US 20250027724A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2025/0027724 A1**

YAMADA et al. (43) **Pub. Date: Jan. 23, 2025**

(54) **HEAT EXCHANGER**

(71) Applicant: **TOKYO ROKI CO., LTD.**, Yokohama-shi (JP)

(72) Inventors: **Tatsuto YAMADA**, Yokohama-shi (JP); **Shunichi KARASAWA**, Yokohama-shi (JP); **Satoshi SASANO**, Yokohama-shi (JP)

(73) Assignee: **TOKYO ROKI CO., LTD.**, Yokohama-shi (JP)

(21) Appl. No.: **18/713,943**

(22) PCT Filed: **Nov. 29, 2021**

(86) PCT No.: **PCT/JP2021/043670**

§ 371 (c)(1),
(2) Date: **May 28, 2024**

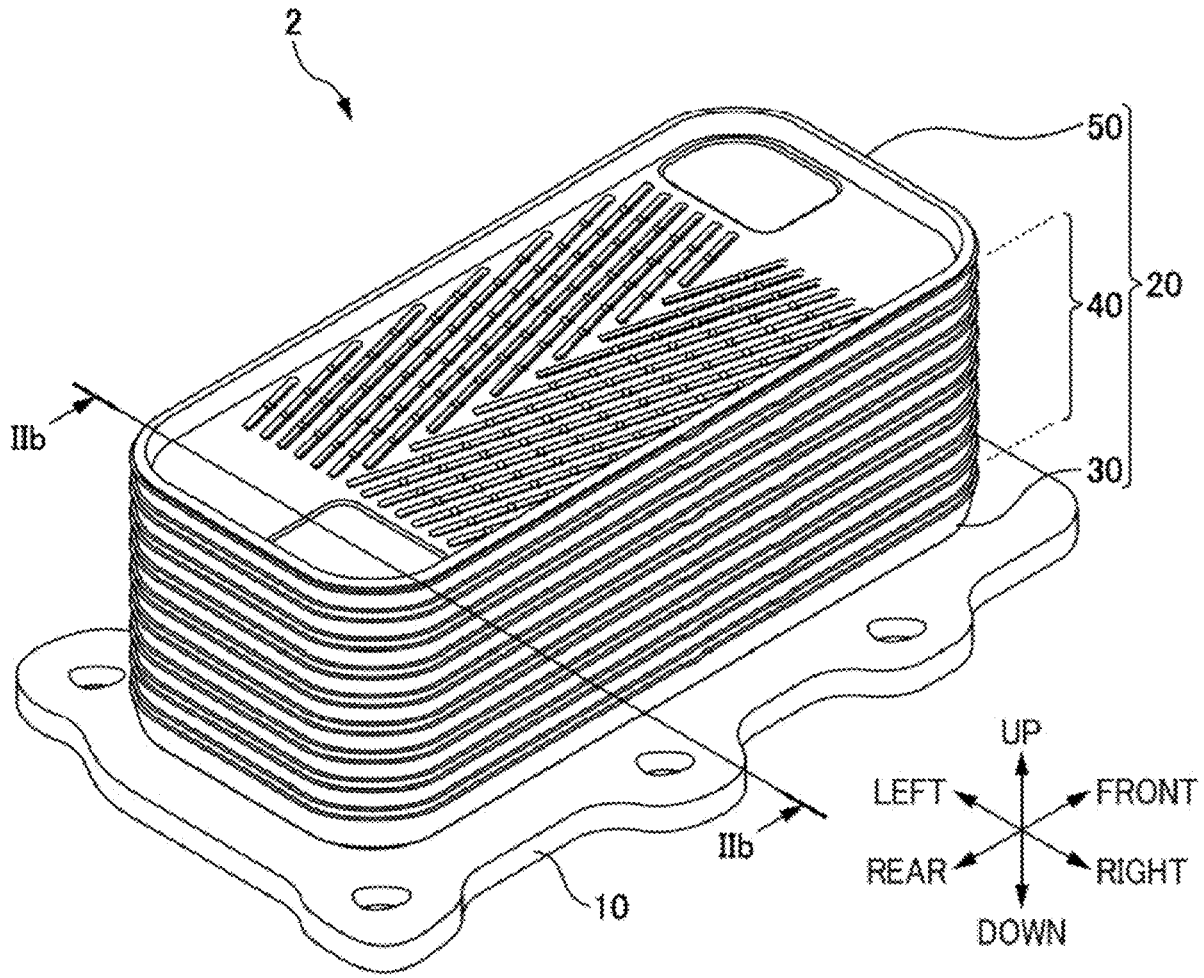
Publication Classification

(51) **Int. Cl.**
F28D 9/00 (2006.01)

(52) **U.S. Cl.**
CPC ***F28D 9/0075*** (2013.01)

(57) **ABSTRACT**

An oil cooler **2** as a heat exchanger includes a male plate **100** having an upper surface **100***a* as a first surface configured to contact cooling water that is a heat medium, and a plurality of linearly extending protrusions **104** are formed at the upper surface **100***a*.



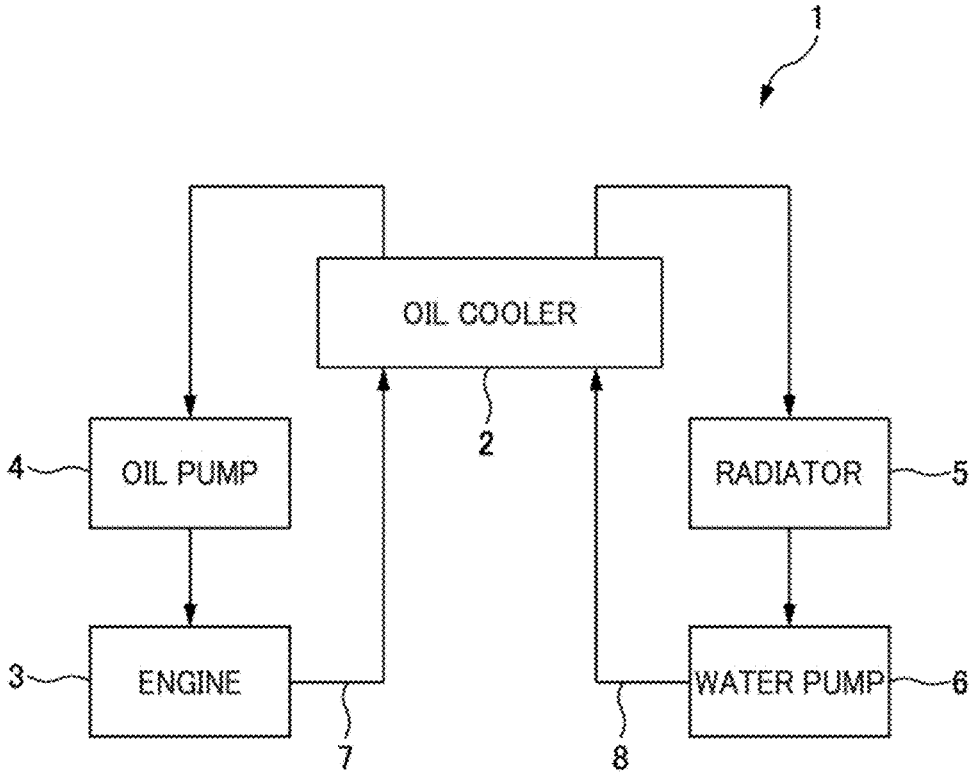


FIG. 1

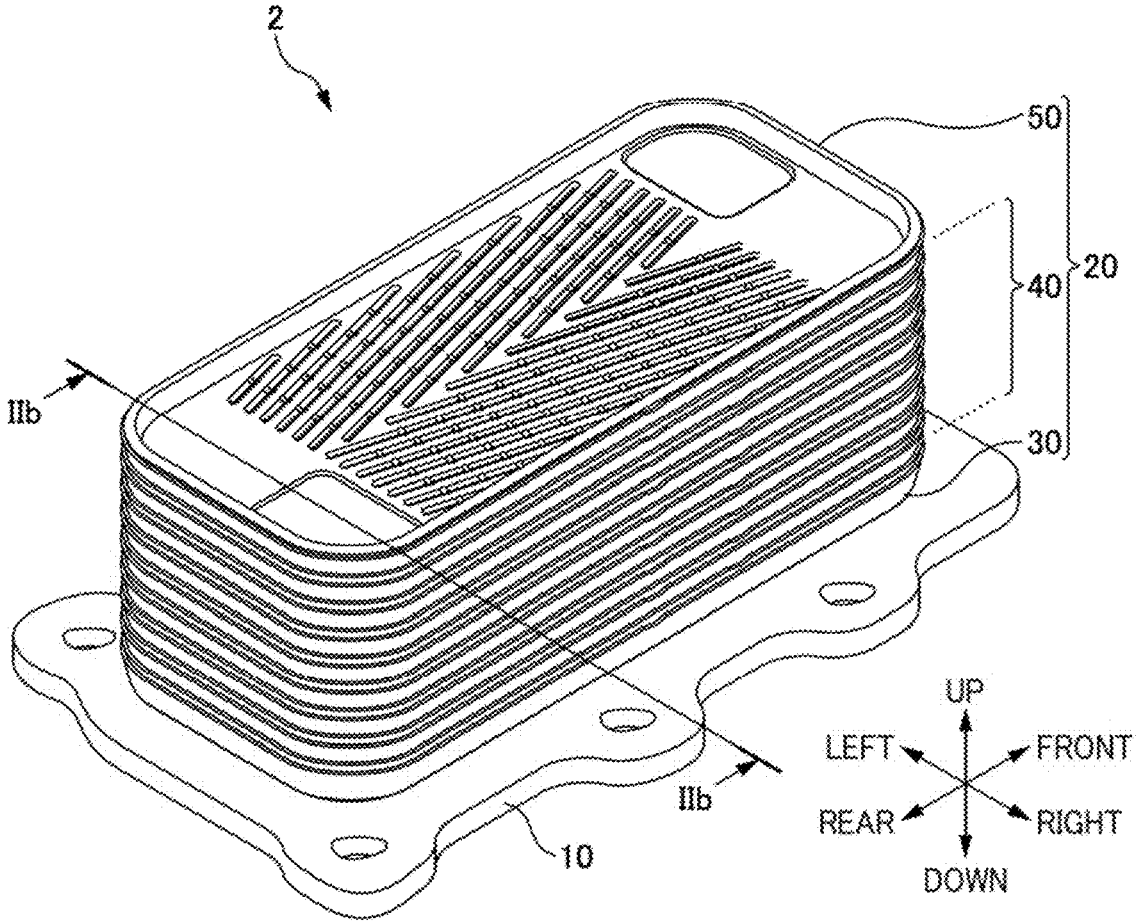

2
50
40
20
30
IIb
IIb
10
UP
LEFT
FRONT
REAR
RIGHT
DOWN

FIG. 2A

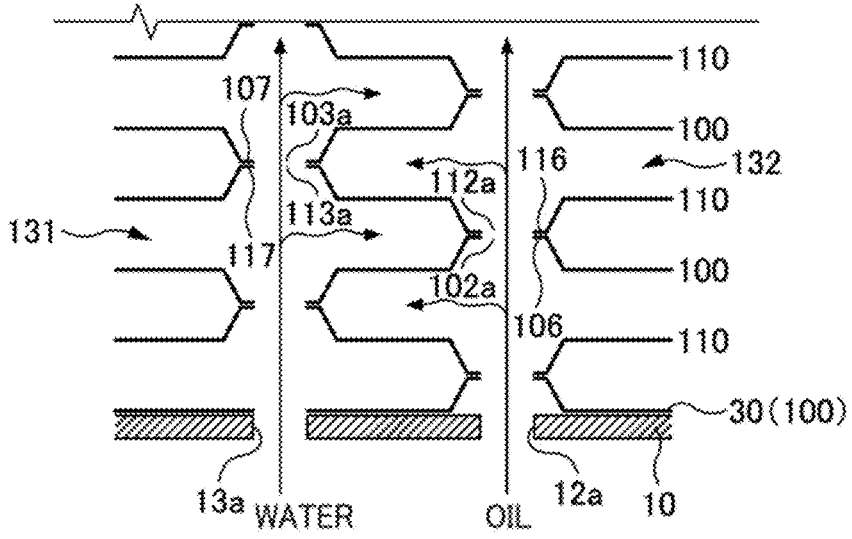

107
103a
110
100
116
132
112a
110
131
113a
117
100
102a
106
110
30(100)
13a
WATER
OIL
12a
10

FIG. 2B

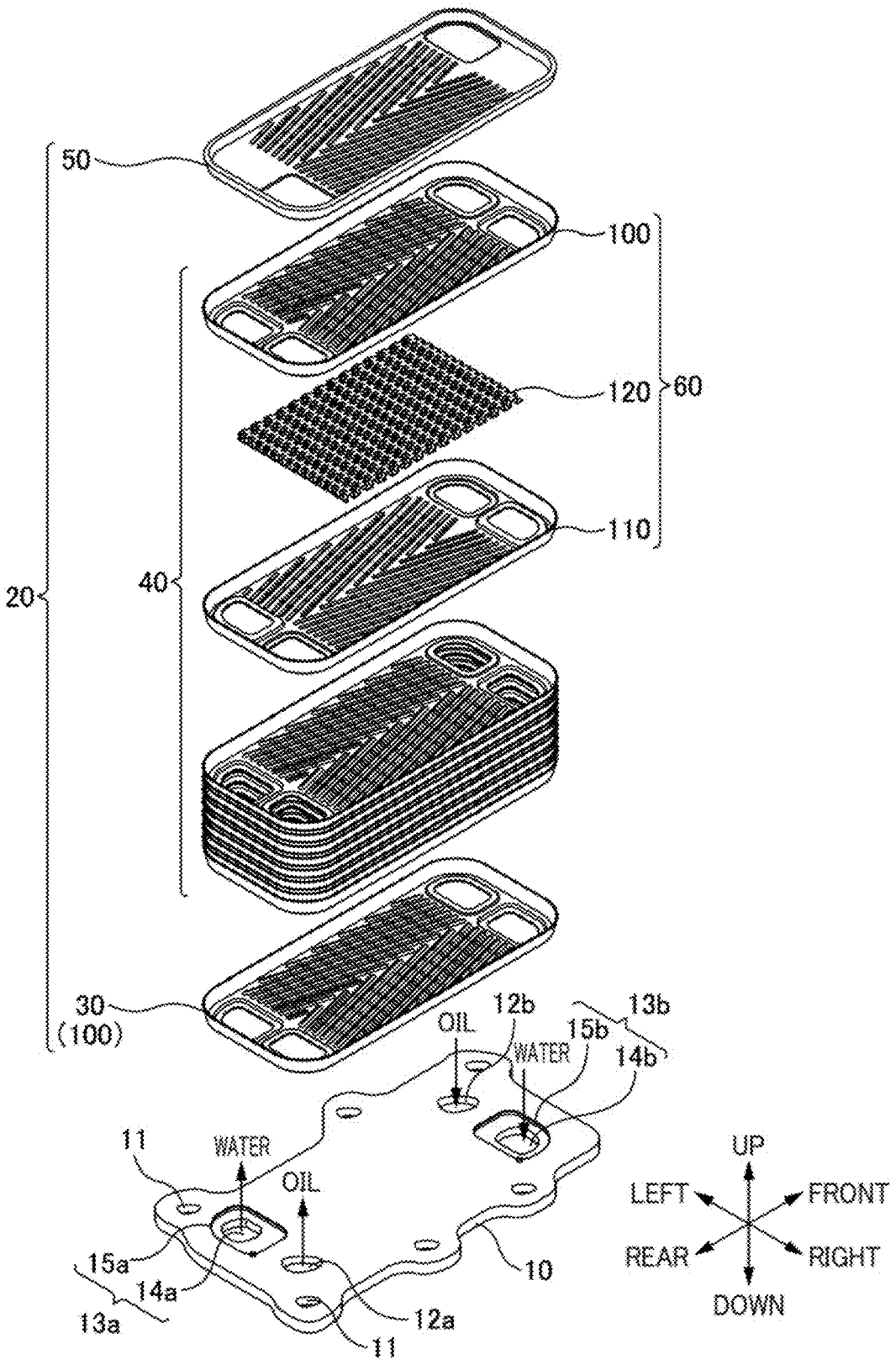

50
100
120
60
110
20
40
30
(100)
OIL
12b
13b
15b
WATER
14b
11
WATER
OIL
15a
14a
13a
10
12a
11
UP
LEFT
FRONT
REAR
RIGHT
DOWN

FIG. 3

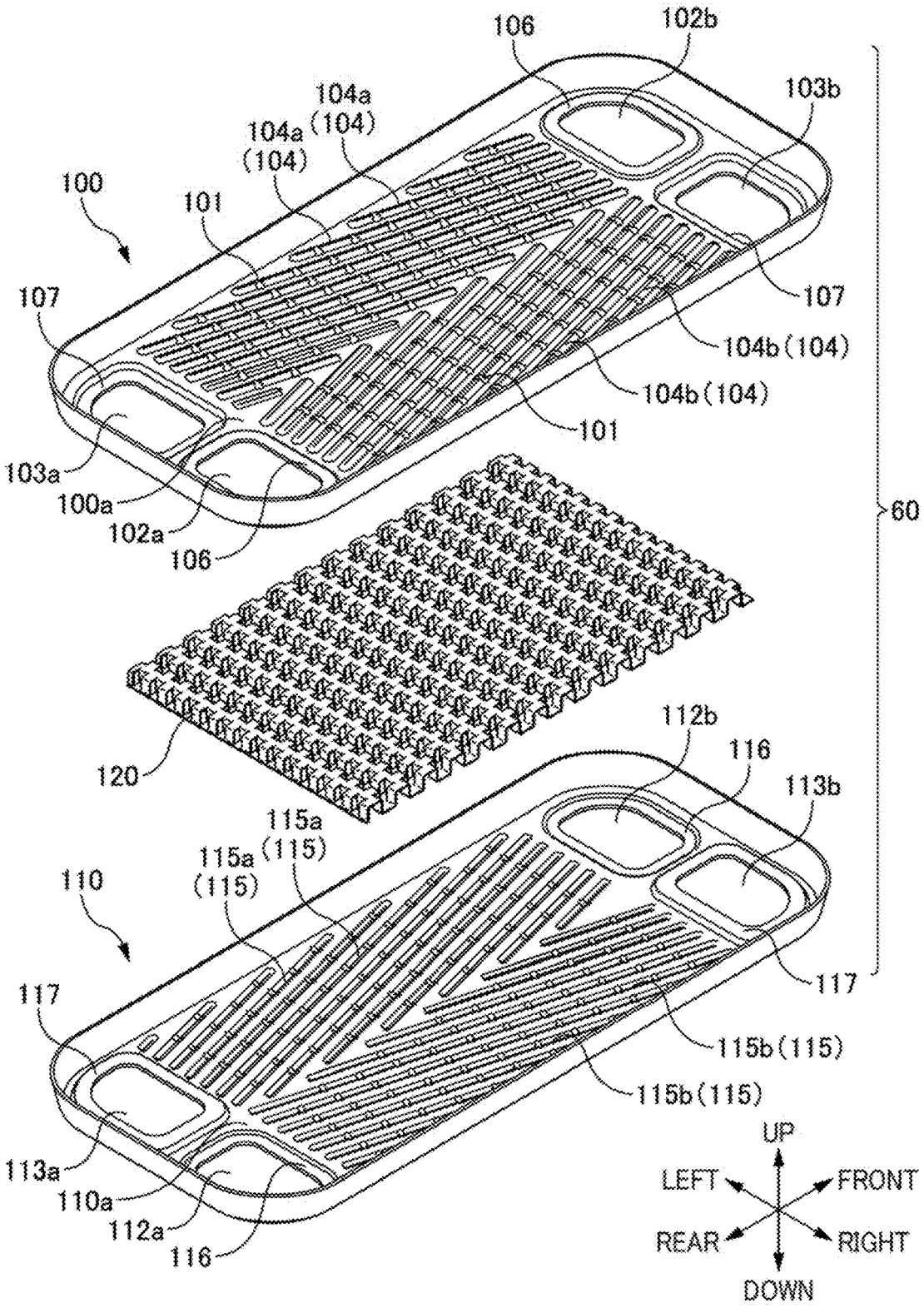

106
102b
103b
104a (104)
104a (104)
100
101
107
107
104b (104)
104b (104)
101
103a
100a
102a
106
60
120
112b
116
113b
115a (115)
115a (115)
110
117
117
115b (115)
115b (115)
113a
110a
112a
116
UP
LEFT
FRONT
REAR
RIGHT
DOWN

FIG. 4

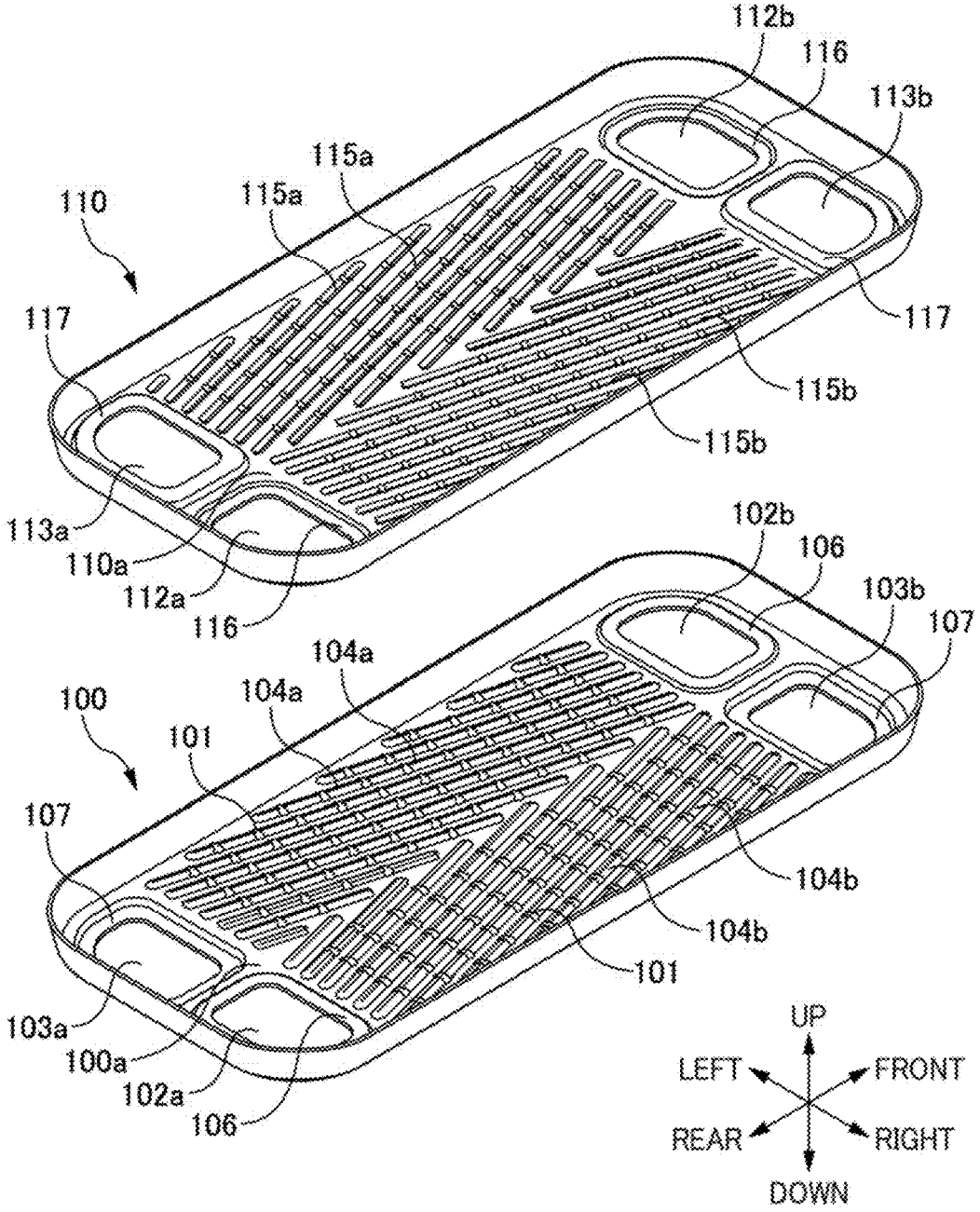

112b
116
113b
115a
115a
110
117
117
115b
115b
113a
110a
112a
116
102b
106
103b
107
104a
104a
100
101
107
104b
104b
101
103a
100a
102a
106
UP
LEFT
FRONT
REAR
RIGHT
DOWN

FIG. 5

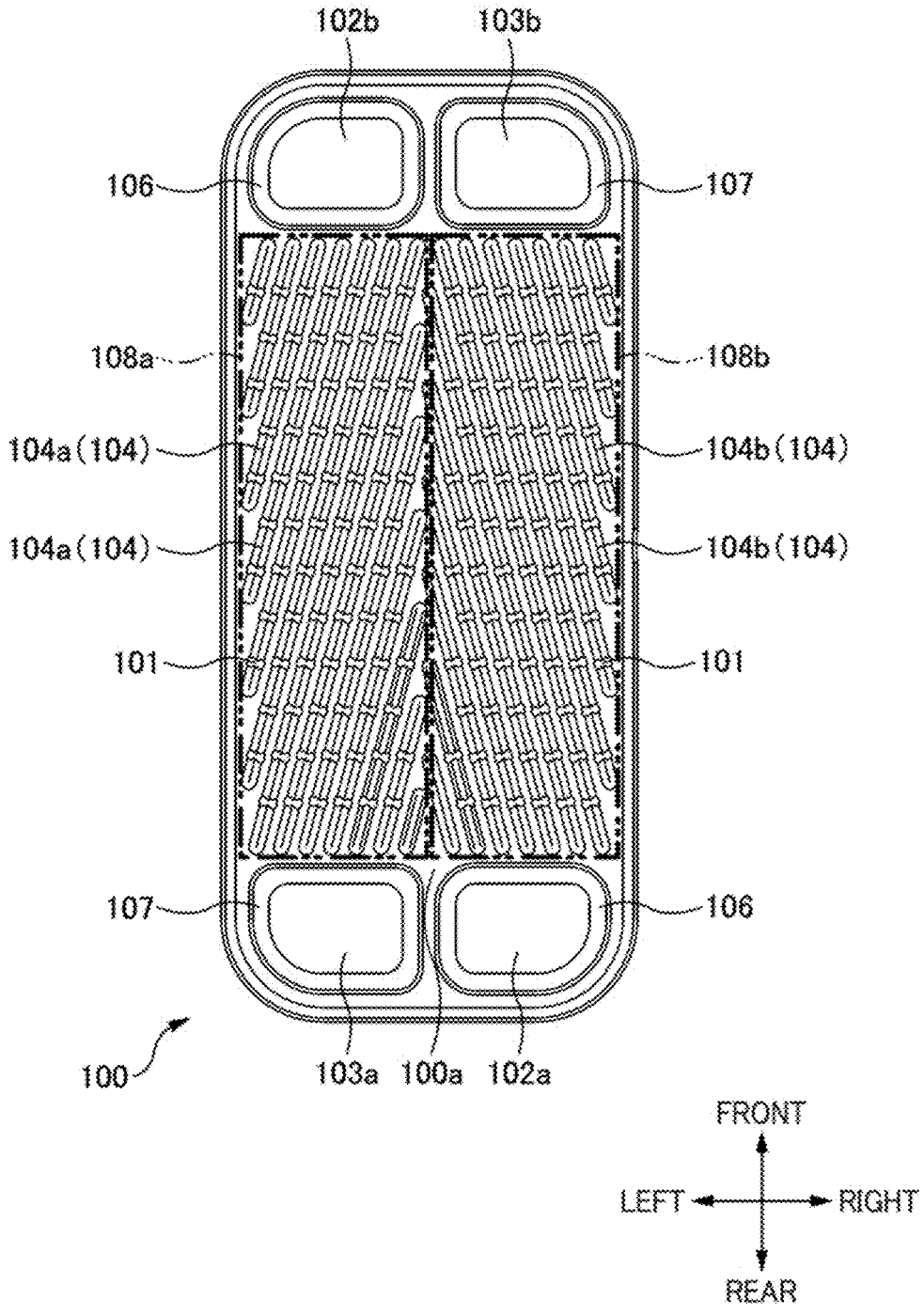

102b
103b
106
107
108a
108b
104a(104)
104b(104)
104a(104)
104b(104)
101
101
107
106
100
103a
100a
102a
FRONT
LEFT
RIGHT
REAR

FIG. 6

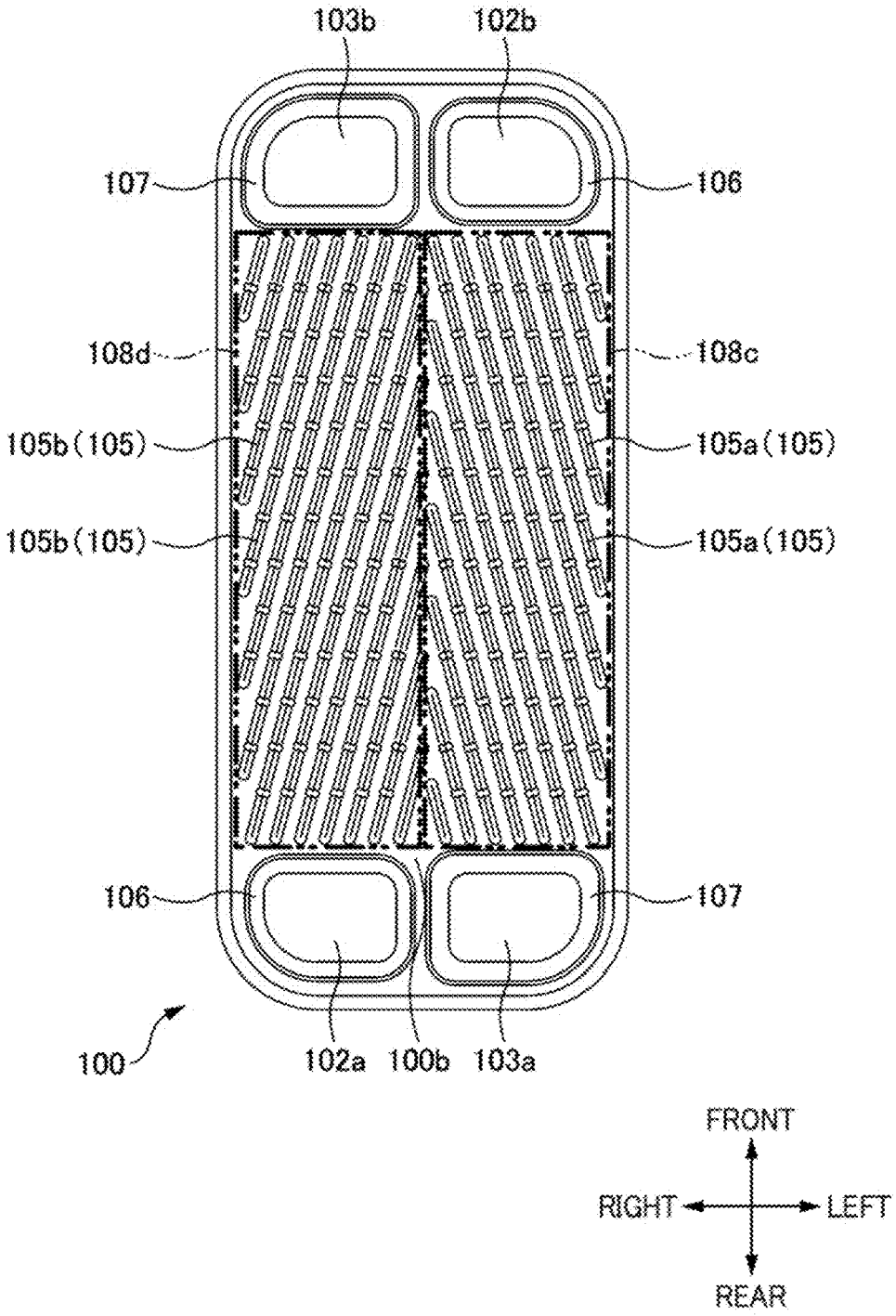

103b
102b
107
106
108d
108c
105b(105)
105a(105)
105b(105)
105a(105)
106
107
100
102a
100b
103a
FRONT
RIGHT
LEFT
REAR

FIG. 7

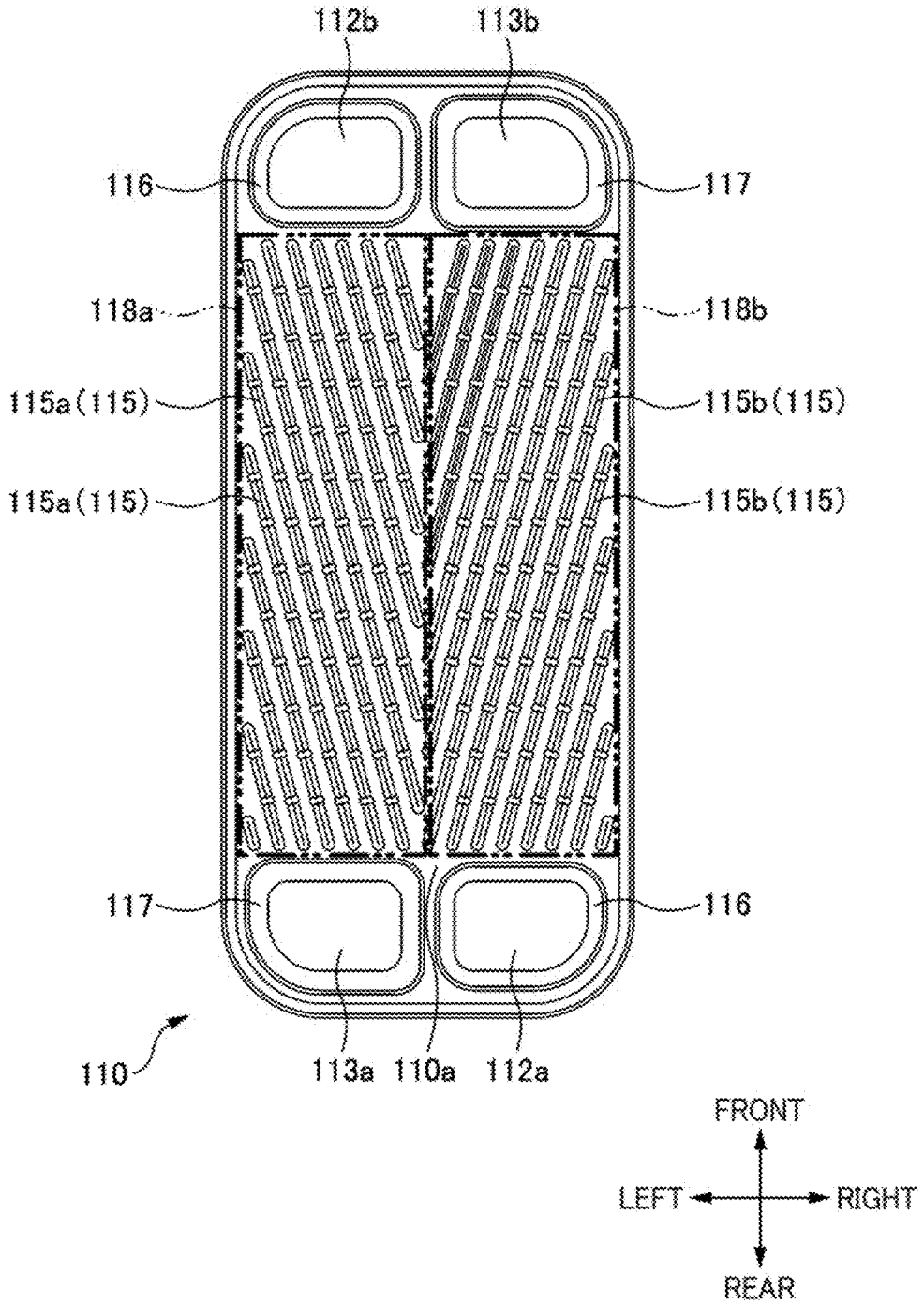

112b
113b
116
117
118a
118b
115a(115)
115b(115)
115a(115)
115b(115)
117
116
110
113a
110a
112a
FRONT
LEFT
RIGHT
REAR

FIG. 8

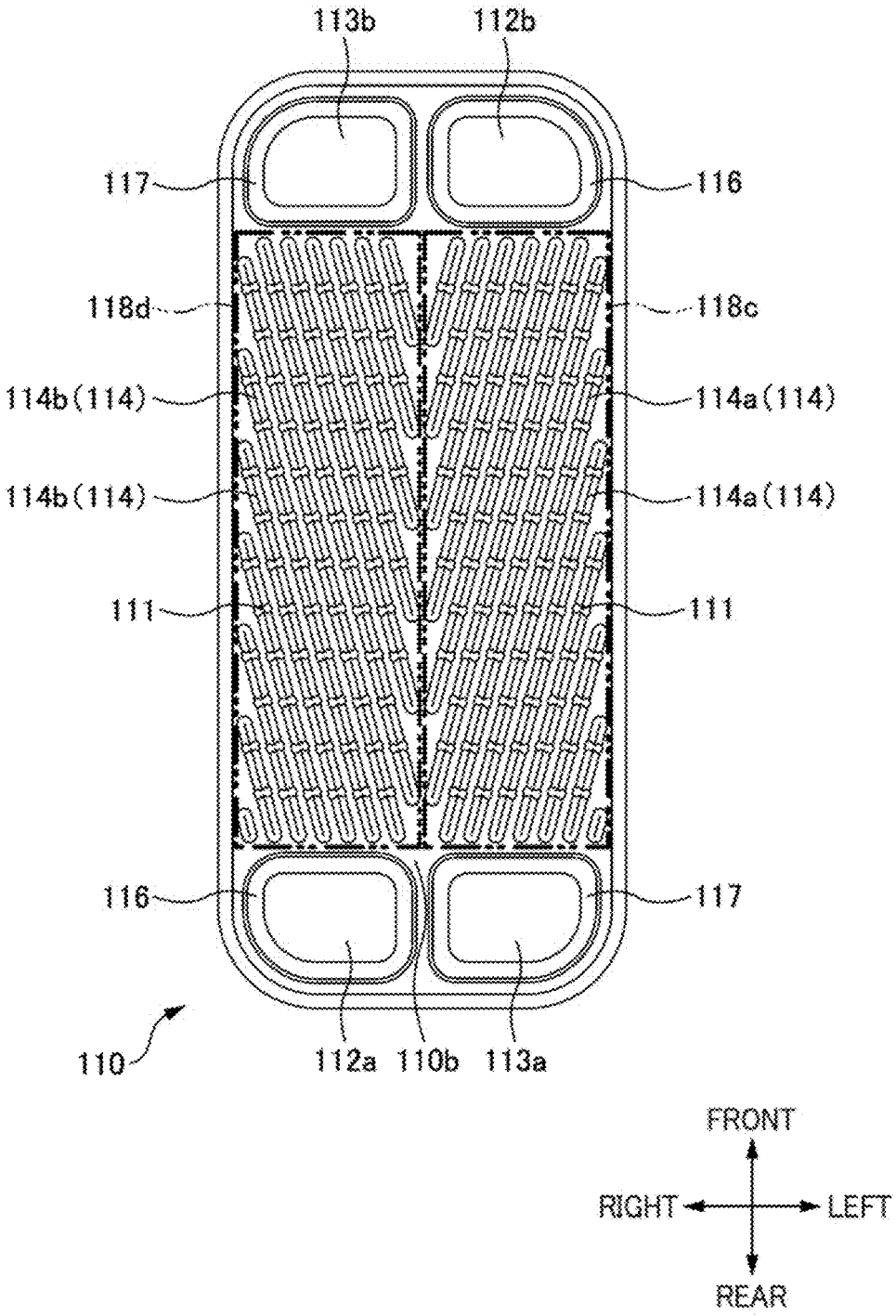

113b
112b
117
116
118d
118c
114b(114)
114a(114)
114b(114)
114a(114)
111
111
116
117
110
112a
110b
113a
FRONT
RIGHT
LEFT
REAR

FIG. 9

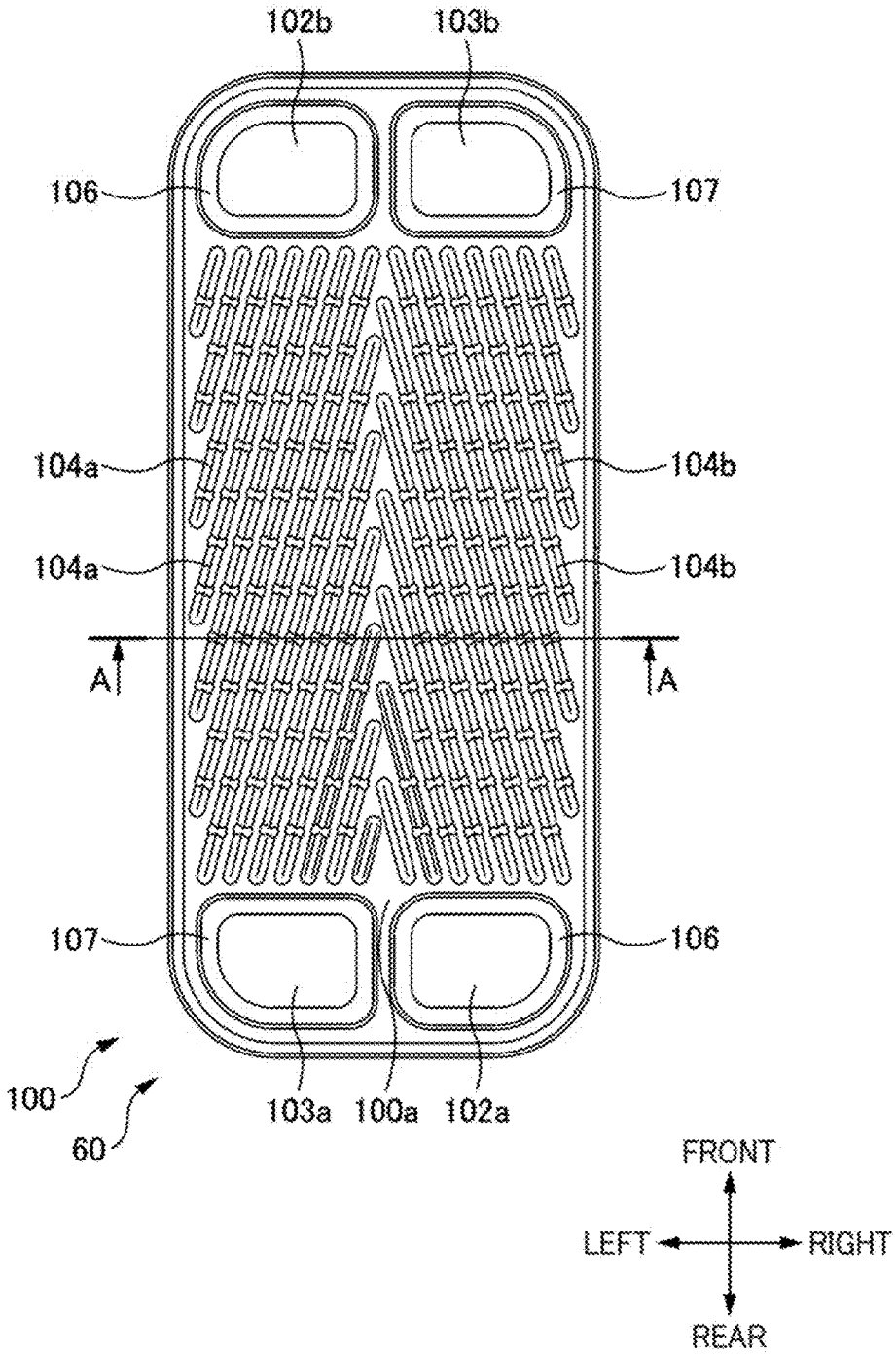
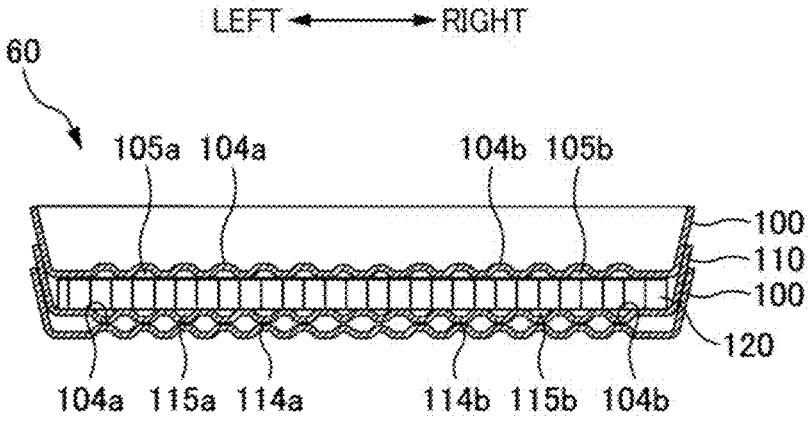

102b
103b
106
107
104a
104b
104a
104b
A
A
107
106
100
60
103a
100a
102a
FRONT
LEFT
RIGHT
REAR

FIG. 10



A-A CROSS-SECTION

FIG. 11

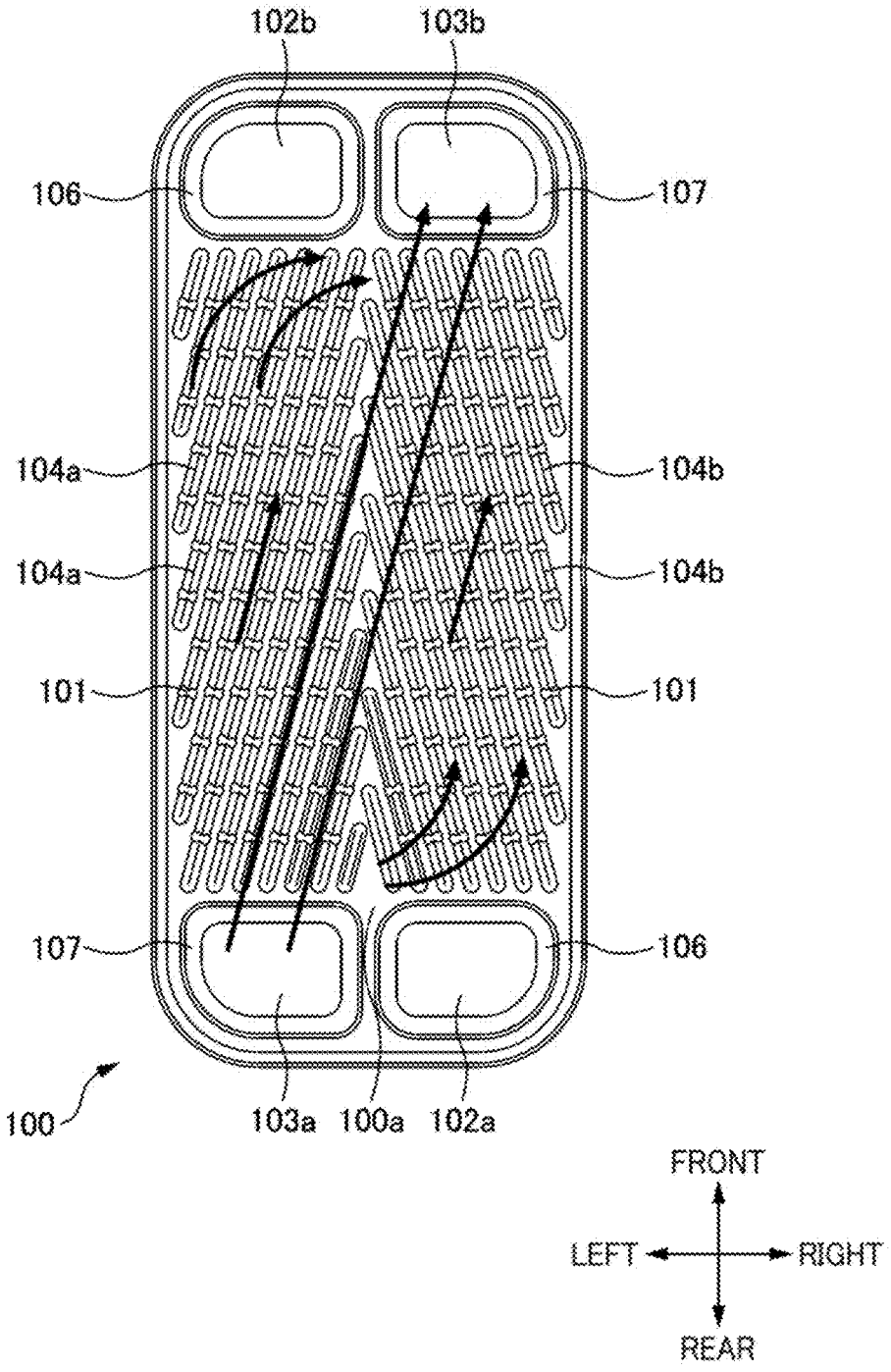

102b
103b
106
107
104a
104b
104a
104b
101
101
107
106
100
103a
100a
102a
FRONT
LEFT
RIGHT
REAR

FIG. 12

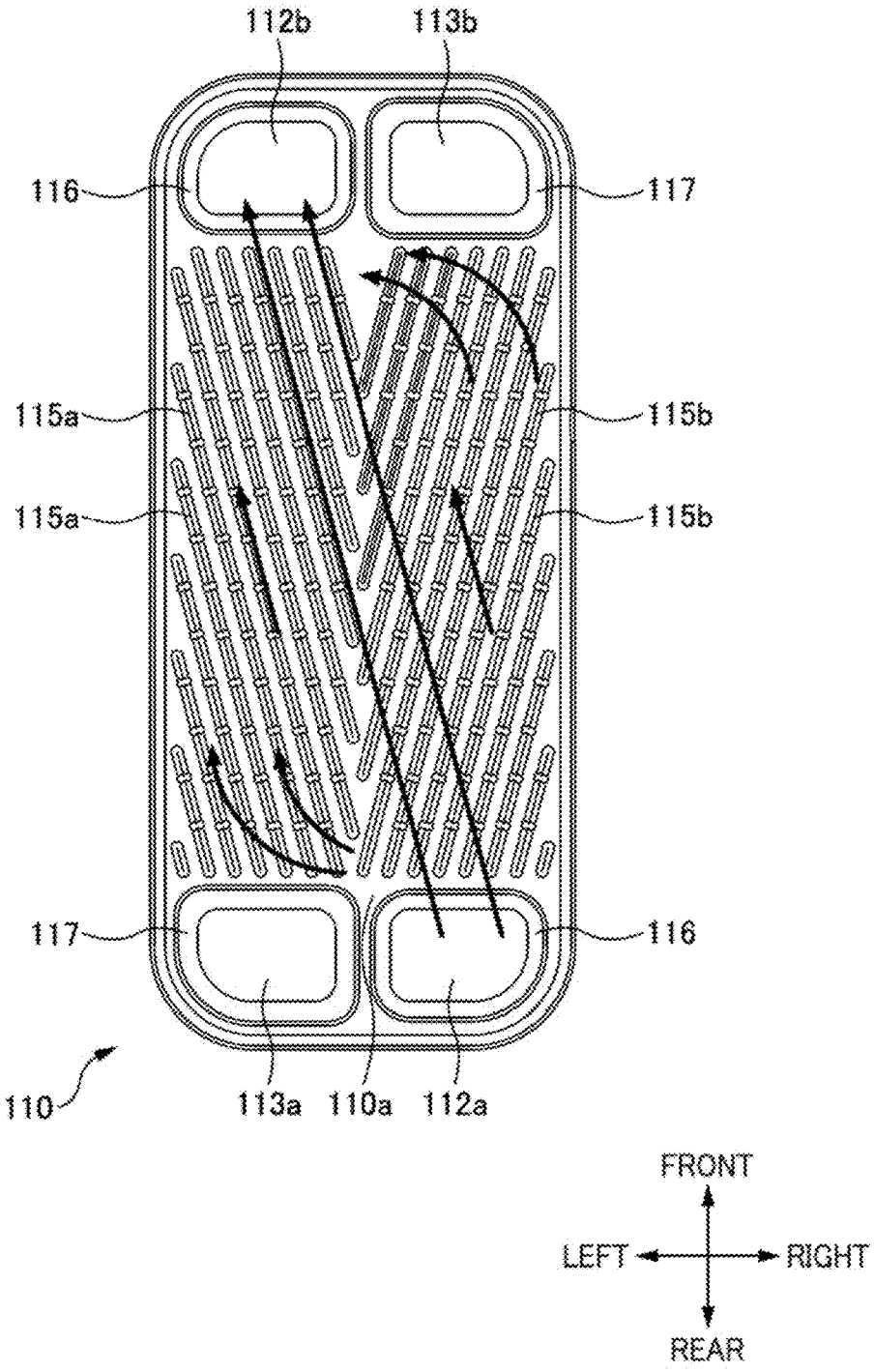

112b
113b
116
117
115a
115b
115a
115b
117
116
110
113a
110a
112a
FRONT
LEFT
RIGHT
REAR

FIG. 13

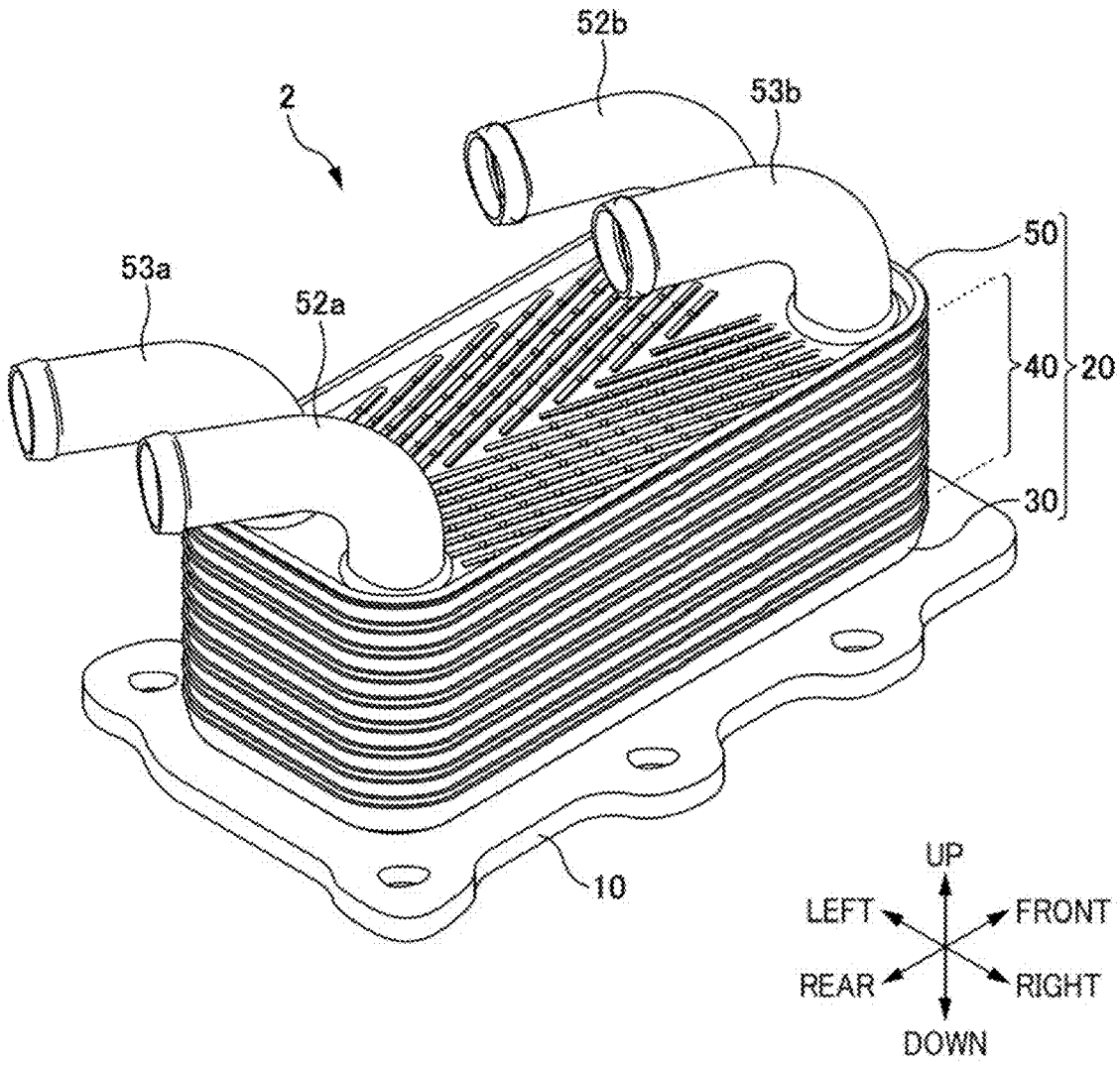


FIG. 14

HEAT EXCHANGER

TECHNICAL FIELD

[0001] The present disclosure relates to a heat exchanger.

BACKGROUND ART

[0002] There are heat exchangers in which a plurality of plate members are stacked such that flow paths through which gas or oil flows and flow paths through which cooling water flows are formed alternately in the stacking direction of the plate members (PTL 1).

CITATION LIST

Patent Literature

[0003] [PTL 1] Japanese Patent No. 4527557

SUMMARY OF INVENTION

Technical Problem

[0004] In the heat exchanger of PTL 1, the first flow path is embossed and provided with protrusions, however, there is a demand for heat exchangers with even higher heat exchange performance.

[0005] Thus, the present disclosure is achieved in view of circumstances described above, and is directed to provision of a heat exchanger with high heat exchange performance.

Solution to Problem

[0006] To address an issue described above, provided is a heat exchanger having a first surface configured to contact a heat medium, the first surface having a plurality of first protrusions extending linearly formed at the first surface.

Advantageous Effects of Invention

[0007] According to a heat exchanger according to the present disclosure, the performance of heat exchange is improved.

BRIEF DESCRIPTION OF DRAWINGS

[0008] FIG. **1** is a schematic diagram illustrating a heat exchange system **1**.

[0009] FIG. **2** is a perspective view of an oil cooler **2**.

[0010] FIG. **3** is an exploded view of an oil cooler **2**.

[0011] FIG. **4** is an exploded view of a plate assembly **60**.

[0012] FIG. **5** is an exploded view of a joint section in which two plate assemblies **60** are stacked.

[0013] FIG. **6** is a top view of a male plate **100**.

[0014] FIG. **7** is a bottom view of a male plate **100**.

[0015] FIG. **8** is a top view of a female plate **110**.

[0016] FIG. **9** is a bottom view of a female plate **110**.

[0017] FIG. **10** is a top view of a plate assembly **60**.

[0018] FIG. **11** is a sectional view of a plate assembly **60**.

[0019] FIG. **12** is a schematic diagram illustrating a flow of cooling water.

[0020] FIG. **13** is a schematic diagram illustrating a flow of oil.

[0021] FIG. **14** is a perspective view of an oil cooler **2** in Modification 18.

DESCRIPTION OF EMBODIMENTS

[0022] Embodiments of the present disclosure will be described below with reference to drawings. However, although various limitations that are technically preferable for carrying out the present disclosure are provided to the embodiments described below, the scope of the present disclosure is not limited to the following embodiments and illustrated examples.

<Overview of Heat Exchange System>

[0023] FIG. **1** is a schematic diagram of a heat exchange system **1**. The heat exchange system **1** includes an oil cooler **2**, an engine **3**, an oil pump **4**, a radiator **5**, a water pump **6**, an oil flow path **7**, and a cooling water flow path **8**.

[0024] The oil cooler **2** is a heat exchanger. The oil cooler **2** exchanges heat between the high temperature engine oil discharged from the engine **3** and the low temperature cooling water cooled by the radiator **5**.

[0025] The oil flow path **7** is a flow path through which engine oil flows. The oil flow path **7** connects the engine **3** and the oil cooler **2**, the oil cooler **2** and the oil pump **4**, and the oil pump **4** and the engine **3**, with piping, and allows the engine oil to circulate therethrough in the direction of the arrows in FIG. **1**.

[0026] The high temperature engine oil discharged from the engine **3** is supplied to the oil cooler **2**. The engine oil is cooled by the oil cooler **2** and then supplied to the oil pump **4**. The engine oil is supplied to the engine **3** by the oil pump **4**

[0027] The cooling water flow path **8** is a flow path through which cooling water flows. The cooling water flow path **8** connects the radiator **5** and the water pump **6**, the water pump **6** and the oil cooler **2**, and the oil cooler **2** and the radiator **5**, with piping, and allows the cooling water to circulate in the direction of the arrows in FIG. **1**.

[0028] The cooling water discharged from the radiator **5** is supplied to the oil cooler **2** by the water pump **6**. The cooling water cools the engine oil at the oil cooler **2**, resulting in reaching a high temperature. The cooling water having reached the high temperature is supplied from the oil cooler **2** to the radiator **5**. The cooling water is cooled by the radiator **5**.

<Structure of Oil Cooler>

[0029] FIG. **2**A is a perspective view of the oil cooler **2**. The oil cooler **2** includes a bottom flange **10** and a heat exchange unit **20**.

(Bottom Flange)

[0030] The bottom flange **10** is a member for attaching the oil cooler **2** to another structure such as an engine block or the like. The bottom flange **10** is a metal plate. The bottom flange **10** has a plurality of through holes **11**, oil inlet/outlet **12***a*, **12***b*, and cooling water inlet/outlet **13***a*, **13***b*. FIG. **3** is an exploded view of the oil cooler **2**.

[0031] A vertical direction is defined as the direction parallel to the thickness of the bottom flange **10**. In addition, as illustrated in FIG. **3** and the like, a front-rear direction is defined as the direction orthogonal to the vertical direction, and a left-right direction is defined as the direction orthogonal to the vertical and front-rear directions.

[0032] The through holes **11** are holes for fixing with a screw. Such a through hole **11** is a hole passing through the bottom flange **10** vertically. The through hole **11** is formed at the outer peripheral edge part of the bottom flange **10** so as not to overlap the attachment part of the heat exchanger **20**. In an embodiment of the present disclosure, the bottom flange **10** has six through holes **11**. The oil cooler **2** is attached to another structure by fitting bolts (not shown) into the through holes **11** and fastening the bolts to the other structure.

[0033] The oil inlet/outlet **12***a*, **12***b* are openings through which the engine oil is to flow. In an embodiment of the present disclosure, the rear opening of the bottom flange **10** is used as the oil inlet **12***a*, and the front opening is used as the oil outlet **12***b*.

[0034] The cooling water inlet/outlet **13***a*, **13***b* are openings through which the cooling water is to flow. In an embodiment of the present disclosure, the rear opening of the bottom flange **10** is used as the cooling water inlet **13***a*, and the front opening is used as the cooling water outlet **13***b*. The cooling water inlet **13***a* has a small diameter opening **14***a* and a large diameter opening **15***a*. The small diameter opening **14***a* is provided from the bottom surface of the bottom flange **10** toward the top surface, to be connected to the large diameter opening **15***a*. The large diameter opening **15***a* is provided from the small diameter opening **14***a* upward to the upper surface of the bottom flange **10**. The large diameter opening **15***a* is larger than the small diameter opening **14***a* when viewed from above, and is provided such that the small diameter opening **14***a* is arranged inside the large diameter opening **15***a*. The cooling water outlet **13***b* has a small diameter opening **14***b* and a large diameter opening **15***b*. The structures of the small diameter opening **14***b* and the large diameter opening **15***b* are the same as those of the small diameter opening **14***a* and the large diameter opening **15***a*.

(Heat Exchange Unit)

[0035] A heat exchange unit **20** is a structure that forms separate flow paths for the engine oil and the cooling water that are fluids, and that exchanges heat between the two fluids flowing through the respective flow paths. The heat exchange unit **20** includes a bottom plate **30**, a stacked section **40**, and a top plate **50**. The heat exchange unit **20** is obtained such that the stacked section **40** is stacked on the upper surface of the bottom plate **30**, and the top plate **50** is further stacked on the upper surface of the stacked section **40**.

(Bottom Plate)

[0036] The bottom plate **30** is a member disposed at the lowest layer of the heat exchange unit **20** and attached to the bottom flange **10**. The bottom plate **30** is attached to the lower surface of the lowest plate of the stacked section **40**. In an embodiment of the present disclosure, the bottom plate **30** is a male plate **100**, which will be described later.

(Stacked Section)

[0037] The stacked section **40** is a structure in which plate members are stacked in the vertical direction to form separate paths for the engine oil and the cooling water. The stacked section **40** is obtained such that a plurality of plate assemblies **60** are stacked and joined together by brazing. In an embodiment of the present disclosure, the stacked section **40** is a stack of four plate assemblies **60**.

(Plate Assembly)

[0038] The plate assembly **60** includes a male plate **100**, a female plate **110**, and a fin **120**. FIG. **4** is an exploded view of the plate assembly **60**. The plate assembly **60** is obtained by stacking such that the male plate **100** is arranged on the upper side, the female plate **110** is arranged on the lower side, and the fin **120** is arranged therebetween. A space is formed inside the plate assembly **60** by the male plate **100** and the female plate **110**, and functions as a second flow path **132** through which the engine oil is to flow.

[0039] FIG. **5** is a diagram in which the female plate **110** is arranged on the upper side, and the male plate **100** is arranged on the lower side. When the two plate assemblies **60** are stacked, the female plate **110** and the male plate **100** are arranged as illustrated in FIG. **5**, in a joint section. A space is formed by the female plate **110** and the male plate **100** in the joint section of the two plate assemblies **60**, and functions as a first flow path **131** through which the cooling water is to flow.

(Structure of Oil Cooler Flow Path)

[0040] FIG. **2**B is a simplified cross-sectional view at a position IIb of FIG. **2**A. The bottom plate **30** is provided to the top surface of the bottom flange **10**. On the bottom plate **30**, the female plates **110** and the male plates **100** are alternately arranged in the vertical direction.

[0041] A space formed by providing the female plate **110** onto the male plate **100** is the first flow path **131**. A space formed by providing the male plate **100** on the female plate **110** is the second flow path **132**. The first and second flow paths **131** and **132** are formed alternately in the vertical direction. The first flow path **131** and the second flow path **132** are formed of spaces partitioned by the male plates **100** and the female plates **110**, and thus are independent from each other.

[0042] The cooling water flows from the cooling water inlet **13***a* and flows into the first flow path **131**. After flowing through the first flow path **131**, the cooling water reaches the cooling water outlet **13***b*. The cooling water flows out from the cooling water outlet **13***b* to the radiator **5**.

[0043] The engine oil flows from the oil inlet **12***a* and flows into the second flow path **132**. After flowing through the second flow path **132**, the engine oil reaches the oil outlet **12***b*. The engine oil flows out from the oil outlet **12***b* to the oil pump **4**.

(Male Plate)

[0044] The male plate **100** is a member that exchanges heat between two fluids (the engine oil, the cooling water) flowing along its upper surface and its lower surface, respectively. The male plate **100** is a metal plate that is one size smaller than the bottom flange **10**. FIG. **6** is a top view of the male plate **100**. The male plate **100** is formed in a substantially rectangular shape with long sides extending in the front-rear direction and short sides extending in the left-right direction, when viewed from above. The male plate **100** has an upper surface **100***a* where linear protrusions **104** are formed, a lower surface **100***b* where linear grooves **105** are

formed, edge parts **106** where oil inlet/outlet **102***a*, **102***b* are formed, edge parts **107** where cooling water inlet/outlet **103***a*, **103***b* are formed.

[0045] The oil inlet/outlet **102***a*, **102***b* are openings through which the engine oil is to flow. The oil inlet/outlet **102***a*, **102***b* are provided at a pair of diagonal positions among the four corners of the male plate **100**. The size of the openings of the oil inlet/outlet **102***a*, **102***b* are larger than that of the oil inlet/outlet **12***a*, **12***b* of the bottom flange **10**. In an embodiment of the present disclosure, the right rear opening of the male plate **100** in FIG. **6** is used as the oil inlet **102***a*, and the left front opening of the male plate **100** is used as the oil outlet **102***b*. The edge parts **106** of the oil inlet and outlet **102***a*, **102***b* protrude upward, and have flat upper surfaces.

[0046] The cooling water inlet/outlet **103***a*, **103***b* are openings through which the cooling water is to flow. The cooling water inlet/outlet **103***a*, **103***b* are provided at a pair of diagonal positions where the oil inlet and outlet **102***a*, **102***b* are not provided among the four corners of the male plate **100**. In an embodiment of the present disclosure, the rear left opening of the male plate **100** in FIG. **6** is used as the cooling water inlet **103***a*, and the right front opening is used as the cooling water outlet **103***b*. The size of the openings of the cooling water inlet and outlet **103***a*, **103***b* is the same as that of the large diameter openings **15***a* and **15***b*. The edge parts **107** protrude downward and have flat lower surfaces. The shape of the edge parts **107** matches the shape of the large diameter openings **15***a* and **15***b*. Further, the length of the edge parts **107** protruding downward matches the depth of the large diameter openings **15***a*, **15***b*.

[0047] The protrusions **104** are protrusions to disturb the flow of the fluid flowing along the upper surface **100***a*, and protrudes upward from a flat part of the upper surface **100***a*, and extends linearly when viewed from above. The plurality of protrusions **104** are provided to the upper surface **100***a*. The upper surface **100***a* is divided into two regions **108***a* and **108***b*, and the plurality of protrusions **104** are provided in each of the regions **108***a* and **108***b*.

[0048] The regions **108***a* and **108***b* are regions provided by dividing the upper surface **100***a*. The regions **108***a* and **108***b* each have a rectangular shape extending in the front-rear direction. The regions **108***a* and **108***b* are obtained by dividing the upper surface **100***a* substantially symmetrically in the left-right direction. In an embodiment of the present disclosure, the region provided on the left side of the upper surface **100***a* is the region **108***a*, and the region provided on the right side is the region **108***b*.

[0049] Here, for the sake of explanation, the protrusions **104** provided in the region **108***a* and the protrusions **104** provided in the region **108***b* will be referred to as protrusions **104***a* and **104***b*, respectively. The plurality of protrusions **104***a* provided within the region **108***a* are arranged so as to be parallel to each other, and the plurality of protrusions **104***b* provided within the region **108***b* are also arranged so as to be parallel to each other. Further, the protrusions **104***a* extend in the direction intersecting the extending direction of the protrusions **104***b*. Note that the plurality of protrusions **104***a* and **104***b* form a so-called herringbone pattern when viewed from above.

[0050] As illustrated in FIG. **11**, the height of the protrusions **104** is about half the height of the space (the first flow path **131**) formed when the female plate **110** is stacked on the male plate **100**. The protrusions **104** have joint parts **101** which are dot-shaped protrusions. The joint parts **101** are each provided at a position at which the protrusion **104** and a protrusion **114** intersect when the female plate **110** is stacked on the male plate **100** when viewed from above.

[0051] The grooves **105** are grooves to disturb the flow of the fluid flowing along the lower surface **100***b*. FIG. **7** is a bottom view of the male plate **100**. The plurality of grooves **105** are provided so as to be recessed upward from a flat part of the lower surface **100***b*, and each extends linearly when viewed from below. Since the grooves **105** and the protrusions **104** are formed by press working, the grooves **105** have the same shape as the shape of the protrusions **104** when viewed in the vertical direction. The grooves **105** are aligned with the protrusions **104** when viewed from below. In other words, the grooves **105** are provided at the lower surface so as to be paired with the respective protrusions **104** having the same shapes, respectively. The lower surface **100***b* is divided into two regions **108***c* and **108***d*, and the plurality of grooves **105** are provided in each of the region **108***c* and **108***d*.

[0052] The regions **108***c* and **108***d* are regions provided by dividing the lower surface **100***b*. The regions **108***c* and **108***d* each have a rectangular shape extending in the front-rear direction. The regions **108***c* and **108***d* are obtained by dividing the lower surface **100***b* substantially symmetrically in the left-right direction. In an embodiment of the present disclosure, the region provided on the right side in the lower surface **100***b* is the region **108***c*, and the region provided on the left side is the region **108***d*. Further, the region provided at the back surface of the region **108***a* is the region **108***c*, and the region provided at the back surface of the region **108***b* is the region **108***d*.

[0053] Here, for the sake of explanation, the grooves **105** provided in the region **108***c* and the grooves **105** provided in the region **108***d* will be referred to as grooves **105***a* and **105***b*, respectively. The grooves **105***a*, **105***b* are respectively paired with the protrusions **104***a*, **104***b* having the same shapes, respectively. The plurality of grooves **105***a* provided in the region **108***c* are arranged so as to be parallel to each other, and the plurality of grooves **105***b* provided in the region **108***d* are also provided so as to be parallel to each other. Further, the grooves **105***a* extend in the direction intersecting the extending direction of the grooves **105***b*. Note that the plurality of grooves **105***a* and **105***b* form a so-called herringbone pattern when viewed from below.

(Female Plate)

[0054] The female plate **110**, similarly to the male plate **100**, is a member that exchanges heat between two fluids (the engine oil, the cooling water) **1** flowing along its upper surface and its upper lower surface, respectively. The female plate **110** is a metal plate having the same size as that of the male plate **100**. FIG. **8** is a top view of the female plate **110**. The female plate **110** is formed in a substantially rectangular shape with long sides extending in the front-rear direction and short sides extending in the left-right direction, when viewed from above. The female plate **110** has an upper surface **110***a* where linear grooves **115** are formed, a lower surface **110***b* where linear protrusions **114** are formed, edge parts **116** where oil inlet/outlet **112***a*, **112***b* are formed, and edge parts **117** where cooling water inlet/outlet **113***a*, **113***b* are formed.

[0055] The oil inlet/outlet **112***a*, **112***b* are openings through which the engine oil is to flow. The oil inlet/outlet

112*a*, **112***b* are provided at a pair of diagonal positions among the four corners of the female plate **110**. The size of the openings of the oil inlet/outlet **112***a*, **112***b* is the same as that of the oil inlet/outlet **102***a*, **102***b*. In an embodiment of the present disclosure, the right rear opening of the female plate **110** in FIG. **8** is used as the oil inlet **112***a*, and the left front opening of the female plate **110** is used as the oil outlet **112***b*. The edge parts **116** of the oil inlet and outlet **112***a*, **112***b* protrude downward, and have flat lower surfaces.

[0056] The cooling water inlet and outlet **113***a*, **113***b* are openings through which the cooling water is to flow. The cooling water inlet and outlet **113***a*, **113***b* are provided at a pair of diagonal positions where the oil inlet and outlet **112***a*, **112***b* are not provided among the four corners of the female plate **110**. In an embodiment of the present disclosure, the rear left opening of the female plate **110** in FIG. **8** is used as the cooling water inlet **113***a*, and the right front opening is used as the cooling water outlet **113***b*. The size of the openings of the cooling water inlet and outlet **113***a*, **113***b* is the same as that of the cooling water inlet and outlet **103***a*, **103***b*. The edge parts **117** protrude upward, and have flat upper surfaces. The shape of the edge parts **117** matches the shape of the edge parts **107**.

[0057] Here, the oil inlet and outlet **102***a*, **102***b* and the oil inlet and outlet **112***a*, **112***b* will be described. In the male plate **100**, the edge parts **106** forming the oil inlet and outlet **102***a*, **102***b* protrude upward from the upper surface **100***a*. In the female plate **110**, the edge parts **116** forming the oil inlet and outlet **112***a*, **112***b* protrude downward from the upper surface **110***a*. Thus, as illustrated in FIG. **2**B, when the female plate **110** is stacked on the male plate **100**, the edge parts **106** and **116** are coupled. Further, the upper and lower second flow paths **132** are connected through the oil inlet and outlet **102***a*, **102***b* and the oil inlet and outlet **112***a*, **112***b*. Accordingly, in the respective second flow paths **132**, the upper and lower second flow paths **132** are connected, and thus all the second flow paths **132** are connected through the oil inlet and outlet **102***a*, **102***b* and the oil inlet and outlet **112***a*, **112***b*.

[0058] Next, the cooling water inlet and outlet **103***a*, **103***b* and the cooling water inlet and outlet **113***a*, **113***b* will be described. In the male plate **100**, the edge parts **107** forming the cooling water inlet and outlet **103***a*, **103***b* protrude downward from the upper surface **100***a*. In the female plate **110**, the edge parts **117** forming the cooling water inlet and outlet **113***a*, **113***b* protrude upward from the upper surface **110***a*. Thus, as illustrated in FIG. **2**B, when the male plate **100** is stacked on the female plate **110**, the edge parts **107** and **117** are coupled. Further, the upper and lower first flow paths **131** are connected through the cooling water inlet and outlet **103***a*, **103***b* and the cooling water inlet and outlet **113***a*, **113***b*. Accordingly, in the respective first flow paths **131**, the upper and lower first flow paths **131** are connected, and thus all the first flow paths **131** are connected through the cooling water inlet and outlet **103***a*, **103***b* and the cooling water inlet and outlet **113***a*, **113***b*.

[0059] Here, the cooling water inlet and outlet **103***a*, **103***b* and the cooling water inlet and outlet **113***a*, **113***b* are open to the first flow paths **131**, but the oil inlet and outlet **102***a*, **102***b* and the oil inlet and outlet **112***a*, **112***b* are closed against the first flow paths **131**. Further, the oil inlet and outlet **102***a*, **102***b* and the oil inlet and outlet **112***a*, **112***b* are open to the second flow paths **132**, but the cooling water inlet and outlet **103***a*, **103***b* and the cooling water inlet and outlet **113***a*, **113***b* are closed against the second flow paths **132**. Thus, the first flow paths **131** are independent from the second flow paths **132**.

[0060] The grooves **115** are grooves to disturb the flow of the fluid flowing along the upper surface **110***a*. The plurality of grooves **115** are provided so as to be recessed downward from a flat part of the upper surface **110***a*, and each of the grooves **115** extends linearly when viewed from above. The upper surface **110***a* is divided into two regions **118***a* and **118***b*, and the plurality of grooves **115** are provided in each of the regions **118***a* and **118***b*.

[0061] The regions **118***a* and **118***b* are regions obtained by dividing the upper surface **110***a*. The regions **118***a* and **118***b* each have a rectangular shape extending in the front-rear direction. The regions **118***a* and **118***b* are obtained by dividing the upper surface **110***a* substantially symmetrically in the left-right direction. In an embodiment of the present disclosure, the region provided on the left side of the upper surface **110***a* is the region **118***a*, and the region provided on the right side is the region **118***b*.

[0062] Here, for the sake of explanation, the grooves **115** provided in the region **118***a* and the grooves **115** provided in the region **118***b* will be referred to as grooves **115***a* and **115***b*, respectively. The plurality of grooves **115***a* provided in the region **118***a* are provided so as to be parallel to each other, and the plurality of grooves **115***b* provided in the region **118***b* are also provided so as to be parallel to each other. Further, the grooves **115***a* extend in the direction intersecting the extending direction of the grooves **115***b*. Note that the plurality of grooves **115** form a so-called herringbone pattern when viewed from above.

[0063] The protrusions **114** are protrusions to disturb the flow of the fluid flowing along the lower surface **110***b*, and protrude downward from a flat part of the lower surface **110***b*, and extends linearly when viewed from below. FIG. **9** is a bottom view of the female plate **110**. The plurality of protrusions **114** are provided at the lower surface **110***b*. Since the protrusions **114** and the grooves **115** are formed by press working, the protrusions **114** have the same shape as that of the grooves **115** when viewed in the vertical direction. The protrusions **114** are aligned with the grooves **115** when viewed from below. In other words, the protrusions **114** are provided at the lower surface **110***b* so as to be paired with the grooves **115** having the same shapes, respectively. The lower surface **110***b* is divided into two regions **118***c* and **118***d*, and the plurality of protrusions **114** are provided in each of the regions **118***c* and **118***d*.

[0064] The regions **118***c* and **118***d* are regions provided by dividing the lower surface **110***b*. The regions **118***c* and **118***d* each have a rectangular shape extending in the front-rear direction. The regions **118***c* and **118***d* are obtained by dividing the lower surface **110***b* substantially symmetrically in the left-right direction. In an embodiment of the present disclosure, the region provided on the right side in the lower surface **110***b* is the region **118***c*, and the region provided on the left side is the region **118***d*. Further, the region provided at the back surface of the region **118***a* is the region **118***c*, and the region provided at the back surface of the region **118***b* is the region **118***d*.

[0065] Here, for the sake of explanation, the protrusions **114** provided in the region **118***c* and the protrusions **114** provided in the region **118***d* will be referred to as protrusions **114***a* and **114***b*, respectively. The protrusions **114***a*, **114***b* are respectively paired with the grooves **115***a*, **115***b* having the

same shapes, respectively. In other words, the plurality of protrusions **114***a* provided in the region **118***c* are provided so as to be parallel to each other, and the plurality of protrusions **114***b* provided in the region **118***d* are also provided so as to be parallel to each other. Further, the protrusions **114***a* extend in the direction intersecting the extending direction of the protrusions **114***b*. Note that the plurality of protrusions **114** form a so-called herringbone pattern when viewed from below. Further, the protrusions **114** are provided in the direction intersecting the direction of the protrusions **104**, when viewed from below, when the male plate **100** and the female plate **110** are stacked.

[0066] As illustrated in FIG. **11**, the height of the protrusions **114** is about half the height of the space (the first flow path **131**) formed when the female plate **110** is stacked on the male plate **100**. The protrusions **114** contact the joint parts **101**, to thereby join the protrusions **104**, so that the joint parts **111** having dot-shaped recesses that are recessed upward from the lower surface of the protrusions **114** are formed. The dot-shaped protrusions of the joint parts **101** are paired with the dot-shaped recesses of the joint parts **111**. The joint parts **111** are provided at positions at which the protrusions **104** and the protrusions **114** intersect, when viewed from below, when the female plate **110** is stacked on the male plate **100**.

(Fin)

[0067] The fin **120** is a member to cause the flows of the fluid running therethrough to be complex and exchange heat with the fluid. The fin **120** is a metal member obtained such that thin plates extending in the front and back and vertical directions, and thin plates extending in the right and left and vertical directions are combined to form a large number of rectangular holes, and has a flat-plate outer shape. The thickness of the fin **120** is substantially the same as the height of the space (the second flow path **132**) formed with the male plate **100** and the female plate **110**, as illustrated in FIG. **11**. The upper surface of the fin **120** contacts the lower surface **100***b*. The lower surface of the fin **120** contacts the upper surface **110***a*.

(Top Plate)

[0068] The top plate **50** is a member disposed as the uppermost layer member of the heat exchange unit **20**. The top plate **50** is a type of the female plate **110**, and has a shape similar to the female plate **110** without the oil inlet/outlet **112***a*, **112***b* and the cooling water inlet/outlet **113***a*, **113***b*. Thus, the top plate **50** will be described, with the constituents thereof that are the same as those in the female plate **110** being given the same reference numerals. The top plate **50** has the upper surface **110***a* where the linear grooves **115** are formed and the lower surface **110***b* where the linear protrusions **114** are formed. The top plate **50** is joined, by brazing, to the upper surface of the male plate **100**, which is the uppermost member of the stacked section **40**. This closes the oil inlet and outlet **102***a*, **102***b* of the male plate **100** that is joined to the lower surface of the top plate **50**.

<Operation of Oil Cooler>

[0069] An operation of the oil cooler **2** will be described. Inside the oil cooler **2**, the cooling water flows through the first flow path **131**. The engine oil flows through the second flow path **132**. The first flow path **131** and the second flow path **132** are vertically adjacent to each other with the male plate **100** or the female plate **110** being placed therebetween. Thus, the cooling water and the engine oil exchange heat through the male plate **100** or the female plate **110**. In other words, the high-temperature engine oil is cooled by the low-temperature cooling water. In contrast, the low temperature cooling water is heated by the high temperature engine oil.

(Cooling Water)

[0070] As given by the arrows in FIG. **2**B, the cooling water is supplied from the cooling water flow path **8** to the cooling water inlet **13***a*. The cooling water flows from the cooling water inlet **13***a* into the first flow path **131** in a bottom layer. The cooling water flows into all the first flow paths **131** through the cooling water inlets **103***a*, **113***a*.

[0071] The cooling water spreads and flows throughout the first flow paths **131** from the cooling water inlets **103***a*, **113***a*, as given by the arrows in FIG. **12**. The cooling water then flows into the cooling water outlets **103***b*, **113***b*.

[0072] A portion of the cooling water that has flown in, contacts the protrusions **104**, **114** while flowing through the first flow path **131**. Since the protrusions **104**, **114** protrude vertically, the cooling water that contacts the protrusions **104**, **114** generates a flow in the vertical direction. Further, since the protrusions **104**, **114** are provided to intersect the flow direction of the cooling water, the cooling water that contacts the protrusions **104**, **114** generates flows in the left-right direction according to the angle at which they intersect. Further, with the protrusions **104**, **114** contacting at the joint parts **101**, **111**, the protrusions **104**, **114** at those positions form columnar shapes. Accordingly, a portion of the cooling water generates flows avoiding the protrusions **104**, **114** formed into columnar shapes. As such, the cooling water generates complex flows when flowing through the first flow path **131**.

[0073] When flowing through the first flow paths **131**, the cooling water exchanges heat with the engine oil through the male plate **100** and the female plate **110**. The surface area of the male plate **100** increases by an amount corresponding to the provided projections **104**. Further, the surface area of the female plate **110** increases by an amount corresponding to the provision of the protrusions **114**. Here, the more the contact area between the cooling water and the member that exchanges heat increases, the more the efficiency of the heat exchange by the cooling water increases. Thus, the efficiency of the heat exchange by the cooling water flowing through the first flow paths **131** is high.

[0074] The cooling water flows through each of the first flow paths **131** and flows into the cooling water outlets **103***b*, **113***b*. The cooling water flows into the cooling water outlet **13***b* through the cooling water outlets **103***b* and **113***b*. The cooling water flows into the radiator **5** through the cooling water flow path **8** from the cooling water outlet **13***b*.

(Engine Oil)

[0075] As given by the arrows in FIG. **2**B, the engine oil is supplied from the oil flow path **7** to the oil inlet **12***a*. The engine oil flows from the oil inlet **12***a* into the second flow path **132** at the bottom layer. The engine oil flows into all the second flow paths **132** through the oil inlets **102***a* and **112***a*.

[0076] The engine oil spreads and flows throughout the second flow paths **132** from the oil inlets **102***a*, **112***a*, as

given by the arrows in FIG. **13**. The engine oil then flows into the oil outlets **102***b*, **112***b*.

[0077] The engine oil that has flown in, contacts the fin **120** while flowing through the second flow path **132**. Further, the engine oil flows through the holes formed in the fin **120** and through the grooves **105**, **115**. The engine oil flowing through the second flow path **132** contacts the fin **120**, and flows through the grooves **105**, **115**, thereby generating flows in the left-right direction and the up-down direction.

[0078] The engine oil exchanges heat with the cooling water through the male plate **100**, the female plate **110**, and the fin **120**, while flowing through the second flow path **132**. Since the fin **120** contacts the lower surface **100***b* and the upper surface **110***a*, heat is exchanged between the fin **120** and the male plate **100** and between the fin **120** and the female plate **110**. In other words, the fin **120** increases the area for the engine oil to exchange heat. Further, the surface area of the male plate **100** increases by an amount corresponding to the provided grooves **105**. Similarly, the surface area of the female plate **110** increases by an amount corresponding to the provided grooves **115**. Thus, the efficiency of the heat exchange by the engine oil flowing through the second flow paths **132** is high.

[0079] The engine oil runs through the fin **120** while flowing through the second flow path **132**. The fin **120** makes it difficult for the engine oil to flow in the second flow path **132**. As a result, the pressure loss in the second flow path **132** increases. However, the upper/lower surfaces of the fin **120** contact the grooves **105**, **115**. Since the size of the grooves **105**, **115** is larger than the size of the flow paths inside the fin **120**, a portion of the engine oil running through the fin **120** flows from the inside of the fin **120** to the grooves **105**, **115**.

[0080] The engine oil flows through the respective second flow paths **132** into the oil outlets **102***b*, **112***b*. The engine oil flows into the oil outlet **12***b* through the oil outlets **102***b*, **112***b*. The engine oil flows into the oil pump **4** through the oil flow path **7** from the oil outlet **12***b*.

<Effects>

[0081] In an embodiment described above, the oil cooler **2** includes the plate (the male plate **100** or the female plate **110**) having the upper surface **100***a* or the lower surface **110***b* configured to contact the cooling water, and the plurality of linearly extending protrusions **104**, **114** are formed at the upper surface **100***a*.

[0082] With the protrusions **104**, **114** configured to contact the cooling water being formed at the plate, the contact area between the cooling water and the plate increases. The more the contact area of the plate that contacts the cooling water during heat exchange increases, the more the efficiency of the heat exchange by the cooling water increases, and thus the efficiency of the heat exchange by the oil cooler **2** increases.

[0083] Further, with the cooling water contacting the protrusions **104**, the flow of the cooling water changes along the projections **104**. Accordingly, the flows of the cooling water become complex. The more the complex flows of the cooling water are generated, the more the efficiency of the heat exchange by the cooling water increases, and thus the efficiency of the heat exchange by the oil cooler **2** increases.

[0084] Further, the plurality of protrusions **104**, **114** of the oil cooler **2** according to an embodiment of present disclosure each extend to intersect the flow direction of the cooling water.

[0085] The plurality of protrusions **104**, **114** extending in the direction intersecting the flow direction of the cooling water, generates a flow of the cooling water according to the angle at which the flow direction of the cooling water intersects the protrusions **104**, **114** when the cooling water contacts the protrusions **104**, **114**. Accordingly, the cooling water generates complex flows, thereby increasing the efficiency of the heat exchange.

[0086] Further, the upper surface **100***a* or the lower surface **110***b* of the oil cooler **2** according to an embodiment of the present disclosure is divided into the region **108***a* and the region **108***b*, or the region **118***c* and the region **118***d*, each extending in the flow direction of the cooling water, and in the plurality of protrusions **104**, **114**, the protrusions **104***a* in the region **108***a* and the protrusions **104***b* in the region **108***b* extend in directions intersecting each other, or the protrusions **114***a* in the region **118***c* and the protrusions **114***b* in the region **118***d* extend in directions intersecting each other.

[0087] The upper surface **100***a* or the lower surface **110***b* is divided into the region **108***a* and the region **108***b*, or the region **118***c* and the region **118***d*, each extending in the flow direction of the cooling water, and in the protrusions **104**, **114**, the protrusions **104***a* in the region **108***a* and the protrusions **104***b* in the region **108***b* extend in directions intersecting each other, or the protrusions **114***a* in the region **118***c* and the protrusions **114***d* in the region **118***d* extend in directions intersecting each other. This causes the flow direction of the cooling water in the region **108***a* to be different from the flow direction of the cooling water in the region **108***b*. Alternatively, the flow direction of the cooling water in the region **118***c* is caused to be different from the flow direction of the cooling water in the region **118***d*. Accordingly, the cooling water generates complex flows, thereby increasing the efficiency of the heat exchange.

[0088] Further, the plate of the oil cooler **2** according to an embodiment of the present disclosure further includes the lower surface **100***b* located on the side opposite to the upper surface **100***a* or the upper surface **110***a* located on the side opposite to the lower surface **110***b*, which are to be contacted by the engine oil that exchanges heat with the cooling water. The plurality of linearly extending grooves **105**, **115** are formed at the lower surface **100***b* or the upper surface **110***a*.

[0089] The plate includes the lower surface **100***b* located on the side opposite to the upper surface **100***a* or the upper surface **110***a* located on the side opposite to the lower surface **110***b*, which are to be contacted by the engine oil that exchanges heat with the cooling water. With the plurality of linearly extending grooves **105**, **115** being formed at the lower surface **100***b* or the upper surface **110***a*, the lower surface **100***b* or the upper surface **110***a* results in a wavy shape. Accordingly, the contact area between the engine oil and the plate increases. The more the contact area between the engine oil and the member to contact the oil during heat exchange increases, the more the efficiency of the heat exchange by the engine oil increases, thereby increasing the efficiency of the heat exchange by the oil cooler **2**.

[0090] Further, with the lower surface **100***b* or the upper surface **110***a* being in a wavy shape, the engine oil flows

along the grooves **105**, **115**. As a result, the engine oil generates complex flows, thereby increasing the efficiency of the heat exchange.

[0091] Furthermore, the cooling water and the engine oil exchange heat through the plates. Not only the efficiency of the heat exchange between the upper surface **100***a* or the lower surface **110***b* and the cooling water, but also the efficiency of the heat exchange between the lower surface **100***b* or the upper surface **110***a* and the engine oil increases, and thus the efficiency of the heat exchange of the entire oil cooler **2** increases.

[0092] Further, the plurality of grooves **105**, **115** of the oil cooler **2** according to an embodiment of the present disclosure each extend to intersect the flow direction of the engine oil.

[0093] With the plurality of grooves **105**, **115** each extending in the direction intersecting the flow direction of the engine oil, a flow of the engine oil is generated according to the angle at which the direction of the flow of the engine oil intersects the grooves **105**, **115**, when the engine oil flows along the grooves **105**, **115**. Accordingly, the engine oil generates complex flows, thereby increasing the efficiency of heat exchange.

[0094] Further, the lower surface **100***b* or the upper surface **110***a* of the oil cooler **2** according to an embodiment of the present disclosure is divided into the region **108***c* and the region **108***d*, or the region **118***a* and the region **118***b*, each extending in the flow direction of the engine oil, and in the plurality of grooves **105**, **115**, the grooves **105***a* in the region **108***c* and the grooves **105***b* in the region **108***d* extend in directions intersecting each other, or the grooves **115***a* in the region **118***a* and the grooves **115***b* in the region **118***b* extend in directions intersecting each other.

[0095] The lower surface **100***b* or the upper surface **110***a* is divided into the region **108***c* and the region **108***d*, or the region **118***a* and the region **118***b*, each extending in the flow direction of the engine oil, and in the grooves **105**, **115**, the grooves **105***a* in the region **108***c* and the grooves **105***b* in the region **108***d* extend in directions intersecting each other, or the grooves **115***a* in the region **118***a* and the grooves **115***b* in the region **118***b* extend in directions intersecting each other, thereby causing the flow direction of the engine oil in the region **108***c* to be different from the flow direction of the engine oil in the region **108***d*. Alternatively, the flow direction of the engine oil into the region **118***a* is caused to be different from the flow direction of the engine oil into the region **118***b*. Accordingly, the engine oil generates complex flows, thereby increasing the efficiency of heat exchange.

[0096] Further, the oil cooler **2** according to an embodiment of the present disclosure further includes the fin **120** configured to diffuse the flow of the cooling water or engine oil that contacts either at least one of the plurality of protrusions **104** or the lower surface **100***b*, or contacts either at least one of the plurality of protrusions **114** or the upper surface **110***a*.

[0097] The flow of the cooling water or engine oil is diffused by the fin **120** configured to diffuse the flow of the cooling water or engine oil that contacts either at least one of the plurality of protrusions **104** or the lower surface **100***b*, or either at least one of the plurality of protrusions **114** or the upper surface **110***a*. Accordingly, the part where the cooling water or engine oil contacts the plates increases, thereby increasing the amount of heat exchange between the cooling water or engine oil and the plates. As a result, the efficiency of the heat exchange of the entire oil cooler **2** increases.

[0098] Further, the fins **120** contact either the protrusions **104** or the lower surface **100***b*, or either the protrusions **114** or the upper surface **110***a*, and thus the fins **120** contacts the plates. Accordingly, the members that exchange heat with the cooling water or engine oil increase. As a result, the efficiency of the heat exchange of the entire oil cooler **2** increases.

[0099] Note that the fin **120** increases the efficiency of the heat exchange as described above. Meanwhile, the fin **120** increases resistance in the flow path of the cooling water or engine oil, which increases the pressure loss in the flow path. Here, the fin **120** contacts either the protrusion(s) **104** or the lower surface **100***b*, and thus the fin **120** contacts, at the contact part, the grooves formed between the plurality of protrusions **104** or the grooves **105** formed at the lower surface **100***b*. Alternatively, the fin **120** contacts either the protrusion(s) **114** or the upper surface **110***a*, and thus the fin **120** contacts, at the contact part, the grooves formed between the plurality of protrusions **114** or the grooves **115** formed at the upper surface **110***a*. Since these grooves function as the flow path for the cooling water or engine oil, the pressure loss in the flow path decreases. In other words, it is possible to achieve the effects of increasing the efficiency of the heat exchange by the fin **120** while suppressing the increase in the pressure loss in the flow path.

[0100] Further, the plurality of protrusions **104**, **114** of the oil cooler **2** according to an embodiment of the present disclosure are aligned with the plurality of grooves **105**, **115** when viewed in the direction orthogonal to the upper surface **100***a* or the lower surface **110***b*.

[0101] The plurality of protrusions **104**, **114** are aligned with the plurality of grooves **105**, **115** when viewed in the direction orthogonal to the upper surface **100***a* or the lower surface **110***b*, so that the protrusions **104** and the grooves **105**, or the protrusions **114** and the grooves **115** are respectively located at the same positions at the front and back surfaces of the plate. Here, in order to provide the grooves **105**, **115** at the lower surface **100***b* or the upper surface **110***a*, the thickness of the plate needs to be thicker than the depth of the grooves **105**, **115**. However, if the protrusions **104** and the grooves **105** or the protrusions **114** and the grooves **115** are respectively located at the same positions at the front and back surfaces of the plate, the grooves **105** can be provided from the lower surface **100***b* with respect to the protruding parts of the corresponding protrusions **104**, or the grooves **115** can be formed from the upper surface **110***a* with respect to the protruding parts of the corresponding protrusions **114**, which makes it possible to make the plate thinner. This results in achieving the thinner oil cooler **2**.

[0102] Further, the oil cooler **2** according to an embodiment of the present disclosure further includes the plate having the lower surface **110***b* or the upper surface **100***a* configured to contact the cooling water, the lower surface **110***b* or the upper surface **100***a* having the plurality of protrusions **114**, **104** extending linearly formed thereat, and the upper surface **100***a* faces the lower surface **110***b*.

[0103] The oil cooler **2** includes the plate having the lower surface **110***b* or the upper surface **100***a* configured to contact the cooling water, the lower surface **110***b* or the upper surface **100***a* having the plurality of protrusions **114**, **104** extending linearly formed thereat. Here, with the upper surface **100***a* and the lower surface **110***b* facing each other,

the cooling water flows between the upper surface **100***a* and the lower surface **110***b*. Accordingly, the cooling water contacts not only the protrusions **104** but also the protrusions **114**, and thus the cooling water generates more complex flows. As a result, the efficiency of the heat exchange increases.

[0104] Further, at least one of the plurality of protrusions **104** of the oil cooler **2** according to an embodiment of the present disclosure contacts corresponding one of the plurality of protrusions **114**.

[0105] With at least one of the plurality of protrusions **104** contacting corresponding one of the plurality of protrusions **114**, the contact portions of such two protrusions form a column or a wall between the upper surface **100***a* and the lower surface **110***b*. Accordingly, the cooling water flows in such a manner as to avoid the column or wall, and thus the cooling water generate more complex flows. As a result, the efficiency of the heat exchange increases.

[0106] Further, since such columns or walls are formed between the plates, the oil cooler **2** has high strength against the force acting in the direction in which the plates face each other.

[0107] Further, each of the plurality of protrusions **104** of the oil cooler **2** according to an embodiment of the present disclosure extends in a direction intersecting the plurality of protrusions **114**.

[0108] Each of the plurality of protrusions **104** extends in the direction intersecting the plurality of protrusions **114**, and thus the direction of the wavy shape formed at the upper surface **100***a* is different from the direction of the wavy shape formed at the lower surface **110***b*. Accordingly, the cooling water generates complex flows, while flowing between the upper surface **100***a* and the lower surface **110***b*. As a result, the efficiency of the heat exchange increases.

<Modifications>

[0109] Variations described below may be applied in combination.

(1) Modification 1

[0110] Immediately after the heat exchange system **1** starts operating, and the like, the temperature of the engine oil may be lower than the temperature of the cooling water. In this case, the oil cooler **2** exchanges heat between the low-temperature engine oil and the high-temperature water. As a result, the engine oil is heated while the water is cooled.

(2) Modification 2

[0111] The configuration of the heat exchange system **1** may be different. For example, the oil pump **4** and the water pump **6** may be disposed at different locations. Further, the engine **3** may be replaced with a transmission or a motor. In this case, the engine oil is replaced with a transmission oil or a motor oil.

(3) Modification 3

[0112] The fluid that exchanges heat with the water may be a gas. For example, the oil cooler **2** functions as an EGR cooler of an Exhaust Gas Recirculation (EGR) system that recirculates the exhaust gas from the engine **3**, to mix it with the intake gas of the engine **3**. The EGR cooler takes in a portion of the exhaust gas discharged from the engine **3**, exchanges heat between the exhaust gas and the water, to thereby cool the exhaust gas. Then, the exhaust gas cooled by the EGR cooler is mixed with the intake gas of the engine **3**. In this case, in the heat exchange system **1**, the oil pump **4** is removed and the oil flow path **7** results in a gas flow path.

(4) Modification 4

[0113] The flow directions of the engine oil and the cooling water may be different. In other words, in an embodiment of the present disclosure, the engine oil flows from the oil flow path **7** in the order of the oil inlet **12***a*, the oil inlet **112***a*, the second flow path **132**, the oil outlet **112***b*, and the oil outlet **12***b*. However, the oil may flow from the oil flow path **7** in the order of the oil outlet **12***b*, the oil outlet **112***b*, the second flow path **132**, the oil inlet **112***a*, and the oil inlet **12***a*. Similarly, the cooling water may flow from the cooling water flow path **8** in the order of the cooling water outlet **13***b*, the cooling water outlet **103***b*, the first flow path **131**, the cooling water inlet **103***a*, and the cooling water inlet **13***a*.

(5) Modification 5

[0114] Each of the plurality of protrusions **104**, **114** does not have to extend in the direction intersecting the flow direction of the cooling water. In this case, at least one of the plurality of protrusions **104**, **114** extends parallel to the flow direction of the cooling water.

(6) Modification 6

[0115] The upper surface **100***a* or the lower surface **110***b* does not have to be divided into the region **108***a* and the region **108***b*, or the region **118***c* and the region **118***d*, each extending in the flow direction of the cooling water, and in the plurality of protrusions **104** or **114**, the protrusions **104***a* in the region **108***a* and the protrusion **104***b* in the region **108***b*, or the protrusions **114***a* in the region **118***c* and the protrusions **114***b* in the region **118***d*, do not have to extend in directions intersecting each other. In this case, the upper surface **100***a* or the lower surface **110***b* is not divided into two regions. Further, at the upper surface **100***a* or the lower surface **110***b*, the plurality of projections **104** or projections **114** may extend in parallel to each other, or may extend in directions intersecting each other.

(7) Modification 7

[0116] The plate does not need to have the plurality of linearly extending grooves **105** or **115** formed at the lower surface **100***b* or the upper surface **110***a*. In this case, the lower surface **100***b* or the upper surface **110***a* may be a flat surface. Further, the lower surface **100***b* or the upper surface **110***a* may be embossed or provided with protrusions or bosses.

(8) Modification 8

[0117] Each of the plurality of grooves **105**, **115** does not have to extend to intersect the flow direction of the engine oil. In this case, at least one of the plurality of grooves **105**, **115** extends parallel to the flow direction of the engine oil.

(9) Modification 9

[0118] The lower surface **100***b* or the upper surface **110***a* does not have to be divided into the region **108***c* and the

region **108***d*, or the region **118***a* and the region **118***b*, each extending in the flow direction of the engine oil. In the plurality of grooves **105** or grooves **115**, the grooves **105***a* in the region **108***c* and the grooves **105***b* in the region **108***d*, or the grooves **115***a* in the region **118***a* and the grooves **115***b* in the region **118***b*, do not have to extend in directions intersecting each other. In this case, the lower surface **100***b* or the upper surface **110***a* is not divided into two regions. Further, at the lower surface **100***b* or the upper surface **110***a*, the plurality of grooves **105** or grooves **115** may extend in parallel to each other, or may extend in directions intersecting each other.

(10) Modification 10

[0119] The oil cooler **2** does not have to include the fin **120** that contacts the lower surface **100***b* or the upper surface **110***a*. In this case, the fin **120** is not provided at the second flow path **132**.

(11) Modification 11

[0120] The oil cooler **2** may include the fin **120** that contacts the protrusions **104**, **114**. In this case, for example, the heights of the protrusions **104**, **114** and the heights of the fin **120** are changed, such that the fin **120** is provided at the first flow path **131** so as to contact the protrusions **104**, **114**.

(12) Modification 12

[0121] The plurality of protrusions **104**, **114** do not have to be aligned with the plurality of grooves **105**, **115** when viewed in the direction orthogonal to the upper surface **100***a* or the lower surface **110***b*. In this case, the plurality of protrusions **104**, **114** are deviated from the plurality of grooves **105**, **115** when viewed in the direction orthogonal to the upper surface **100***a* or the lower surface **110***b*, and thus the thickness of the plate increases by an amount corresponding to the depth of the grooves **105**, **115**.

(13) Modification 13

[0122] The oil cooler **2** may include only either the male plate **100** or the female plate **110**. For example, the stacked section **40** can be configured such that the male plates **100** and plates other than the female plate **110** are alternately stacked in the vertical direction, or the female plates **110** and plates other than the male plate **100** are alternately stacked in the vertical direction.

(14) Modification 14

[0123] The plurality of protrusions **104**, **114** do not have to contact the plurality of protrusions **114**, **104**. In this case, for example, the heights of the plurality of protrusions **104** and **114** are lower than half of the heights of the first flow path **131** and the second flow path **132**.

(15) Modification 15

[0124] The plurality of protrusions **104**, **114** do not have to extend in the directions intersecting the plurality of protrusions **114**, **104**, respectively. In this case, at least one of the plurality of protrusions **104**, **114** extends parallel to the plurality of protrusions **114**, **104**.

(16) Modification 16

[0125] The plurality of protrusions **104**, **114** and the plurality of grooves **105**, **115** do not have to be linear. The lines formed by the plurality of protrusions **104**, **114** and the plurality of grooves **105**, **115** include not only straight lines but also curved lines and broken lines. Thus, the plurality of protrusions **104**, **114** and the plurality of grooves **105**, **115** may have a curved-line shape or broken-line shape. The broken line shape includes, for example, a V-shape, an inverted V-shape, an X-shape, and the like, and also includes a combination of these shapes.

(17) Modification 17

[0126] The plurality of protrusions **104**, **114** and grooves **105**, **115** may include a plurality of line types. In this case, for example, the plurality of protrusions **104**, **114** and the plurality of grooves **105**, **115** include those having a linear shape and a curved shape within one plate.

(18) Modification 18

[0127] In an embodiment of the present disclosure, the engine oil and the cooling water flow into or out of the oil cooler **2** through the oil inlets/outlets **12***a*, **12***b* and the cooling water inlets/outlets **13***a*, **13***b*, but other structures may be used. For example, as illustrated in FIG. **14**, the top plate **50** may be have oil inlet/outlet **52***a*, **52***b* and cooling water inlet/outlet **53***a*, **53***b*. The oil inlet/outlet **52***a*, **52***b* and the cooling water inlet/outlet **53***a*, **53***b* are tubular members attached to openings provided at the four corners of the top plate **50**, and the member attached at the rear right when viewed from above is the oil inlet **52***a*. The member attached to the front left is the oil outlet **52***b*, the member attached to the rear left is the cooling water inlet **53***a*, and the member attached to the front right is the cooling water outlet **53***b*. The oil inlet and outlet **52***a*, **52***b* are connected to the oil flow path **7** to form an engine oil flow path. Similarly, the cooling water inlet and outlet **53***a*, **53***b* are connected to the cooling water flow path **8** to form a cooling water flow path.

(19) Modification 19

[0128] In an embodiment of the present disclosure, the plurality of protrusions **104**, **114** and the grooves **105**, **115** are provided in the rectangular regions **108***a*, **108***b*, **108***c*, **108***d*, **118***a*, **118***b*, **118***c*, and **118***d*, but may be provided in the upper surfaces **100***a*, **110***a* and the lower surfaces **100***b*, **110***b* other than the above. For example, it is assumed that in the male plate **100**, the sizes of the oil inlet and outlet **102***a*, **102***b* and the cooling water inlet and outlet **103***a*, **103***b* are reduced only in the left-right direction, and are arranged at the end portions of the male plate **100** in the left-right direction. In this case, at the upper surface **100***a* and the lower surface **100***b*, a flat part is formed between the oil inlet **102***a* and the cooling water inlet **103***a* and between the oil outlet **102***b* and the cooling water outlet **103***b*. The protrusions **104** and the grooves **105** are provided at these flat parts.

(20) Modification 20

[0129] In an embodiment of the present disclosure, the regions **108***a*, **108***b*, **108***c*, **108***d*, **118***a*, **118***b*, **118***c*, and **118***d* are rectangular, but may be square.

(21) Modification 21

[0130] In an embodiment of the present disclosure, the size of the angle formed by the protrusions **104***a* and **104***b* intersecting with the center line extending in the front-rear direction when viewed from above is the same as the size of the angle formed by the protrusions **114***a* and **114***b* intersecting with the center line extending in the front-rear direction when viewed from above, but may be different therefrom. For example, the angle formed by the protrusions **104***a* and **104***b* intersecting with the center line that is a straight line extending in the front-rear direction when viewed from above is set to 30 degrees, and the angle formed by the protrusions **114***a*, **114***b* intersecting with the center line that is a straight line extending in the front-rear direction when viewed from above is 120 degrees.

REFERENCE SIGNS LIST

[0131] **2** Oil cooler (heat exchanger)
[0132] **100** male plate (first plate)
[0133] **100***a* upper surface (first surface)
[0134] **100***b* lower surface (opposite surface)
[0135] **104** protrusion (first protrusion)
[0136] **105** groove
[0137] **108***a* region (first region)
[0138] **108***b* region (second region)
[0139] **108***c* region (third region)
[0140] **108***d* region (fourth region)
[0141] **110** female plate (second plate)
[0142] **110***a* lower surface (second surface)
[0143] **114** protrusion (second protrusion)
[0144] **120** fin (diffusion member)

1. A heat exchanger comprising:
a first plate having a first surface configured to contact a heat medium, the first surface having a plurality of first protrusions extending linearly formed at the first surface.

2. The heat exchanger according to claim **1**, wherein each of the plurality of first protrusions extends to intersect a flow direction of the heat medium.

3. The heat exchanger according to claim **1**, wherein
the first surface is divided into a first region and a second region each extending in a flow direction of the heat medium, and
in the plurality of first protrusions, protrusions in the first region and protrusions in the second region extend in directions intersecting each other.

4. The heat exchanger according to claim **1**, wherein
the first plate further includes an opposite surface located on a side opposite to the first surface, the opposite surface being configured to contact a fluid to exchange heat with the heat medium, and
a plurality of grooves extending linearly are formed at the opposite surface.

5. The heat exchanger according to claim **4**, wherein each of the plurality of grooves extends to intersect a flow direction of the fluid.

6. The heat exchanger according to claim **4**, wherein
the opposite surface is divided into a third region and a fourth region, the third region and the fourth region each extending in a flow direction of the fluid, and
in the plurality of grooves, grooves in the third region and grooves in the fourth region extend in directions intersecting each other.

7. The heat exchanger according to claim **4**, further comprising
a diffusion member configured to diffuse a flow of the heat medium or fluid that contacts either the opposite surface or at least one of the plurality of first protrusions.

8. The heat exchanger according to claim **4**, wherein the plurality of first protrusions are aligned with the plurality of grooves, when viewed in a direction orthogonal to the first surface.

9. The heat exchanger according to claim **1**, further comprising:
a second plate having a second surface configured to contact the heat medium, the second surface having a plurality of second protrusions extending linearly formed at the second surface, wherein
the first surface faces the second surface.

10. The heat exchanger according to claim **9**, wherein at least one of the plurality of first protrusions contacts corresponding one of the plurality of second protrusions.

11. The heat exchanger according to claim **9**, wherein each of the plurality of first protrusions extends in a direction intersecting the plurality of second protrusions.

* * * * *