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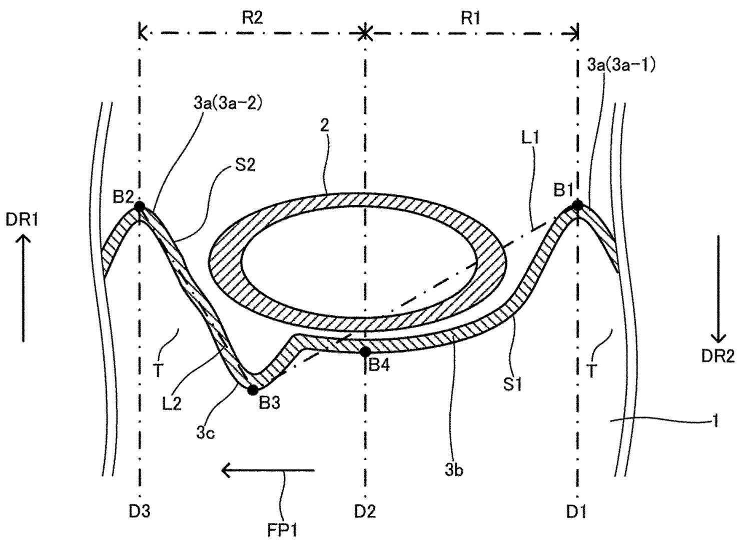
(54) HEAT EXCHANGER AND REFRIGERATION CYCLE DEVICE

(57) In the heat exchanger according to the present invention, when an n-th turn of a helix of the ridge is defined as a first ridge, an (n+1)-th turn of the helix of the ridge is defined as a second ridge, and the trough between the first ridge and the second ridge is defined as an intermediate trough, and when a portion of the first pipe including the first ridge, the second ridge, and the intermediate trough is viewed in a section along the flow direction of the first heat medium, the recess is formed such that a vertex of the recess is positioned downstream of a center point of the intermediate trough in the flow direction of the first heat medium.

FIG. 6



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Description

Technical Field

[0001] The present invention relates to a heat exchanger including a first pipe and a second pipe wound around the first pipe, and a refrigeration cycle device including the heat exchanger.

Background Art

[0002] An existing heat exchanger includes a first pipe formed with a flow path allowing for passage of a first heat medium and a second pipe wound around an outer surface of the first pipe and formed with a flow path allowing for passage of a second heat medium. In such a heat exchanger, the first heat medium flowing in the first pipe exchanges heat with the second heat medium flowing in the second pipe. The first pipe may be referred to as a core pipe, and the second pipe may be referred to as an outer pipe. Examples of the first heat medium include water and antifreeze. Examples of the second heat medium include refrigerant.

[0003] As one of such a heat exchanger, Patent Literature 1 discloses a twisted tube-type heat exchanger "formed by a twisting process and including a first fluid pipe and a second fluid pipe, the first fluid pipe including, on an outer surface thereof, multiple ridge and trough parts each being continuous and helical, the second fluid pipe being helically wound around the outer surface of the first fluid pipe along a shape of the ridge and trough parts, wherein the second fluid pipe is fitted into the ridge and trough parts of the first fluid pipe to join the first fluid pipe and the second fluid pipe in a heat transferable manner."

[0004] To increase a contact area between the first pipe and the second pipe, the heat exchanger of Patent Literature 1 is provided with the ridges protruding in a diameter-increasing direction of the first pipe and the troughs having a smaller diameter than the portions of the first pipe where the ridges are formed. The heat exchanger of Patent Literature 1 thus can have an increased heat transfer area, which improves heat exchange performance between water, which is the first heat medium, flowing in the first pipe and refrigerant, which is the second heat medium, flowing in the second pipe.

Citation List

Patent Literature

[0005] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2010-091266

Summary of Invention

Technical Problem

[0006] In the heat exchanger of Patent Literature 1, flow of water as the first heat medium flowing in the first pipe tends to stagnate in the portions where the ridges are formed. Thus, the heat exchanger of Patent Literature 1 has a low heat transfer rate in the portions where the ridges are formed, which results in a small heat exchange amount in the portions where the ridges are formed. As a result, the heat exchanger of Patent Literature 1 achieves only limited improvement in heat exchange performance, despite the increased contact area between the first pipe and the second pipe.

[0007] The present invention has been made in view of the above problems, and aims at providing a heat exchanger that can prevent stagnation of the first heat medium flow in the first pipe for improved heat exchange performance and to provide a refrigeration cycle device including the heat exchanger.

Solution to Problem

[0008] According to one embodiment of the present invention, there is provided a heat exchanger comprising: a first pipe including a first flow path allowing a first heat medium to flow; and a second pipe including a second flow path allowing a second heat medium to flow, the second pipe being wound around the first pipe, wherein the first pipe includes: a ridge protruding in a diameter-increasing direction in which a diameter of the first pipe increases; and a trough having an outer diameter smaller than an outer diameter of a portion of the first pipe where the ridge is formed, the trough allowing the second pipe to be wound thereon, the ridge is formed helically in a flow direction of the first heat medium in the first flow path, the trough is formed helically along the ridge, the trough includes a recess along a helical direction in which the trough runs, the recess being depressed in a diameter-decreasing direction in which the diameter of the first pipe decreases, and when an n-th turn of a helix of the ridge is defined as a first ridge, an (n+1)-th turn of the helix of the ridge is defined as a second ridge, and the trough between the first ridge and the second ridge is defined as an intermediate trough, and when a portion of the first pipe including the first ridge, the second ridge, and the intermediate trough is viewed in a section taken along the flow direction of the first heat medium, the recess is formed such that a vertex of the recess is positioned downstream of a center point of the intermediate trough in the flow direction of the first heat medium.

Advantageous Effects of Invention

[0009] In the heat exchanger according to one embodiment of the present invention, by defining the position of the recess formed on the trough, flow speed of the first heat medium in a stagnation zone near the ridge downstream of the recess is hardly reduced, helping to improve heat exchange performance.

Brief Description of Drawings

[0010]

[Fig. 1] Fig. 1 is a schematic configuration diagram showing an exemplary circuit structure of a refrigeration cycle device including a heat exchanger according to Embodiment 1 of the present invention.
[Fig. 2] Fig. 2 is a perspective view schematically showing a configuration of the heat exchanger according to Embodiment 1 of the present invention.
[Fig. 3] Fig. 3 is an external view showing an exemplary structure of a first pipe of the heat exchanger according to Embodiment 1 of the present invention.
[Fig. 4] Fig. 4 is a schematic diagram showing a part of the exemplary structure of the first pipe of the heat exchanger according to Embodiment 1 of the present invention.
[Fig. 5] Fig. 5 is a schematic diagram showing a part of the exemplary structure of the heat exchanger according to Embodiment 1 of the present invention.
[Fig. 6] Fig. 6 is a schematic, enlarged sectional view of a part of the heat exchanger according to Embodiment 1 of the present invention.
[Fig. 7] Fig. 7 is an explanatory diagram showing a flow speed distribution of a first heat medium in the first pipe without recesses.
[Fig. 8] Fig. 8 is an explanatory diagram showing a flow speed distribution of the first heat medium in the first pipe of the heat exchanger according to Embodiment 1 of the present invention.
[Fig. 9] Fig. 9 is an explanatory diagram showing, for comparison, a streamline of the first heat medium in the first pipe formed with recesses at the center of a trough.
[Fig. 10] Fig. 10 is an explanatory diagram showing a streamline of the first heat medium in the first pipe of the heat exchanger according to Embodiment 1 of the present invention.
[Fig. 11] Fig. 11 is an explanatory diagram showing a streamline of the first heat medium in the first pipe of the heat exchanger according to Embodiment 1 of the present invention.
[Fig. 12] Fig. 12 is a schematic sectional view of the first pipe of the heat exchanger according to Modification 1, taken along a flow direction of the first heat medium.
[Fig. 13] Fig. 13 is a schematic sectional view of the first pipe of the heat exchanger according to Modification 1, taken along a direction perpendicular to the flow direction of the first heat medium.
[Fig. 14] Fig. 14 is a schematic sectional view of the first pipe of the heat exchanger according to Modification 2, taken along the flow direction of the first heat medium.
[Fig. 15] Fig. 15 is a schematic sectional view of the first pipe of the heat exchanger according to Modification 2, taken along a direction perpendicular to the flow direction of the first heat medium.
[Fig. 16] Fig. 16 is an explanatory diagram showing a streamline of the first heat medium in the first pipe of the heat exchanger according to Embodiment 2 of the present invention.
[Fig. 17] Fig. 17 is an explanatory diagram showing, for comparison, a streamline of the first heat medium in the first pipe formed with recesses having a round shape in plan view.
[Fig. 18] Fig. 18 is an explanatory diagram showing a streamline of the first heat medium in the first pipe of the heat exchanger according to Embodiment 3 of the present invention.
[Fig. 19] Fig. 19 is an explanatory diagram showing recesses on the first pipe of the heat exchanger according to Embodiment 4 of the present invention.
[Fig. 20] Fig. 20 is an enlarged, schematic sectional view of a sectional structure of the recess on the first pipe of the heat exchanger according to Embodiment 4 of the present invention.

Description of Embodiments

[0011] Embodiments of the present invention will be described below with reference to the drawings. Throughout the drawings, including Fig. 1, size relationships between elements may differ from actual ones. Also, throughout the drawings, including Fig. 1, like reference numerals refer to like or corresponding parts, and this holds true for the entire specification. Throughout the specification, the forms of elements as given below are by way of example only and not restrictive.

Embodiment 1

[0012] Fig. 1 is a schematic configuration diagram showing an exemplary circuit structure of a refrigeration cycle device 200 including a heat exchanger 100 according to Embodiment 1 of the present invention. Referring to Fig. 1, the refrigeration cycle device 200 will be described.

[0013] In Embodiment 1, the first heat medium is assumed to be water, and the second heat medium is assumed to be refrigerant.

<Overall configuration of the refrigeration cycle device 200>

[0014] The refrigeration cycle device 200 includes a refrigerant circuit A1 and a heat medium circuit A2. The refrigerant circuit A1 and a heat medium circuit A2 are thermally connected through a heat exchanger 100. The heat medium circuit A2 is also connected to a water supply circuit A3 through a hot water storage tank 207. The water supply circuit A3 is connected to a hot water using unit U and supplies hot water to the hot water using unit U. Examples of the hot water using unit U include at least one of load-side devices requiring hot water, such as household tap and bath. The water supply circuit A3 is connected to water pipes or other conduits so that the water supply circuit A3 can supply water.

[0015] Refrigerant circulates in the refrigerant circuit A1 through refrigerant pipes 20A. The refrigerant may be carbon dioxide. The refrigerant circuit A1 includes a compressor 201 compressing the refrigerant, the heat exchanger 100 serving as a condenser, an expansion device 202, and a heat exchanger 203 serving as an evaporator.

[0016] The compressor 201 compresses the refrigerant. After being compressed by the compressor 201, the refrigerant is discharged from the compressor 201 into the heat exchanger 100. The compressor 201 may be a rotary compressor, a scroll compressor, a screw compressor, or a reciprocating compressor, for example.

[0017] The heat exchanger 100 serves as a condenser and transfers heat between high-temperature and high-pressure refrigerant flowing in the refrigerant circuit A1 and water flowing in the heat medium circuit A2, whereby the heat exchanger 100 heats the water and condenses the refrigerant. The heat exchanger 100 is a water-refrigerant heat exchanger transferring heat between water and refrigerant. The heat exchanger 100 will be described in detail later.

[0018] The heat exchanger 100 corresponds to the heat exchanger of the present invention.

[0019] The expansion device 202 expands the refrigerant having exited the heat exchanger 100 to reduce pressure on the refrigerant. For example, the expansion device 202 may be an electric expansion valve capable of adjusting a flow rate of refrigerant. Besides the electric expansion valve, a mechanical expansion valve using a pressure-receiving diaphragm or a capillary tube may be used as the expansion device 202.

[0020] The heat exchanger 203 serves as an evaporator and exchanges heat between the low-temperature and low-pressure refrigerant having exited the expansion device 202 and air supplied by a fan 203A and thereby evaporates the low-temperature and low-pressure liquid or two-phase refrigerant. The heat exchanger 203 may be, for example, a fin-and-tube heat exchanger, a microchannel heat exchanger, a shell-and-tube heat exchanger, a heat pipe heat exchanger, a double pipe heat exchanger, or a plate heat exchanger.

[0021] The fan 203A is attached to the heat exchanger 203.

[0022] The water circulates in the heat medium circuit A2 through heat medium pipes 10A. The heat medium circuit A2 includes the heat exchanger 100 and a pump 205 delivering the water.

[0023] The refrigeration cycle device 200 further includes a controller 60 configured to control the entire refrigeration cycle device 200. The controller 60 controls driving frequencies of the compressor 201. The controller 60 further controls opening degree of the expansion device 202 according to operating conditions. The controller 60 further controls operation of the fan 203A and the pump 205. That is, the controller 60 controls each of the actuators including the compressor 201, the expansion device 202, the fan 203A, and the pump 205 in response to operational instructions and based on inputs from temperature sensors (not shown) and pressure sensors (not shown).

[0024] Each function of the controller 60 is implemented in a dedicated hardware module or a micro processing unit (MPU) executing programs stored in a memory.

<Configuration of the heat exchanger 100>

[0025] Fig. 2 is a perspective view schematically showing a configuration of the heat exchanger 100.

[0026] The heat exchanger 100 includes a first pipe 1 and a second pipe 2. The first pipe 1 is formed with a first flow path FP1 through which the water as the first heat medium flows. The second pipe 2 is formed with a second flow path FP2 through which the refrigerant as the second heat medium flows. One or more second pipes 2 are wound around an outer surface of the first pipe 1 and contact the first pipe 1. The first pipe 1 forms part of the heat medium pipes 10A. The second pipe 2 forms part of the refrigerant pipes 20A.

[0027] The first pipe 1 is formed with a water inlet port 1a and a water outlet port 1 b communicating with the first flow path FP1. Also, the second pipe 2 is formed with a refrigerant inlet port 2a and a refrigerant outlet port 2b communicating with the second flow path FP2.

[0028] The heat exchanger 100 is connected to the refrigerant circuit A1 and the heat medium circuit A2 such that a flow direction of the water in the first pipe 1 and a flow direction of the refrigerant in the second pipe 2 are opposite to each other. This allows for efficient heat exchange between the heat medium and the refrigerant.

<Operation of the refrigeration cycle device 200>

[0029] Returning to Fig. 1, a description will be given on operation of the refrigeration cycle device 200.

[0030] The refrigeration cycle device 200 is capable of supplying hot water in response to instructions from the load-side device.

[0031] Operation of each actuator is controlled by the controller 60.

[0032] The low-temperature and low-pressure refrigerant is compressed by the compressor 201, whereby the refrigerant turns into high-temperature and high-pressure gas refrigerant before being discharged from the compressor 201. The high-temperature and high-pressure gas refrigerant discharged from the compressor 201 flows into the heat exchanger 100. Upon entering the heat exchanger 100, the refrigerant flows through the second pipe 2, where the refrigerant transfers heat with the water flowing through the first pipe 1. Thus, the refrigerant is condensed to turn into low-temperature and high-pressure liquid refrigerant before exiting the heat exchanger 100. When the refrigerant is carbon dioxide, the refrigerant changes its temperature while remaining in a supercritical state.

[0033] Meanwhile, the water having entered the first pipe 1 is heated by the refrigerant flowing through the second pipe 2, and then supplied to the load-side device.

[0034] After exiting the heat exchanger 100, the low-temperature and high-pressure liquid refrigerant passes through the expansion device 202, where the refrigerant turns into low-temperature and low-pressure liquid or two-phase refrigerant before entering the heat exchanger 203. Upon entering the heat exchanger 203, the refrigerant exchanges heat with air supplied by the fan 203A attached to the heat exchanger 203 and turns into low-temperature and low-pressure gas refrigerant before exiting the heat exchanger 203. The refrigerant having exited the heat exchanger 203 is suctioned into the compressor 201 again.

[0035] Fig. 1 shows an example where the refrigerant flows in the refrigerant circuit A1 in a fixed direction. However, a channel switching device may be provided on a discharge side of the compressor 201 so that the flow of refrigerant is reversible. With the channel switching device in place, the heat exchanger 100 also serves as an evaporator, and the heat exchanger 203 also serves as a condenser. For example, the channel switching device may be a combination of two-way valves, a combination of three-way valves, or a four-way valve.

[0036] Although the refrigerant used for the refrigeration cycle device 200 is preferably carbon dioxide, the refrigerant is not limited to carbon dioxide. Besides carbon dioxide, a natural refrigerant such as carbon hydride and helium, a chlorine-free substitute refrigerant such as HFC410A, HFC407C, and HFC404A, or a fluorocarbon refrigerant used in existing products such as R22 and R134a may be used.

<Detailed structure of the heat exchanger 100>

[0037] Fig. 3 is an external view showing an exemplary structure of the first pipe 1 of the heat exchanger 100. Fig. 4 is a schematic diagram showing a part of the exemplary structure of the first pipe 1 of the heat exchanger 100. Fig. 5 is a schematic diagram showing a part of the exemplary structure of the heat exchanger 100. Fig. 6 is a schematic, enlarged sectional view of a part of the heat exchanger 100. Referring to Figs. 3 to 6, the structure of the heat exchanger 100 will be described in detail.

[0038] Fig. 6 is a schematic enlarged view of partial sections of the first pipe 1 and the second pipe 2 of the heat exchanger 100 taken along the flow direction of the first heat medium. Also, Fig. 6 shows an inner surface S1 of the first pipe 1, the outer surface S2 of the first pipe 1, a diameter-increasing direction DR1, a diameter-decreasing direction DR2, the first flow path FP1, and stagnation zones T.

[0039] The diameter-increasing direction DR1 refers to a direction going from the inner surface S1 side to the outer surface S2 side of the first pipe 1. The diameter-decreasing direction DR2 refers to a direction heading from the outer surface S2 side to the inner surface S1 side of the first pipe 1. The first flow path FP1 refers to a flow path in the first pipe 1. The inner surface S1 of the first pipe 1 refers to an inner surface forming an inner wall of the first pipe 1. The outer surface S2 of the first pipe 1 refers to an outer surface forming an outer wall of the first pipe 1. The stagnation zone T refers to an area in the first flow path FP1 where the flow speed of the first heat medium reduces.

[0040] The first pipe 1 includes a ridge 3a protruding in the diameter-increasing direction DR1 in which the diameter of the first pipe 1 increases. The ridge 3a is formed helically in the flow direction of the water in the first flow path FP1.

[0041] The first pipe 1 further includes a trough 3b with a smaller outer diameter than the portion of the first pipe 1 where the ridge 3a is formed. The trough 3b is formed helically along the ridge 3a.

[0042] That is, the ridge 3a and the trough 3b run parallel to each other. As shown in Figs. 5 and 6, the second pipe 2 is wound on the trough 3b. Accordingly, the second pipe 2 is also helically wound around the first pipe 1.

[0043] In this description, an example is given where a single ridge 3a is formed on the first pipe 1. To facilitate understanding on how the ridge 3a is formed on the first pipe 1, in Figs. 3 to 5, four portions of the ridges 3a are shown on an upper side of the first pipe 1 and four portions of the ridges 3a are shown on a lower side of the first pipe 1, but in reality, the first pipe 1 is formed with only one (not multiple) ridge 3a that extends helically. When multiple ridges 3a are formed on the first pipe 1, each of these multiple ridges 3a will extend helically.

[0044] Since the ridge 3a is helical, it is wound around the first pipe 1 multiple times. Likewise, the trough 3b is wound around the first pipe 1 multiple times. Since the trough 3b extends along the ridge 3a, the trough 3b is formed between the n-th turn of the helix of the ridge 3a and the (n+1)-th turn of the helix of the ridge 3a. In other words, the ridge 3a is formed between the n-th turn of the helix of the trough 3b and the (n+1)-th turn of the helix of the ridge 3a. Note that n is a natural number. Also, it is assumed that the n-th turn of the helix is closer to the inlet port 1a and the (n+1)-th turn of the helix is closer to the outlet port 1b.

[0045] The trough 3b is formed with recesses 3c. The recesses 3c are arranged in a helical direction in which the trough 3b extends, and depressed in the diameter-decreasing direction DR2 in which the diameter of the first pipe 1 reduces.

[0046] Referring to Fig. 6, the recesses 3c will be described in detail. Fig. 6 shows a part of the heat exchanger 100 including the n-th turn of the helix of the ridge 3a, the (n+1)-th turn of the helix of the ridge 3a, and the n-th turn of the trough 3b positioned intermediately between these ridges 3a. For convenience' sake, in Fig. 6, the n-th turn of the helix of the ridge 3a is denoted as a first ridge 3a-1, and the (n+1)-th turn of the helix of the ridge 3a is denoted as a second ridge 3a-2. In Fig. 6, the part of the heat exchanger 100 is divided into a first region R1 and a second region R2.

[0047] The first region R1 refers to a region that lies between a straight line D1 passing through a vertex B1 of the first ridge 3a-1 perpendicularly to the first flow path FP1 and a straight line D2 passing through a center point B4 of the trough 3b perpendicularly to the first flow path FP1. That is, in the section shown in Fig. 6, the first region R1 is located upstream of the center point B4 of the trough 3b in the flow direction of the first heat medium in the first flow path FP1.

[0048] The second region R2 refers to a region that lies between the straight line D2 and a straight line D3 passing through a vertex B2 of the second ridge 3a-2 perpendicularly to the first flow path FP1. That is, in the section shown in Fig. 6, the second region R2 is located downstream of the center point B4 of the trough 3b in the flow direction of the first heat medium in the first flow path FP1.

[0049] The center point B4 of the trough 3b refers to a point located in the middle of the trough 3b in the flow direction of the first heat medium in the first flow path FP1.

[0050] Fig. 6 also shows a line segment L1 connecting a vertex B3 of the recess 3c and the vertex B1 of the first ridge 3a-1 and a line segment L2 connecting the vertex B3 of the recess 3c and the vertex B2 of the second ridge 3a-2.

[0051] The vertex B3 of the recess 3c refers to a deepest point of the recess 3c in the diameter-decreasing direction DR2.

[0052] As shown in Fig. 6, the recess 3c is formed in the second region R2. This means that the recess 3c is formed such that its vertex B3 is positioned downstream of the center point B4 of the trough 3b in the flow direction of the first heat medium in the first flow path FP1. In other words, the recess 3c is at a position where the line segment L2 becomes shorter than the line segment L1. That is, when the part including the first ridge 3a-1, the second ridge 3a-2 and the intermediate trough 3b positioning therebetween is viewed in a section, the first ridge 3a-1, the trough 3b, the recess 3c, and the second ridge 3a-2 are arranged in this order from the upstream side in the flow direction of the first heat medium.

[0053] Further, as shown in Fig. 6, the wall of the recess 3c on the downstream side in the flow direction of the first heat medium is formed by extending the inner surface S1 and the outer surface S2 of the first pipe 1, which form the wall of the trough 3b including this recess 3c. This means that the recess 3c is formed such that, when its vertex B3 is viewed from the vertex B2 of the second ridge 3a-2, the line segment L2 heads for the upstream side in the flow direction of the first medium and toward the diameter-decreasing direction DR2. When the vertex B2 of the second ridge 3a-2 is viewed from the vertex B3 of the recess 3c, the line segment L2 heads for the downstream side in the flow direction of the first heat medium and toward the diameter-increasing direction DR1.

[0054] Typically, in the heat exchanger 100 having the above ridge 3a and trough 3b structure, the flow of the first heat medium tends to stagnate at the ridge 3a in particular. In other words, the flow of the first heat medium tends to stagnate at the first ridge 3a-1 and the second ridge 3a-2, where stagnation zones T are formed as shown in Fig. 6. Heat exchange performance may decrease in these stagnation zones T.

[0055] In view of this, the heat exchanger 100 includes the recess 3c on the trough 3b, and this can reduce decrease in the flow speed of the first heat medium in the stagnation zones T and thus can improve heat exchange performance. Below a description will be given on how decrease in the flow speed of the first heat medium can be avoided.

<Flow speed distribution of the first heat medium in the first pipe 1>

[0056] Fig. 7 is an explanatory diagram showing a flow speed distribution of the first heat medium in the first pipe 1 without the recesses 3c. Fig. 8 is an explanatory diagram showing a flow speed distribution of the first heat medium in the first pipe 1 of the heat exchanger 100.

[0057] Although Fig. 7 shows a comparative example, the same reference numerals as those for the heat exchanger 100 are used for the sake of convenience. In Figs. 7 and 8, the flow of the first heat medium in the first pipe 1 is represented by arrows of flow FL1, flow FL2, and flow FL3. In Figs. 7 and 8, it is presumed that the flow speed of the first heat medium decreases in the order of the flow FL1, the flow FL2 and the flow FL3.

[0058] As shown in Fig. 7, the flow FL1 is formed in the middle of the first pipe 1, where the flow speed is high.

[0059] As shown in Fig. 7, the flow FL2 is formed along the inner surface S1 of the first pipe 1, where the flow speed is slower than the flow FL1.

[0060] As shown in Fig. 7, the flow FL3 is formed in some portions of the first pipe 1 in which the stagnation zones T are formed, where the flow speed is even slower than the flow FL2.

[0061] On the other hand, although the flow FL2 is formed along the inner surface S1 of the first pipe 1 as shown in Fig. 8, its flow speed is closer to the flow FL1, as compared to Fig. 7. This is because the first heat medium avoids the recesses 3c as it flows toward the ridge 3a, which increases the flow speed of the flow FL2.

[0062] Also, although the flow FL3 is formed in some portions of the first pipe 1 in which the stagnation zones T are formed as shown in Fig. 8, its flow speed is closer to the flow FL2, as compared to Fig. 7. This is because the first heat medium avoids the recesses 3c as it flows toward the ridge 3a, which increases the flow speed of the flow FL3 in the stagnation zones T.

[0063] Thus, comparing the heat exchanger 100 formed with the recesses 3c and the heat exchanger without the recesses 3c, the heat exchanger 100 formed with the recesses 3c can reduce a decline in flow speed of the first heat medium even when it flows along the inner surface S1 of the first pipe 1. As such, by virtue of the recesses 3c, the heat exchanger 100 can reduce a decline in flow speed of the first heat medium even in the stagnation zones T, helping to improve heat exchange performance.

<Streamline of the first heat medium in the first pipe 1>

[0064] Fig. 9 is an explanatory diagram showing, for comparison, a streamline of the first heat medium in the first pipe 1 formed with the recesses 3c at the center of the trough 3b. Figs. 10 and 11 are explanatory diagrams showing a streamline of the first heat medium in the first pipe 1 of the heat exchanger 100. Fig. 10 schematically shows an internal state of the first pipe 1. Fig. 11 schematically shows the internal state of the first pipe 1 as viewed from the outside.

[0065] Although Fig. 9 shows a comparative example, the same reference numerals as those for the heat exchanger 100 are used for the sake of convenience. In Fig. 9, some parts of the flow of the first heat medium in the first pipe 1 are represented by arrows of swirling flow FL4. In Figs. 10 and 11, some parts of the flow of the first heat medium in the first pipe 1 are represented by arrows of swirling flow FL5.

[0066] As shown in Fig. 9, the swirling flow FL4 stagnates downstream of the recess 3c in the flow direction of the first heat medium and along the inner surface S1 of the first pipe 1. There is a fear that this swirling flow FL4 may induce corrosion of the first pipe 1. Probably this is partly due to the fact that an oxide film is not formed on a portion of the inner surface S1 of the first pipe 1 near the generating point of the swirling flow FL4 and thus that portion has low corrosion resistance. Forming the recess 3c at the center of the trough 3b means that the portion of the inner surface S1 of the first pipe 1 forming the trough 3b is present continuously from the recess 3c on the downstream side of the recess 3c. Accordingly, the swirling flow FL4 caused by the recess 3c is generated along that portion of the inner surface S1 of the first pipe 1 forming the trough 3b. This inhibits formation of the oxide film on this portion.

[0067] In Figs. 10 and 11 too, the swirling flow FL5 is generated downstream of the recess 3c in the flow direction of the first heat medium. In the heat exchanger 100, however, there is no inner surface S1 of the first pipe 1 immediately downstream behind the recess 3c in the flow direction of the first heat medium. Further, the swirling flow FL5 is not generated from the flow near the ridge 3a. More specifically, the swirling flow FL5 caused by the recess 3c does not stagnate near the portion of the inner surface S1 of the first pipe 1 forming the trough 3b, but exhibits a form like flow FL5a shown in Fig. 10. This does not inhibit formation of the oxide film on this portion.

[0068] As described above, the recesses 3c are formed in the second region R2 in the heat exchanger 100, and this can prevent the swirling flow FL5 produced downstream of the recesses 3c in the flow direction of the first heat medium from stagnating near the inner surface S1 of the first pipe 1, which in turn prevents a decrease in corrosion resistance of this portion.

[0069] The recesses 3c may be formed by a dimpling process. This means that the recesses 3c have a round shape in plan view. The recesses 3c are, however, not limited to those formed by a dimpling process. The recesses 3c may have a linear shape in plan view. That is, the recesses 3c may be a groove-like recess.

[0070] Although the recesses 3c have been described as having a round shape in plan view, the shape of the recesses 3c is not limited to this. The recesses 3c may have any polygonal shape in plan view, such as triangle and square.

[0071] Although the recesses 3c have been described as having the same shape, they may have mutually different shapes.

[0072] In the above description, one ridge 3a and one trough 3b are formed on the first pipe 1, but the number of ridges 3a and the number of troughs 3b are not limited to a particular number. As described in Modifications 1 and 2 below, multiple ridges 3a and multiple troughs 3b may be formed on the first pipe 1.

[Modification 1 of the first pipe 1]

[0073] Fig. 12 is a schematic sectional view of the first pipe 1 of the heat exchanger 100 according to Modification 1, taken along the flow direction of the first heat medium. Fig. 13 is a schematic sectional view of the first pipe 1 of the heat exchanger 100 according to Modification 1, taken along a direction perpendicular to the flow direction of the first heat medium.

[0074] Figs. 12 and 13 each show the first pipe 1 formed with three ridges 3a and three troughs 3b.

[0075] In Fig. 12, three ridges 3a and three troughs 3b are formed. This means that the first pipe 1 is formed with a ridge 3a1, a ridge 3a2, and a ridge 3a3, and also formed with a trough 3b1, a trough 3b2, and a trough 3b3.

[0076] The trough 3b1 lies between the ridge 3a1 and the ridge 3a2. The trough 3b2 lies between the ridge 3a2 and the ridge 3a3. The trough 3b3 lies between the ridge 3a3 and the ridge 3a1.

[0077] Increasing the number of ridges 3a results in each ridge 3a protruding less in the diameter-increasing direction DR1. In other words, increasing the number of ridges 3a results in a shape where the first heat medium hardly stagnates in the stagnation zones T. This, combined with the recesses 3c positioned as they are, can reduce a decline in flow speed at the stagnation zones T. As such, providing three ridges 3a helps further improve heat exchange performance.

[Modification 2 of the first pipe 1]

[0078] Fig. 14 is a schematic sectional view of the first pipe 1 of the heat exchanger 100 according to Modification 2, along the flow direction of the first heat medium. Fig. 15 is a schematic sectional view of the first pipe 1 of the heat exchanger 100 according to Modification 2, along a direction perpendicular to the flow direction of the first heat medium.

[0079] Figs. 14 and 15 each show the first pipe 1 formed with four ridges 3a and four troughs 3b.

[0080] In Fig. 14, four ridges 3a and four troughs 3b are formed. This means that the first pipe 1 is formed with a ridge 3a1, a ridge 3a2, a ridge 3a3, and a ridge 3a4, and also formed with a trough 3b1, a trough 3b2, a trough 3b3, and a ridge 3a4.

[0081] The trough 3b1 lies between the ridge 3a1 and the ridge 3a2. The trough 3b2 lies between the ridge 3a2 and the ridge 3a3. The trough 3b3 lies between the ridge 3a3 and the ridge 3a4. The trough 3b4 lies between the ridge 3a4 and the ridge 3a1.

[0082] Similarly to Modification 1, increasing the number of ridges 3a results in a shape where the first heat medium hardly stagnates in the stagnation zones T. This, combined with the recesses 3c positioned as they are, can reduce a decline in flow speed at the stagnation zones T. As such, providing four ridges 3a helps further improve heat exchange performance.

[Advantageous effects of the heat exchanger 100 and the refrigeration cycle device 200]

[0083] As described above, the recesses 3c are formed in the second region R2 of the heat exchanger 100. This can reduce a decline in flow speed even in the stagnation zones T, helping to improve heat exchange performance.

[0084] Providing the recesses 3c in the second region R2 of the heat exchanger 100 can also prevent the swirling flow F5 generated downstream of the recesses 3c in the flow direction of the first heat medium from flowing along the inner surface S1 of the first pipe 1. Thus, the heat exchanger 100 can avoid a decrease in corrosion resistance in its portion downstream of the recesses 3c in the flow direction of the first heat medium.

[0085] Each of the recesses 3c of the heat exchanger 100 is at a position where the line segment L2 is shorter than the line segment L1. This means the recesses 3c are formed in the second region R2, which can reduce a decline in flow speed in the stagnation zones T.

[0086] Each of the recesses 3c of the heat exchanger 100 is formed such that, when its vertex B3 is viewed from the vertex B2 of the second ridge 3a-2, the line segment L2 heads for the upstream side in the flow direction of the first medium and for the diameter-decreasing direction DR2. Thus, the recess 3c is distinctively depressed in the diameter-decreasing direction DR2 relative to the trough 3b. This can reduce a decline in flow speed in the stagnation zones T without allowing the recess 3c to have a complex shape.

[0087] Each of the recesses 3c of the heat exchanger 100 has a round shape in plan view. This means that the recesses 3c can be formed by a dimpling process, eliminating the need for a complicated and expensive mechanism for forming the recesses 3c.

[0088] The heat exchanger 100 may have multiple ridges 3a and troughs 3b. This can more effectively prevent the first heat medium from stagnating in the stagnation zones T.

[0089] The refrigeration cycle device 200 has the above-described heat exchanger as a condenser. This helps improve heat exchange performance of the condenser.

Embodiment 2

[0090] Fig. 16 is an explanatory diagram showing a streamline of the first heat medium in the first pipe 1 of the heat exchanger according to Embodiment 2 of the present invention. Referring to Fig. 16, a description will be given on a streamline of the first heat medium in the first pipe 1 of the heat exchanger according to Embodiment 2.

[0091] The following description will focus on differences between Embodiment 2 and Embodiment 1, and accordingly the same parts as those in Embodiment 1 will be denoted by the same reference numerals and detailed explanation thereof will be omitted.

[0092] In Embodiment 2, the recess 3c has a different shape from that of the recess 3c as described in Embodiment 1. More specifically, the recess 3c has a streamlined shape in sectional view, as shown in Fig. 16. In other words, a portion of the recess 3c along the flow direction of the first heat medium is made longer than a portion of the recess 3c perpendicular to the flow direction of the first heat medium, and this longer portion is smoothly curved. Forming the recess 3c in a streamlined shape can prevent generation of a swirling flow near the recess 3c. Thus, the heat exchanger according to Embodiment 2 can more effectively avoid a decrease in corrosion resistance.

[0093] Also in this case, the recess 3c may be formed by a dimpling process. Specifically, a die for forming the recess 3c in a dimpling process may be given a streamlined shape in sectional view, so that the recess 3c of that shape can be formed.

[0094] All of the recesses 3c may have a streamlined shape in sectional view; alternatively, only some of the recesses 3c may have a streamlined shape in sectional view.

[0095] Modification 1 or Modification 2 as explained in Embodiment 1 above may also be applied to Embodiment 2.

[Advantageous effects of the heat exchanger according to Embodiment 2]

[0096] The recesses 3c of the heat exchanger according to Embodiment 2 are formed in a streamlined shape in sectional view. This can more effectively prevent generation of a swirling flow near the recesses 3c, further helping to avoid a decrease in corrosion resistance.

Embodiment 3

[0097] Fig. 17 is an explanatory diagram showing, for comparison, a streamline of the first heat medium in the first pipe 1 formed with recesses 3c having a round shape in plan view. Fig. 18 is an explanatory diagram showing a streamline of the first heat medium in the first pipe 1 of the heat exchanger according to Embodiment 3 of the present invention. Referring to Figs. 17 and 18, a description will be given of a streamline of the first heat medium in the first pipe 1 of the heat exchanger according to Embodiment 3 of the present invention.

[0098] The below description will focus on differences between Embodiment 3 and Embodiments 1 and 2, and accordingly the same parts as those in Embodiments 1 and 2 will be denoted by the same reference numerals and detailed explanation thereof will be omitted.

[0099] Fig. 17 shows, for comparison, the configuration of the first pipe 1 of the heat exchanger 100 according to Embodiment 1. In Fig. 17, flow of the first heat medium in the first pipe 1 is indicated by arrows of flow FL6. In Fig. 18, flow of the first heat medium in the first pipe 1 is indicated by arrows of flow FL7.

[0100] In Embodiment 3, the recess 3c has a different shape from that of the recess 3c as described in Embodiment 1. More specifically, the recess 3c has an elliptical shape in plan view, as shown in Fig. 18. In other words, the recess 3c has an elliptical shape with its minor axis ma1 extending in a helical direction and its major axis ma2 extending in a direction perpendicular to the helical direction. The helical direction refers to the direction parallel to the straight line L3 shown in Fig. 18. The straight line L3 is a line connecting two vertices of the ridge 3a running in the up-down direction in the figure.

[0101] Allowing the recess 3c to be in an elliptical shape in plan view means that the recess 3c serves more efficiently as a dam against the flow of the first heat medium along the helical direction. In other words, the recess 3c serves as a wall having a width of the major axis ma2 and blocking the flow of the first heat medium along the helical direction. Thus, allowing the recess 3c to be in an elliptical shape in plan view can increase the effect of the flow FL7 shown in Fig. 18 that guides the first heat medium toward the ridge 3a, as compared to the flow FL6 shown in Fig. 17. This can reduce a decline in flow speed of the first heat medium in the stagnation zones T, helping to improve heat exchange performance.

[0102] Also in this case, the recess 3c may be formed by a dimpling process. Specifically, a die for forming the recess 3c in a dimpling process may be given an elliptical shape in plan view, so that the recess 3c of that shape can be formed.

[0103] All of the recesses 3c may have an elliptical shape in plan view; alternatively, only some of the recesses 3c may have an elliptical shape in plan view.

[0104] Modification 1 or Modification 2 as explained in Embodiment 1 above may also be applied to Embodiment 3.

[Advantageous effects of the heat exchanger according to Embodiment 3]

[0105] The heat exchanger 100 includes the recesses 3c formed in an elliptical shape in plan view with the minor axis ma1 extending in the helical direction and the major axis ma2 extending in the direction perpendicular to the helical direction. This means that each recess 3c serves more efficiently as a dam against the flow of the first heat medium along the helical direction. Thus, the heat exchanger according to Embodiment 3 can increase the effect of guiding flow toward the ridge 3a.

Embodiment 4

[0106] Fig. 19 is an explanatory diagram showing the recesses 3c on the first pipe 1 of the heat exchanger according to Embodiment 4 of the present invention. Fig. 20 is an enlarged, schematic sectional view of a sectional structure of the recess 3c on the first pipe 1 of the heat exchanger according to Embodiment 4 of the present invention. Referring to Figs. 19 and 20, a description will be given on the recesses 3c on the first pipe 1 of the heat exchanger according to Embodiment 4 of the present invention.

[0107] The following description will focus on differences between Embodiment 4 and Embodiments 1, 2 and 3, and accordingly the same parts as those in Embodiments 1, 2, and 3 will be denoted by the same reference numerals and detailed explanation thereof will be omitted.

[0108] Fig. 20 schematically shows an enlarged section of the first pipe 1 in the helical direction including the recess 3c. In Fig. 20, the flow of the first heat medium along the helical direction from the inlet port 1a to the outlet port 1b of the first flow path FP1 is indicated by an arrow of flow FL8.

[0109] In Embodiment 4, the recess 3c has a different shape from that of the recess 3c as described in Embodiment 1. Specifically, the vertex B3 of the recess 3c is positioned upstream of the center of the recess 3c in the direction in which the helical direction runs, as shown in Figs 19 and 20.

[0110] As the vertex B3 of the recess 3c is positioned upstream of the center of the recess 3c in the direction in which the helical direction runs, the recess 3c assumes a streamlined shape relative to the flow FL8 shown in Fig. 20. This can prevent generation of a swirling flow near the recess 3c, similarly to Embodiment 2. Thus, the heat exchanger according to Embodiment 4 can be expected to be capable of further suppressing lowering in its corrosion resistance.

[0111] Modification 1 or Modification 2 as explained in Embodiment 1 above may also be applied to Embodiment 4.

[Advantageous effects of the heat exchanger according to Embodiment 4]

[0112] The vertex B3 of the recess 3c of the heat exchanger according to Embodiment 4 is positioned upstream of the center of the recess 3c in the direction in which the helical direction along the flow direction of the first heat medium in the first pipe 1 runs. Thus, similarly to the heat exchanger according to Embodiment 2, the heat exchanger according to Embodiment 4 can more effectively prevent generation of a swirling flow near the recess 3c, and the heat exchanger according to Embodiment 4 can be expected to be able to further reduce its corrosion resistance.

[0113] Embodiments of the present invention have been individually described above. However, specific configurations of the present invention are not limited to those described in the above embodiments, and may be modified within the scope of the present invention.

Reference Signs List

[0114]

1 first pipe 1a inlet port 1b outlet port 2 second pipe 2a inlet port 2b outlet port 3a ridge 3a-1 first ridge 3a-2 second ridge
3a1 ridge 3a2 ridge 3a3 ridge 3a4 ridge 3b trough 3b1 trough
3b2 trough 3b3 trough 3b4 trough 3c recess 10A heat medium pipe 20A refrigerant pipe 60 controller 100 heat exchanger 200 refrigeration cycle device 201 compressor 202 expansion device
203 heat exchanger 203A fan 205 pump 207 hot water storage tank A1 refrigerant circuit A2 heat medium circuit A3 water supply circuit
B1 vertex of the first ridge B2 vertex of the second ridge B3 vertex of the recess B4 center point of the intermediate trough DR1 diameter-increasing direction of the first pipe DR2 diameter-decreasing direction of the first pipe
FP1 first flow path FP2 second flow path R1 first region R2 second region S1 inner surface S2 outer surface T stagnation zone U hot water using unit

Claims

1. A heat exchanger comprising:

a first pipe including a first flow path allowing a first heat medium to flow; and
a second pipe including a second flow path allowing a second heat medium to flow, the second pipe being wound around the first pipe, wherein
the first pipe includes:

at least one ridge protruding in a diameter-increasing direction in which a diameter of the first pipe increases; and
at least one trough having an outer diameter smaller than an outer diameter of a portion of the first pipe where the ridge is formed, the trough allowing the second pipe to be wound thereon,

the ridge is formed helically in a flow direction of the first heat medium in the first flow path,
the trough is formed helically along the ridge,
the trough includes a recess along a helical direction in which the trough runs, the recess being depressed in a diameter-decreasing direction in which the diameter of the first pipe decreases, and
when an n-th turn of a helix of the ridge is defined as a first ridge, an (n+1)-th turn of the helix of the ridge is defined as a second ridge, and the trough between the first ridge and the second ridge is defined as an intermediate trough, and when a portion of the first pipe including the first ridge, the second ridge, and the intermediate trough is viewed in a section taken along the flow direction of the first heat medium, the recess is formed such that a vertex of the recess is positioned downstream of a center point of the intermediate trough in the flow direction of the first heat medium.

2. The heat exchanger of claim 1, wherein the recess is formed at a position where a straight line connecting the vertex of the recess and a vertex of the second ridge is shorter than a straight line connecting the vertex of the recess and a vertex of the first ridge.

3. The heat exchanger of claim 1 or 2, wherein a wall of the recess on a downstream side in the flow direction of the first heat medium is formed by extending a part of a wall of the intermediate trough.

4. The heat exchanger of any one of claims 1 to 3, wherein the recess is formed in a round shape in plan view.

5. The heat exchanger of any one of claims 1 to 3, wherein the recess is formed in a streamlined shape in sectional view.

6. The heat exchanger of any one of claims 1 to 3, wherein the recess is formed in an elliptical shape in plan view.

7. The heat exchanger of any one of claims 1 to 3, wherein the recess is formed in an elliptical shape in plan view with a minor axis extending in the helical direction and a major axis extending in a direction perpendicular to the helical direction.

8. The heat exchanger of any one of claims 1 to 3, wherein the vertex of the recess is positioned upstream of a center of the recess in a direction in which the helical direction runs along the flow direction of the first heat medium in the first pipe.

9. The heat exchanger of any one of claims 1 to 8, wherein the first pipe includes a plurality of the ridges and a plurality of the troughs.

10. A refrigeration cycle device comprising the heat exchanger of any one of claims 1 to 9 as a condenser, wherein
in the heat exchanger, the first heat medium flowing in the first flow path of the first pipe forming the heat exchanger is heated by the second heat medium flowing in the second flow path of the second pipe forming the heat exchanger.

FIG. 1

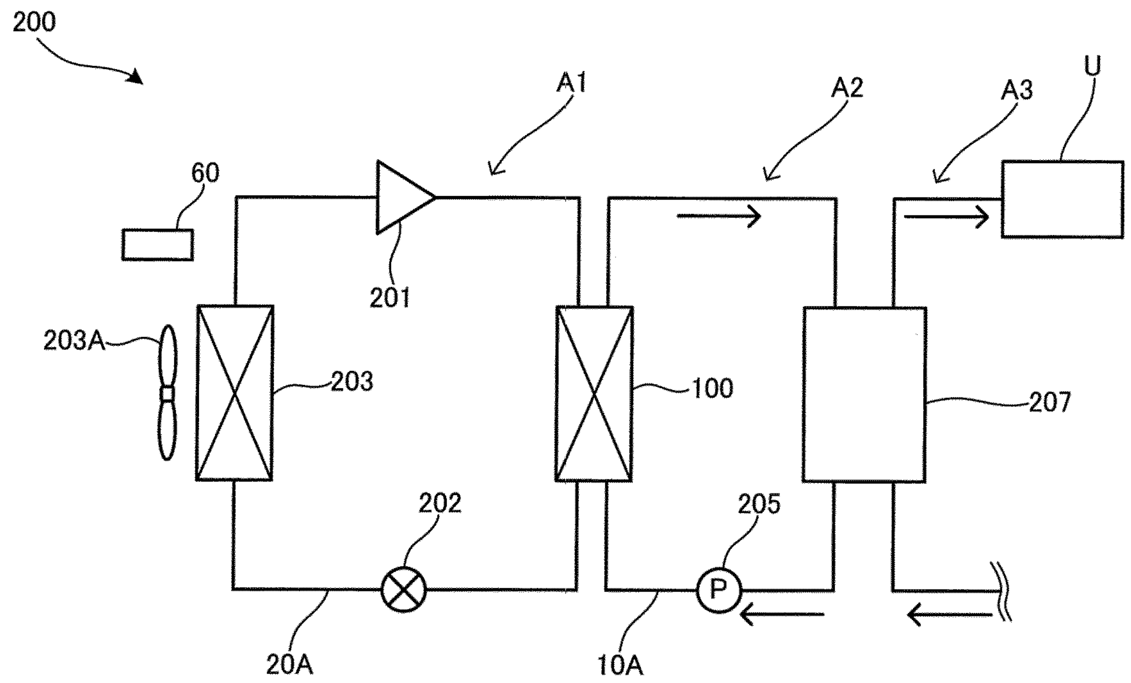

200
60
A1
A2
A3
U
201
203A
203
100
207
202
205
P
20A
10A

FIG. 2

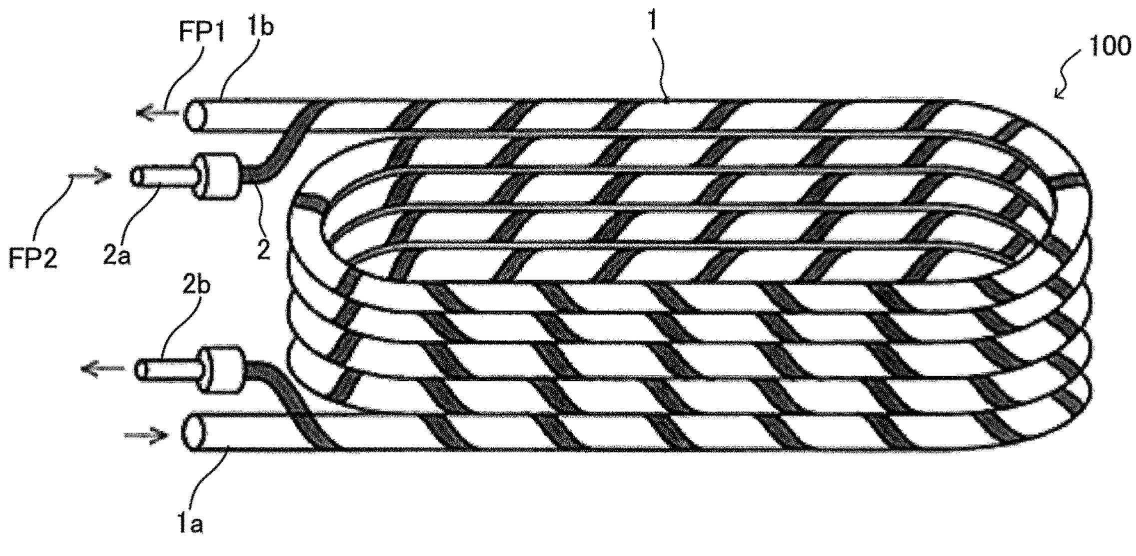
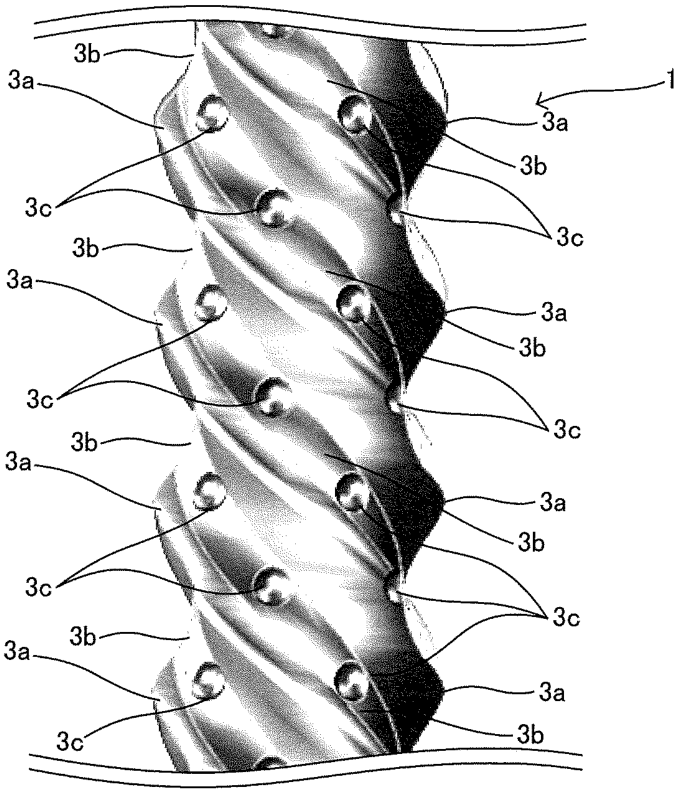

FP1
1b
1
100
FP2
2a
2
2b
1a

FIG. 3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3c
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3a
3a
3b
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3a
3a
3b
3c
3c
3b
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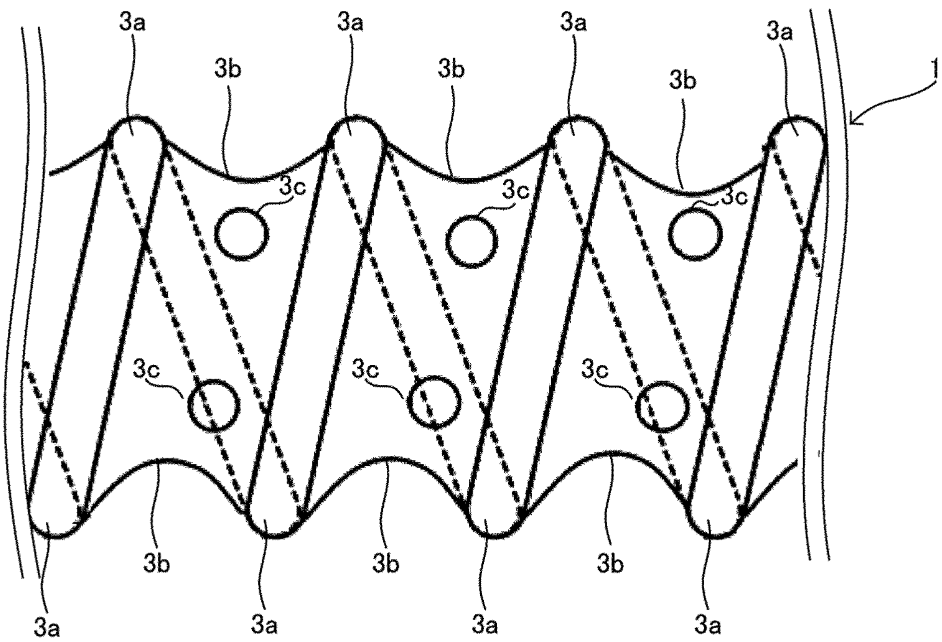
3a
3c
3b

FIG. 4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3a
3a
3b
3b
3b
1
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3c
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3c
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3b
3b
3a
3a
3a
3a

FIG. 5

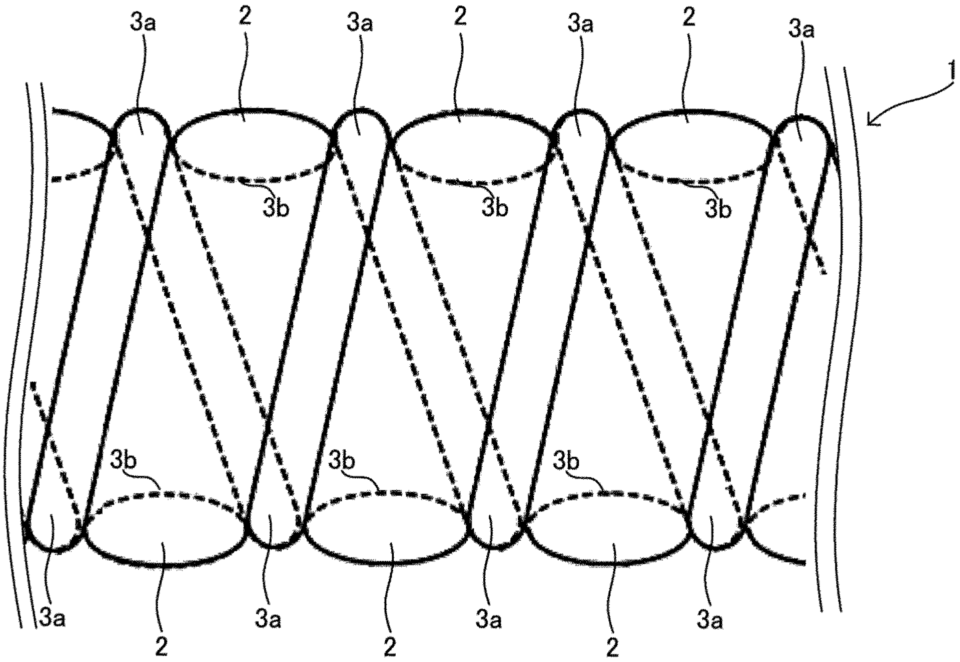

3a
2
3b
1
3a
2

FIG. 6

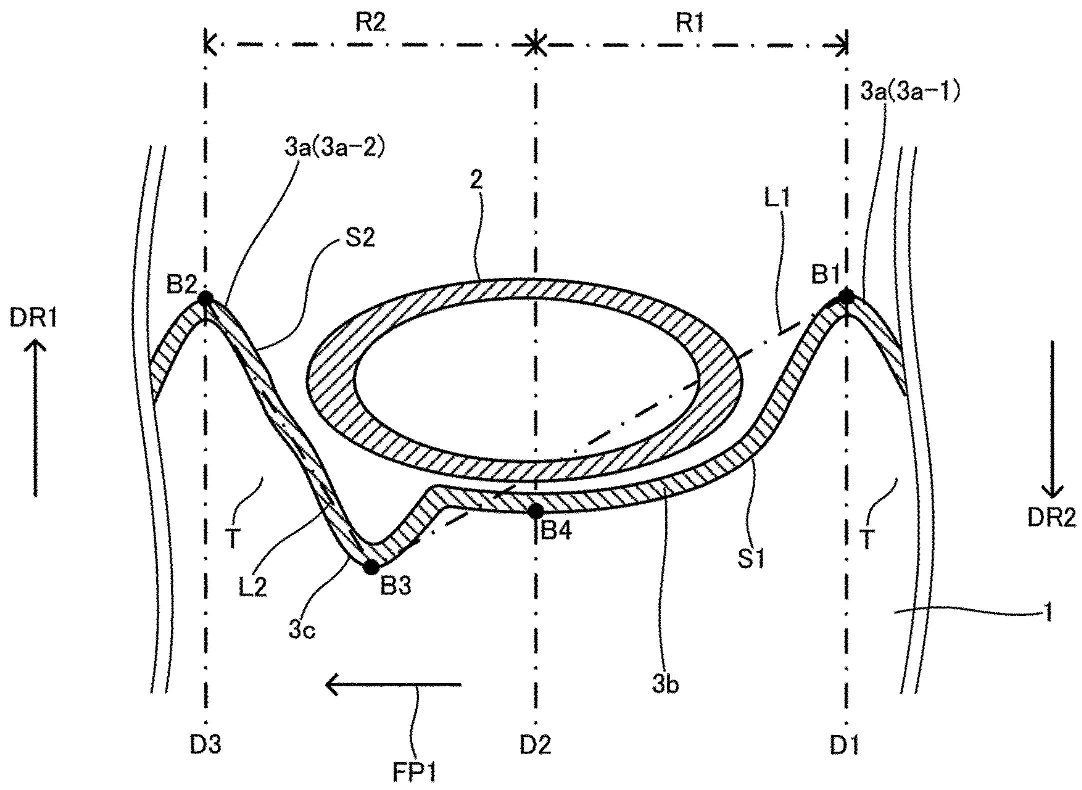

R2
R1
3a(3a-1)
3a(3a-2)
2
L1
S2
B2
B1
DR1
DR2
T
B4
B3
L2
3c
S1
3b
1
D3
D2
D1
FP1

FIG. 7

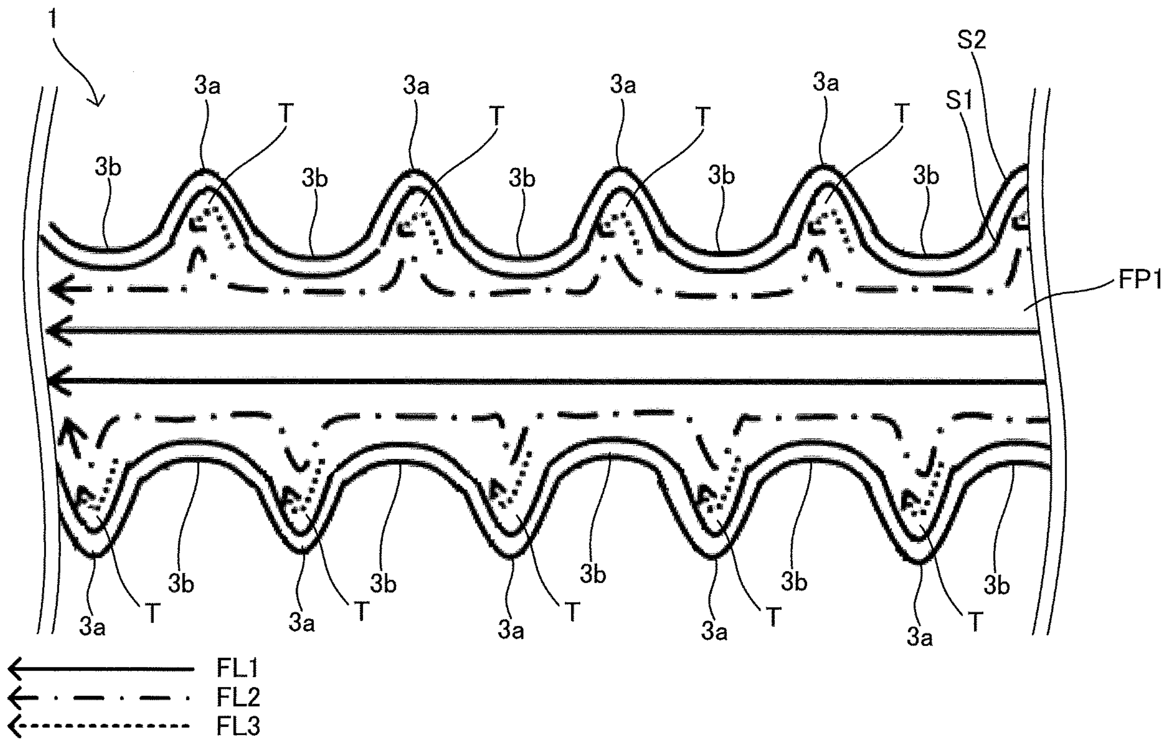


FIG. 8

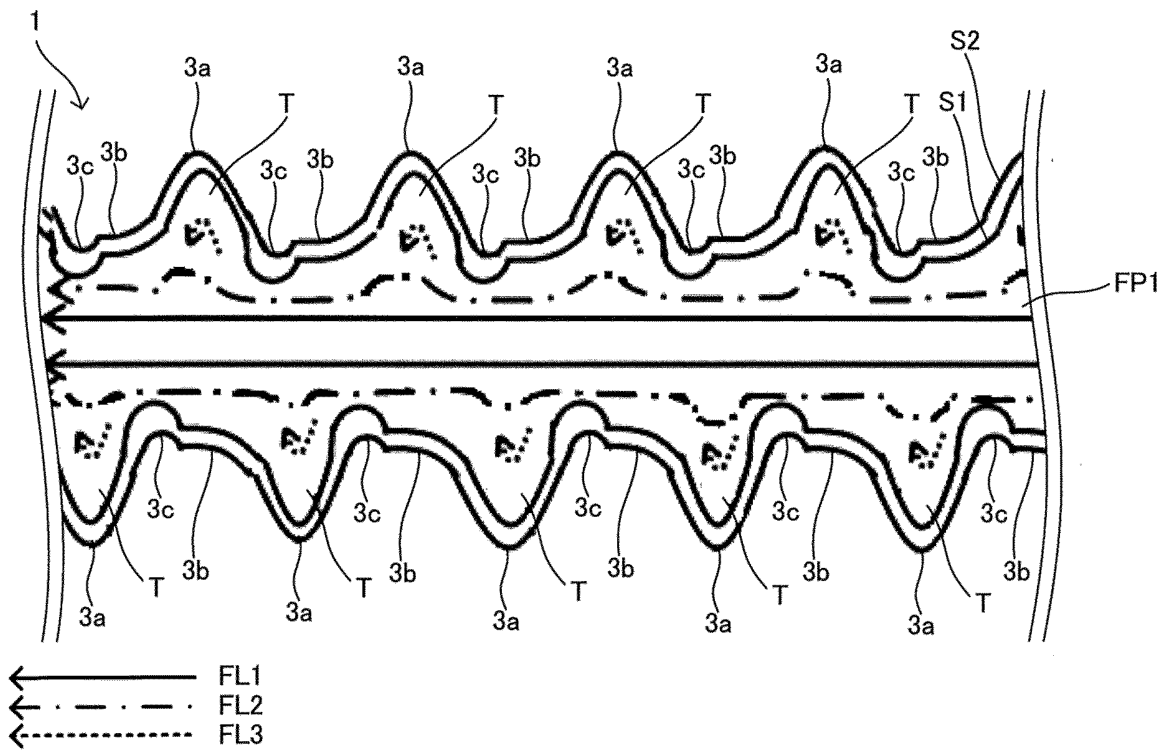


FIG. 9

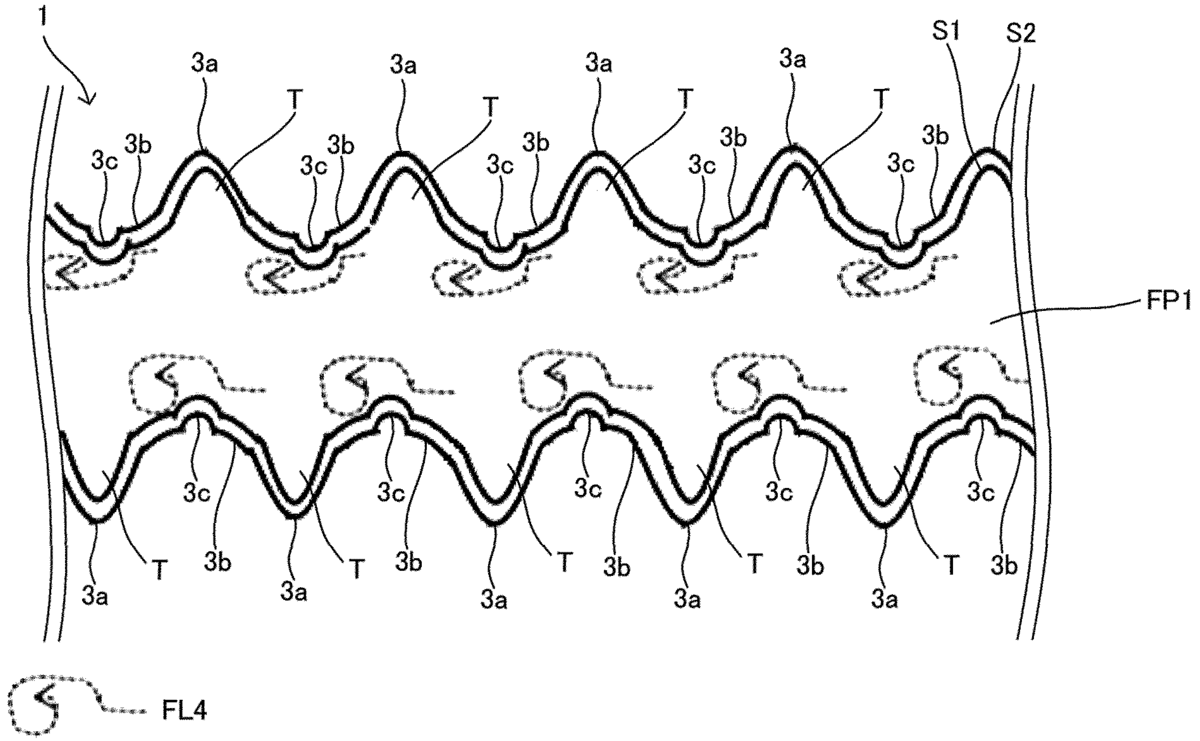
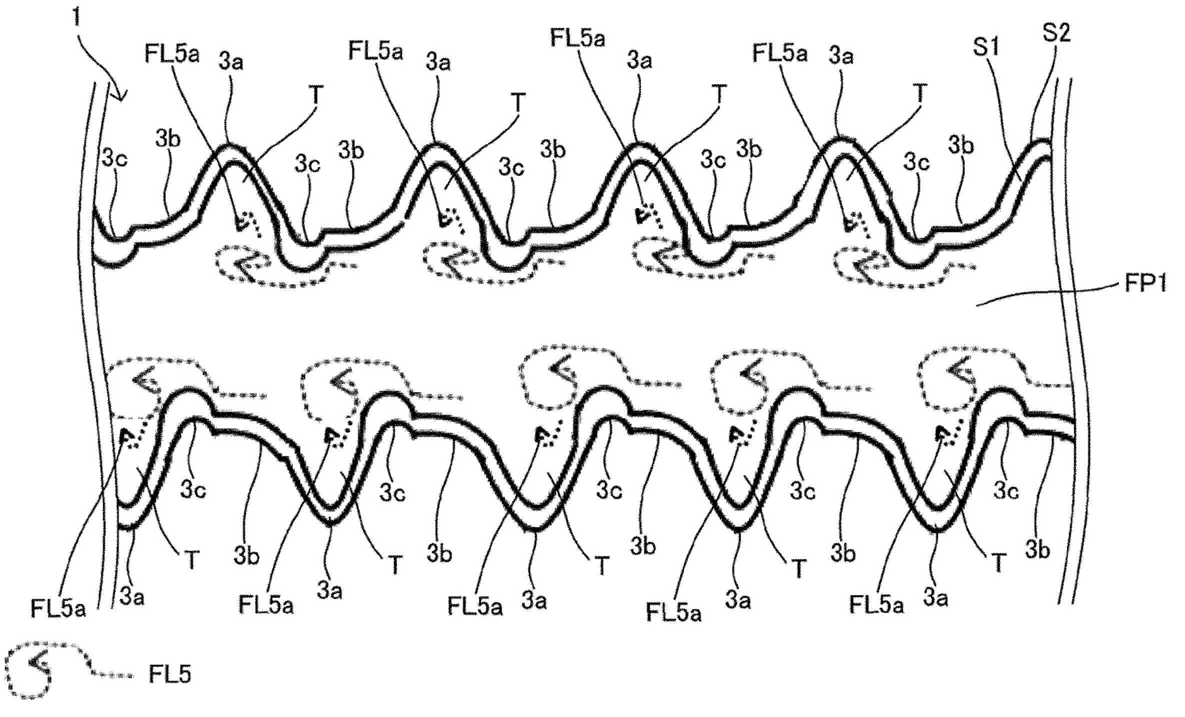

1
3a
3a
3a
3a
S1
S2
T
T
T
T
3c
3b
3c
3b
3c
3b
3c
3b
3c
3b
FP1
3c
3c
3c
3c
3c
T
3b
T
3b
T
3b
T
3b
T
3b
3a
3a
3a
3a
3a
FL4

FIG. 10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3a
FL5a
3a
FL5a
3a
FL5a
3a
S1
S2
T
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T
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3b
3c
3b
3c
3b
3c
3b
3c
3b
FP1
3c
3c
3c
3c
3c
T
3b
T
3b
T
3b
T
3b
T
3b
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FL5a
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FL5a
3a
FL5a
3a
FL5a
3a
FL5

FIG. 11

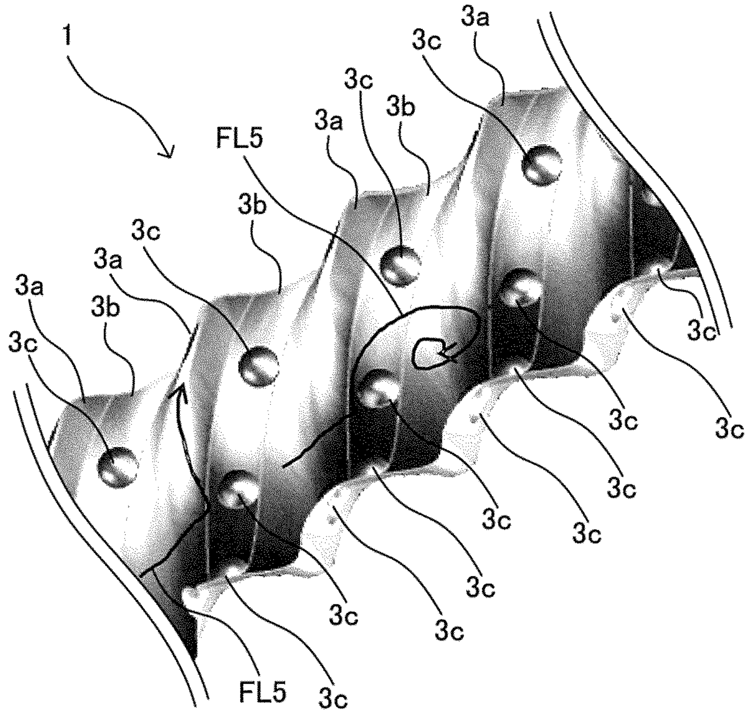

1
3a
3c
3c
3b
3a
FL5
3b
3c
3a
3a
3b
3c
3c
3c
3c
3c
3c
3c
3c
3c
3c
3c
3c
FL5
3c

FIG. 12

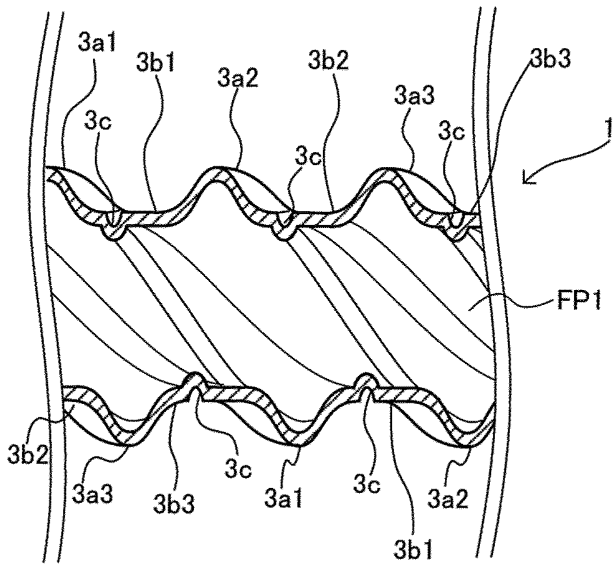
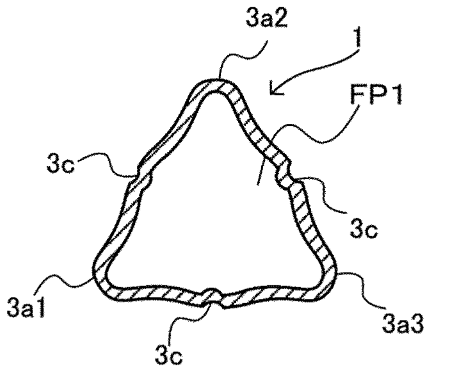

3a1
3b1
3a2
3b2
3a3
3b3
3c
3c
3c
1
FP1
3b2
3a3
3b3
3c
3a1
3c
3a2
3b1

FIG. 13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FP1
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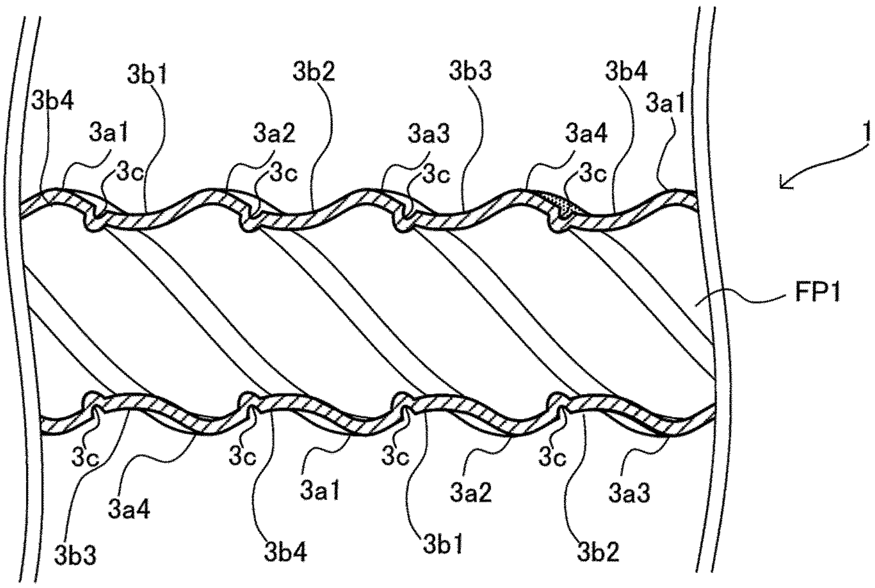
3a1
3a3
3c

FIG. 14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3a2
3a3
3a4
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1
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3c
FP1
3c
3c
3c
3c
3a4
3a1
3a2
3a3
3b3
3b4
3b1
3b2

FIG. 15

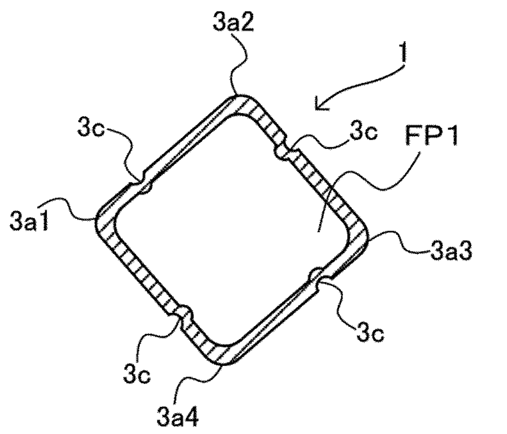


FIG. 16

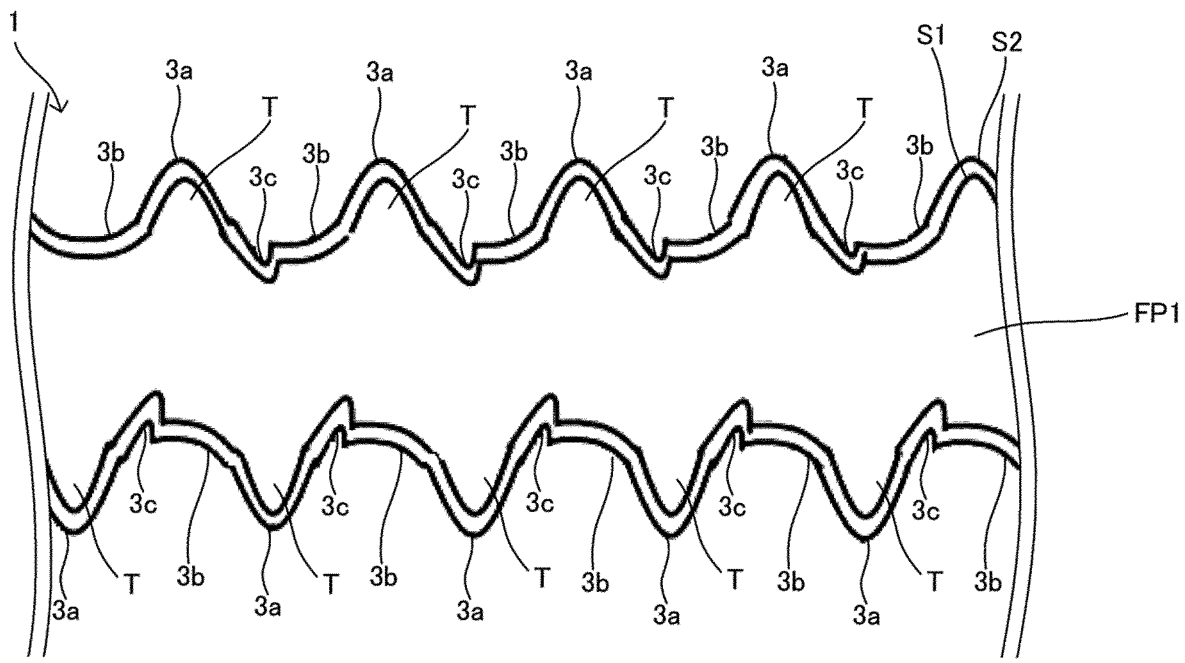
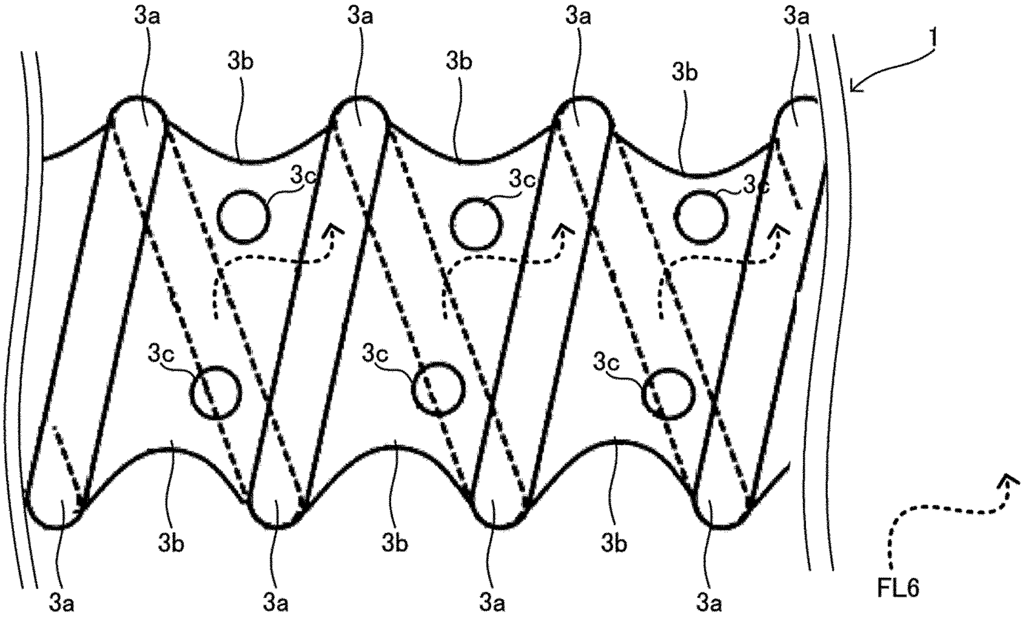


FIG. 17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3a
3a
3a
3b
3b
3b
1
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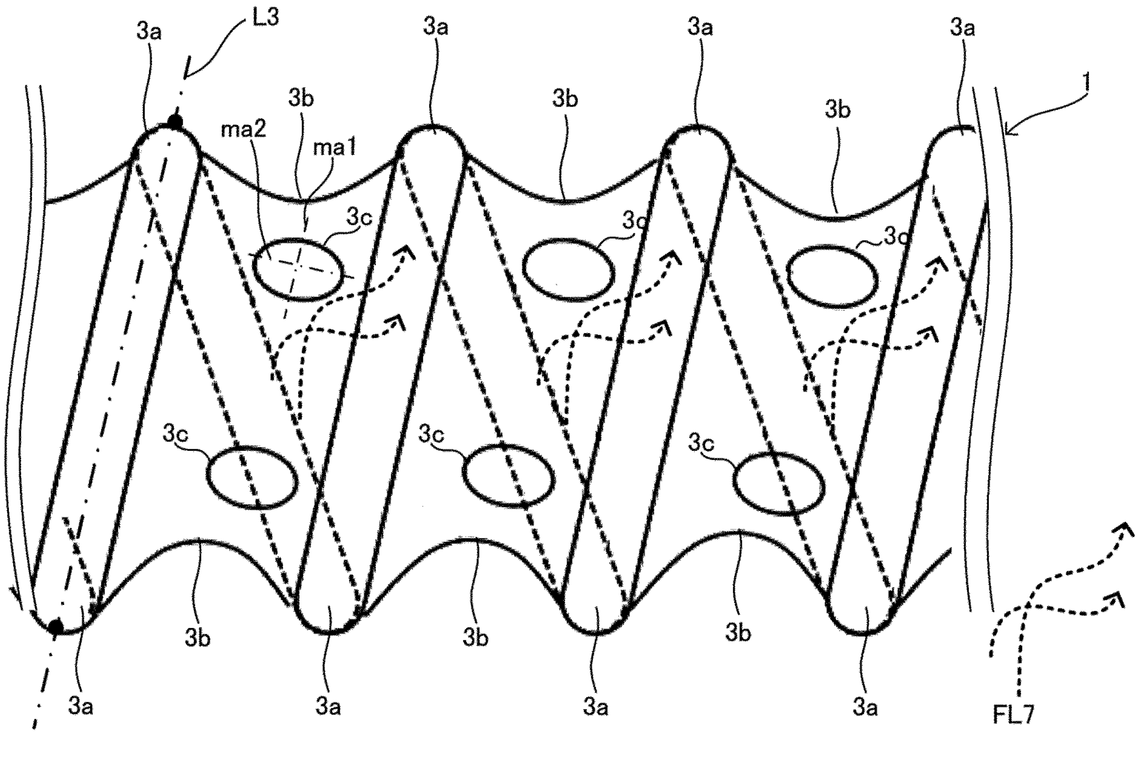
3a
FL6

FIG. 18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3a
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3b
3b
3b
1
ma2
ma1
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3a
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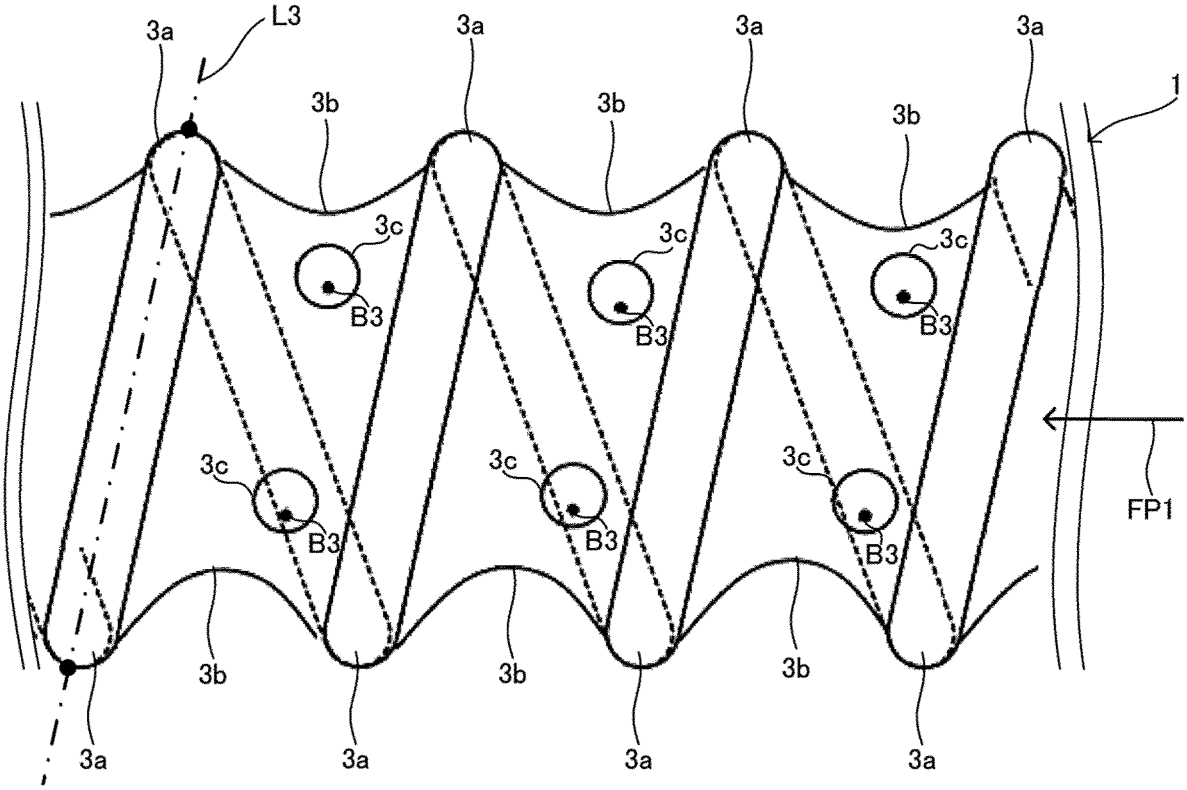
FL7

FIG. 19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3a
3b
3b
3b
1
3c
3c
3c
B3
B3
B3
3c
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B3
B3
B3
FP1
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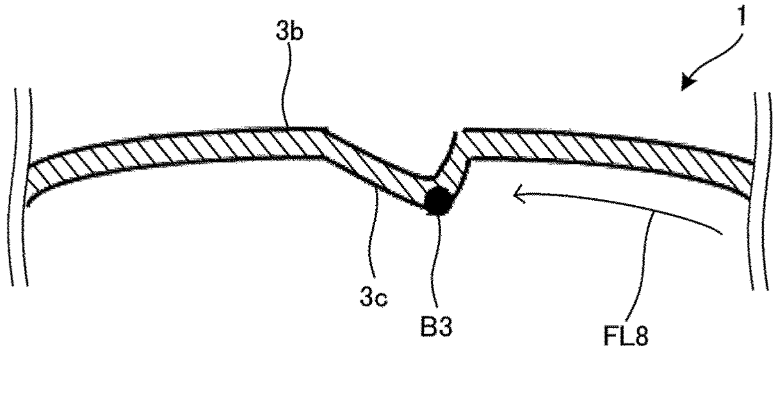
3a
3a
3a

FIG. 20


3b
1
3c
B3
FL8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2017/026674

A. CLASSIFICATION OF SUBJECT MATTER
F28D7/02(2006.01)i, *F25B30/02*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28D7/02, F25B30/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2017
Kokai Jitsuyo Shinan Koho	1971-2017	Toroku Jitsuyo Shinan Koho	1994-2017

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2009-41880 A (Sumitomo Light Metal Industries, Ltd.), 26 February 2009 (26.02.2009), paragraphs [0030] to [0031]; fig. 1 to 3 (Family: none)	1-10
A	JP 2008-190787 A (The Furukawa Electric Co., Ltd.), 21 August 2008 (21.08.2008), paragraphs [0019] to [0022]; fig. 1 to 3 (Family: none)	1-10

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

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Date of the actual completion of the international search	Date of mailing of the international search report
02 October 2017 (02.10.17)	10 October 2017 (10.10.17)

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2015-45482 A (Kobelco & Materials Copper Tube, Ltd.), 12 March 2015 (12.03.2015), paragraph [0014]; fig. 1 to 3 & DE 102014216920 A1 & CN 104422327 A & KR 10-2015-0026937 A	1-10
A	JP 10-103887 A (Poongsan Corp.), 24 April 1998 (24.04.1998), paragraphs [0019], [0063]; fig. 4, 10 & US 6026892 A fig. 4, 9C; column 5, lines 21 to 40 & KR 10-0245383 B1 & CN 1180160 A	1-10
A	JP 2011-208824 A (The Furukawa Electric Co., Ltd.), 20 October 2011 (20.10.2011), paragraphs [0039] to [0040]; fig. 3 (Family: none)	1-10
A	WO 2008/029639 A1 (Tsinghua University), 13 March 2008 (13.03.2008), paragraph [0005]; fig. 5 & US 2009/0250198 A1 fig. 5; paragraph [0014] & EP 2071266 A1 & CN 1924507 A & AU 2007292663 A & KR 10-2009-0055604 A	1-10

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2010091266 A **[0005]**