



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
17.06.2009 Bulletin 2009/25

(51) Int Cl.:
F28F 1/40 (2006.01) F28D 7/02 (2006.01)
F28F 1/10 (2006.01) F28F 13/12 (2006.01)

(21) Application number: **07792965.1**

(86) International application number:
PCT/JP2007/066436

(22) Date of filing: **24.08.2007**

(87) International publication number:
WO 2008/029639 (13.03.2008 Gazette 2008/11)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK RS

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(30) Priority: **08.09.2006 CN 200610113027**

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(54) **CORRUGATED HEAT EXCHANGER TUBE FOR HOT WATER SUPPLY**

(57) The present invention relates to a hot water corrugated heat transfer tube that exchanges heat between its interior and exterior. A plurality of projections, each whose height (H1) is in the range of 0.5 mm - 1.5 mm is provided in at least one part of the inner surface of a portion positioned in a section of a corrugated heat transfer tube, where the Reynolds number (Re) of the fluid flowing in the interior of the tube is less than 7,000. The height H1 of the projections is in the range of 0.05 - 0.15 times the inner diameter D or the height H1 of the projections is in the range of 1 - 3 times the depth (Hm) of the corrugated grooves. As a result, with a simple structure, the heat transfer performance in the low Reynolds number zone is improved, and the pressure loss inside the tube is small.

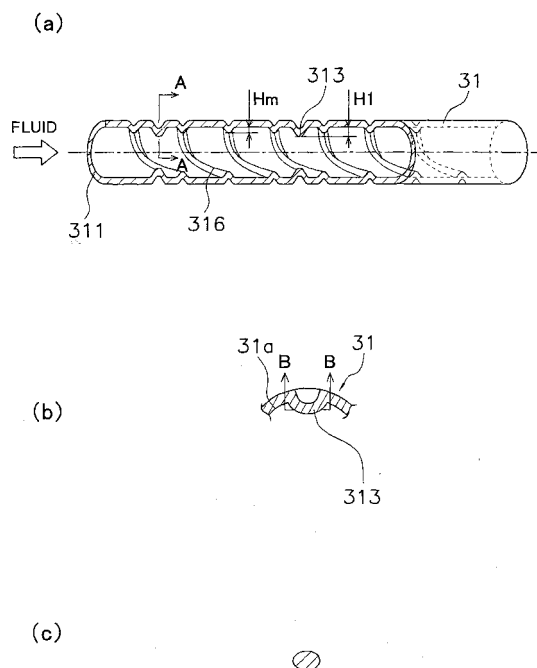


Fig. 5

Description**TECHNICAL FIELD**

5 **[0001]** The present invention relates to hot water heater technology. More specifically, the present invention relates to a hot water corrugated heat transfer tube in which the Reynolds number Re of a fluid flowing inside the tube is less than 7,000.

BACKGROUND ART

10 **[0002]** Heat exchangers used in air conditioners, hot water heaters, and the like, are provided with a heat transfer tube in which a fluid such as water flows and which exchanges heat due to the temperature differential between the tube interior and exterior. Furthermore, to improve the heat transfer performance of the heat transfer tube, a grooved tube in which grooves are formed on the tube inner surface is used in some cases. In addition, a technology has also been
15 proposed which improves the heat transfer performance by providing projections on the inner surface of the heat transfer tube.

[0003] Providing projections inside the heat transfer tube in this manner increases the heat transfer surface area of the heat transfer tube and agitates the fluid, thereby increasing the heat transfer coefficient of the heat transfer surface and improving the heat transfer performance. However, when projections are provided inside the heat transfer tube, the
20 projections increase the friction factor inside the tube and raise the pressure loss of the flow inside the tube. Therefore, a technology has been proposed that provides projections 0.45 - 0.6 mm in height inside the heat transfer tube, thereby suppressing the pressure loss while promoting the transfer of heat with the refrigerant (Patent Document 1). In addition, a technology that improves the heat transfer performance by employing a corrugated heat transfer tube has been also suggested (Patent Document 2).

PATENT DOCUMENT 1

Japanese Examined Patent Application No. H06-70556

PATENT DOCUMENT 2

Japanese Unexamined Patent Application No. 2002-228370

DISCLOSURE OF THE INVENTION

<Object to be Achieved by the Invention>

35 **[0004]** However, when the flow speed of the fluid inside the heat transfer tube is extremely low and the flow of the fluid inside the tube is in the transition zone where the flow transitions from the laminar flow zone to the turbulent flow zone, the improvement in the heat transfer performance is small, even when projections are provided each whose height is 0.45 - 0.6 mm, as disclosed in the Patent Document 1.

[0005] For example, in a heat pump type hot water heater, as shown in Figure 1, the water is heated in a single pass
40 from approximately 10° C to approximately 90° C over a long period of time in order to efficiently utilize inexpensive nighttime electric power. In this case, the flow volume of the water flowing inside the heat transfer tube is set to an extremely small value (e.g., 0.8 L/min) in order to make the product compact and to ensure high efficiency. In a heat transfer tube in which the water flow volume inside the tube is small as described above, a method is employed that improves the heat transfer performance by reducing the inner diameter of the heat transfer tube and thereby increasing
45 the flow speed inside the tube. However, even in this case, since the water flow volume inside the tube is small, the water flow inside the tube is therefore in the transition zone ($Re = 1500 - 3000$) where the flow transitions from the laminar flow zone to the turbulent flow zone in the vicinity of the inlet, and is approximately in the initial stage of the turbulent flow ($Re = 7,000$) even in the vicinity of the outlet. In addition, efficient heat exchange cannot be expected because the thermal conductivity is also small in the low temperature section in the vicinity of the water inlet.

50 **[0006]** In addition, when the flow speed of the fluid inside the heat transfer tube is extremely low and the flow of the fluid inside the tube is in the transition zone where the flow transitions from the laminar flow zone to the turbulent flow zone, the improvement in the heat transfer performance simply by means of the corrugated tube is small. Further, since the corrugated tube causes a strong turbulence at the boundary of the tube wall, the friction factor inside the tube increases considerably compared to a smooth tube depending on the depth of the corrugated groove, which consequently
55 increases the pressure loss of the flow inside the tube.

[0007] It is an object of the present invention to overcome the abovementioned problems of the background art, and to provide a hot water corrugated heat transfer tube wherein, with a simple structure, the heat transfer performance in the low Reynolds number zone is improved, and the pressure loss inside the tube is small.

<Means to Achieve the Object>

[0008] A hot water corrugated heat transfer tube according to a first aspect of the invention is a hot water corrugated heat transfer tube that exchanges heat between its interior and exterior, in which a plurality of projections each having a height H1 of 0.5 - 1.5 mm is provided in at least one part of the inner surface of a portion positioned in a section where the Reynolds number Re of a fluid flowing in the interior is less than 7,000.

[0009] When a corrugated tube is employed as a heat transfer tube, turbulence is caused by a corrugated groove, which results in the improvement of the heat transfer performance. On the other hand, in the low Reynolds number section where the laminar flow zone is produced and the transition from the laminar flow zone to the turbulent flow zone occurs, the depth of the corrugated groove needs to be increased in order to achieve the improvement in the heat transfer performance by simply employing a corrugated tube. In this manner, the friction factor inside the tube increases and the pressure loss inside the tube increases.

[0010] Consequently, a plurality of projections that protrude toward the inside of the tube and have a height of 0.5 - 1.5 mm is provided on the inner surface of the portion positioned in the low Reynolds number section where the laminar flow zone is produced and the transition from the laminar flow zone to the turbulent flow zone occurs, i.e., in the section where the Reynolds number Re is less than 7,000. As a result, the projections provided inside the corrugated tube and the tube improve the heat transfer coefficient, the depth of the corrugated grooves is reduced, and the impact of the projections on the pressure loss inside the tube is small, thereby improving the performance of the entire hot water corrugated heat transfer tube.

[0011] A hot water corrugated heat transfer tube according to a second aspect of the invention is a hot water corrugated heat transfer tube that exchanges heat between its interior and exterior, in which a plurality of projections each whose height H1 is 0.05 - 0.15 times an inner diameter D is provided in at least one part of the inner surface of a portion positioned in a section where the Reynolds number Re of a fluid flowing in the interior is less than 7,000.

[0012] When projections are provided inside the tube, the friction factor inside the tube is a function of the Reynolds number Re and the relative roughness. Here, the ratio of the height of the projections provided inside the tube to the tube inner diameter (i.e., the relative roughness) is used to represent the impact of the projections inside the tube on the friction factor inside the tube. Setting the relative roughness of the tube inner wall surface to a prescribed range in the low Reynolds number section, where the transition from the laminar flow zone to the turbulent flow zone occurs, improves the heat transfer effect and enables to minimize the impact of the pressure loss.

[0013] Consequently, a plurality of projections each whose height H1 is 0.05 - 0.15 times the inner diameter D is provided on the inner surface of the portion positioned in the low Reynolds number section where the laminar flow zone is produced and the transition from the laminar flow zone to the turbulent flow zone occurs, i.e., in the section where the Reynolds number Re is less than 7,000. As a result, the projections provided inside the tube improve the heat transfer coefficient, and reduce the impact of the projections on the pressure loss inside the tube, thereby improving the performance of the entire hot water corrugated heat transfer tube.

[0014] A hot water corrugated heat transfer tube according to a third aspect of the invention is a heat transfer tube used in a heat exchanger of a hot water heater and configured to exchange heat between its interior and exterior, in which a plurality of projections each whose height (H1) is in the range of 1 - 3 times the depth (Hm) of the corrugated grooves is provided in at least one part of the inner surface of a portion positioned in a section where the Reynolds number (Re) of a fluid flowing in the interior is less than 7,000.

[0015] When the projections are provided in the heat transfer tube in which the corrugated grooves are provided, it is necessary to improve the heat transfer effect by the height (H1) of the projections and the depth (Hm) of the corrugated grooves and also minimize the impact caused by the pressure loss. In the low Reynolds number section where the Reynolds number (Re) is less than 7,000, when the height (H1) of the plurality of projections is in the range of 1 - 3 times the depth (Hm) of the corrugated grooves, the corrugated tube and the projections provided inside the tube improve the heat transfer coefficient, the depth of the corrugated grooves is reduced, and the impact of the projections on the pressure loss inside the tube is small, thereby improving the performance of the entire hot water corrugated heat transfer tube.

[0016] A hot water corrugated heat transfer tube according to a fourth aspect of the invention is a heat transfer tube used in a heat exchanger of a hot water heater and configured to exchange heat between its interior and exterior, in which a plurality of projections is provided in at least one part of the inner surface of a portion positioned in a section where the Reynolds number (Re) of a fluid flowing in the interior is less than 7,000, and the value of the pitch (P1) of the plurality of projections is different from the value of the pitch (Pm) of the corrugated grooves.

[0017] When the projections and the corrugated grooves are provided at positions where they overlap each other, the friction factor inside the tube increases and there is a risk that the pressure loss inside the tube rapidly increases. Here, setting the value of the pitch (P1) of the projections to be different from the value of the pitch (Pm) of the corrugated grooves will allow the projections and the corrugated grooves to be disposed at positions where they do not overlap each other, and thus the rapid increase in the pressure loss inside the tube can be suppressed.

[0018] A hot water corrugated heat transfer tube according to a fifth aspect of the invention is a heat transfer tube

used in a heat exchanger of a hot water heater and configured to exchange heat between its interior and exterior, in which a plurality of projections each whose height H_1 is 0.5 - 1.5 mm is provided on the inner surface of a portion positioned in the vicinity of an inlet into which water, which is the fluid flowing in the interior, flows.

[0019] The flow of the water in the vicinity of the inlet of the heat transfer tube used in the hot water heat exchanger corresponds to the laminar flow zone and/or the transition zone where the flow transitions from the laminar flow zone to the turbulent flow zone. The water temperature in the vicinity of the inlet of the heat transfer tube is low, and the heat transfer coefficient is also low. Accordingly, in the present invention, a plurality of projections each having a height of 0.5 - 1.5 mm is provided on the inner surface of the portion positioned at least in the vicinity of the water inlet, thereby improving the heat transfer coefficient due to the projections provided inside the tube. In addition to improving the heat transfer coefficient due to the projections, the impact of the projections on the pressure loss inside the tube is small, thereby improving the performance of the entire hot water corrugated heat transfer tube.

[0020] A hot water corrugated heat transfer tube according to a sixth aspect of the invention is a heat transfer tube used in a heat exchanger of a hot water heater and configured to exchange heat between its interior and exterior, in which a plurality of projections each whose height H_1 is 0.05 - 0.15 times the inner diameter D is provided on the inner surface of a portion positioned in the vicinity of a fluid inlet into which water, which is the fluid flowing in the interior, flows.

[0021] In the hot water heat exchanger, the flow of the water in the vicinity of the inlet of the heat transfer tube corresponds to the laminar flow zone and/or the transition zone where the flow transitions from the laminar flow zone to the turbulent flow zone. In addition, the water temperature in the vicinity of the inlet of the heat transfer tube is low, and the heat transfer coefficient is also low. Accordingly, in this hot water heat exchanger, a plurality of projections each whose height is 0.05 - 0.15 times the heat transfer tube inner diameter is provided on the inner surface of the heat transfer tube positioned at least in the vicinity of the water inlet. As a result, the heat transfer coefficient due to the projections provided inside the tube is improved, and the impact of the projections on the pressure loss inside the tube is suppressed, thereby improving the performance of the entire hot water corrugated heat transfer tube.

[0022] A hot water corrugated heat transfer tube according to a seventh aspect of the invention is a heat transfer tube used in a heat exchanger of a hot water heater and configured to exchange heat between its interior and exterior, in which a plurality of projections each whose height (H_1) is in the range of 1 - 3 times the depth (H_m) of the corrugated grooves is provided on the inner surface of the portion positioned in the vicinity of an inlet into which water, which is the fluid flowing in the interior, flows.

[0023] The flow of the water in the vicinity of the inlet of the heat transfer tube corresponds to the laminar flow zone and/or the transition zone where the flow transitions from the laminar flow zone to the turbulent flow zone. In addition, the water temperature in the vicinity of the inlet of the heat transfer tube is low, and the heat transfer coefficient is also low. Here, the projections are provided inside the heat transfer tube in which the corrugated grooves are provided in order to improve the heat transfer coefficient. However, when the projections are provided in the heat transfer tube in which the corrugated grooves are provided, it is necessary to improve the heat transfer effect by the height (H_1) of the projections and the depth (H_m) of the corrugated grooves and also minimize the impact caused by the pressure loss. In the low Reynolds number section where the Reynolds number (Re) is less than 7,000, when the height (H_1) of the plurality of projections is in the range of 1 - 3 times the depth (H_m) of the corrugated grooves, the corrugated tube and the projections provided inside the tube improve the heat transfer coefficient, the depth of the corrugated grooves is reduced, and the impact of the projections on the pressure loss inside the tube is small, thereby improving the performance of the entire hot water corrugated heat transfer tube.

[0024] A hot water corrugated heat transfer tube according to an eighth aspect of the invention is a heat transfer tube used in a heat exchanger of a hot water heater and configured to exchange heat between its interior and exterior, in which a plurality of projections is provided on the inner surface of the portion positioned in the vicinity of an inlet into which water, which is the fluid flowing in the interior, flows, and the value of the pitch (P_1) of the plurality of projections is different from the value of the pitch (P_2) of the corrugated grooves.

[0025] The flow of the water in the vicinity of the inlet of the heat transfer tube corresponds to the laminar flow zone and/or the transition zone where the flow transitions from the laminar flow zone to the turbulent flow zone. In addition, the water temperature in the vicinity of the inlet of the heat transfer tube is low, and the heat transfer coefficient is also low. Here, the projections are provided inside the heat transfer tube in which the corrugated grooves are provided in order to improve the heat transfer coefficient. However, when the projections and the corrugated grooves are provided at positions where they overlap each other, the friction factor inside the tube increases and there is a risk that the pressure loss inside the tube rapidly increases. Therefore, setting the value of the pitch (P_1) of the projection to be different from the value of the pitch (P_2) of the corrugated grooves will allow the projections and the corrugated grooves to be disposed at positions where they do not overlap each other, and thus the rapid increase in the pressure loss inside the tube can be suppressed.

[0026] A hot water corrugated heat transfer tube according to a ninth aspect of the invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention, in which the flow speed of the fluid flowing in the interior is 0.1 - 0.6 m/s. Furthermore, it is preferable that the flow speed of the fluid

flowing inside the hot water corrugated heat transfer tube is 0.2 - 0.4 m/s. Here, when the flow speed of the fluid inside the tube is less than 0.1 m/s, the heat transfer coefficient of the corrugated heat transfer tube is extremely low. On the other hand, when the flow speed of the fluid inside the corrugated tube exceeds 0.6 m/s, the friction factor inside the corrugated tube increases and the pressure loss inside the tube increases. Accordingly, the range of the flow speed of the fluid flowing in the interior is set to 0.1 - 0.6 m/s. As a result, the heat transfer coefficient due to the corrugated groove and the projections provided inside the tube improves, and the impact of the projections on the pressure loss inside the tube is suppressed, thereby improving the performance of the entire hot water corrugate heat transfer tube.

[0027] A hot water corrugated heat transfer tube according to a tenth aspect of the invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention, in which the cross sectional shape at an arbitrary height of each projection is a smooth curve like a circle, an ellipse, or an approximate circle.

[0028] Examples of factors that influence the pressure loss of the fluid inside the tube due to the projections inside the corrugated tube include the height of the corrugated grooves, the Reynolds number and flow speed of the fluid inside the tube, the height of the projections, as well as the shape of the projections. When the projections are acute angle shaped, separation vortices are generated by the flow rounding the angle, which increases the pressure loss of the fluid.

[0029] Consequently, the cross sectional shape at an arbitrary height of a projection comprises a smooth curve, such as a circle, an ellipse, or an approximate circle. In other words, because the outer circumferential surface of the projections are formed with a smooth curved surface, the generation of separation vortices can be suppressed compared with projections that are acute angle shaped, and the impact of the loss of pressure of the fluid inside the tube is suppressed, thereby improving the performance of the entire corrugated heat transfer tube.

[0030] A hot water corrugated heat transfer tube according to an eleventh aspect of the invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention, in which the projections are not provided in a section positioned in the vicinity of a fluid outlet out of which the fluid flows.

[0031] When the temperature of the fluid is high at a fluid outlet part of the corrugated heat transfer tube and, for example, the fluid is water, there is a risk of scaling on the inner surface of the corrugated tube. When projections are provided in such a section, there is a risk that the projections will promote scaling. Accordingly, scaling is suppressed by the usage of a tube not provided with projections, e.g., by using a smooth tube, in the section positioned in the vicinity of the fluid outlet, where the temperature of the fluid is high.

[0032] A hot water corrugated heat transfer tube according to a twelfth aspect of the invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention, in which grooves each having a depth shallower than the height H1 of each projection are formed on the tube inner surface.

[0033] In the low Reynolds number zone, among the projections provided on the corrugated heat transfer tube inner surface, the large projections contribute more to the improvement in the heat transfer coefficient than the small projections. Accordingly, providing inside the corrugated heat transfer tube projections each whose height is greater than the depth of grooves in a grooved tube improves the heat transfer effect. However, in the high Reynolds number zone, grooves shallower than the height of the projections contribute more to the improvement in the heat transfer coefficient. Accordingly, in the high Reynolds zone, the heat transfer performance of the corrugated heat transfer tube is further improved by the usage of the grooved tube in which grooves shallower than the height of the projections are formed on the inner surface.

[0034] A hot water corrugated heat transfer tube according to a thirteenth aspect of the invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention in which the plurality of projections is provided parallel to the tube axial direction.

[0035] By providing projections in the tube axial direction, the promotion of heat transfer is performed in a continuous manner. In addition, because the fluid flows linearly in the tube axial direction, the additional pressure loss is small, thereby improving the performance of the entire heat transfer tube.

[0036] A hot water corrugated heat transfer tube according to a fourteenth aspect of the invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention, in which the plurality of projections is helically provided.

[0037] Helically providing the projections generates a turning in the flow of the fluid inside the tube, and increases the length of the passage of the fluid, thereby further increasing the heat transfer performance.

[0038] A hot water corrugated heat transfer tube according to a fifteenth aspect of the invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention, in which the plurality of projections is provided such that they are paired at opposing positions in the radial direction of the heat transfer tube.

[0039] Providing projections such that they form pairs at opposing positions in the radial direction reduces the cross sectional area in the vicinity of the projections, promotes the mixing of the fluid, and further improves the heat transfer performance.

[0040] A hot water corrugated heat transfer tube according to a sixteenth aspect of the invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention, in which

the ratio of a pitch P1 of the plurality of projections to the heat transfer tube inner diameter D is 0.5 - 10.

[0041] When the ratio of the pitch P1 of the projections to the heat transfer tube inner diameter D is equal to or less than 0.5, heat transfer is promoted, and the pressure loss increases due to the effect of the projections on the upstream side. In addition, when the ratio of the pitch P1 of the projections to the heat transfer tube inner diameter D is equal to or greater than 10, the promotion of heat transfer decreases.

[0042] Consequently, by setting the ratio of the pitch P1 of the projections to the heat transfer tube inner diameter D to 0.5 - 10, the promotion of heat transfer is maintained. At the same time, the increase in the pressure loss is small, and the performance of the entire heat transfer tube improves.

[0043] A hot water corrugated heat transfer tube according to a seventeenth invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention, in which small projections each whose height (H2) is less than 0.5 mm are provided between the plurality of projections.

[0044] In the low Reynolds number zone, the large projections contribute more to the improvement in the heat transfer coefficient than the small projections, and, in the high Reynolds number zone, the small projections (small projections) contribute more to the improvement in the heat transfer coefficient than the large projections. Accordingly, providing small projections between the large projections achieves a synergistic effect in that the heat transfer performance due to the large projections is improved in the section where the Reynolds number is low, and the heat transfer performance due to the small projections is improved in the section where the Reynolds number is high, thereby improving the performance of the entire heat exchanger.

[0045] A hot water corrugated heat transfer tube according to an eighteenth invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention, in which a smooth part not provided with projections exists on the inner surface of the heat transfer tube.

[0046] In the smooth part without projections, the cross sectional area inside the heat transfer tube is maximal. In other words, there is maximal variation in the shape of the inner surface between the portion where the projections are provided and the portion where the projections are not provided, which improves the heat transfer performance. On the other hand, when a smooth part does not exist on the inner surface of the heat transfer tube, the effect is the same as that obtained in a heat transfer tube whose inner diameter is reduced, i.e., the flow speed of the fluid increases and the heat transfer is promoted, but the pressure loss inside the tube increases.

[0047] A hot water corrugated heat transfer tube according to a nineteenth aspect of the invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention, in which the projections are formed by the application of force from the exterior, are formed in a linear part, and are not formed in a bent part.

[0048] When the projections are formed on the inner surface of the heat transfer tube by the application of an external force, it is often the case that the outer surface is depressed, and the projections are formed toward the inside of the tube on the inner surface corresponding to the depressed outer surface. In addition, the heat transfer tube generally has a linear part and a bent part. An additional pressure loss due to bending exists in the bent part besides the pressure loss in the linear part. Here, when projections are further provided on the inner surface of the bent part, there is a risk that the pressure loss in the bent part will increase further. In addition, the bending work process creates a large deformation in the depressed region of the outer surface of the heat transfer tube, which creates a risk of breakages, and the like. Therefore, the projections are provided in the linear part, and projections are not provided in the bent part.

[0049] A hot water corrugated heat transfer tube according to a twentieth aspect of the invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention, in which the projections are formed by the application of force from the exterior, and are not formed in a section that intersects the bent surface in the bent part.

[0050] In the bent part of the heat transfer tube, the amount of deformation is greatest in the portion that intersects the bent surface. Therefore, in the bent part of the heat transfer tube, projections are not provided in the section that intersects the bent surface. For example, when the heat transfer tube is bent at a horizontal surface, projections are not provided at the section that intersects the horizontal surface in the bent part.

[0051] A hot water corrugated heat transfer tube according to a twenty-first aspect of the invention is the hot water corrugated heat transfer tube according to any one of the first aspect through the eighth aspect of the invention, in which a second heat transfer tube is disposed in the exterior to flow a second fluid that supplies heat to the fluid; the second heat transfer tube contacts an outer surface; and the projections are formed on the inner surface by depressing the outer surface, and are formed at a location outside of the portion that contacts the second heat transfer tube.

[0052] Here, the projections are formed on the inner surface by depressing the outer surface, and depressions are consequently formed on the outer surface corresponding to the region where the projections are formed on the inner surface. Projections are formed at the portion that contacts the second heat transfer tube. In other words, when depressions are formed on the outer surface, the contact between the heat transfer tube and the second heat transfer tube worsens, thereby reducing the heat transfer effect from the second heat transfer tube. Therefore, by not providing projections in the section of contact with the second heat transfer tube, it is possible to prevent a reduction in the effect

of transferring heat from the second heat transfer tube.

BRIEF DESCRIPTION OF DRAWINGS

[0053]

Figure 1 is a schematic diagram of a heat pump type hot water heater.

Figure 2 is a schematic diagram of a water heat exchanger.

Figure 3 is a plan view of a corrugated heat transfer tube.

Figure 4 is a graph that depicts the Reynolds number of the flow inside the corrugated heat transfer tube.

Figure 5(a) is a cross sectional perspective view of the corrugated heat transfer tube; Figure 5(b) is a cross sectional view taken along the A-A arrow in Figure 5(a); and Figure 5(c) is a cross sectional view taken along the B-B arrow in Figure 5(b).

Figure 6 is a graph to show results of Experiment 1.

Figure 7 is a graph to show results of Experiment 2.

Figure 8 is a graph to show results of Experiment 3.

Figure 9 is a graph to show results of Experiment 4.

Figure 10 is a plan view of a corrugated heat transfer tube according to a first embodiment.

Figure 11 is a plan view of a corrugated heat transfer tube according to a second embodiment.

Figure 12(a) is a plan view of a corrugated heat transfer tube according to a third embodiment; and 12(b) is a perspective view of the corrugated heat transfer tube according to the third embodiment.

Figure 13 is a plan view of a corrugated heat transfer tube according to a fourth embodiment.

Figure 14 is a plan view of a corrugated heat transfer tube according to a fifth embodiment; Figure 14(a) is a plan view of a corrugated heat transfer tube according to a fifth embodiment; and 14(b) is a perspective view of the corrugated heat transfer tube according to the fifth embodiment.

Figure 15 is a plan view of a corrugated heat transfer tube according to a sixth embodiment.

Figure 16 is a plan view of a corrugated heat transfer tube according to a seventh embodiment.

Figure 17 is a plan view of a corrugated heat transfer tube according to an eighth embodiment.

Figure 18 is a plan view of a corrugated heat transfer tube according to a ninth embodiment.

Figure 19(a) is a plan view of a corrugated heat transfer tube according to a tenth embodiment; and Figure 19(b) is a perspective view of the corrugated heat transfer tube according to the tenth embodiment.

Figure 20 is a plan view of a corrugated heat transfer tube according to an eleventh embodiment.

Figure 21 (a) is a perspective view of a corrugated heat transfer tube; Figure 21(b) is a perspective view of a high-fin heat transfer tube; and Figure 21 (c) is a perspective view of a floral-printed heat transfer tub.

DESCRIPTION OF THE REFERNECE NUMERALS

[0054]

1	hot water supply unit
100	heat pump type hot water heater
2	heat pump unit
30	water heat exchanger
311	water inlet
312	water outlet
313, 413, 513, 613	projection
315	small projection
316,416,516,616	corrugated groove
644	groove

BEST MODE FOR CARRYING OUT THE INVENTION

[0055] A hot water corrugated heat transfer tube according to the present invention will now be described based on the attached drawings and the embodiments.

[0056] Figure 1 is a schematic diagram of a heat pump type hot water heater that uses a hot water corrugated heat transfer tube of the present invention. Here, the heat pump type hot water heater comprises a hot water supply unit 1, and a heat pump unit 2. The following are successively connected in the hot water supply unit 1: a service water tube 11, a hot water storage tank 12, a water circulation pump 13, a water supply tube 3, a corrugated heat transfer tube 31

that constitutes a water heat exchanger 30, a hot water tube 16, a mixing valve 17, and a hot water supply tube 18. Here, service water is supplied from the water supply tube 11 to the hot water storage tank 12. Low temperature water is supplied by the water circulation pump 13 from the bottom part of the hot water storage tank 12 to the corrugated heat transfer tube 31 of the water heat exchanger 30, and heated. The heated hot water flows into the upper part of the hot water storage tank 12. The high temperature hot water that exits from the upper part of the hot water storage tank 12 via the hot water tube 16 is mixed with the cold water of a mixed water tube 19 by the mixing valve 17. This mixing valve 17 regulates the temperature of the supplied hot water, which is supplied to the user by the hot water supply tube 18.

[0057] Next, the heat pump unit 2 is provided with a refrigerant circulation circuit that comprises a compressor 21, the water heat exchanger 30, an expansion valve 23, and an air heat exchanger 24, which are connected sequentially by a refrigerant tube 32. The refrigerant is compressed to a high pressure by the compressor 21, and is then sent to the water heat exchanger 30. The refrigerant whose heat was exchanged in the water heat exchanger 30 passes through the expansion valve 23, and is supplied to the air heat exchanger 24. The refrigerant absorbs heat from the surroundings, and then is circulated back to the compressor 21.

[0058] Figure 2 is a schematic diagram of the water heat exchanger 30 in the heat pump type hot water heater. As shown in Figure 2, the water heat exchanger 30 comprises the corrugated heat transfer tube 31 and the refrigerant tube 32. The corrugated heat transfer tube 31 is spirally formed in the same plane so as to be an oval shape, and forms a water passageway W. The refrigerant tube 32 is helically wound around the outer circumference of the heat transfer tube 31, and forms a refrigerant passageway R. Further, the outer circumferential side of the spiral shaped corrugated heat transfer tube 31 is a water inlet 311, and the center side of the spiral shaped corrugated heat transfer tube 31 is a water outlet 312. In the water heat exchanger 30, the refrigerant inside the refrigerant tube 32 flows into the refrigerant inlet 322 in the A22 direction, and radiates heat. Subsequently, the refrigerant flows out of the refrigerant outlet 321 in the A21 direction. The service water supplied into the water inlet 311 in the A11 direction is heated by this heat, turns into hot water, and flows out of the water outlet 312 in the A12 direction.

[0059] Next, the corrugated heat transfer tube 31 is described. As shown in Figure 3, on the tube inner surface of the corrugated heat transfer tube 31, corrugated grooves 316 are formed and a plurality of projections 313 each having a height H1 is provided vertically symmetric in the tube axial direction. In Figure 3, only the projections 313 are provided upward when viewed from the paper surface are shown. In the present embodiment, the water temperature at the water inlet 311 of the heat transfer tube 31 is set to approximately 10° C, and the water temperature at the water outlet 312 is set to approximately 90° C. Here, the flow volume of the water in the corrugated heat transfer tube is approximately 0.8 L/min. In addition, the outer diameter of the corrugated heat transfer tube is preferably 8.0 - 14.0 mm (inner diameter is 6.0 - 12.0 mm).

[0060] Figure 4 is a chart of the Reynolds number Re of the flow inside the corrugated heat transfer tube 31. As shown in Figure 4, the Reynolds number Re at the water inlet 311 of the corrugated heat transfer tube 31 is approximately 2,000, and the flow inside the tube is in the laminar flow zone. As the water flow advances, the water that flows in from the inlet 311 exchanges heat with the refrigerant tube 32 shown in Figure 2, thereby increasing the water temperature. The increased water temperature decreases the coefficient of viscosity of the water, which gradually increases the Reynolds number Re. In Figure 4, the Reynolds number Re at the water outlet 312 is approximately 7,000, and the flow inside the tube is in the transition zone where the flow transitions from laminar flow to turbulent flow. Here, the following experiments were performed to investigate the impact of the plurality of projections 313 provided on the tube inner surface of the corrugated heat transfer tube 31 on the improvement in the heat transfer performance, and on the pressure loss.

(1) EXPERIMENT 1

[0061] Figure 5(a) is a cross sectional perspective view of the corrugated heat transfer tube 31. In Experiment 1, projections each having the height H1 are provided vertically symmetric on the tube inner surface having an inner diameter D of 8.0 mm in which the corrugated grooves 316 having a depth of Hm are provided. Figure 5(b) is a cross sectional view taken along the A-A arrow in Figure 5(a), and Figure 5(c) is a cross sectional view taken along the B-B arrow in Figure 5(b). As shown in Figure 5(a) and Figure 5(b), the projections 313 are formed on the inner surface by depressing the outer surface of the heat transfer tube. In addition, as shown in Figure 5(c), each projection 313 is formed such that its shape in the transverse sectional view is elliptical. Here, flat surfaced parts 31a not provided with projections exist on the inner surface of the corrugated heat transfer tube 31.

[0062] Figure 6(a) graphs, for each Reynolds number Re in the low Reynolds number section where the laminar flow zone is produced and the transition of the flow inside the tube from the laminar flow zone to the turbulent flow zone occurs, the heat transfer performance in the case of using a corrugated tube not provided with projections and in the case of using a corrugated tube in which the depth of the corrugated grooves is Hm and the height H1 of the projections is 1.2 mm. Here, the horizontal axis represents the value of the Reynolds number Re. The vertical axis represents the ratio (Nu/Nuo), which is the ratio of the Nusselt number Nu of the corrugated heat transfer tube provided with the

projections 313 and the corrugated heat transfer tube not provided with projections to the Nusselt number Nu_o of the smooth heat transfer tube. Here, the Nusselt number is the heat transfer coefficient converted to a dimensionless number, which serves as an index of how easily heat transfers from the solid wall to the fluid: the larger that number, the easier that heat conducts from the solid wall to the fluid. Accordingly, the larger the Nu/Nu_o value, the greater the improvement in the heat transfer performance of the heat transfer tube due to the projections and corrugated grooves. The solid line represents the experimental results in the case of using the corrugated heat transfer tube provided with the projections 313, and the dotted line represents the experimental results in the case of using the corrugated heat transfer tube not provided with the projections. As shown in Figure 6(a), the heat transfer performance of the corrugated heat transfer tube not provided with the projections is approximately three times that of the smooth tube, regardless of the Reynolds number. On the other hand, in the case of using the corrugated heat transfer tube provided with the projections 313 each whose height H_1 is 1.2 mm, when the Reynolds number Re is equal to or less than 4,000, the improvement in the heat transfer performance due to the projections 313 provided inside the tube is clear. However, when the Reynolds number Re is equal to or greater than 4,000, the improvement in the heat transfer performance due to the projections 313 provided inside the tube is modest.

[0063] Figure 6(b) graphs, for each Reynolds number Re in the low Reynolds number section where the laminar flow zone is produced and the transition of the flow inside the tube from the laminar flow zone to the turbulent flow zone occurs, the trend in the pressure loss inside the tube in the case of using a corrugated tube not provided with projections and in the case of using the corrugated heat transfer tube 31 whose depth of the corrugated grooves is H_m and the height H_1 of the projections is 1.2 mm. Here, the horizontal axis represents the value of the Reynolds number Re . The vertical axis represents the ratio (f/f_o) , which is the ratio of the Fanning friction factor f of the corrugated heat transfer tube provided with the projections 313 and the corrugated heat transfer tube not provided with projections to the Fanning friction factor f_o of the smooth tube. Here, the Fanning friction factor is a dimensionless number that indicates the pressure loss of the flow inside the tube: the larger that number, the greater the pressure loss of the flow inside the tube. Accordingly, the larger the f/f_o value, the greater the water pressure loss inside the tube. The solid line represents the experimental results in the case of using the corrugated heat transfer tube provided with the projections 313, and the dotted line represents the experimental results in the case of using the corrugated heat transfer tube not provided with the projections. As shown in Figure 6(b), when the Reynolds number Re is equal to or less than 7,000, the increase of the pressure loss due to the projections 313 provided on the tube inner surface is substantially stable.

(2) EXPERIMENT 2

[0064] To investigate the impact of the height H_1 of the projections 313 on the heat transfer performance and on the pressure loss of the flow inside the tube, Experiment 2 was performed by varying the height H_1 of the projections 313 provided on the tube inner surface. Figure 7(a) graphs the heat transfer performance for the case where projections having differing heights H_1 are provided vertically symmetric in a corrugated heat transfer tube having an inner diameter D of 8.0 mm such that the pitch P in the tube axial direction is 15 mm. Here, the horizontal axis represents the value of the height H_1 of the projections 313. The vertical axis represents the ratio (Nu/Nu_o) , which is the ratio of the Nusselt number Nu of the corrugated heat transfer tube 31 provided with the projections 313 to the Nusselt number Nu_o of the smooth tube not provided with projections. The solid line represents the experimental results for the case where the Reynolds number Re is 4,000, and the dotted line represents the experimental results for the case where the Reynolds number Re is 2,000. As shown in Figure 7(a), the greater the height H_1 of the projections 313, the greater the improvement in the heat transfer performance, for both the case where the Reynolds number Re is 4,000 and 2,000.

[0065] Figure 7(b) graphs the trend in the pressure loss inside the tube. Here, the horizontal axis represents the value of the height H_1 of the projections 313. The vertical axis represents the ratio (f/f_o) , which is the ratio of the Fanning friction factor f of the corrugated heat transfer tube 31 provided with the projections 313 to the Fanning friction factor f_o of the smooth tube not provided with projections. The solid line represents the experimental results for the case where the Reynolds number Re is 4,000, and the dotted line represents the experimental results for the case where the Reynolds number Re is 2,000. As shown in Figure 7(b), the greater the height H_1 of the projections 313, the greater the pressure loss inside the tube, for both the case where the Reynolds number Re is 4,000 and 2,000. In particular, when the ratio H_1 is equal to or greater than 1.0, an increase in the pressure loss inside the tube is remarkable.

[0066] Figure 7(c) graphs the performance of the entire heat transfer tube for the case where projections having differing heights H_1 were provided vertically symmetric at a 15.0 mm pitch (in the tube axial direction) in a corrugated heat transfer tube having the inner diameter D of 8.0 mm. In other words, the performance comprehensively taking into consideration the improvement in the heat transfer performance and the suppression of the pressure loss is represented. Here, the horizontal axis represents the value of the height of the projections. The vertical axis represents the value of the ratio (Nu/Nu_o) , which is the ratio of the Nusselt number Nu of the corrugated heat transfer tube provided with projections to the Nusselt number Nu_o of the smooth tube not provided with projections, divided by the ratio (f/f_o) , which is the ratio of the Fanning friction factor f of the heat transfer tube provided with projections to the Fanning friction factor

fo of the smooth tube not provided with projections. As discussed above, the larger the Nu/Nu_o value, the greater the improvement in the heat transfer performance; and the larger the f/f_o value, the greater the water pressure loss inside the tube. Accordingly, the larger the value of Nu/Nu_o divided by f/f_o , the greater the improvement in the heat transfer performance, the smaller the impact that the projections have on the pressure loss inside the tube, and the greater the improvement in the performance of the entire heat transfer tube.

[0067] In Figure 7(c), the solid line represents the experimental results for the case where the Reynolds number Re is 4,000, and the dotted line represents the experimental results for the case where the Reynolds number Re is 2,000. As shown in Figure 7(c), when the Reynolds number Re is 2,000 and the height of the projections provided inside the heat transfer tube is 0.79 mm, the value of Nu/Nu_o divided by f/f_o is largest. When the height of the projections exceeds 2.0 mm, the value decreases remarkably. In other words, in the low Reynolds number section, the performance of the entire heat transfer tube improves when the height of the projections is in the range of 0.5 - 1.5 mm. In particular, it is preferable that the height of the projections is in the range of 0.5 - 0.79 mm.

(3) EXPERIMENT 3

[0068] In Experiment 3, instead of assigning the height H_1 of the projections 313, as is, as an index, the relative roughness (H_1/D) serves as the index. To investigate the impact of this relative roughness (H_1/D) on the heat transfer performance and on the pressure loss of the flow inside the tube, this experiment was performed by varying the relative roughness (H_1/D). Figure 8(a) graphs the heat transfer performance of the corrugated heat transfer tube by varying the relative roughness (H_1/D) in the states when the Reynolds number Re is 2,000 and 4,000. Here, the horizontal axis represents the value of the relative roughness (H_1/D). The vertical axis represents the ratio (Nu/Nu_o), which is the ratio of the Nusselt number Nu of the corrugated heat transfer tube 31 provided with the projections 313 to the Nusselt number Nu_o of the smooth heat transfer tube not provided with projections. As shown in Figure 8(a), the larger the value of the relative roughness (H_1/D) of the projections, the greater the improvement in the heat transfer performance. In addition, as can be seen from the dotted line in Figure 8(a), in the state when the Reynolds number is 2,000, the projections yield little improvement in the heat transfer performance when the value of the relative roughness (H_1/D) is equal to or less than 0.1.

[0069] Figure 8(b) graphs the trend in the pressure loss inside the tube. Here, the horizontal axis represents the value of the relative roughness (H_1/D). The vertical axis represents the ratio (f/f_o), which is the ratio of the Fanning friction factor f of the corrugated heat transfer tube 31 provided with the projections 313 to the Fanning friction factor f_o of the smooth tube not provided with projections. The solid line represents the experimental results for the case where the Reynolds number Re is 4,000, and the dotted line represents the experimental results for the case where the Reynolds number Re is 2,000. As shown in Figure 8(b), the greater the height H_1/D of the projections 313, the greater the pressure loss inside the tube, for both the case where the Reynolds number Re is 4,000 and 2,000. In particular, when the ratio H_1/D is equal to or greater than 0.12, an increase in the pressure loss inside the tube is remarkable.

[0070] Figure 8(c) graphs the heat transfer performance of the entire corrugated heat transfer tube by varying the relative roughness (H_1/D) of the projections. Here, the horizontal axis represents the value of the relative roughness (H_1/D). The vertical axis represents the value of the ratio (Nu/Nu_o), which is the ratio of the Nusselt number Nu of the heat transfer tube provided with projections to the Nusselt number Nu_o of the smooth tube not provided with projections, divided by the ratio (f/f_o), which is the ratio of the Fanning friction factor f of the corrugated heat transfer tube provided with projections to the Fanning friction factor f_o of the smooth tube not provided with projections. As discussed above, the larger the Nu/Nu_o value, the greater the improvement in the heat transfer performance; and the larger the f/f_o value, the greater the water pressure loss inside the tube. Accordingly, the larger the value of Nu/Nu_o divided by f/f_o , the greater the improvement in the heat transfer coefficient, the smaller the impact of the projections on the pressure loss inside the tube, and the greater the improvement in the performance of the entire corrugated heat transfer tube. As shown in Figure 8(c), in the state when the Reynolds number Re is 2,000, the value of Nu/Nu_o divided by f/f_o is largest when the relative roughness (H_1/D) of the projections provided inside the corrugated heat transfer tube is 0.1, and the value decreases remarkably when the relative roughness (H_1/D) of the projections exceeds 0.20. In other words, in the low Reynolds number Re section, the performance of the entire heat transfer tube improves when the relative roughness (H_1/D) of the projections is in the range of 0.05 - 0.15. In particular, it is preferable that the relative roughness (H_1/D) of the projections is in the range of 0.05 - 0.15.

(4) EXPERIMENT 4

[0071] In Experiment 4, besides the height H_1 of the projections 313 as the index, the ratio (H_1/H_m) of the height H_1 of the projections 313 to the depth H_m of the corrugated grooves serves as the index. To investigate the impact of this relative height (H_1/H_m) on the heat transfer performance and on the pressure loss of the flow inside the tube, this experiment was performed by varying the relative height (H_1/H_m). Figure 9(a) graphs the heat transfer performance by

varying the relative height ($H1/Hm$) in the states when the Reynolds number Re is 2,000 and 4,000. Here, the horizontal axis represents the value of the relative height ($H1/Hm$). The vertical axis represents the ratio (Nu/Nuo), which is the ratio of the Nusselt number Nu of the corrugated heat transfer tube 31 provided with the projections 313 to the Nusselt number Nuo of the smooth tube not provided with projections. As shown in Figure 9(a), the larger the value of the relative height ($H1/Hm$) of the projections, the greater the improvement in the heat transfer performance. In addition, as can be seen from the dotted line in Figure 9(a), in the state when the Reynolds number is 2,000, the projections yield little improvement in the heat transfer performance when the value of the relative height ($H1/Hm$) is equal to or less than 0.5.

[0072] Figure 9(b) graphs the trend in the pressure loss inside the tube. Here, the horizontal axis represents the value of the relative height ($H1/Hm$). The vertical axis represents the ratio (f/fo), which is the ratio of the Fanning friction factor f of the corrugated heat transfer tube 31 provided with the projections 313 to the Fanning friction factor fo of the smooth tube not provided with projections. The solid line represents the experimental results for the case where the Reynolds number Re is 4,000, and the dotted line represents the experimental results for the case where the Reynolds number Re is 2,000. In addition, as shown in Figure 8(b), when the Reynolds number is 2,000, the greater the relative height ($H1/Hm$) of the projections 313, the greater the improvement in the pressure loss inside the tube. In particular, when the ratio $H1/Hm$ is equal to or greater than 1.8, an increase in the pressure loss inside the tube is remarkable.

[0073] Figure 9(c) graphs the heat transfer performance of the entire heat transfer tube by varying the relative height ($H1/Hm$) of the projections. Here, the horizontal axis represents the value of the relative height ($H1/Hm$). The vertical axis represents the value of the ratio (Nu/Nuo), which is the ratio of the Nusselt number Nu of the heat transfer tube provided with projections to the Nusselt number Nuo of the smooth tube not provided with projections, divided by the ratio (f/fo), which is the ratio of the Fanning friction factor f of the heat transfer tube provided with projections to the Fanning friction factor fo of the smooth tube not provided with projections. As shown in Figure 9(c), when the Reynolds number Re is 2,000 and the relative height ($H1/Hm$) of the projections provided inside the heat transfer tube is 1.8, the value of Nu/Nuo divided by f/fo is largest. When the relative height ($H1/Hm$) of the projections exceeds 3.0, the value decreases remarkably. In other words, in the low Reynolds number section, the performance of the entire heat transfer tube improves when the relative height ($H1/Hm$) of the projections is in the range of 1.0 - 3.0. In particular, it is preferable that the relative height ($H1/Hm$) of the projections is in the range of 1.0 - 2.0.

[0074] The following embodiments further describe structures that differ from the hot water corrugated heat transfer tube according to the present invention (in the following embodiments, values such as the inner diameter D , the depth Hm of the corrugated grooves, the heights $H1$, $H2$ and the pitch of the projections, and the depths of the grooves, are merely for illustrative purposes, and it is also possible to use in these embodiments the values used in the abovementioned experiments, as well as the numerical ranges of the various parameters described in the claims).

<FIRST EMBODIMENT>

[0075] Figure 10 shows the structure of a corrugated heat transfer tube 41 used in Experiment 1. As shown in Figure 10(a), corrugated grooves 416 each having a groove depth Hm of 0.5 mm and the pitch Pm in the tube axial direction of 10.0 mm is provided on a smooth tube whose diameter D is 8.0 mm. As shown in Figure 10(b), projections 413 each having a height $H1$ of 1.0 mm are provided vertically symmetric such that the pitch P in the tube axial direction is 15.0 mm. Here, setting the value of the pitch ($P1$) of the plurality of projections to be different from the value of the pitch (Pm) of the corrugated grooves will allow the projections 413 and the corrugated grooves 416 to be disposed at positions where they do not overlap each other, and thus the rapid increase in the pressure loss inside the tube can be suppressed.

<SECOND EMBODIMENT>

[0076] As shown in Figure 11, in a corrugated heat transfer tube 51 of a second embodiment, corrugated grooves 516 are provided and small projections 515 each having a height $H2$ of 0.3 mm are provided between projections 513 each having a height $H1$ of 1.0 mm. In the low Reynolds number zone, the large projections contribute to the improvement in the heat transfer coefficient more than the small projections, whereas in the high Reynolds number zone, the small projections contribute to the improvement in the heat transfer coefficient more than the large projections. Therefore, by providing the small projections 515 each whose height $H2$ is 0.3 mm between the projections 513 each whose height $H1$ is 1.0 mm, a synergistic effect is achieved in that the corrugated groove 516 and the projections 513 improve the heat transfer performance in the section where the Reynolds number is low, and the corrugated grooves 516 and the small projections 515 improve heat transfer performance in the section where the Reynolds number is high, thereby improving the performance of the entire heat exchanger.

<THIRD EMBODIMENT>

[0077] As shown in Figure 12, a corrugated heat transfer tube 61 employed in a third embodiment is provided with

projections 613 along a helix C1 on the tube inner surface. Figure 12(a) is a plan view of the corrugated heat transfer tube 61, and Figure 12(b) is a perspective view of the corrugated heat transfer tube 61. Here, the height H1 of the projections 613 is 1.0 mm, a pitch P1 in the circumferential direction is 6.0 mm, and a pitch P2 in the tube axial direction is 6.0 mm.

<FOURTH EMBODIMENT>

[0078] As shown in Figure 13, a corrugated heat transfer tube 63 employed in a fourth embodiment comprises a section 63a provided with projections 633, and a section 63b not provided with projections, on a heat transfer tube provided with corrugated grooves 636 having a depth of 0.5 mm. Here, the section 63b not provided with projections is positioned in the vicinity of a water outlet 632. The temperature of the waster, which is a fluid, is high in the vicinity of the outlet 632 of the heat transfer tube 63, and there is therefore a risk of scaling of the tube wall. When projection parts are provided in such a section, it may promote scaling. Therefore, scaling is suppressed by not providing projections in the section 63b positioned in the vicinity of the water outlet 632, where the water temperature is high.

<FIFTH EMBODIMENT>

[0079] As shown in Figure 14, a corrugated heat transfer tube 64 employed in a fifth embodiment is a grooved tube provided with corrugated grooves 646 each having a depth of 0.5 mm and grooves 644 each having a depth of 0.2 mm, in which projections 643 each having a height H1 of 1.0 mm are provided vertically symmetric such that their pitch P in the tube axial direction is 15.0 mm. Here, the corrugated grooves 646 are represented by solid lines and the grooves 644 are represented by fine solid lines. Here, providing the projections 643 in the tube provided with the grooves 644 achieves a synergistic effect for the entire heat transfer tube due to the corrugated groove 646, the grooves 644, and the projections 643.

<SIXTH EMBODIMENT>

[0080] As shown in Figure 15, a corrugated heat transfer tube 65 employed in a sixth embodiment comprises a section 65a and a section 65b. A corrugated heat transfer tube not provided with projections is used in the section 65b positioned in the vicinity of a water outlet 652; in the other section 65a, projections 653 each having a height of 1.0 mm are provided in the grooved tube provided with corrugated grooves 656 each having a depth of 0.5 mm and grooves 654 each having a depth of 0.2 mm. The corrugated grooves 656 are represented by solid lines, and the grooves 654 are represented by fine solid lines. In addition to the corrugated grooves 656, the grooves 654, and the projections 653 achieving a synergistic effect for the entire heat transfer tube, scaling is suppressed in the section 65b positioned in the vicinity of the water outlet 652, where the water temperature is high.

<SEVENTH EMBODIMENT>

[0081] As shown in Figure 16, a corrugated heat transfer tube 66 employed in a seventh embodiment comprises three sections: a section 66a, a section 66b, and a section 66c. In the section 66a from a water inlet 661 until the Reynolds number Re inside the tube is 4,000, a grooved tube provided with corrugated grooves 666 each having a depth of 0.5 mm and grooves 664 each having a depth of 0.2 mm, in which projections 663 each having a height of 1.0 mm are provided, is employed; in the section 66c positioned in the vicinity of a water outlet 662, a corrugated heat transfer tube provided with the corrugated grooves 666 each having a depth of 0.5 mm is employed; and the grooved tube 66b provided with the corrugated grooves 666 each having a depth of 0.5 mm and grooves 664 each having a depth of 0.2 mm is employed between the section 66a and the section 66c. Here, the corrugated grooves 666 are represented by solid lines, and the grooves 664 are represented by fine solid lines. Here, a synergistic effect is achieved in that the projections 663, the grooves 664, and the corrugated grooves 666 improve heat transfer performance in the section where the Reynolds number is low, and the grooves 664 and the corrugated grooves 666 improve heat transfer performance in the section where the Reynolds number is high, thereby improving the performance of the entire heat exchanger. In addition, scaling is suppressed by the corrugated grooves 666 in the section 66c positioned in the vicinity of the water outlet 662, where the water temperature is high.

<EIGHTH EMBODIMENT>

[0082] As shown in Figure 17, a heat transfer tube 67 employed in an eighth embodiment comprises three sections: a section 67a, a section 67b, and a section 67c. In the section 67a from a water inlet 671 until the Reynolds number Re inside the tube is 4,000, a corrugated tube provided with the corrugated grooves 666 each having a depth of 0.5 mm,

in which projections 673 each having a height of 1.0 mm are provided, is employed; in the section 67c positioned in the vicinity of a water outlet 672, a corrugated heat transfer tube provided with corrugated grooves 676 each having a depth of 0.5 mm is employed; and the grooved tube 67b provided with the corrugated grooves 676 each having a depth of 0.5 mm and grooves 674 each having a depth of 0.2 mm is employed between the section 67a and the section 67c. Here, the corrugated grooves 676 are represented by solid lines, and the grooves 674 are represented by fine solid lines. Here, a synergistic effect is achieved in that the corrugated grooves 676 and the projections 673 improve heat transfer performance in the section where the Reynolds number is low, and the corrugated grooves 676 and the grooves 674 improve heat transfer performance in the section where the Reynolds number is high, thereby improving the performance of the entire heat exchanger. In addition, scaling is suppressed by the corrugated grooves 676 in the section 67c positioned in the vicinity of the water outlet 672, where the water temperature is high.

<NINTH EMBODIMENT>

[0083] As shown in Figure 18, in a corrugated heat transfer tube 68 used in a ninth embodiment projections 683 are provided in a linear part 684, but projections are not provided in bent parts B1 - B7 (dotted area). Not providing projections on the inner surface of the bent parts B1 - B7 can avoid increasing the pressure loss in the tube, and can also avoid the occurrence of large deformations, breaks, and the like, during the bending work process.

<TENTH EMBODIMENT>

[0084] Figure 19(a) is a plan view of a corrugated heat transfer tube 69 employed in a tenth embodiment, and Figure 19(b) is a perspective view of the heat transfer tube 69. Here, projections 693 are provided in a linear part 694, but projections are not provided in a section 695 that intersects with a bent surface S1 in a bent part C - C.

<ELEVENTH EMBODIMENT>

[0085] As shown in Figure 20, in a corrugated heat transfer tube 70 used in an eleventh embodiment, projections are not used in a contact region between an outer surface 71 of the corrugated heat transfer tube and a refrigerant tube 72. When depressions are provided on the tube outer surface corresponding to the region around which the refrigerant tube 72 is wound, the contact between the refrigerant tube 72 and the heat transfer tube outer surface 71 degrades, creating a risk of decreasing the effect of the transfer of heat from the refrigerant tube 72. Therefore, providing projections 713 in the region where the refrigerant tube 72 is not wound around can prevent a reduction in the effect of transferring heat from the refrigerant tube 72.

<OTHER EMBODIMENT>

[0086] In the above described experiments and embodiments, as shown in Figure 21 (a), a corrugated tube having corrugated grooves, which serves as a heat transfer tube, is provided with projections. Note that, a high-fin tube provided with projections may be employed as a heat transfer tube as shown in Figure 21(b); or a flower printed tube provided with projections maybe employed as a heat transfer tube as shown in Figure 21(c).

Claims

1. A hot water corrugated heat transfer tube configured to exchange heat between its interior and exterior, wherein helically corrugated grooves are provided inside the tube, and a plurality of projections each whose height (H1) is 0.5 - 1.5 mm is provided in at least one part of the inner surface of a portion positioned in a section where the Reynolds number (Re) of a fluid flowing in the interior is less than 7,000.
2. A hot water corrugated heat transfer tube configured to exchange heat between its interior and exterior, wherein helically corrugated grooves are provided inside the tube, and a plurality of projections each whose height (H1) is 0.05 - 0.15 times an inner diameter (D) is provided in at least one part of the inner surface of a portion positioned in a section where the Reynolds number (Re) of a fluid flowing in the interior is less than 7,000.
3. A hot water corrugated heat transfer tube configured to exchange heat between its interior and exterior, wherein helically corrugated grooves are provided inside the tube, and a plurality of projections each whose height (H1) is 1 - 3 times a depth (Hm) of the corrugated grooves is provided

in at least one part of the inner surface of a portion positioned in a section where the Reynolds number (Re) of a fluid flowing in the interior is less than 7,000.

4. A hot water corrugated heat transfer tube configured to exchange heat between its interior and exterior, wherein helically corrugated grooves are provided inside the tube, and a plurality of projections is provided in at least one part of the inner surface of a portion positioned in a section where the Reynolds number (Re) of a fluid flowing in the interior is less than 7,000, and the value of a pitch (P1) of the plurality of projections is different from the value of a pitch (Pm) of the corrugated grooves.
5. A hot water corrugated heat transfer tube used in a heat exchanger of a hot water heater and configured to exchange heat between its interior and exterior, wherein helically corrugated grooves are provided inside the tube, and a plurality of projections each whose height (H1) is 0.5 mm - 1.5 mm is provided on the inner surface of a portion positioned in the vicinity of an inlet into which water, which is the fluid flowing in the interior, flows.
6. A hot water corrugated heat transfer tube used in a heat exchanger of a hot water heater and configured to exchange heat between its interior and exterior, wherein helically corrugated grooves are provided inside the tube, and a plurality of projections each whose height (H1) is 0.05 - 0.15 times an inner diameter (D) is provided on the inner surface of a portion positioned in the vicinity of a fluid inlet into which water, which is the fluid flowing in the interior, flows.
7. A hot water corrugated heat transfer tube used in a heat exchanger of a hot water heater and configured to exchange heat between its interior and exterior, wherein helically corrugated grooves are provided inside the tube, and a plurality of projections each whose height (H1) is 1 - 3 times a depth (Hm) of the corrugated grooves is provided on the inner surface of a portion positioned in the vicinity of a fluid inlet into which water, which is the fluid flowing in the interior, flows.
8. A hot water corrugated heat transfer tube used in a heat exchanger of a hot water heater and configured to exchange heat between its interior and exterior, wherein helically corrugated grooves are provided inside the tube, and a plurality of projections is provided on the inner surface of a portion positioned in the vicinity of a fluid inlet into which water, which is the fluid flowing in the interior, flows, and the value of a pitch (P1) of the plurality of projections is different from the value of a pitch (Pm) of the corrugated grooves.
9. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein the flow speed of the fluid flowing in the interior is 0.1 - 0.6 m/s.
10. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein the cross sectional shape at an arbitrary height of each of the projections is a smooth curve like a circle, an ellipse, or an approximate circle.
11. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein a smooth part not provided with the projections is formed in the inner surface of a portion positioned in the vicinity of a fluid outlet out of which the fluid flows.
12. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein a groove having a depth shallower than the height (H1) of each of the projections is formed on the inner surface.
13. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein the plurality of projections is provided parallel to the tube axial direction.
14. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein the plurality of projections is helically provided.

15. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein the plurality of projections is provided such that they are paired at opposing positions in the radial direction.

5 16. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein the ratio of the pitch (P1) of the plurality of projections to the inner diameter (D) is 0.5 - 10.

17. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein small projections each whose height (H2) is less than 0.5 mm are provided between the plurality of projections.

10 18. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein a smooth part not provided with the projections exists on the inner surface.

15 19. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein the projections are formed by the application of force from the exterior, the projections are formed in a linear part, and the projections are not formed in a bent part.

20 20. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein the projections are formed by the application of force from the exterior, and the projections are not formed in a portion that intersects a bent surface in a bent part .

25 21. The hot water corrugated heat transfer tube according to any one of Claim 1 through Claim 8, wherein a second heat transfer tube configured to flow a second fluid that exchanges heat with the fluid is disposed in the exterior of the hot water corrugated heat transfer tube;
the second heat transfer tube contacts an outer surface of the hot water corrugated heat transfer tube; and
the projections are formed on the inner surface by depressing the outer surface, and are formed at a location outside
of the portion that contacts the second heat transfer tube.

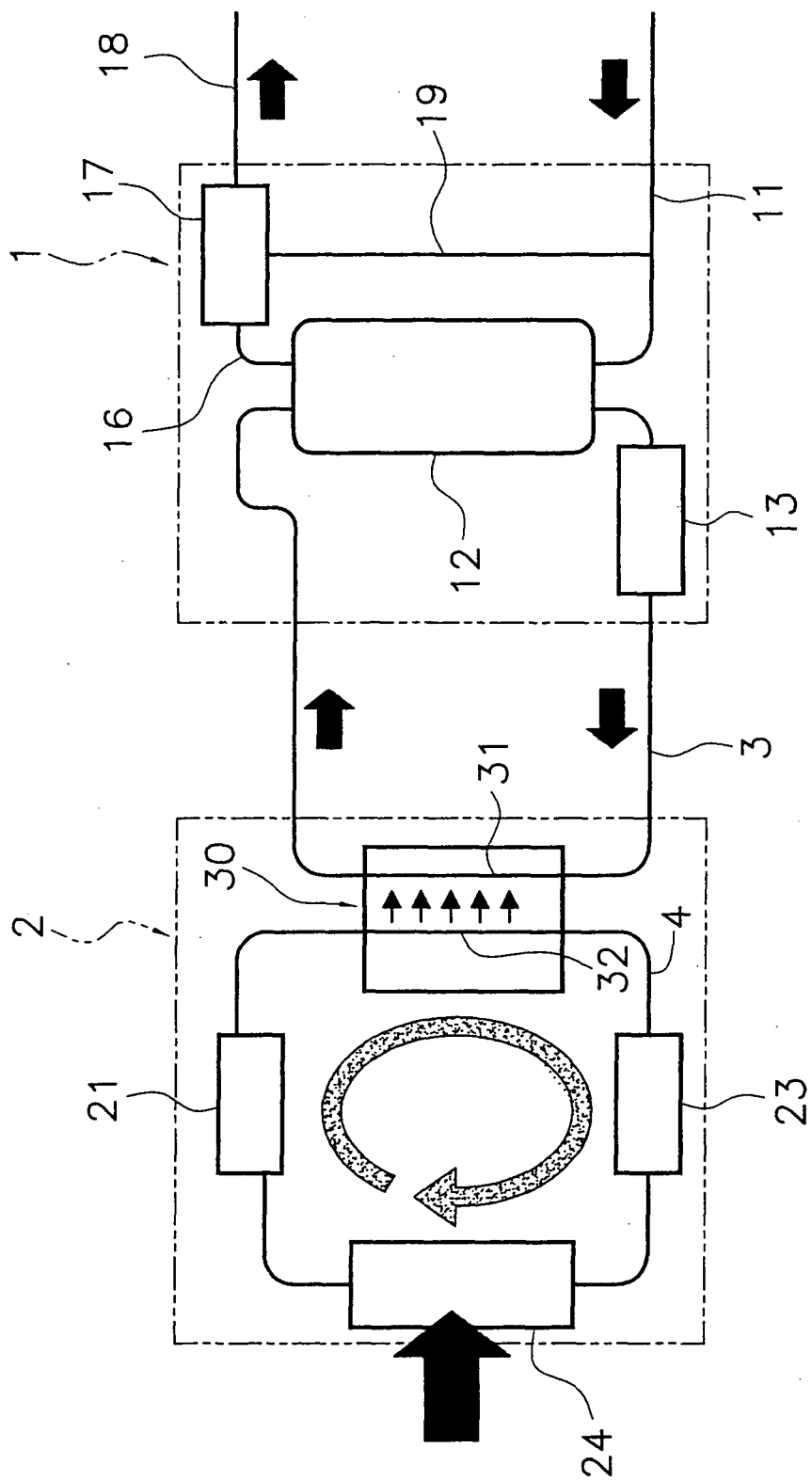


Fig. 1

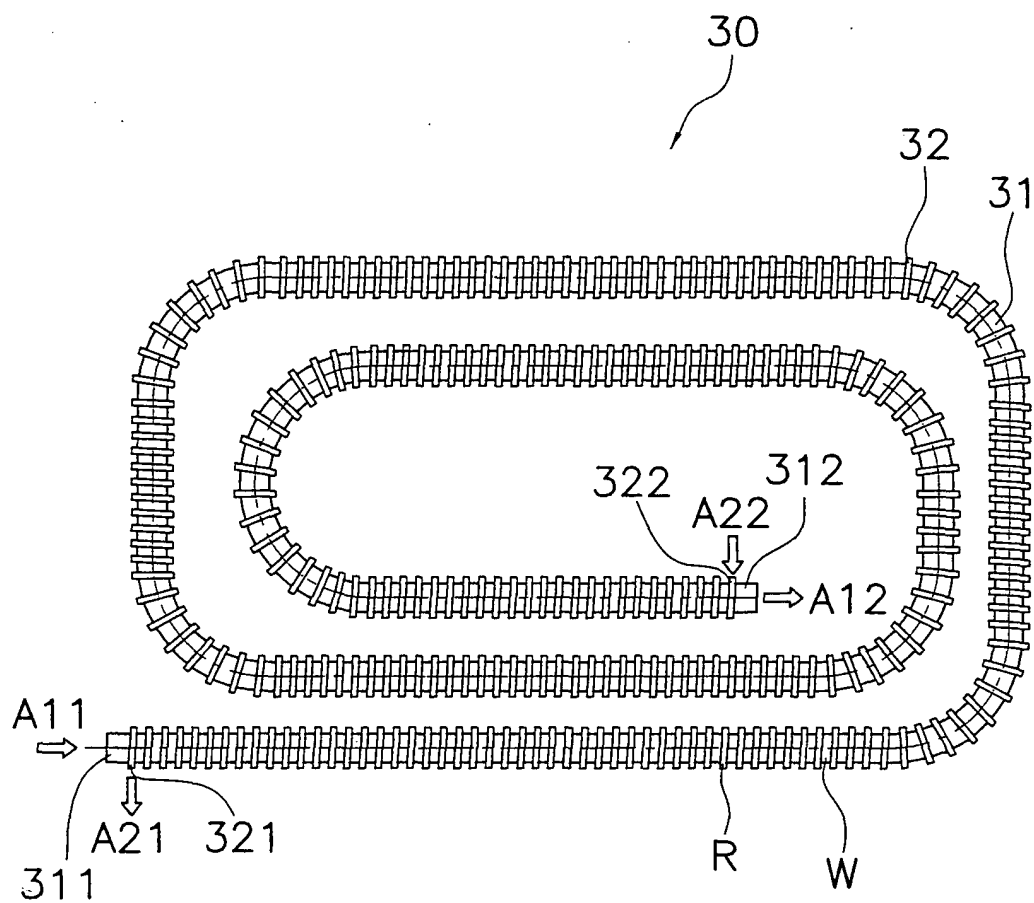


Fig. 2

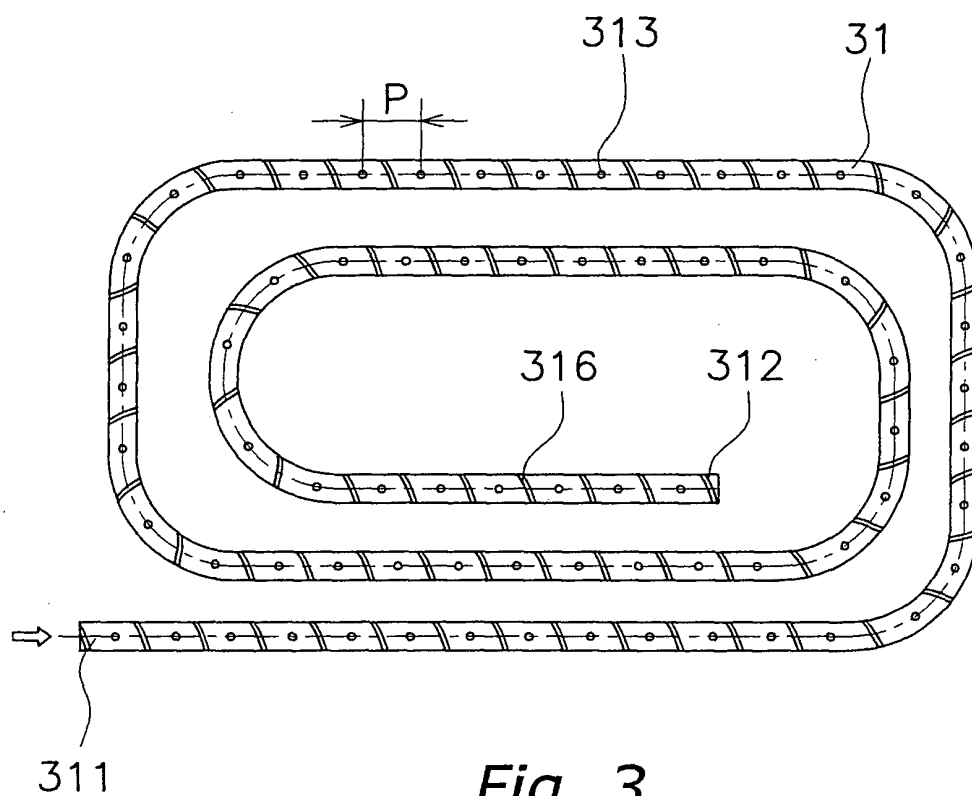


Fig. 3

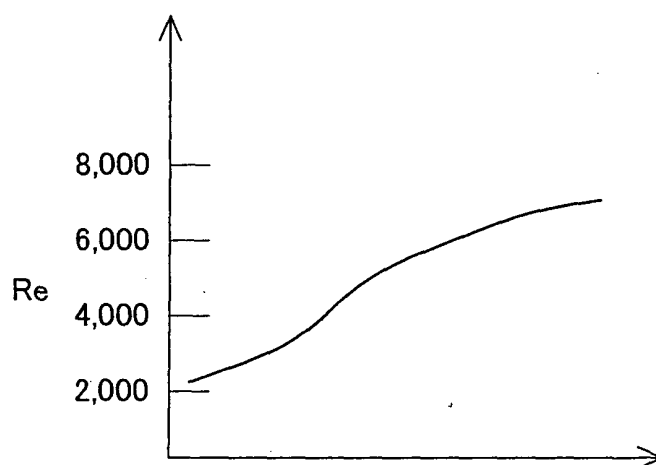


Fig. 4

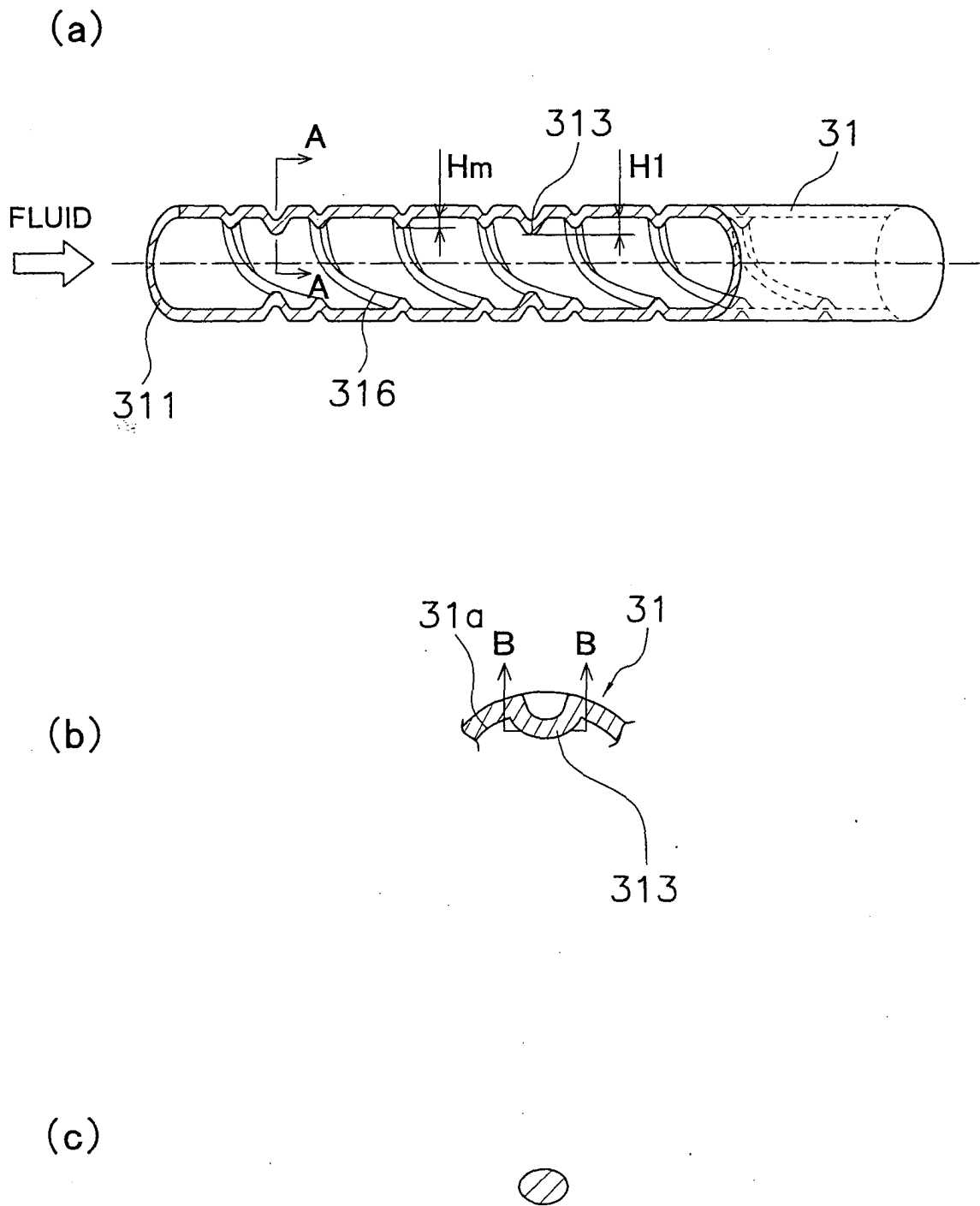
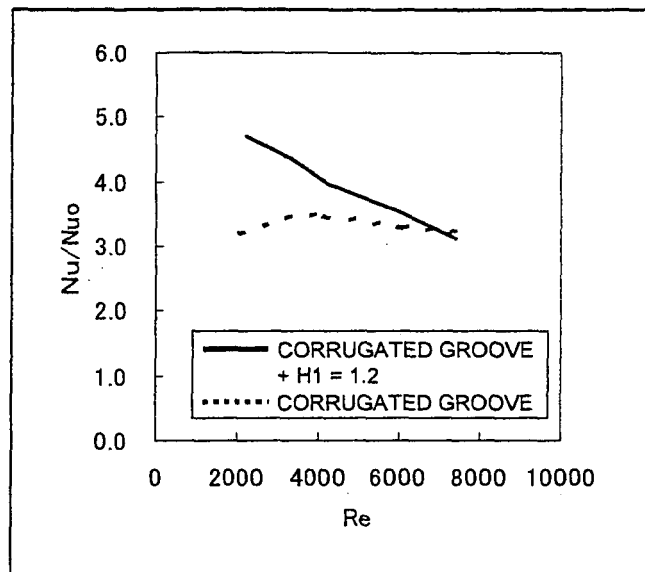


Fig. 5

(a)



(b)

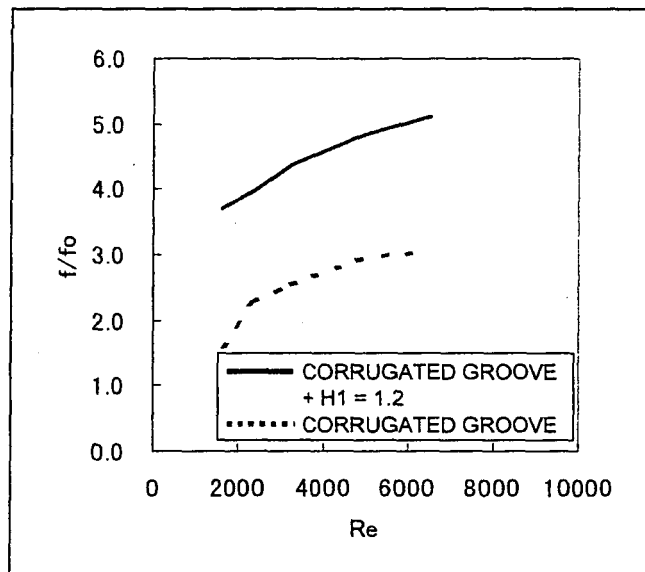
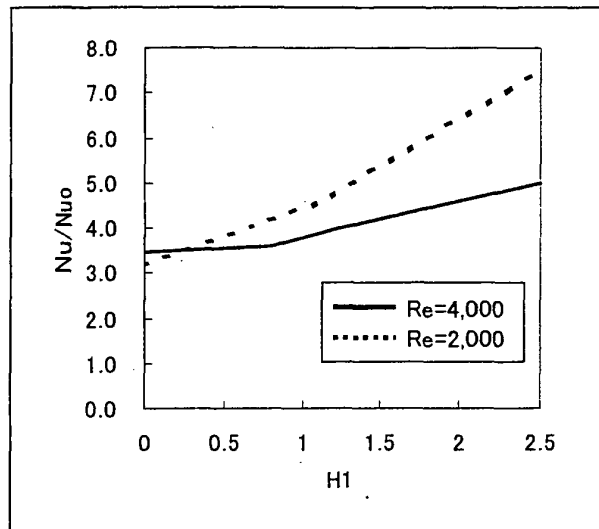
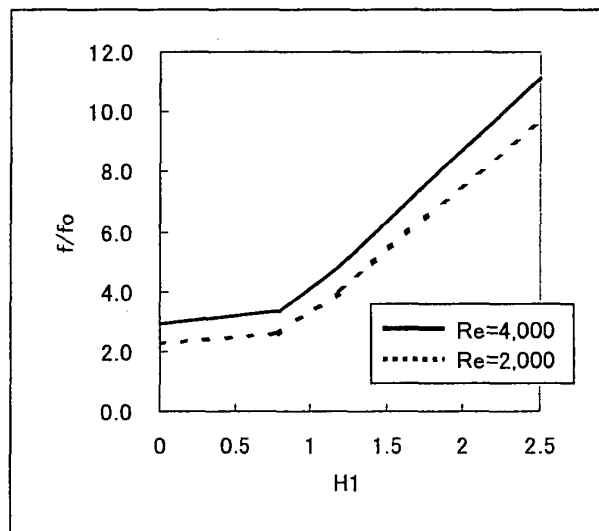


Fig. 6

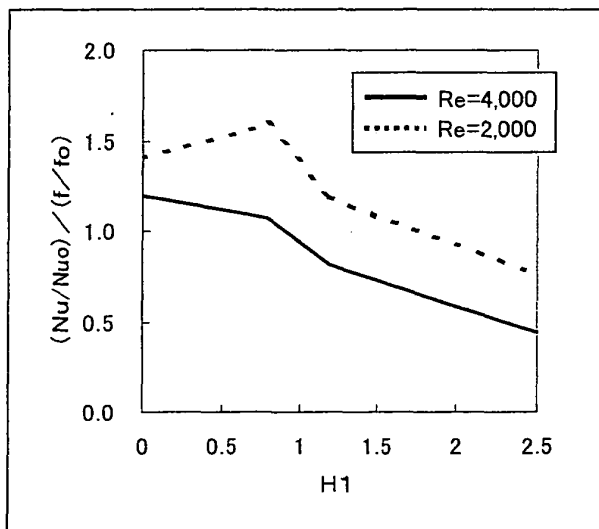
(a)



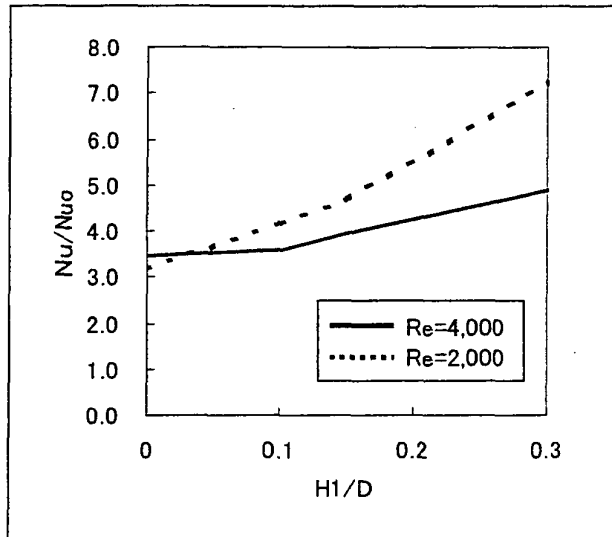
(b)



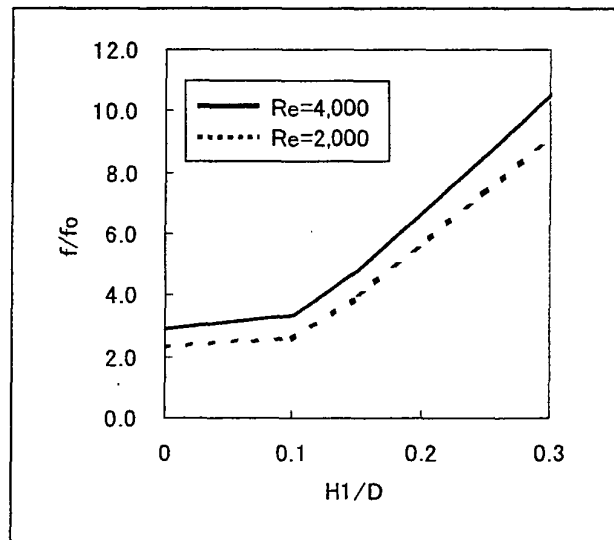
(c)

*Fig. 7*

(a)



(b)



(c)

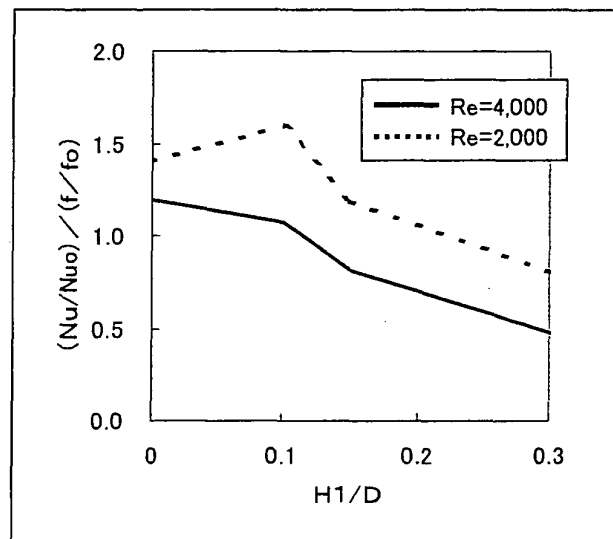
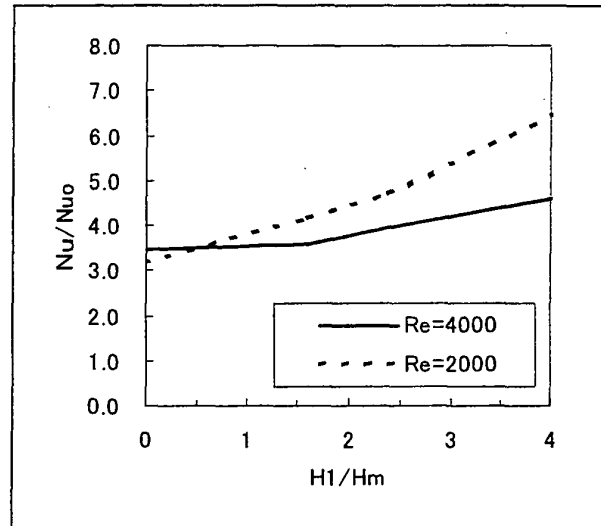
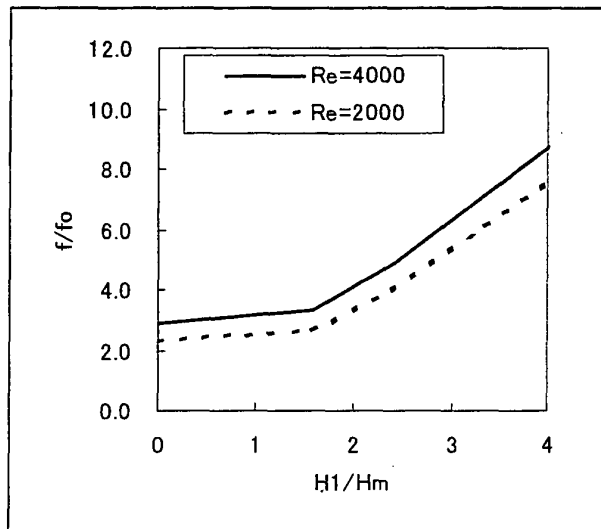


Fig. 8

(a)



(b)



(c)

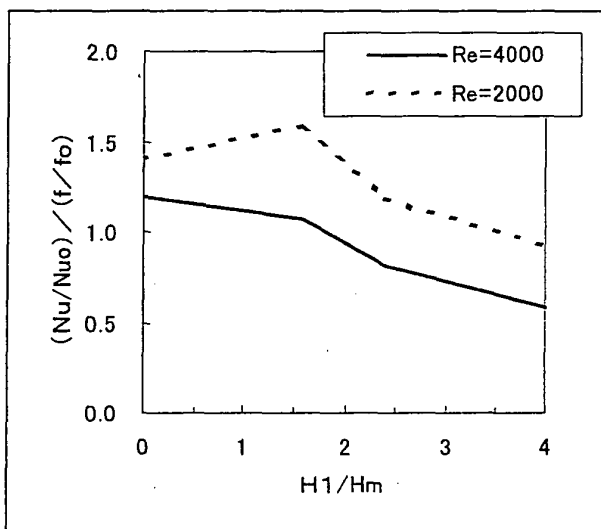


Fig. 9

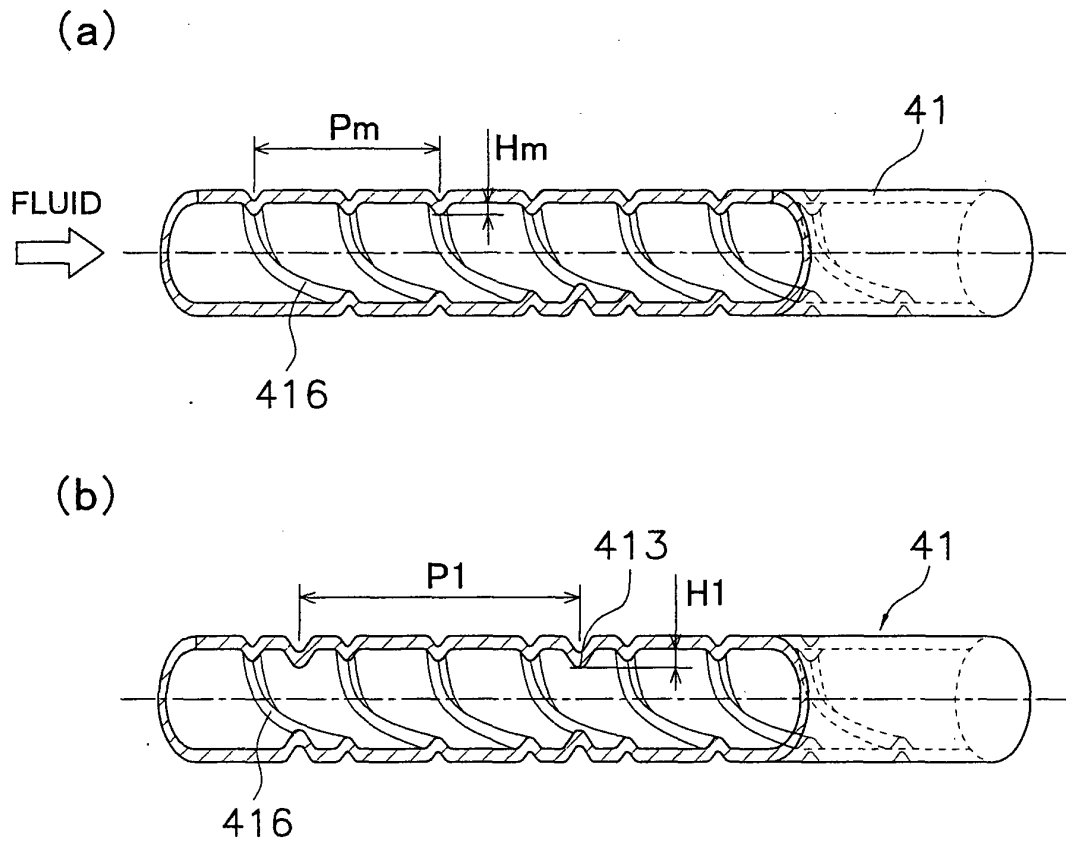


Fig. 10

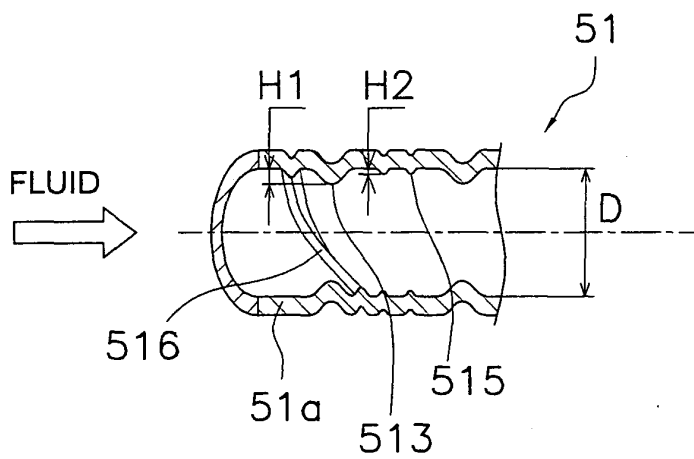


Fig. 11

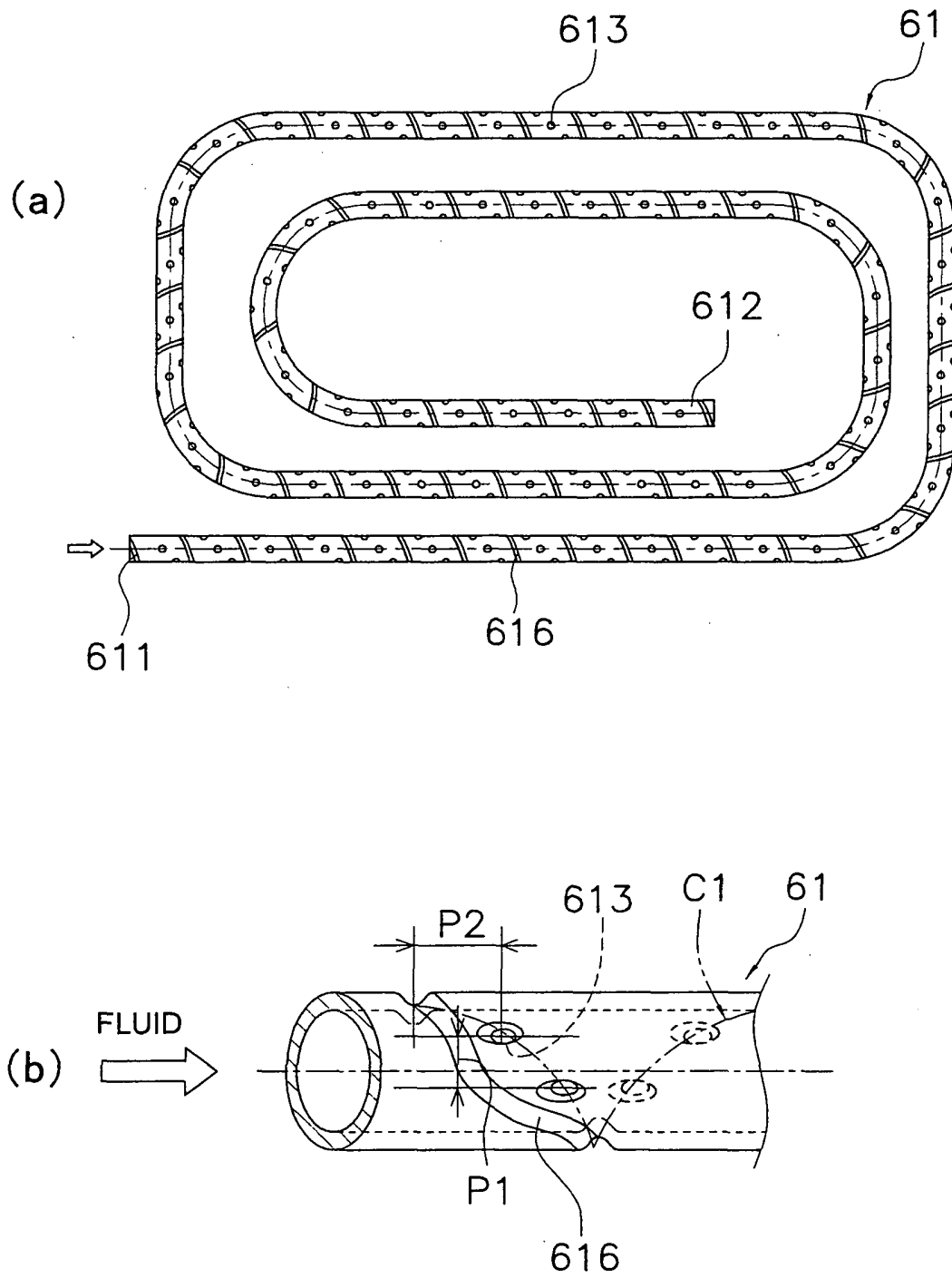


Fig. 12

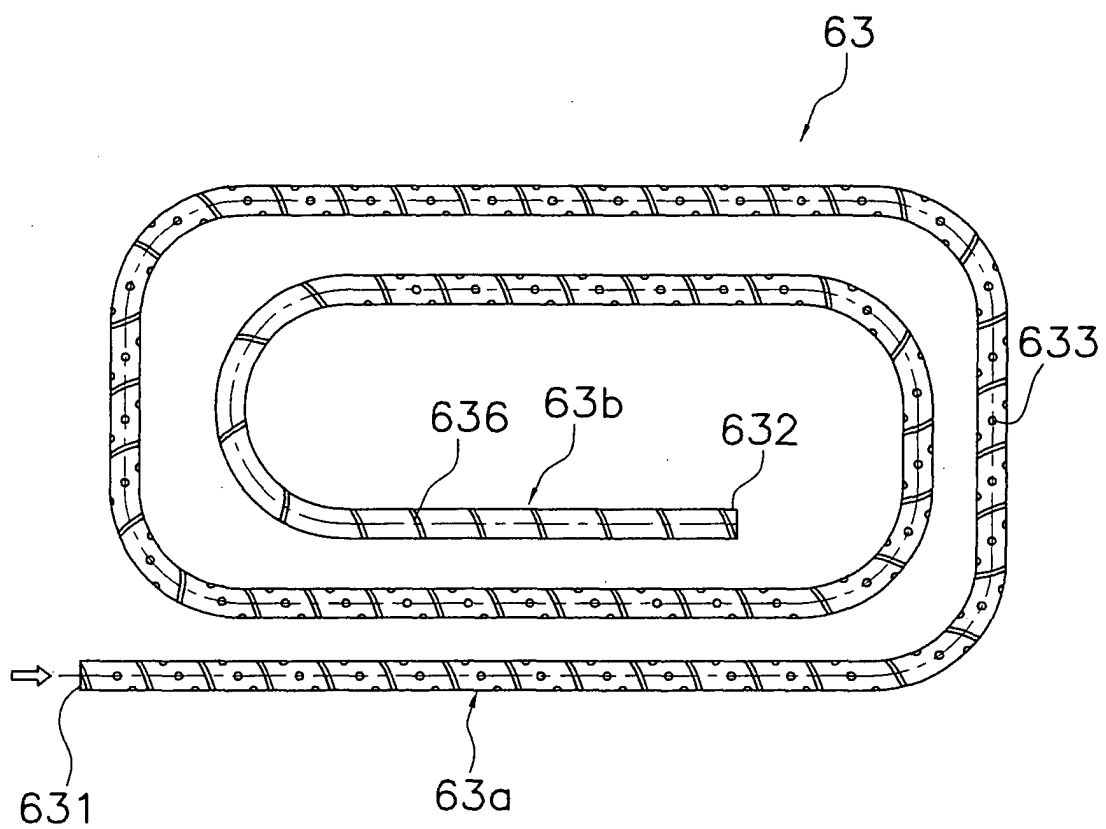


Fig. 13

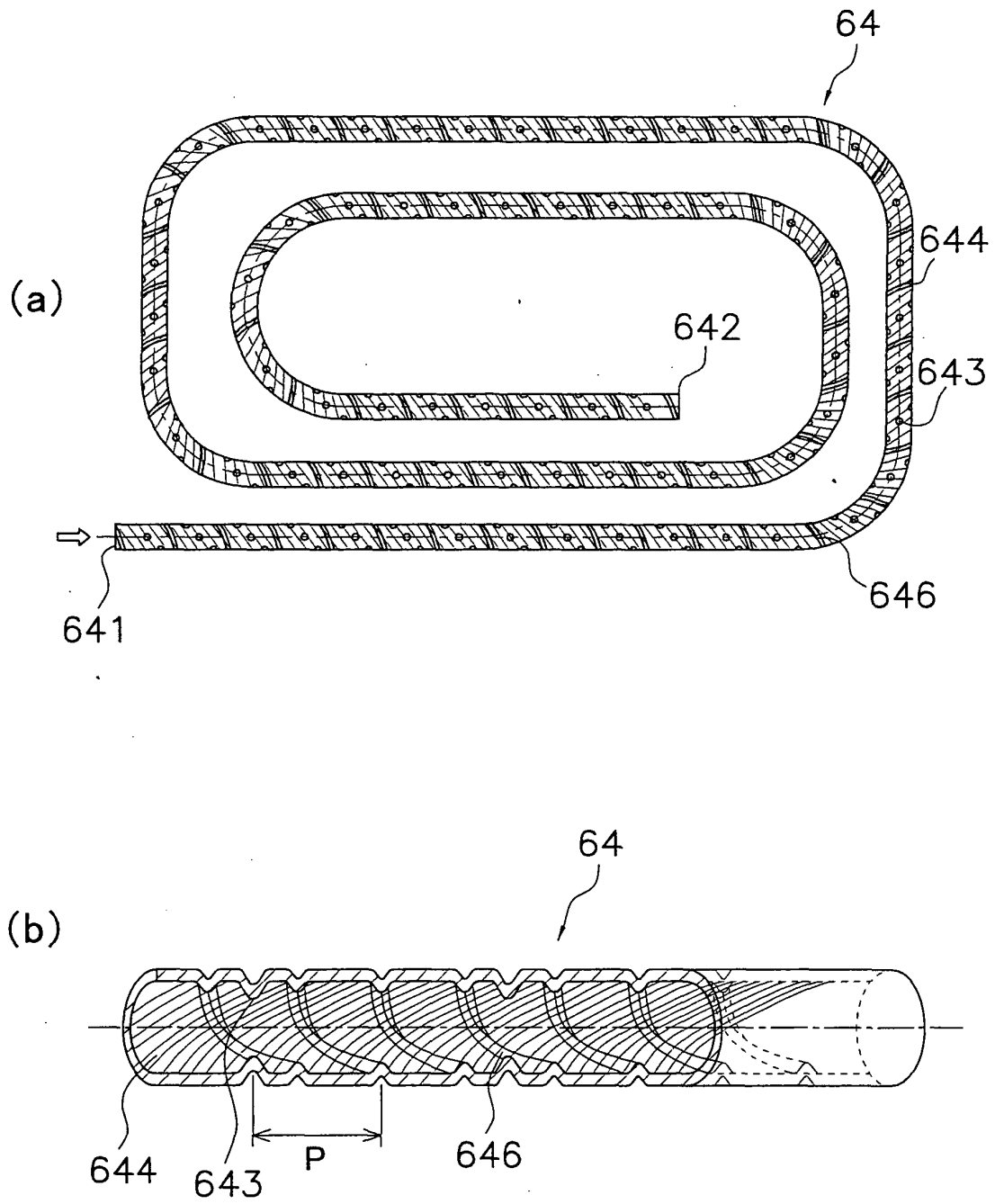


Fig. 14

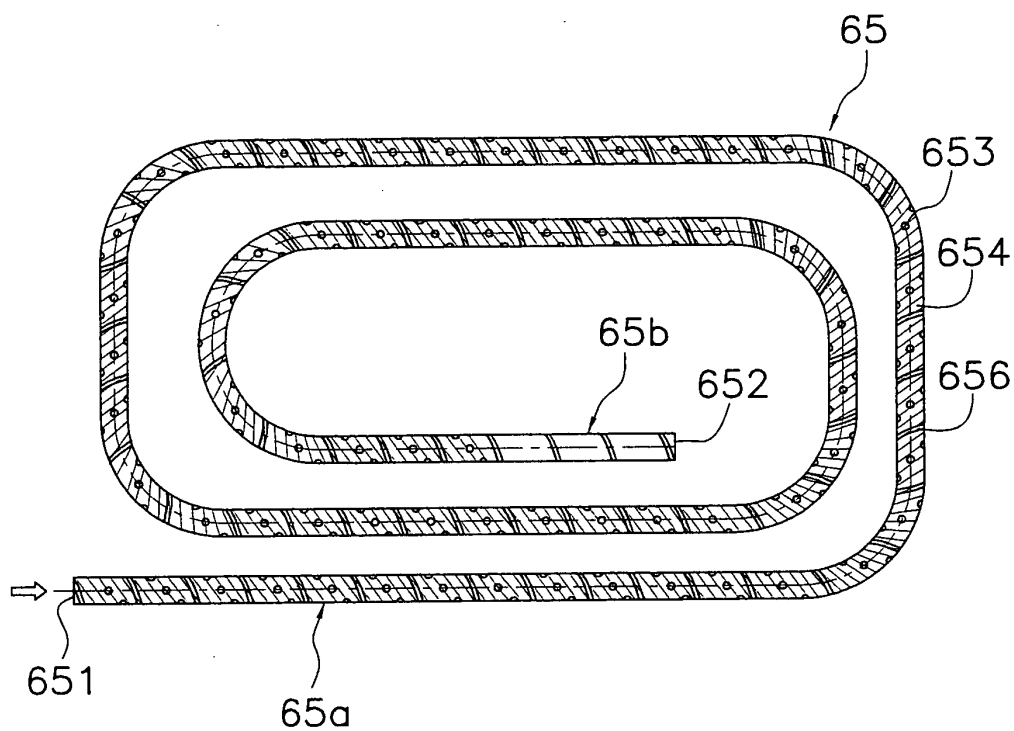


Fig. 15

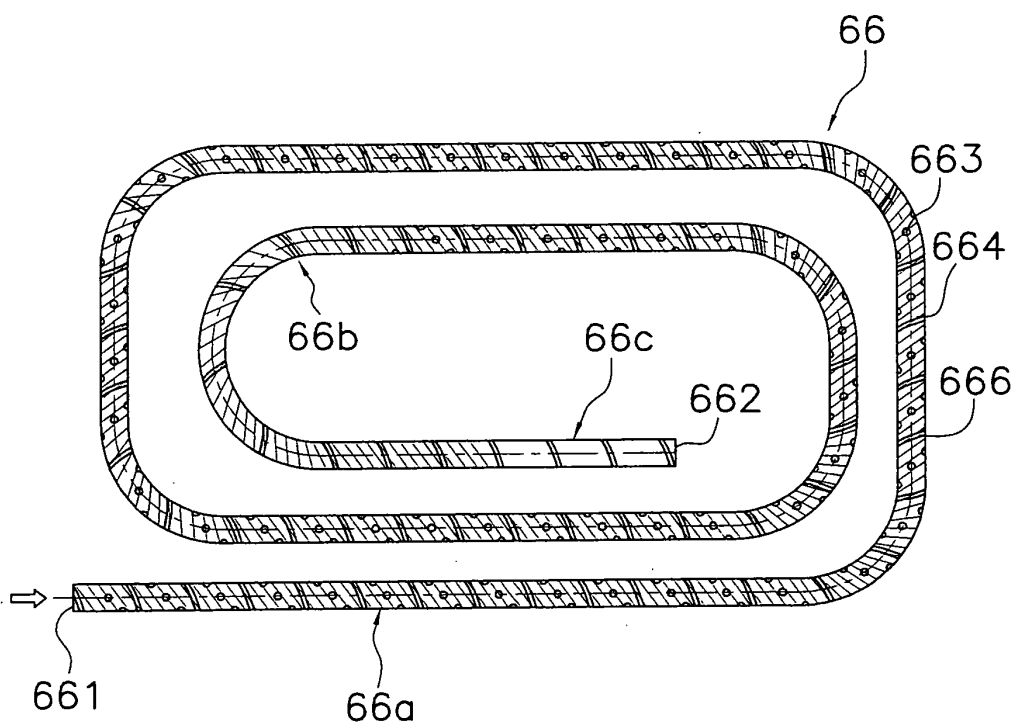


Fig. 16

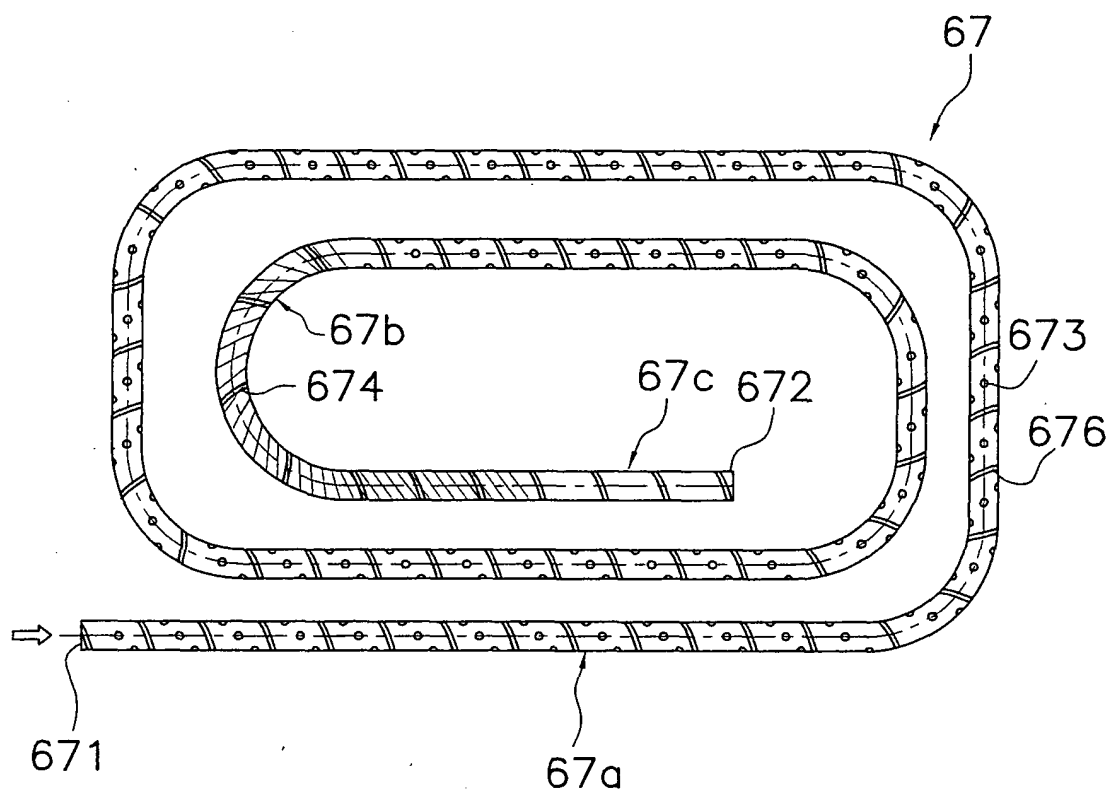


Fig. 17

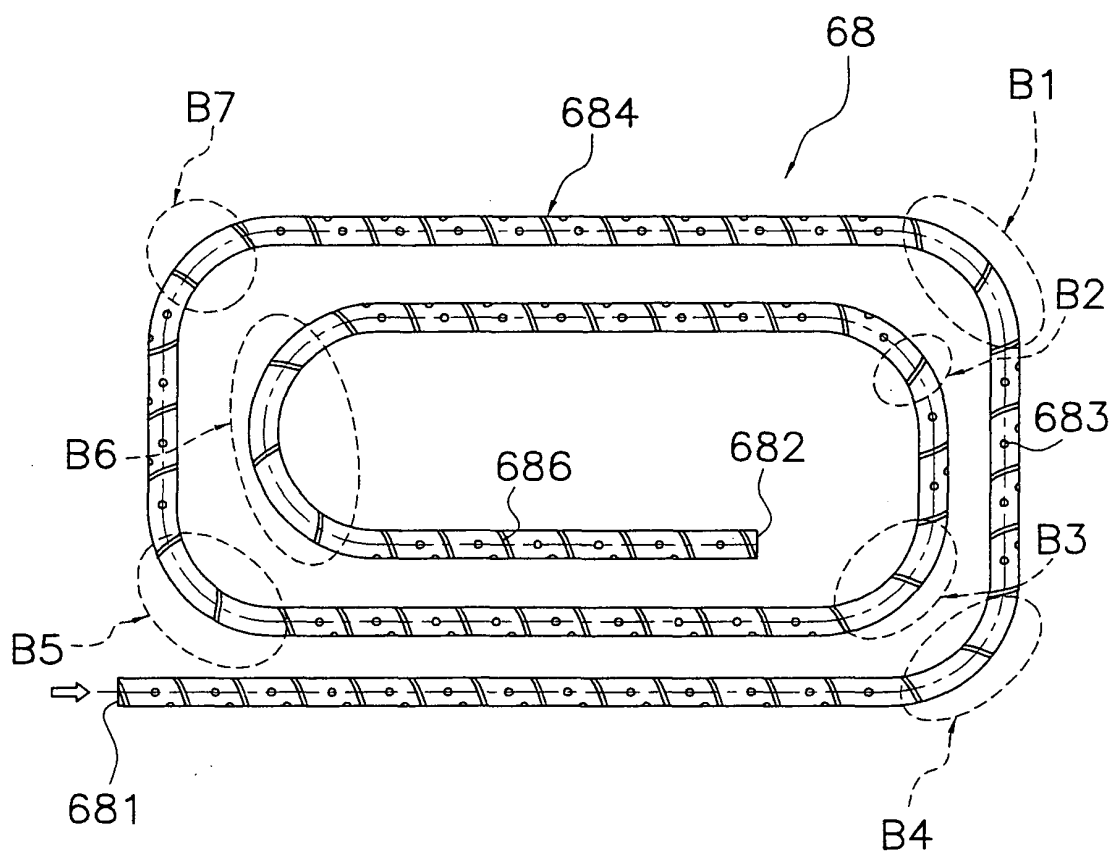


Fig. 18

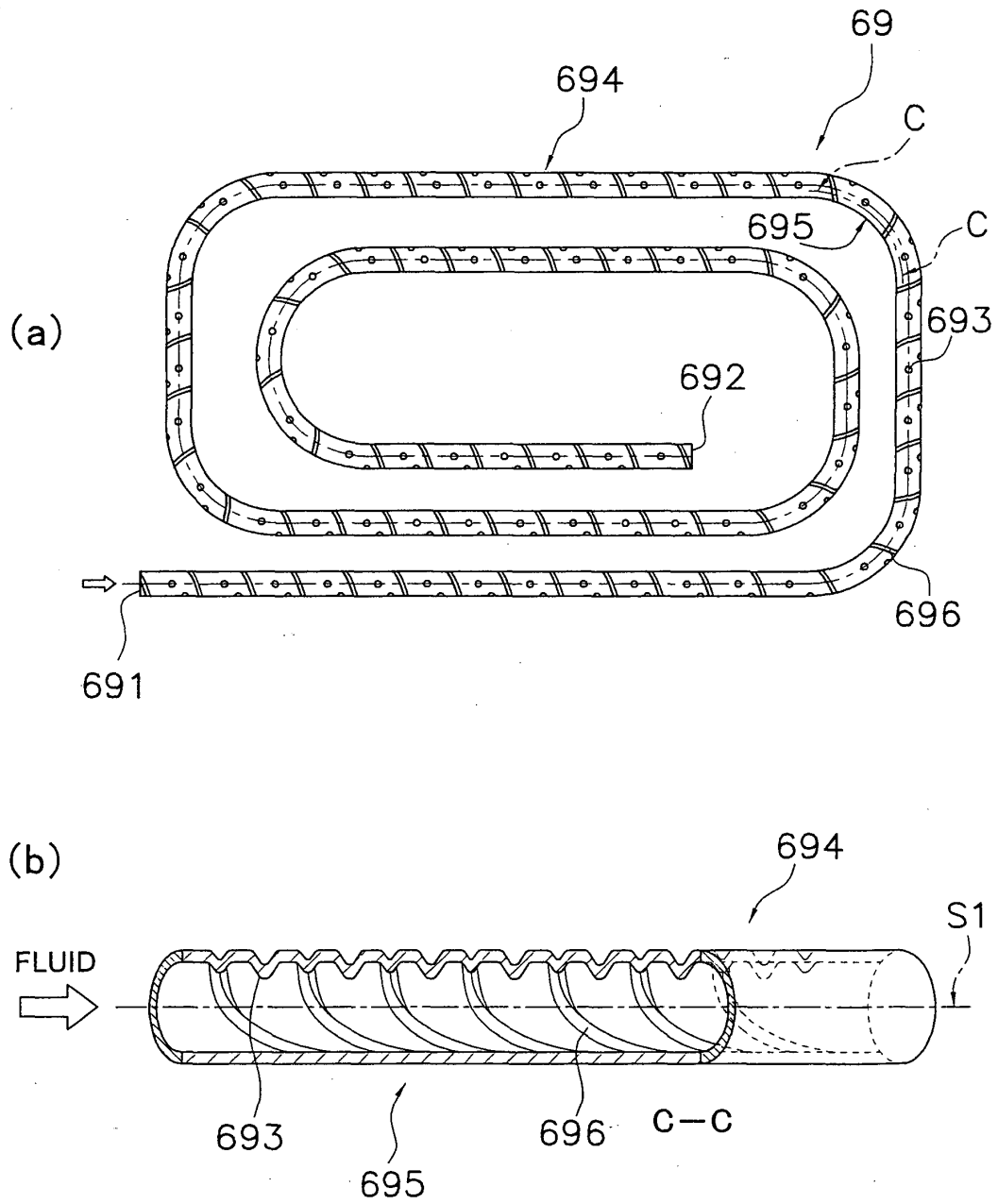


Fig. 19

Fig. 20

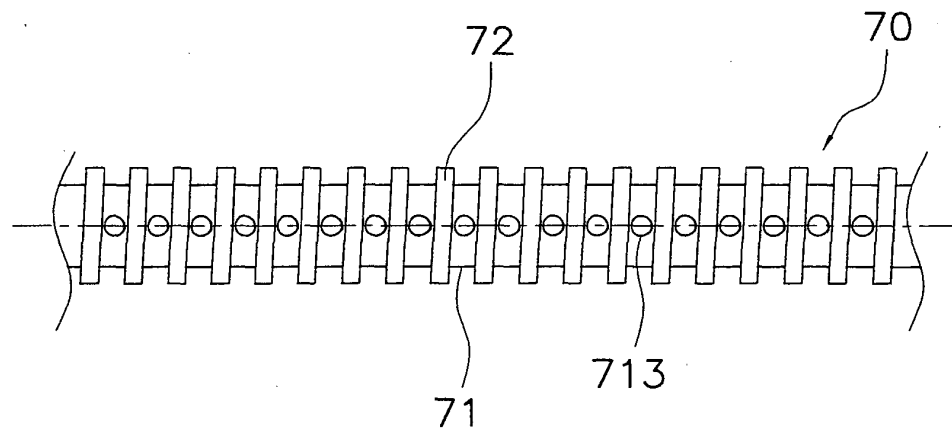
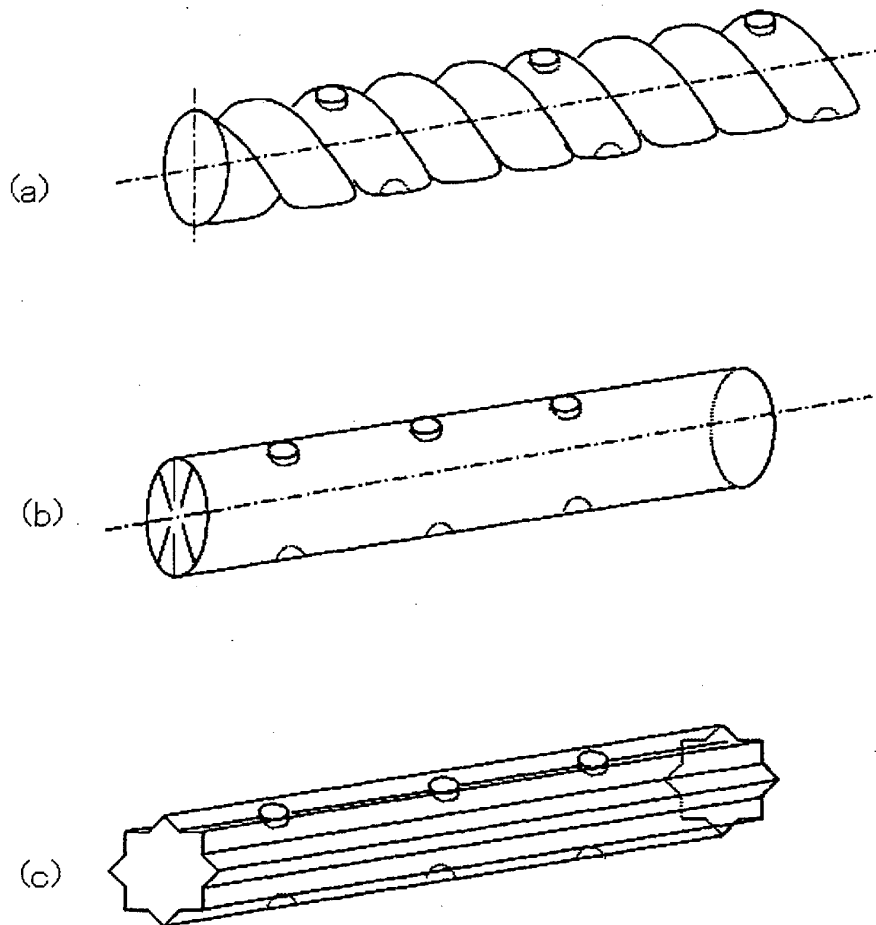


Fig. 21



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/066436

A. CLASSIFICATION OF SUBJECT MATTER <i>F28F1/40(2006.01)i, F28D7/02(2006.01)i, F28F1/10(2006.01)i, F28F13/12(2006.01)i</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) <i>F28F1/40, F28D7/02, F28F1/10, F28F13/12</i> 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 1996-2007 Kokai Jitsuyo Shinan Koho 1971-2007 Toroku Jitsuyo Shinan Koho 1994-2007 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 8-75384 A (Hitachi, Ltd.), 19 March, 1996 (19.03.96), Par. Nos. [0024], [0025], [0029]; Figs. 3, 4, 8, 9 & US 2000/6018963 A1 & CN 1122444 A	1-20
Y	JP 2005-221172 A (Daikin Industries, Ltd.), 18 August, 2005 (18.08.05), Par. No. [0027]; Fig. 1 & EP 1719964 A1 & WO 2005/075914 A1	1-20
Y	JP 6-317362 A (Hitachi Cable, Ltd.), 15 November, 1994 (15.11.94), Par. Nos. [0011], [0012]; Fig. 1 (Family: none)	4, 10
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 15 October, 2007 (15.10.07)		Date of mailing of the international search report 30 October, 2007 (30.10.07)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/066436

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-56995 A (Komatsu Electronics Kabushiki Kaisha), 26 February, 2003 (26.02.03), Par. Nos. [0069] to [0072], [0077], [0078]; Figs. 9, 11 (Family: none)	5-11, 18-20

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H0670556 B [0003]
- JP 2002228370 A [0003]