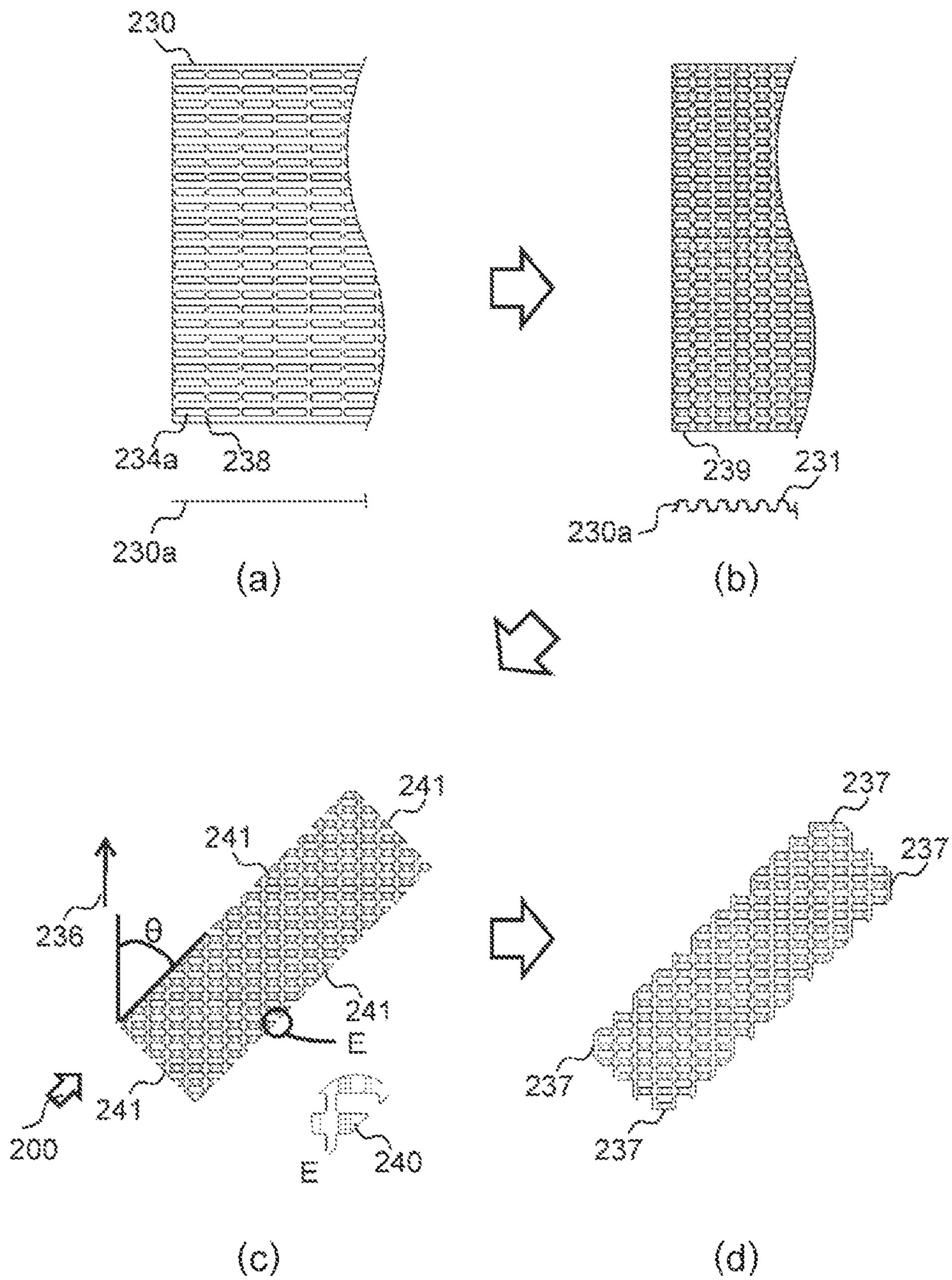

210
250
270a
270
D
D
230
220
271
DIRECTION OF COOLING WATER

(a)


231a
231
230
270
271
270a
270b

(b)

FIG. 12



230
234a
238
230a
(a)
239
231
230a
(b)
241
241
236
θ
241
E
200
241
E
240
(c)
237
237
237
237
(d)

HEAT EXCHANGER, POWER CONVERSION DEVICE INCLUDING HEAT EXCHANGER, AND METHOD FOR MANUFACTURING INNER FIN FOR HEAT EXCHANGER

TECHNICAL FIELD

[0001] The present invention relates to a heat exchanger, a power conversion device including the heat exchanger, and a method for manufacturing an inner fin for a heat exchanger.

BACKGROUND ART

[0002] As a background art of the invention of the present application, the following PTL 1 describes a heat exchanger having a fin shape in which a planar portion is arranged in parallel with a flow of cooling water in order to reduce a pressure loss of a passage without deteriorating heat exchanging performance.

CITATION LIST

Patent Literature

[0003] PTL 1: JP 2018-169073 A

SUMMARY OF INVENTION

Technical Problem

[0004] In order to further improve the performance of the fin in view of the technique of PTL 1, the present invention aims to provide a heat exchanger with improved heat radiation performance, a power conversion device including the heat exchanger, and a method for manufacturing an inner fin for the heat exchanger.

Solution to Problem

[0005] In a heat exchanger including an inner fin having heat transference and disposed in a flat passage, and a power conversion device including the heat exchanger, the inner fin is formed by a plurality of fin portions having a convex shape formed by a top surface portion and a side surface portion and having a hollow inside the convex shape; when a direction in which the plurality of fin portions are formed and lined to be continuous via a coupling portion is defined as a first direction and a direction in which slits are formed between the plurality of fin portions and lined is defined as a second direction, the plurality of fin portions are arranged at a predetermined interval in the second direction; and the inner fin is arranged such that the first direction and the second direction respectively forms an acute angle with respect to a flow of a refrigerant flowing in the flat passage.

[0006] A method for manufacturing an inner fin for a heat exchanger disposed in a flat passage of the heat exchanger and having heat transference includes a first step of performing rectangular punching at a predetermined interval along a side of a plate material having heat conductivity; a second step of performing bending with respect to a longitudinal direction of the plate material to form a plurality of fin portions; a third step of cutting the plate material in an oblique direction with respect to the side so as to be accommodated in the flat passage; and a fourth step of removing a plurality of incomplete fin portions produced by the cutting in the third step.

Advantageous Effects of Invention

[0007] A heat exchanger with improved heat radiation performance, a power conversion device including the heat exchanger, and a method for manufacturing an inner fin for a heat exchanger can be provided.

BRIEF DESCRIPTION OF DRAWINGS

[0008] FIG. **1** is a block diagram of an entire power conversion device.

[0009] FIG. **2** is a circuit diagram of a molded body of the power conversion device.

[0010] FIG. **3** is an external view of the molded body of FIG. **1**.

[0011] FIG. **4** is a cross-sectional view taken along line A-A of the molded body of FIG. **2**.

[0012] FIG. **5** is an exploded view of a power module including the heat exchanger of the present invention.

[0013] FIG. **6** is an exploded view of a first water channel of FIG. **4**.

[0014] FIG. **7** is an exploded view of a second water channel of FIG. **4**.

[0015] FIG. **8** is a structural diagram of a cooling water channel according to the first embodiment of the present invention.

[0016] FIG. **9** is a schematic flow diagram of the cooling water in the cooling water channel according to the first embodiment of the present invention.

[0017] FIG. **10** is a cross-sectional view taken along line D-D of FIG. **7**.

[0018] FIG. **11** is a structural diagram of a cooling water channel according to a second embodiment of the present invention.

[0019] FIG. **12** is a fin manufacturing process of the present invention.

[0020] Hereinafter, embodiments of the present invention will be described with reference to the drawings. The following description and drawings are examples for describing the present invention, and are omitted and simplified as appropriate for the sake of clarity of description. The present invention can be implemented in various other forms. Unless otherwise specified, each component may be singular or plural.

[0021] Positions, sizes, shapes, ranges, and the like of the components illustrated in the drawings may not represent actual positions, sizes, shapes, ranges, and the like in order to facilitate understanding of the invention. Therefore, the present invention is not necessarily limited to the position, size, shape, range, and the like disclosed in the drawings.

FIRST EMBODIMENT AND OVERALL CONFIGURATION

[0022] FIG. **1** is a block diagram of an entire power conversion device.

[0023] A power conversion device **1** is a device for converting direct current from a direct current (DC) power supply (battery) **2** into alternating current (AC) and outputting the alternating current to a motor **6**. The power conversion device **1** includes a capacitor **3**, a control device **4**, an upper arm **300**U, and a lower arm **300**L. The capacitor **3** smooths the DC power output from the DC power supply **2**. The control device **4** controls switching operations of the upper arm **300**U and the lower arm **300**L, which are switching elements.

[0024] FIG. **2** is a circuit diagram of a molded body of the power conversion device.

[0025] A molded body **300** having a function of a power module includes power semiconductor elements **321**, **321**L, **322**U, and **322**L. The power semiconductor elements **321**U and **321**L are insulated gate bipolar transistors (IGBTs). The power semiconductor elements **322**U and **322**L are diodes. The power semiconductor elements **321**U, **321**L, **322**U, and **322**L can be alternatively applied with a field effect transistor (FET) or the like.

[0026] The molded body **300** is configured by an upper arm **300**U and a lower arm **300**L. The upper arm **300**U is configured by an IGBT **321**U and a diode **322**U. The lower arm **300**L is configured by an IGBT **321**L and a diode **322**L. The upper arm **300**U has a DC positive electrode terminal **311** and a signal terminal **314**. The lower arm **300**L has a DC negative electrode terminal **312** and a signal terminal **315**.

[0027] The DC positive electrode terminal **311** and the DC negative electrode terminal **312** are connected to the capacitor **3** and the like, and supply power from the outside of the molded body **300**. The signal terminals **314** and **315** are connected to a control substrate including the control device **4**, and control switching operation of the power semiconductor element. The molded body **300** includes an AC terminal **313**. The AC terminal **313** electrically connects the upper arm **300**U and the lower arm **300**L, and outputs an AC current to the outside of the molded body **300**.

[0028] FIG. **3** is an external view of the molded body of FIG. **1**.

[0029] The molded body **300** is sealed with a sealing resin **330**. The DC positive electrode terminal **311** is exposed from the sealing resin **330**. The DC negative electrode terminal **312** is exposed from the sealing resin **330**. The AC terminal **313** is exposed from the sealing resin **330**. The signal terminals **314** and **315** are exposed from the sealing resin **330**. The molded body **300** includes a heat conduction member **350**.

[0030] FIG. **4** is a cross-sectional view taken along line A-A of the molded body in FIG. **3**.

[0031] Main surfaces of the semiconductor elements **321**U, **321**L, **322**U, **322**L are bonded to the first heat radiation plate **341** by way of a first bonding material **345**. The semiconductor elements **321**U, **321**L, **322**U, **322**L have the main surface and the surface on the opposite side bonded to the second heat radiation plate **342** by way of a second bonding material **346**.

[0032] The first bonding material **345** and the second bonding material **346** are solder, a sintered material, or the like. The first heat radiation plate **341** and the second heat radiation plate **342** are an insulating substrate made of metal such as copper and aluminum, or having a copper wiring, or the like.

[0033] The sealing resin **330** seals the semiconductor elements **321**U, **321**L, **322**U, and **322**L, the first heat radiation plate **341**, the second heat radiation plate **342**, the first bonding material **345**, and the second bonding material **346**. The first heat radiation plate **341** has a first heat radiation surface **343**. The first heat radiation surface **343** is located on a surface of the first heat radiation plate **341** opposite to a surface bonded to the first bonding material **345**. The first heat radiation surface **343** is exposed from the sealing resin **330**.

[0034] The second heat radiation plate **342** has a second heat radiation surface **344**. The second heat radiation surface **344** is located on a surface of the second heat radiation plate **342** opposite to a surface bonded to the second bonding material **346**. The second heat radiation surface **344** is exposed from the sealing resin **330**. The two heat conduction members **350** are in close contact with the first heat radiation surface **342** and the second heat radiation surface **344**, respectively.

[0035] The heat conduction member **350** is made of resin or ceramic having insulating property. In a case where the heat conduction member **350** is made of ceramic, the heat conduction member is brought into close contact with the molded body **300** and a first water channel **110** and a second water channel **210**, described later, via grease or the like. The heat conduction member **350** is grease when an insulating board or a resin insulating member is provided inside the molded body **300**.

[0036] The molded body **300** is a heat generating body that generates heat when a current flows through each of the semiconductor elements **321**U, **321**L, **322**U, and **322**L. The molded body **300** is cooled by releasing heat to the refrigerant in each of the water channels through the heat conduction member **350**, the first water channel **110** and the second water channel **210** described later.

[0037] FIG. **5** is an exploded view of a power module including the heat exchanger of the present invention.

[0038] The molded body **300** is disposed so as to be sandwiched between the first water channel **110** and the second water channel **210** which are heat exchangers. The first water channel **110** has a first water channel connecting portion **111**. The second water channel **210** has a second water channel connecting portion **211**. The first water channel connecting portion **111** is connected to the second water channel connecting portion **211** so as to form a water channel. A connecting portion between the first water channel connecting portion **111** and the second water channel connecting portion **211** is sealed with a seal material **400**.

[0039] FIG. **6** is an exploded view of the first water channel of FIG. **5**.

[0040] The first water channel **110** includes a first water channel base **120**, a first fin **130**, a first water channel cover **150**, a first pipe **160**, and a water channel connecting flange **170**. The water channel connecting flange **170** has a water channel attachment surface **173**. The water channel attachment surface **173** is connected to a case or the like for supplying cooling water from the outside.

[0041] The water channel connecting flange **170** has a water channel attachment hole **172**. The water channel attachment hole **172** is a screw hole for fixing to a case or the like for supplying cooling water from the outside. Note that, in the case of fixing to the case other than by screw fastening, the water channel attachment hole **172** is unnecessary. The water channel connecting flange **170** has a water channel opening **171**. The water channel opening **171** is an inlet or an outlet of the cooling water.

[0042] The first water channel cover **150** has two first water channel cover openings **151** at both ends in the longitudinal direction. The first water channel cover opening **151** is connected to the water channel opening **171**, and the cooling water flows therethrough. The first water channel base **120** has two first water channel base openings **121** at both ends in the longitudinal direction.

[0043] Two first pipes **160** are disposed at both ends of the first water channel **110**. The first pipe **160** has a first pipe opening **161**. The first pipe **160** is connected to the first water channel base opening **121** to form a water channel. The first pipe **160** has a seal material accommodating portion **162**. The seal material accommodating portion **162** is a region that accommodates the seal material **400**.

[0044] The first water channel base **120** has a first water channel base heat radiation surface **122**. The first water channel base heat radiation surface **122** is in close contact with the molded body **300** to contribute to cooling of the molded body **300**. The first fin **130**, which is an inner fin having heat transference, is bonded to the first water channel base **120** on the opposite side of the first water channel base heat radiation surface **122**.

[0045] The first fin **130** is bonded to the first water channel cover **150**. The first water channel cover **150** is bonded to the water channel connecting flange **170**. This bonding portion is bonded by brazing or laser welding.

[0046] FIG. **7** is an exploded view of the second water channel of FIG. **5**.

[0047] The second water channel **210** includes a second water channel base **220**, a second fin **230**, a second water channel cover **250**, and a second pipe **260**. The second water channel base **220** has two second water channel base openings **221** at both ends in the longitudinal direction.

[0048] The second water channel base opening **221** at one end causes cooling water to flow to one end of the second fin **230**. The second water channel base opening **221** at the other end causes cooling water to flow to the other end of the second fin **230**.

[0049] Two second pipes **260** are disposed at both ends of the second water channel **210**. The second pipe **260** has a second pipe opening **261**. The second pipe **260** is connected to the second water channel base opening **221** to form a water channel.

[0050] The second water channel base **220** has a second water channel base heat radiation surface **222**. The second fin cover heat radiation surface **221** is in close contact with the molded body **300** to cool the molded body **300**. The second water channel base **220** has a second water channel base heat radiation surface **222** for cooling the molded body **300**. The second fin **230** is bonded to the second water channel base **220** on the surface opposite to the second water channel base heat radiation surface **222**.

[0051] The second fin **230** cools the molded body **300** through the second water channel base heat radiation surface **222**. The second fin **230** is bonded to the second water channel cover **250**. This bonding is performed by brazing or laser welding similarly to the first water channel **110**.

[0052] FIG. **8** is a structural diagram of a cooling water channel according to the first embodiment of the present invention.

[0053] FIG. **8**(*a*) is obtained by removing the cover **250** from the second water channel **210** of FIG. **5**. FIG. **8**(*b*) is a plan view of a cross section B (a position where the bonding surface between the second water channel cover **250** and the second fin **230** is cut). FIG. **8**(*c*) is an enlarged view of a portion C in FIG. **8**(*a*).

[0054] Since the same applies to the first water channel **110** and the first fin **130**, only the description of the second water channel **210** and the second fin **230** will be given, and the description of the configurations of the first water channel **110** and the first fin **130** will be omitted.

[0055] The second water channel **210** forms a fin flow path **280**. The fin flow path **280** is formed such that the cooling water **200** passes through the second fin **230**. The second fin **230** has a plurality of fin portions **239** and a fin coupling portion **238**. In the fin portion **239**, two fin side surface portions **232** and a fin top surface portion **233** form a hollow convex shape **231**. The hollow convex shape **231** is a structure in which the cooling water **200** flows to the hollow portion.

[0056] The fin portion **239** is arranged obliquely with respect to the direction in which the cooling water **200** flows (the longitudinal direction of the flow path **280**), and the next fin portion **239** is formed at the same inclination with an interval **234** provided on the extension thereof. A slit **234***a* is provided between the obliquely arranged fin portions **239**.

[0057] The fin top surface portion **233** is bonded to the second water channel cover **250**. A plurality of fin portions **239** are formed in a row along a first direction **235** via the coupling portion **238**. In addition, the fin portions **239** are repeatedly arranged to form a fin row along a second direction **236** in which slits **234***a* are formed and arranged between the plurality of fin portions **239**, the second direction being a direction different from the first direction **235**. Note that a right angle is defined between the first direction **235** and the second direction **236**.

[0058] In this fin row, a predetermined fin interval **234** is provided between the fin portions **239** as described above, and the slit **234***a* is formed in a portion of the predetermined interval **234**. This is a portion where punching is performed on a sheet metal in a fin manufacturing process described later.

[0059] The plurality of fin portions **239** are connected to each other by the fin coupling portion **238**. The fin **230** can be processed and formed from one plate by providing the fin coupling portion **238**, and productivity can be improved. Note that a method for manufacturing the fin **230** will be described later with reference to FIG. **12**. The fin side surface portion **232** is formed on a straight line parallel to the second direction **236**. In this way, when the fin **230** is manufactured by machining using a sheet metal press or the like, mold can be simplified as the fi can be formed simply by being processed linearly, and hence productivity is improved.

[0060] Both the first direction **235** and the second direction **236** form an acute angle with respect to the cooling water flow direction **200**. That is, the fin **230** has a structure of being inclined with respect to the flow of the cooling water **200**. In this manner, the heat radiation performance can be improved by raising the flow speed in the vicinity of the wall surface portion of the fin **230**.

[0061] FIG. **9** is a schematic flow diagram of the cooling water in the cooling water channel according to the first embodiment of the present invention.

[0062] The size of the arrow of the cooling water **200** represents the flow speed, and the length of the arrow is illustrated so as to become longer as the speed becomes higher. The fins **230** are arranged to be inclined with respect to the flow of cooling water **200** such that the angle θ formed by the second direction **236** and the cooling water flow direction is larger than 0° and smaller than 90° (acute angle), and the cooling water **200** flowing through the fin interval **234** hits the fin side surface portion **232**. In this way, the flow speed in the vicinity of the fin side surface portion **232** increases, and high cooling performance is obtained. In the verification result compared with the prior art in which the fin side surface portion **232** is parallel to the direction in which the cooling water **200** flows (the angle θ is 0°), it was found that, in the configuration of the present invention, the relative value of the heat transfer rate is improved by 60% as compared with the prior art according to the heat transfer analysis.

[0063] The angle θ formed by the second direction **236** and the cooling water flow direction is preferably from 15° to 75° from the viewpoint of improving the cooling performance. In the verification, it was found that the method for installing the fin **230** so that the angle of the fin is 60° with respect to the flow of the cooling water has the highest performance. Furthermore, although description has been made with a configuration in which the fin **230** is arranged inclined to the left in the drawing, the fin may be arranged inclined to the right.

[0064] FIG. **10** is a cross-sectional view taken along line D-D of FIG. **8**(*b*).

[0065] In the hollow convex shape **231**, the inside is formed to a cavity so that dust (contamination) that has a possibility of being contained in the cooling water is not clogged, and the diameter **231***a* of the largest circle entering the inside is defined. Similarly, the diameter **238***b* of the largest circle entering between adjacent fin portions **239** through the coupling portion **238** in the first direction **235** is defined. At this time, the diameter **238***b* is greater than or equal to the diameter **231***a*. Although not illustrated in FIG. **10**, the fin interval **234** is also greater than or equal to the diameter **231***a*. In this way, dust clogging can be prevented even on the fin interval **234** or the fin coupling portion **238**.

[0066] It is also possible to further improve the cooling performance by unifying the diameter **231***a*, the diameter **238***b*, and the fin interval **234** to substantially the same size and increasing the number of fins as much as possible to increase the heat radiation surface. The angle φ formed by the thickness direction (up-down direction in the plane of drawing) of the second water channel base **220** and the fin side surface portion **232** is preferably greater than or equal to 0° in view of sheet metal press moldability.

SECOND EMBODIMENT

[0067] FIG. **11** is a structural diagram of a cooling water channel according to a second embodiment of the present invention.

[0068] In the flow path **210**, a fin plate **270** (see an enlarged view D) is installed between the fin **230** and the flow path base **220**. The fin plate **270** has a groove **270***a*, and protrusions **271** that face each other are formed on a side surface of the groove **270***a*. The groove **270***a* has a structure in which the protrusion **271** is formed in accordance with the hollow **231** portion of the fin **230** (see FIG. **11**(*b*)), and thus has a structure in which the protrusion **271** overlaps the bottom portion of the hollow **231** portion. The width **270***b* between the protrusions **271** is smaller than the diameter **231***a*.

[0069] With such a configuration, a turbulent flow speed of the cooling water **200** can be locally increased to improve cooling performance, so that heat radiation performance can be improved. In addition, the heat radiation surface area can be increased by providing the fin plate **270**. Furthermore, problems such as contamination clogging can also be solved. According to this configuration, a verification result was obtained that the heat transfer rate improved by 17% as compared with the configuration without the fin plate **270**.

[0070] FIG. **12** is a diagram describing a fin manufacturing process of the present invention.

[0071] As a method for manufacturing the second fin **230**, sheet metal press is preferable in consideration of productivity. The manufacturing process of the second fin **230** is divided into a punching process (a), a bending process (b), an outer shape trimming process **1**(*c*), and an outer shape trimming process **2**(*d*). Note that the outer shape trimming process **1** and the outer shape trimming process **2** may be performed simultaneously.

[0072] First, in the punching process, the second fin **230** is subjected to a rectangular punching process at predetermined intervals along the side of one plate material, thereby forming the fin interval **234** and the fin coupling portion **238** on the plate.

[0073] Next, in the bending process, the fin portion **239** is bent with respect to the longitudinal direction of the plate material to form a hollow convex shape **231** (see the fin plane viewpoint **230***a* in FIGS. **12**(*a*) and **12**(*b*)). The bending may be performed for each fin row or may be collectively performed.

[0074] Next, in the outer shape trimming process, cutting is performed in an oblique direction with respect to the plate material so as to be accommodated in the flat passage, in other words, punching is performed so that the fin outer shape **241** becomes an angle θ formed by the second direction **236** and the cooling water flow direction **200**. At this time, an incomplete fin portion **240** in which the fin side surface portion **232** is not coupled with the fin coupling portion **238** is formed in the fin portion **239**.

[0075] Finally, in the outer shape trimming process **2**, the incomplete fin portion **240** produced in the previous process is removed by punching. Since there is a high possibility that the incomplete fin portion **240** is easily deformed in handling during transportation of a component and becomes a defective product, removal facilitates handling and improves productivity. After the outer shape trimming process **2**, a fin positioning portion **237** is formed on the fin outer shape **241** and a shape to be accommodated in the flow path is obtained.

[0076] By adopting such a fin manufacturing method, a fin inclined with respect to the flow of cooling water can be made by using a simple process of bending in a right angle direction of the material, and the configuration of the present invention in which a plurality of fin portions **239** are repeatedly arranged in parallel in the second direction **236** and fin members are continuously formed can be realized.

[0077] According to the first and second embodiments of the present invention described above, the following operational effects are achieved.

[0078] (1) In a heat exchanger including an inner fin **130**, **230** having heat transference and disposed in a flat passage, the inner fin **130**, **230** is formed by a plurality of fin portions **239** having a convex shape **231** formed by a top surface portion **233** and a side surface portion **232** and having a hollow inside the convex shape **231**, where when a direction in which the plurality of fin portions **239** are formed and lined to be continuous via a coupling portion **238** is defined as a first direction **235** and a direction in which slits **234***a* are formed between the plurality of fin portions **239** and lined is defined as a second direction **236**, the plurality of fin portions **239** are arranged at a predetermined interval **234** in the second direction **236**, and the inner fin **130**, **230** is arranged such that the first direction **235** and the second direction **236** respectively forms an acute angle with respect to a flow of a refrigerant flowing in the flat passage. With this configuration, a heat exchanger with improved heat radiation performance can be provided.

[0079] (2) In the plurality of fin portions **239**, when the diameter of the largest circle entering the hollow is defined as a first diameter **231***a*, and the diameter of the largest circle entering the coupling portion **238** connecting the respective side surface portions **232** of the adjacent fin portions **239** is defined as a second diameter **238***b*, the second diameter **238***b* has a size greater than or equal to the first diameter **231***a*. In this way, dust clogging can be prevented on the fin interval **234** or the fin coupling portion **238**.

[0080] (3) In the flat passage, a fin plate **270** having a plurality of groove **270***a* is provided between the flat passage lower portion **220** and the inner fin **130**, **230**. With such a configuration, a turbulent flow speed of the cooling water **200** can be locally increased to improve cooling performance, so that heat radiation performance can be improved. In addition, the heat radiation surface area can be increased. Furthermore, contamination (dust) clogging can be prevented.

[0081] (4) The groove **270***a* of the fin plate **270** is formed with a plurality of protrusions **271**, and a width **270***b* between the plurality of protrusions **271** facing each other is smaller than the first diameter **231***a*. With such a configuration, a turbulent flow speed of the cooling water **200** can be locally increased to improve cooling performance.

[0082] (5) The power conversion device **1** includes the heat exchanger of the present invention. Therefore, the present invention can be applied to a vehicle or the like on which the power conversion device **1** is mounted.

[0083] (6) A method for manufacturing the inner fin **130**, **230** for a heat exchanger disposed in a flat passage of the heat exchanger and having heat transference includes a first step of performing rectangular punching at a predetermined interval along a side of a plate material having heat conductivity, a second step of performing bending with respect to a longitudinal direction of the plate material to form a plurality of fin portions **239**, a third step of cutting the plate material in an oblique direction with respect to the side so as to be accommodated in the flat passage, and a fourth step of removing a plurality of incomplete fin portions **240** produced by the cutting in the third step. The heat exchanger of the present invention thus can be realized.

[0084] Note that the present invention is not limited to the above embodiments, and various modifications and other configurations can be combined within a scope not deviating from the gist of the present invention. In addition, the present invention is not limited to those including all the configurations described in the above embodiments, and also includes those in which a part of the configuration is deleted.

REFERENCE SIGNS LIST

[0085] **1** power conversion device
[0086] **2** DC power supply (battery)
[0087] **3** capacitor
[0088] **4** control device
[0089] **6** motor
[0090] **110** first water channel
[0091] **111** first water channel connecting portion
[0092] **120** first water channel base
[0093] **121** first water channel base opening
[0094] **122** first water channel base heat radiation surface
[0095] **130** first fin
[0096] **150** first water channel cover
[0097] **151** first water channel cover opening
[0098] **160** first pipe
[0099] **161** first pipe opening
[0100] **162** seal material accommodating portion
[0101] **170** water channel connecting flange
[0102] **171** water channel opening
[0103] **172** water channel attachment hole
[0104] **173** water channel attachment surface
[0105] **200** (flowing direction of) cooling water
[0106] **210** second water channel
[0107] **211** second water channel connecting portion
[0108] **220** second water channel base
[0109] **221** second water channel base opening
[0110] **222** second water channel base heat radiation surface
[0111] **230** second fin
[0112] **230***a* fin plane viewpoint
[0113] **231** hollow convex shape
[0114] **231***a* diameter of hollow convex shape
[0115] **232** fin side surface portion
[0116] **233** fin top surface portion
[0117] **234** fin interval
[0118] **234***a* slit
[0119] **235** first direction
[0120] **236** second direction
[0121] **237** fin positioning unit
[0122] **238** fin coupling portion
[0123] **238***b* diameter of fin coupling portion
[0124] **239** fin portion
[0125] **240** incomplete fin portion
[0126] **241** fin outer shape
[0127] **250** second water channel cover
[0128] **260** second pipe
[0129] **270** fin plate
[0130] **270***a* groove
[0131] **270***b* width between fin plate protrusions
[0132] **271** fin plate protrusion
[0133] **271***a* fin plate gap
[0134] **280** fin flow path
[0135] **300** molded body
[0136] **400** seal material

1. A heat exchanger comprising an inner fin having heat transference and disposed in a flat passage,

wherein

the inner fin is formed by a plurality of fin portions having a convex shape formed by a top surface portion and a side surface portion and having a hollow inside the convex shape;

when a direction in which the plurality of fin portions are formed and lined to be continuous via a coupling portion is defined as a first direction and a direction in which slits are formed between the plurality of fin portions and lined is defined as a second direction, the plurality of fin portions are arranged at a predetermined interval in the second direction; and

the inner fin is arranged such that the first direction and the second direction respectively forms an acute angle with respect to a flow of a refrigerant flowing in the flat passage.

2. The heat exchanger according to claim **1**, wherein in the plurality of fin portions, when a diameter of a largest circle entering the hollow is defined as a first diameter, and a diameter of a largest circle entering a coupling portion connecting the respective side surface portions of the adjacent fin portions is defined as a second diameter, the second diameter has a size greater than or equal to the first diameter.

3. The heat exchanger according to claim **2**, wherein in the flat passage, a fin plate including a plurality of grooves is provided between a flat passage lower portion and the inner fin.

4. The heat exchanger according to claim **3**, wherein
- the groove is formed with a plurality of protrusions; and
- a width between the plurality of protrusions facing each other is smaller than the first diameter.

5. A power conversion device comprising the heat exchanger according to claim **1**.

6. A method for manufacturing an inner fin disposed in a flat passage of a heat exchanger and having heat transference, the method comprising:
- a first step of performing rectangular punching at a predetermined interval along a side of a plate material having heat conductivity;
- a second step of performing bending with respect to a longitudinal direction of the plate material to form a plurality of fin portions;
- a third step of cutting the plate material in an oblique direction with respect to the side so as to be accommodated in the flat passage; and
- a fourth step of removing a plurality of incomplete fin portions produced by the cutting in the third step.

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