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(54) Heat exchanger

(57) A heat exchanger is provided with finned tubes (10) each fabricated by attaching fins (12) to a tube (11). Radial slits (13) are formed in a peripheral portion of the fin (12) to divide the peripheral portion into a plurality of

segments. A portion of each of the segments is bent in an axial direction of the finned tube (10) along a bending line (14) extending from a point on the radial slit to form a plurality of bent portions (15).

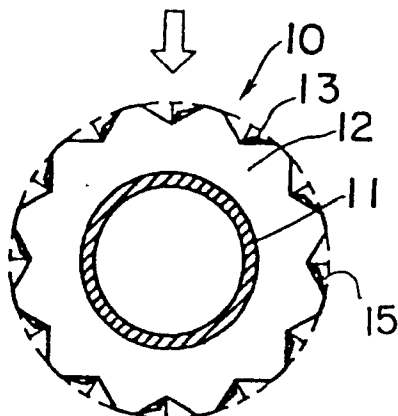


FIG. 1a

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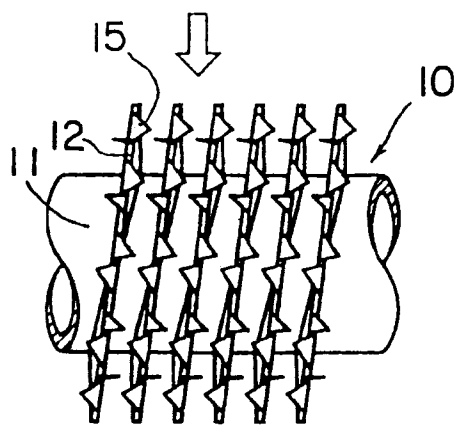


FIG. 1b

Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a heat exchanger having finned tubes for heat transfer formed by attaching fins to the outer surface of tubes, to make an internal fluid that flows through the finned tubes and an external fluid that flows outside the finned tubes exchange heat therethrough.

Description of the Related Art

Generally, a heat exchanger has a plurality of properly arranged finned tubes for heat transfer, and makes an internal fluid, such as cooling water, flowing through the finned tubes and an external fluid, such as a fluid to be cooled, flowing in a direction intersecting the axes of the finned tubes exchange heat.

The finned tubes of the heat exchanger is provided with fins to provide a large external heat transfer area and to increase the heat transfer coefficient of each finned tube. Referring to Fig. 33 showing a heat exchanger in a sectional view, a plurality parallel finned tubes 1 are arranged in a staggered arrangement. An external fluid is made to flow through the casing in the direction of the arrow intersecting the axes of the finned tubes 1, and an internal fluid is made to flow through the finned tubes 1.

A solid-fin tube as shown in Figs. 34a and 34b, and a serrated-fin tube as shown in Figs. 35a and 35b are used prevalently in heat exchangers. In Figs. 34a, 34b, 35a, 35b, 36, 37a, 37b, 38a and 38b, the arrows indicate the flowing direction of an external fluid.

The solid-fin tube shown in Figs. 34a and 34b is formed by attaching solid fins 3 to the outer circumference of a tube 2. The serrated-fin tube is formed by attaching serrated fins 3 each having segments 4, i.e., radial teeth, to the outer surface of a tube 2. Although the heat transfer area of the serrated-fin tube is smaller than that of the solid-fin tube of the same dimensions, the segments 4 of the serrated fins 3 prevents the development of a thermal boundary layer and hence the external heat transfer coefficient of the serrated-fin tube is higher than that of the solid-fin tube, and the heat-carrying capacity, i.e., the product of heat transfer area and external heat transfer coefficient, of the serrated-fin tube is not less than that of the solid-fin tube. Accordingly, the solid-fin tube or the serrated-fin tube are used selectively according to purposes.

The external fluid and the internal fluid exchange heat through the respective surfaces of the tubes 2 and the fins 3 as the external fluid flows in the direction of the arrow intersecting the axes of the fin tubes through spaces between the fin tubes. Therefore, the number of the heat exchanging tubes and the dimensions of a fin

tube heat exchanger may be smaller than those of a bare tube heat exchanger for the same heat exchanging capacity, and the heat exchanging capacity of a fin tube heat exchanger is greater than that of a bare tube heat exchanger for the same number of heat exchanging tubes.

As indicated by streamlines in Fig. 36, the flow of an external fluid flowing in the direction of the arrow separates from the outer surface of the solid-fin tube consisting of a tube and solid fins at an angular position on the outer surface of tube at an angular distance from a stagnation point to form a wake behind the tube. The flow velocity of the external fluid in the wake is substantially zero or the external fluid flows in the reverse direction in the wake. Therefore, local external heat transfer coefficient is very low. Accordingly, a portion of the fin in the wake contributes scarcely to heat transfer and the effect of the fin on increasing heat transfer area is not fully exercised. The condition of a wake formed behind the serrated-fin tube is substantially the same as that of the wake formed behind the solid-fin tube, and even the serrated fin has a portion which does not contribute to heat transfer.

An invention proposed in JP-A No.165897/1981 to improve external heat transfer coefficient by suppressing the separation of the flow of an external fluid attaches resistors 5 having the shape of a plate of an appropriate width to fins 3 at positions obliquely behind a tube 2 where the flow of an external fluid separates from the tube 2 as shown in Figs. 37a and 37b or bends portions of fins 3 at positions obliquely behind a tube 2 as shown in Figs. 38a and 38b to form resistors 6. These resistors 5 and 6 deflect the flow of the external fluid separating from the tube 2 toward the downstream side of the fin tube to enhance the external heat transfer coefficient of the fin tube.

The position where the flow of the external fluid separates from the tube and the shape and condition of the wake are dependent on matters specifying the condition of the external fluid, such as the type, temperature, pressure and flow velocity of the external fluid. Therefore, the position, the range **L** covered by the bent portion (Figs. 37a and 38a) and the height **h** (Fig. 38b) of the bent portion must be determined taking into consideration matters specifying the condition of the external fluid.

The range **L** covered by the bent portion 5 of Figs. 37a and 37b can be adjusted by properly determining the width of the bent portion 5, however, the range **L** covered by the resistor 6 of Figs. 38a and 38b is dependent on the height **h** of the fin 3. The sectional area of passages between the fins 3 is reduced by the resistors 5, and if the range **L** is great, the reduction of the sectional area of the passages causes an unignorable pressure loss of the external fluid, and the resistors 5 increase the weight of the heat exchanger. In the fin 3 of Figs. 38a and 38b, the height **h** of the resistor 6 is geometrically dependent on the range **L**.

Thus, it is difficult to determine an optimum range

to be covered by a bent portion and an optimum size, which are the most important factors for suppressing the separation of the external fluid from the tube, by the prior art method and hence the prior art method is unable to provide an optimum wake control effect.

SUMMARY OF THE INVENTION

The present invention has been made in view of the foregoing problems in the prior art and it is therefore an object of the present invention to provide a heat exchanger of a high heat transfer performance provided with finned tubes each having fins provided in their peripheral portions with bent portions of a shape having a high degree of freedom of design according to the condition of an external fluid, and capable of effectively controlling the separation of the flow of the external fluid from the tube and of reducing a wake on the downstream side of the corresponding finned tube to enhance the local external heat transfer coefficient by the heat transfer area increasing effect thereof.

According to a first aspect of the present invention, a heat exchanger comprises a tube having an axis intersecting a flow direction of an external fluid, and fins attached to an outer surface of the tube. Each fin is provided in its peripheral portion with a plurality of bent portions. The bent portions are formed by forming radial slits in the peripheral portion of the fin to divide the peripheral portion into a plurality of segments, and bending each segment in an axial direction of the tube along a bending line extending from a point on the radial slit.

In the heat exchanger in the first aspect of the present invention, each of the bending lines may extend between the point on the radial slit and a point on the outer circumference of the fin.

In the heat exchanger in the first aspect of the present invention, each of the bending lines may extend between the point on the radial slit and a point on another radial slit adjacent to the radial slit. In this heat exchanger, the point on one of the adjacent radial slits and the point on the other radial slit may not be on the same circle having its center on the axis of the tube. In this heat exchanger, the point on one of the adjacent radial slits and the point on the other radial slit may be on the same circle having its center on the axis of the tube.

In the heat exchanger according to the first aspect of the present invention, the bent portions may be formed by in the same direction bending the segments formed by dividing the peripheral region of the fin by the radial slits.

In the heat exchanger according to the present invention, the bent portions may be formed by alternately in opposite directions bending the segments formed by dividing the peripheral portion of the fin by the radial slits.

In the heat exchanger according to the present invention, the bent portions may be formed by bending

the alternate segments formed by dividing the peripheral portion of the fin by the radial slits.

In the heat exchanger according to the present invention, the bent portions may be formed by in the same direction bending the alternate segments formed by dividing the peripheral portion of the fin by the radial slits.

In the heat exchanger according to the present invention, the bent portions may be formed only in a specific circumferential range in the peripheral portion of each fin corresponding to a region in which streams of the external fluid separate from the tube.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the present invention will be described hereinafter with reference to the accompanying drawings, in which:

Fig. 1a is a sectional view of a finned tube employed in a heat exchanger in a first embodiment according to the present invention;

Fig. 1b is a side view of the finned tube of Fig. 1a; Fig. 2 is a fragmentary plan view of a fin of assistance in explaining bent portions shown in Figs. 1a and 1b;

Fig. 3 is a perspective view of bent portions shown in Figs. 1a and 1b;

Fig. 4 is a diagrammatic view showing streamlines representing the flow of an external flow around the finned tube of Fig. 1a;

Fig. 5 is a graph showing the external heat transfer characteristic of a heat exchanger in accordance with the present invention;

Fig. 6 is a sectional view of a finned tube provided with fins having the same bent portions as those of the fins employed in the first embodiment only in a specific circumferential range in the peripheral portion of each fin;

Fig. 7a is a sectional view of a finned tube employed in a heat exchanger in a second embodiment according to the present invention;

Fig. 7b is a side view of the finned tube of Fig. 7a; Fig. 8 is a perspective view of a bent portion shown in Figs. 7a and 7b;

Fig. 9 is a sectional view of a finned tube provided with fins having the same bent portions as those of the fins employed in the second embodiment only in a specific circumferential range in the peripheral portion of each fin;

Fig. 10a is a sectional view of a finned tube employed in a heat exchanger in a third embodiment according to the present invention;

Fig. 10b is a side view of the finned tube of Fig. 10a; Fig. 11 is a sectional view of a finned tube provided with fins having the same bent portions as those of the fins employed in the third embodiment only in a specific circumferential range in the peripheral portion of each fin;

Fig. 12a is a sectional view of a finned tube employed in a heat exchanger in a fourth embodiment according to the present invention;

Fig. 12b is a side view of the finned tube of Fig. 12a;

Fig. 13 is a perspective view of bent portions shown in Figs. 12a and 12b;

Fig. 14 is a sectional view of a finned tube provided with fins having the same bent portions as those of the fins employed in the fourth embodiment only in a specific circumferential range in the peripheral portion of each fin;

Fig. 15a is a sectional view of a finned tube employed in a heat exchanger in a fifth embodiment according to the present invention;

Fig. 15b is a side view of the finned tube of Fig. 15a;

Fig. 16 is a sectional view of a finned tube provided with fins having the same bent portions as those of the fins employed in the fifth embodiment only in a specific circumferential range in the peripheral portion of each fin;

Fig. 17a is a sectional view of a finned tube employed in a heat exchanger in a sixth embodiment according to the present invention;

Fig. 17b is a side view of the finned tube of Fig. 17a;

Fig. 18 is a fragmentary plan view of a fin of assistance in explaining bent portions shown in Figs. 17a and 17b;

Fig. 19 is a perspective view of a bent portion shown in Figs. 17a and 17b;

Fig. 20 is a sectional view of a finned tube provided with fins having the same bent portions as those of fins employed in the sixth embodiment only in a specific circumferential range in the peripheral portion of each fin;

Figs. 21a is a sectional view of a finned tube employed in a heat exchanger in a seventh embodiment according to the present invention;

Fig. 21b is a side view of the finned tube of Fig. 21a;

Fig. 22 is a fragmentary plan view of a fin of assistance in explaining bent portions shown in Figs. 21a and 21b;

Fig. 23 is a perspective view of bent portions shown in Figs. 21a and 21b;

Fig. 24 is a perspective view of inappropriate bent portions;

Fig. 25 is a sectional view of a finned tube provided with fins having the same bent portions as those of the fins employed in the seventh embodiment only in a specific circumferential range in the peripheral portion of each fin;

Fig. 26a is a sectional view of a finned tube employed in a heat exchanger in an eighth embodiment according to the present invention;

Fig. 26b is a side view of the finned tube of Fig. 26a;

Fig. 27 is a perspective view of bent portions shown in Figs. 26a and 26b;

Fig. 28 is a sectional view of a finned tube provided with fins having the same bent portions as those of

the fins employed in the eighth embodiment only in a specific circumferential range in the peripheral portion of each fin;

Fig. 29a is a sectional view of a finned tube employed in a heat exchanger in a ninth embodiment according to the present invention;

Fig. 29b is a side view of the finned tube of Fig. 29a;

Fig. 30 is a perspective view of bent portions shown in Figs. 29a and 29b;

Fig. 31 is a sectional view of a finned tube provided with fins having the same bent portions as those of the fins employed in the ninth embodiment only in a specific circumferential range in the peripheral portion of each fin;

Fig. 32 is a sectional view of a finned tube employed in a heat exchanger in a tenth embodiment according to the present invention;

Fig. 33 is a longitudinal sectional view of a heat exchanger;

Fig. 34a is a sectional view of a conventional solid-fin tube;

Fig. 34b is a side view of the solid-fin tube of Fig. 34a;

Fig. 35a is a sectional view of a conventional serrated-fin tube;

Fig. 35b is a side view of the serrated-fin tube of Fig. 35a;

Fig. 36 is a diagrammatic view showing streamlines representing the flow of an external fluid around a conventional finned tube;

Fig. 37a is a sectional view of another conventional finned tube;

Fig. 37b is a side view of the finned tube of Fig. 37a;

Fig. 38a is a sectional view of a third conventional finned tube;

Fig. 38b is a side view of the finned tube of Fig. 38a.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figs. 1a and 1b are sectional view and a side view, respectively, of a finned tube 10 employed in a heat exchanger in a first embodiment according to the present invention. The finned tube 10 is fabricated by attaching fins 12 having the shape of a circular plate to the outer surface of a tube 11. The arrows shown in Figs. 1a through 32, similarly to that shown in Fig. 33, indicate the flowing direction of an external fluid.

A plurality of radial slits 13, twelve radial slits in Fig. 1a, are formed in a peripheral portion of the fin 12 to divide the peripheral portion into a plurality of segments, and portions of each segment are bent in an axial direction of the tube 11 along bending lines 14, which will be described below.

Referring to Fig. 2, the radial slits 13 are formed in the peripheral portion of the fin 12. The bending lines 14 extend between a point **a** on each radial slit and points **b** on the circumference of the fin 12 on the opposite

sides of the radial slit 13, respectively. Substantially triangular portions of the fin 12 defined by the bending lines 14, the radial slit 13 and sections of the outer circumference of the fin 12 are bent in opposite directions substantially perpendicular to the surface of the fin 12 along the bending lines 14 to form substantially triangular bent portions 15. Thus, the bent portions 15 project alternately in opposite directions from one of the surfaces of the fin 12 and the other surface of the same as shown in Fig. 3.

The point **a** need not necessarily be at the inner end of the radial slit 13 as shown in Fig. 2, but may be at any suitable point between the outer and the inner end of the radial slit 13 as indicated at **a'** in Fig. 2 depending on the length of the radial slit 13 and intervals between the fins 12 on the tube 11.

The optimum dimensions and optimum positions of the bent portions 15 can be determined by properly determining the length and positions of the radial slits 13. Thus, the bent portions 15 has a high degree of freedom of design.

The finned tubes 10 thus fabricated are arranged with their axes extended so as to intersect the flowing direction of the external fluid indicated by the arrow to construct a heat exchanger. Referring to Fig. 4 showing streamlines representing the flow of the external fluid around one of the finned tubes 10 of this heat exchanger, the external fluid is deflected by an upstream section of the outer surface of the tube 11 so as to flow along an upper section and a lower section of the outer surface of the tube 11, and then streams of the external fluid flowing along upper and lower sections of the outer surface of the tube 11 are deflected by the bent portions 15 toward a region directly behind the tube 11 so that the external fluid flows substantially along a downstream section of the outer surface of the tube 11 and a wake is scarcely formed behind the tube 11. Although a region in which the external fluid separates from the tube 11 and the size of a wake are dependent on the type and the flow velocity of the external fluid, the size of the wake is reduced greatly by the bent portions 15 formed by bending the segments formed by dividing the peripheral portion of the disk 12 by the radial slits 13 as mentioned above, and the size of the wake is far smaller than that of a wake which would be formed if the disks 12 are not provided with the bent portions 15.

Since the external fluid flows toward the region behind the finned tube 10, in which a wake is formed if the fins 12 are not provided with the bent portions 15, the flow velocity of the external fluid increases in the region behind the finned tube 10, whereby local external heat transfer coefficient is increased; that is, the entire surfaces of the fins 12 contribute to heat transfer, so that the effective heat transfer area of the fins 12 can be increased. Since the disadvantage of the conventional finned tube that the local external heat transfer coefficient of the downstream side of the finned tube is very low as compared with that of the upstream side of the

same can be overcome by the present invention, and the average external heat transfer coefficient of the finned tube 10 is very high as compared with that of the conventional finned tube.

Fig. 5 is a graph comparatively showing the respective heat transfer characteristics of the heat exchanger of the present invention and a conventional heat exchanger, in which approach flow velocity is measured to the right on the horizontal axis and average external heat transfer coefficient is measured upward on the vertical axis. It is known from Fig. 5 that the bent portions 15 increases the average external heat transfer coefficient of the finned tube greatly.

Incidentally, since each fin of the finned tubes employed in the heat exchanger in this embodiment is provided with the bent portions 15 distributed over the entire outer circumference thereof, the finned tubes are suitable for use in a heat exchanger which is required to operate under conditions where the flow velocity of the external fluid varies in a wide flow velocity range, and a region in which the streams of the external fluid tend to separate from the tube of the finned tube and a region in which a wake is formed are variable.

If the flow velocity of the external fluid is constant, and a region in which the streams of the external fluid tend to separate from the tube of the finned tube and a region in which a wake is formed are invariable, the radial slits 13 may be formed in a specific circumferential range in the peripheral portion of the fin 12 as shown in Fig. 6 to form the bent portions 15 only in the specific circumferential range in the peripheral portion of the fin 12 corresponding to a region in which the streams of the external fluid tend to separate from the tube of the finned tube and a region in which a wake is formed. The bent portions 15 formed only in such a specific circumferential range in the peripheral portion of each fin 12 are effective in deflecting the flow of the external fluid toward the region directly behind the tube 11 in which a wake is liable to be formed, and the reduced number of the bent portions 15 limits pressure loss to the least unavoidable extent.

Figs. 7a and 7b are sectional view and a side view, respectively, of a finned tube 10 employed in a heat exchanger in a second embodiment according to the present invention. The finned tube 10 is fabricated by attaching fins 12 to a tube 11. A plurality of slits 13 are formed in a peripheral portion of each fin 12 to divide the peripheral portion into a plurality of segments. Only one portion of each segment is bent to form a bent portion 15. The segments are bent alternately in opposite directions so that the bent portions 15 project alternately in opposite directions. Fig. 8 is a perspective view of the bent portion 15.

The bent portions 15, similarly to those of the finned tube 10 employed in the first embodiment, deflect streams of the external fluid flowing along upper and lower sections of the outer surface of the tube 11 toward a region directly behind the tube 11 so that the external

fluid flows substantially along a downstream section of the outer surface of the tube 11 and a wake is scarcely formed behind the tube 11.

Since the external fluid flows toward the region behind the finned tube 10, in which a wake is formed if the fins 12 are not provided with the bent portions 15, the flow velocity of the external fluid increases in the region behind the finned tube 10, whereby local external heat transfer coefficient is increased; that is, the entire surfaces of the fins 12 contribute to heat transfer, so that the effective heat transfer area of the fins 12 can be increased. Consequently, the flow velocity of the external fluid in the region behind the tube 11 increases, local external heat transfer coefficient is increased and hence the average external heat transfer coefficient is increased greatly.

The radial slits 13 may be formed in a specific circumferential range in the peripheral portion of the fin 12 as shown in Fig. 9 to form the bent portions 15 only in the specific circumferential range in the peripheral portion of the fin 12 corresponding to a region in which the streams of the external fluid tend to separate from the tube 11 of the finned tube 10. The bent portions 15 formed only in such a specific circumferential range in the peripheral portion of each fin 12 are effective in deflecting the flow of the external fluid toward the region directly behind the tube 11 in which a wake is liable to be formed and exercise the same effect as those previously mentioned in connection with the description of the first embodiment.

Figs. 10a and 10b are sectional view and a side view, respectively, of a finned tube 10 employed in a heat exchanger in a third embodiment according to the present invention. The finned tube 10 is fabricated by attaching fins 12 to a tube 11. A plurality of slits 13 are formed in a peripheral portion of each fin 12 to divide the peripheral portion into a plurality of segments, and the segments are bent in the same direction to form bent portions 15 projecting from one of the surfaces of the fin 12. The finned tube 10 is similar in other respects to the finned tube 10 employed in the heat exchanger in the second embodiment shown in Figs. 7a, 7b and 8.

The bent portions 15, similarly to those of the finned tube 10 employed in the second embodiment, deflect streams of the external fluid which tend to separate from the tube 11 toward a region directly behind the tube 11 so that the external fluid flows substantially along a downstream section of the outer surface of the tube 11 and, therefore, a wake is scarcely formed behind the tube 11. Consequently, the flow velocity of the external fluid in the region behind the finned tube 10 increases, whereby the average external heat transfer coefficient of the finned tube 10 is increased greatly.

The radial slits 13 may be formed in a specific circumferential range in the peripheral portion of the fin 12 as shown in Fig. 11 to form the bent portions 15 only in the specific circumferential range in the peripheral portion of the fin 12 corresponding to a region in which the

streams of the external fluid tend to separate from the tube 11 of the finned tube 10.

Figs. 12a and 12b are sectional view and a side view, respectively, of a finned tube 10 employed in a heat exchanger in a fourth embodiment according to the present invention. The finned tube 10 is fabricated by attaching fins 12 to a tube 11. A plurality of slits 13 are formed in a peripheral portion of each fin 12 to divide the peripheral portion into a plurality of segments. Adjacent substantially triangular sections of the adjacent segments respectively on the opposite sides of each radial slit 13 (Fig. 2) are bent in the same direction to form a pair of bent portions 15, as shown in Fig. 13. Thus, the pairs of adjacent substantially triangular sections of the segments are bent alternately in opposite directions so that the pairs of bent portions project alternately in opposite directions from one of the surfaces of the fin 12 and from the other surface of the same.

The bent portions 15, similarly to those of the finned tube 10 employed in the first embodiment, deflect streams of the external fluid which tend to separate from the tube 11 toward a region directly behind the tube 11 so that the external fluid flows substantially along a downstream section of the outer surface of the tube 11 and, therefore, a wake is scarcely formed behind the tube 11. Consequently, the flow velocity of the external fluid in the region behind the finned tube 10 increases and local external heat transfer coefficient is increased, whereby the average external heat transfer coefficient of the finned tube 10 is increased greatly.

The radial slits 13 may be formed in a specific circumferential range in the peripheral portion of the fin 12 as shown in Fig. 14 to form the bent portions 15 only in the specific circumferential range in the peripheral portion of the fin 12 corresponding to a region in which the streams of the external fluid tend to separate from the tube 11 of the finned tube 10.

Figs. 15a and 15b are sectional view and a side view, respectively, of a finned tube 10 employed in a heat exchanger in a fifth embodiment according to the present invention. The finned tube 10 is fabricated by attaching fins 12 to a tube 11. A plurality of slits 13 are formed in a peripheral portion of each fin 12 to divide the peripheral portion into a plurality of segments. Substantially triangular sections of the segments are bent in the same direction to form bent portions 15, as shown in Fig. 13.

The bent portions 15, similarly to those of the finned tube 10 employed in the first embodiment, deflect streams of the external fluid which tend to separate from the tube 11 toward a region directly behind the tube 11 so that the external fluid flows substantially along a downstream section of the outer surface of the tube 11 and, therefore, a wake is scarcely formed behind the tube 11. Consequently, the flow velocity of the external fluid in the region behind the finned tube 10 increases and local external heat transfer coefficient is increased, whereby the average external heat transfer coefficient

of the finned tube 10 is increased greatly.

The radial slits 13 may be formed in a specific circumferential range in the peripheral portion of the fin 12 as shown in Fig. 16 to form the bent portions 15 only in the specific circumferential range in the peripheral portion of the fin 12 corresponding to a region in which the streams of the external fluid tend to separate from the tube 11 of the finned tube 10.

Figs. 17a and 17b are sectional view and a side view, respectively, of a finned tube 10 employed in a heat exchanger in a sixth embodiment according to the present invention. The finned tube 10 is fabricated by attaching fins 12 having the shape of a circular plate to the outer surface of a tube 11.

The fin 12 has bent portions 15 of a shape different from those of the finned tubes 10 employed in the foregoing embodiments. A plurality of radial slits 13 are formed in a peripheral portion of the fin 12 to divide the peripheral portion into a plurality of segments, and the segments are bent in the same direction along bending lines 17 to form bent portions 18 as shown in Fig. 19. As shown in Fig. 18, each bending line 17 extends between a first point **a** on one of the radial slit 13 and a second point **a'** on another radial slit 13' adjacent to the former radial slit 13. The first point **a** and the second point **a'** are on the same circle **R** having its center on the center axis of the finned tube 10. A substantially quadrangular portion of the segment defined by the radial slits 13 and 13', the bending line 17, and a section of the circumference of the fin 12 corresponding to the segment is bent along the bending line 17 perpendicularly to the surface of the fin 12 to form the bent portion 18. In the finned tube 10 shown in Fig. 17a, the substantially quadrangular portions of the alternate segments are bent in the same direction so that the bent portions 18 project in the same direction from one of the surfaces of the fin 12 and the adjacent bent portions 18 may not be continuous.

The bent portions 18, similarly to the bent portions 15 of the finned tube 10 employed in the first embodiment, deflect streams of the external fluid which tend to separate from the tube 11 toward a region directly behind the tube 11 so that the external fluid flows substantially along a downstream section of the outer surface of the tube 11 and, therefore, a wake is scarcely formed behind the tube 11. Consequently, the average external heat transfer coefficient of the finned tube 10 is increased greatly.

The bent portions 18 may be formed only in a specific circumferential range in the peripheral portion of the fin 12 corresponding to a region in which the streams of the external fluid tend to separate from the tube 11 of the finned tube 10 as shown in Fig. 20 if the flow velocity of the external fluid varies in a fixed range of flow velocity, and the region in which the streams of the external fluid tend to separate from the tube 11 and the condition of a wake are invariable.

Figs. 21a and 21b are sectional view and a side

view, respectively, of a finned tube 10 employed in a heat exchanger in a seventh embodiment according to the present invention. The finned tube 10 is fabricated by attaching fins 12 having the shape of a circular plate to the outer surface of a tube 11.

The fin 12 has substantially quadrangular bent portions 16 of a shape different from those of the finned tubes 10 employed in the foregoing embodiments. As shown in Fig. 22, a plurality of radial slits 13 are formed in a peripheral portion of the fin 12 to divide the peripheral portion into a plurality of segments, and the segments are bent substantially perpendicularly to the surface of the fin 12 in the same direction along bending lines 17 to form the bent portions 16 as shown in Fig. 23. As shown in Fig. 22, each bending line 17 extends between a first point **a** on one of the radial slit 13 and a second point **c** on another radial slit 13' adjacent to the former radial slit 13. The first point **a** and the second point **c** are not on the same circle **R** having its center on the center axis of the finned tube 10. That is, the points **a** and **c** are on different concentric circles of different diameters, respectively. A substantially quadrangular portion of the segment defined by the radial slits 13', the bending line 17, and a section of the circumference of the fin 12 corresponding to the segment is bent along the bending line 17 substantially perpendicularly to the surface of the fin 12 to form the bent portion 16. In the finned tube 10 shown in Fig. 21a, since the substantially quadrangular portions are bent along the bending lines 17 each extending between the points **a** and **c** on different concentric circles, the adjacent bent portions 16 are not arranged one upon another as shown in Fig. 24 to obstruct the flow of the external fluid along the surface of the fin 12 from which the bent portions 16 project.

The finned tube 10 employed in the seventh embodiment exercises the same effect as that exercised by the finned tube 10 employed in the first embodiment.

The bent portions 16, similarly to the bent portions 15 of the finned tube 10 employed in the first embodiment, deflect streams of the external fluid which tend to separate from the tube 11 toward a region directly behind the tube 11 so that the external fluid flows substantially along a downstream section of the outer surface of the tube 11 and, therefore, a wake is scarcely formed behind the tube 11. Consequently, the flow velocity of the external fluid in the region behind the finned tube increases and local external heat transfer coefficient is increased, whereby the average external heat transfer coefficient of the finned tube 10 is increased greatly.

The bent portions 16 may be formed only in a specific circumferential range in the peripheral portion of the fin 12 corresponding to a region in which the streams of the external fluid tend to separate from the tube 11 of the finned tube 10 as shown in Fig. 25 if the flow velocity of the external fluid varies in a fixed range of flow velocity, and the region in which the streams of the external fluid tend to separate from the tube 11 and the condition of a wake are invariable.

Figs. 26a and 26b are sectional view and a side view, respectively, of a finned tube 10 employed in a heat exchanger in an eighth embodiment according to the present invention. The finned tube 10 is fabricated by attaching fins 12 having the shape of a circular plate to the outer surface of a tube 11, and each fin 12 has bent portions 16 projected alternately in opposite directions from one of the surfaces of the fin 12 and from the other surface of the same. The finned tube 10 employed in the eighth embodiment is similar in other respects to the finned tube 10 shown in Figs. 21a, 21b and 22 employed in the seventh embodiment.

The bent portions 16, similarly to the bent portions 16 of the finned tube 10 employed in the seventh embodiment, deflect streams of the external fluid which tend to separate from the tube 11 toward a region directly behind the tube 11 so that the external fluid flows substantially along a downstream section of the outer surface of the tube 11 and, therefore, a wake is scarcely formed behind the tube 11. Consequently, the flow velocity of the external fluid in the region behind the finned tube increases and local external heat transfer coefficient is increased, whereby the average external heat transfer coefficient of the finned tube 10 is increased greatly.

The bent portions 16 may be formed only in a specific circumferential range in the peripheral portion of the fin 12 corresponding to a region in which the streams of the external fluid tend to separate from the tube 11 of the finned tube 10 as shown in Fig. 28.

Figs. 29a, 29b and 30 show a finned tube employed in a heat exchanger in a ninth embodiment according to the present invention. The finned tube is formed by attaching fins 12 to the outer surface of a tube 11. Each fin 12 has bent portions 18 projected alternately in opposite directions from one of the surfaces of the fin 12 and from the other surface of the same. The finned tube employed in the ninth embodiment is similar in other respects to the finned tube 10 shown in Figs. 17a, 17b and 18 employed in the sixth embodiment.

The bent portions 18, similarly to the bent portions 18 of the finned tube 10 employed in the sixth embodiment, deflect streams of the external fluid which tend to separate from the tube 11 toward a region directly behind the tube 11 so that the external fluid flows substantially along a downstream section of the outer surface of the tube 11 and, therefore, a wake is scarcely formed behind the tube 11. Consequently, the flow velocity of the external fluid in the region behind the finned tube increases and local external heat transfer coefficient is increased, whereby the average external heat transfer coefficient of the finned tube 10 is increased greatly.

The bent portions 18 may be formed only in a specific circumferential range in the peripheral portion of the fin 12 corresponding to a region in which the streams of the external fluid tend to separate from the tube 11 of the finned tube 10 as shown in Fig. 31.

In the foregoing embodiments, the length of the ra-

dial slits and the height of the bent portions may be determined properly taking into consideration the type, temperature, pressure and flow velocity of the external fluid, intervals between the fins, required heat exchange rate, allowable pressure loss and such.

For example, in the finned tube 10 shown in Figs. 15a and 15b employed in the fifth embodiment, the respective lengths of the radial slits 13 may be varied sequentially to form the successive bent portions 15 in gradually varying heights, respectively, so that the bent portions 15 in a region in which streams of the external fluid tend to separate from the tube 11 have a maximum height as shown in Fig. 32.

Although the fins of the finned tubes illustrated in the drawings are continuous fins formed by helically winding a strip around a tube, the fins may be separate rings attached separately to the outer surface of a tube.

As is apparent from the foregoing description, according to the present invention, each of the fins of the finned tube has the plurality of bent portions on its outer circumference, and each bent portion is formed by bending each of the segments formed by dividing the peripheral portion of the fin by the radial slits in an axial direction of the tube along the bending line extending from a point on one of the radial slit. Thus, the bent portions have a high degree of freedom of design and can be formed in an optimum shape capable of effectively suppressing the separation of streams of the external fluid from the finned tube. Accordingly, the region in which a wake is formed due to the separation of streams of the external fluid from the tube of the finned tube can be reduced, so that the local external heat transfer coefficient of the downstream section of the finned tube is enhanced, the heat transfer area of the finned tube can be effectively increased and, consequently, the heat exchanging performance of a heat exchanger employing the finned tube of the present invention can be improved.

Claims

1. A heat exchanger comprising:

a tube having an axis intersecting a flow direction of an external fluid; and
fins attached to an outer surface of the tube;
wherein each fin is provided in a peripheral portion thereof with a plurality of bent portions, the bent portions being formed by forming radial slits in the peripheral portion of the fin to divide the peripheral portion into a plurality of segments, and bending each segment in an axial direction of the tube along a bending line extending from a point on the radial slit.

2. The heat exchanger according to claim 1, wherein each of the bending lines extends between

the point on the radial slit and a point on an outer circumference of the fin.

3. The heat exchanger according to claim 1, wherein each of the bending lines extends between the point on the radial slit and a point on another radial slit adjacent to the radial slit.
4. The heat exchanger according to claim 3, wherein the point on one of the adjacent radial slits and the point on the other radial slit are not on the same circle having its center on the axis of the tube.
5. The heat exchanger according to claim 3, wherein the point on one of the adjacent radial slits and the point on the other radial slit are on the same circle having its center on the axis of the finned tube.
6. The heat exchanger according to claim 1, wherein the bent portions are formed by in the same direction bending the segments formed by dividing the peripheral portion of the fin by the radial slits.
7. The heat exchanger according to claim 1, wherein the bent portions are formed by alternately in opposite directions bending the segments formed by dividing the peripheral portion of the fin by the radial slits.
8. The heat exchanger according to claim 2, wherein the bent portions are formed by alternately in opposite directions bending the segments formed by dividing the peripheral portion of the fin by the radial slits.
9. The heat exchanger according to claim 3, wherein the bent portions are formed by alternately in opposite directions bending the segments formed by dividing the peripheral portion of the fin by the radial slits.
10. The heat exchanger according to claim 5, wherein the bent portions are formed by alternately in opposite directions bending the segments formed by dividing the peripheral portion of the fin by the radial slits.
11. The heat exchanger according to claim 1, wherein the bent portions are formed by bending the alternate segments formed by dividing the peripheral portion of the fin by the radial slits.
12. The heat exchanger according to claim 2, wherein the bent portions are formed by bending the alternate segments formed by dividing the peripheral portion of the fin by the radial slits.
13. The heat exchanger according to claim 3, wherein

the bent portions formed by bending the alternate segments formed by dividing the peripheral portion of the fin by the radial slits.

14. The heat exchanger according to claim 5, wherein the bent portions are formed by in the same direction bending the alternate segments formed by dividing the peripheral portion of the fin by the radial slits.
15. The heat exchanger according to claim 1, wherein the bent portions are formed only in a specific circumferential range in the peripheral portion of each fin corresponding to a region in which streams of the external fluid separate from the tube.
16. The heat exchanger according to claim 2, wherein the bent portions are formed only in a specific circumferential range in the peripheral portion of each fin corresponding to a region in which streams of the external fluid separate from the tube.
17. The heat exchanger according to claim 3, wherein the bent portions are formed only in a specific circumferential range in the peripheral portion of each fin corresponding to a region in which streams of the external fluid separate from the tube.
18. The heat exchanger according to claim 6, wherein the bent portions are formed only in a specific circumferential range in the peripheral portion of each fin corresponding to a region in which streams of the external fluid separate from the tube.
19. The heat exchanger according to claim 7, wherein the bent portions are formed only in a specific circumferential range in the peripheral portion of each fin corresponding to a region in which streams of the external fluid separate from the tube.
20. The heat exchanger according to claim 11, wherein the bent portions are formed only in a specific circumferential range in the peripheral portion of each fin corresponding to a region in which streams of the external fluid separate from the tube.

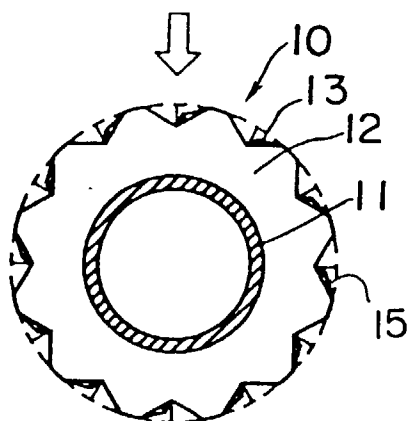


FIG. 1a

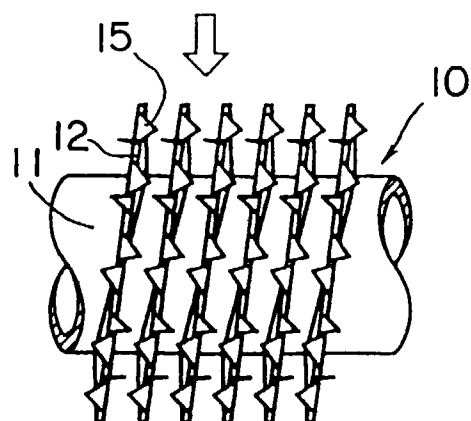


FIG. 1b

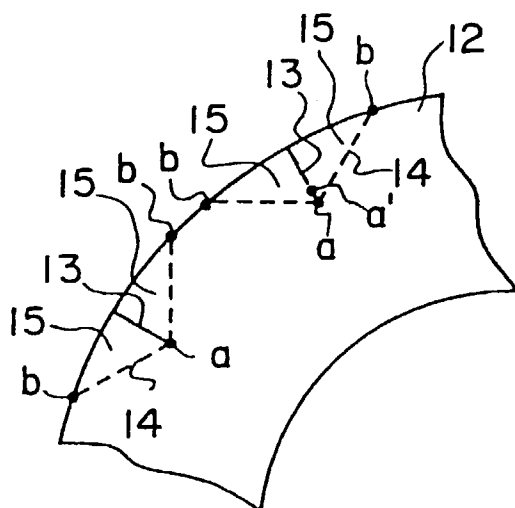


FIG. 2

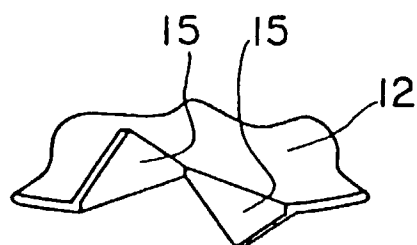


FIG. 3

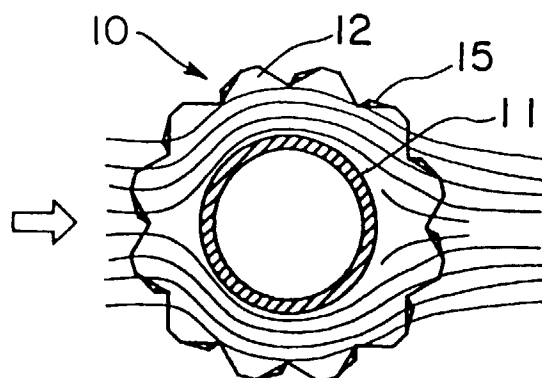


FIG. 4

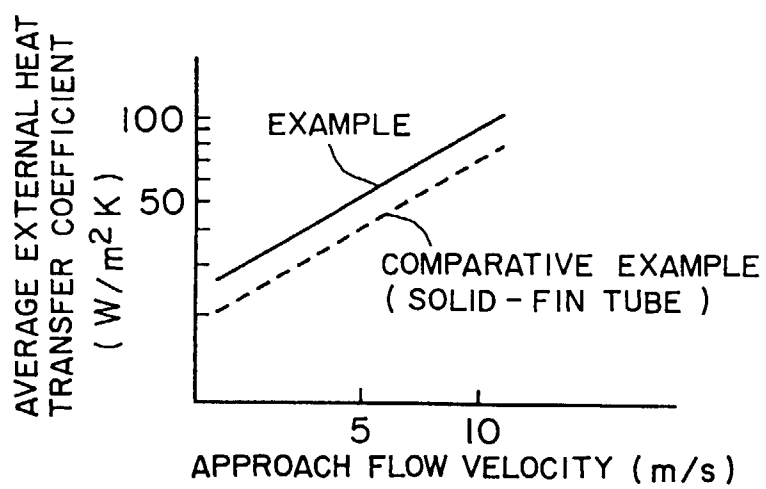


FIG. 5

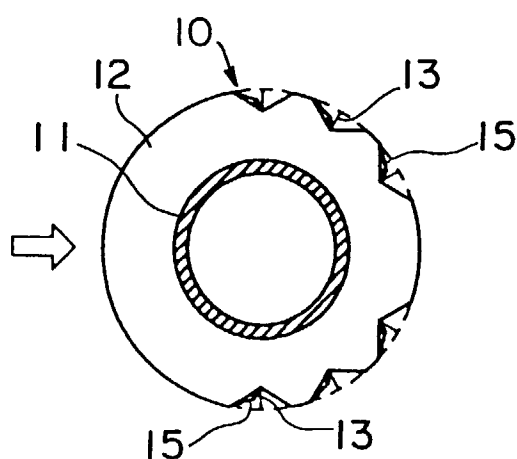


FIG. 6

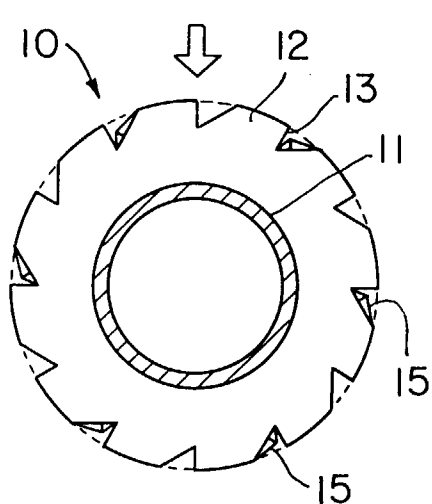


FIG. 7a

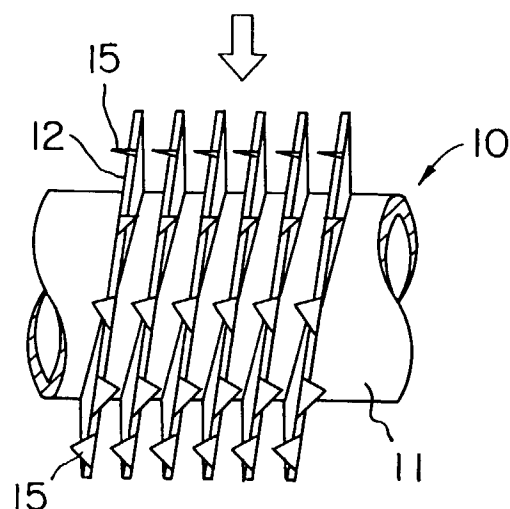


FIG. 7b

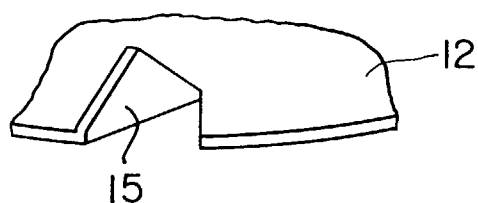


FIG. 8

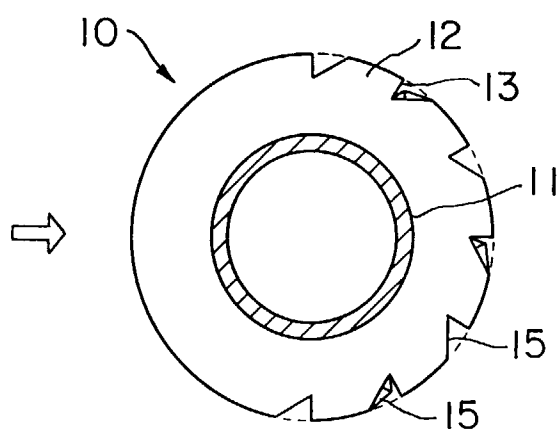


FIG. 9

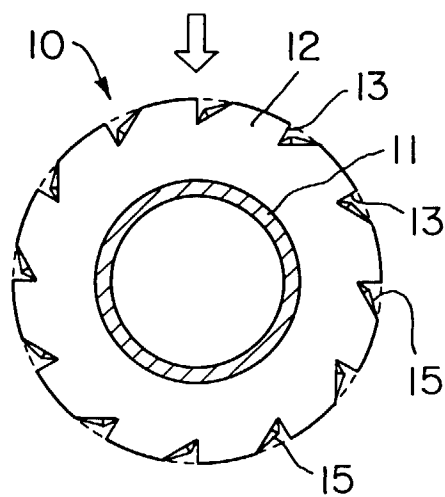


FIG. 10a

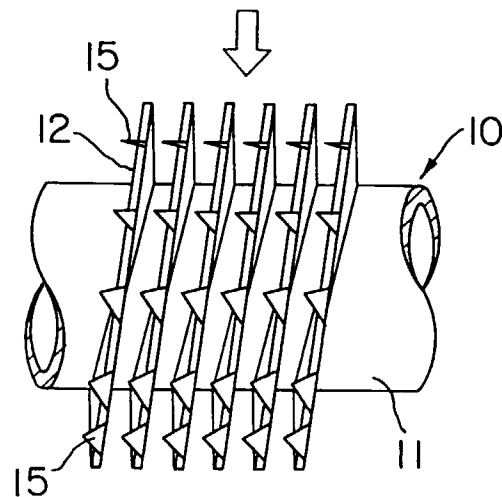


FIG. 10b

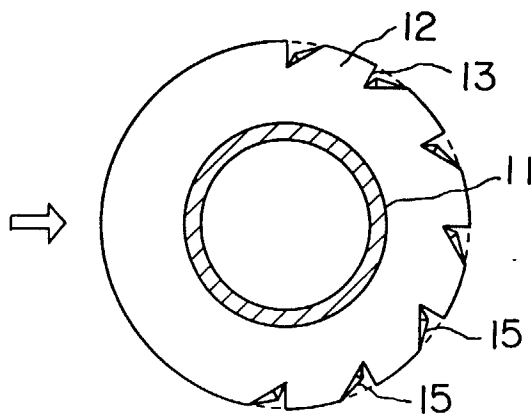


FIG. 11

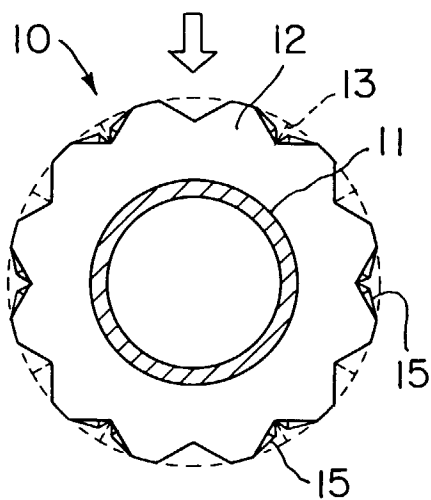


FIG. 12a

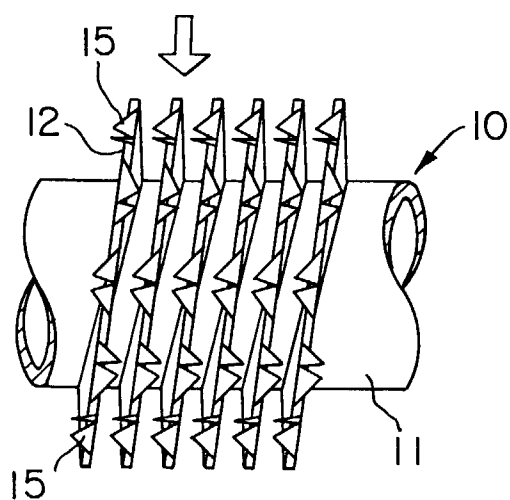


FIG. 12b

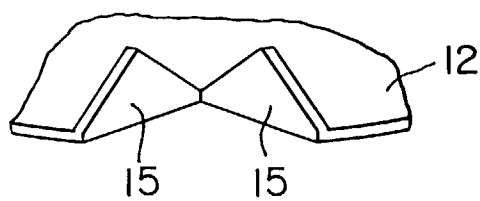


FIG. 13

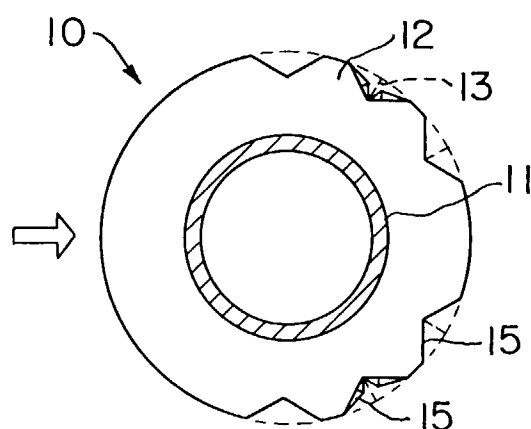


FIG. 14

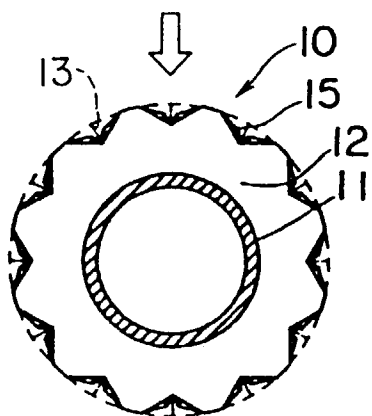


FIG. 15a

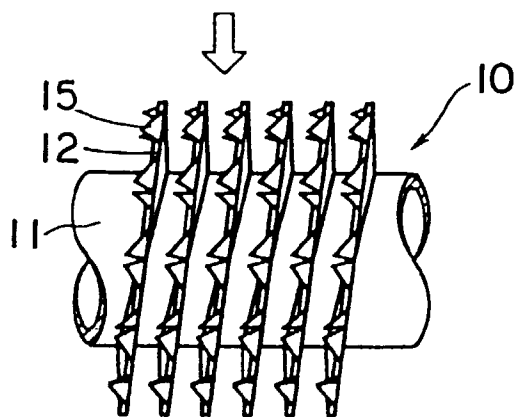


FIG. 15b

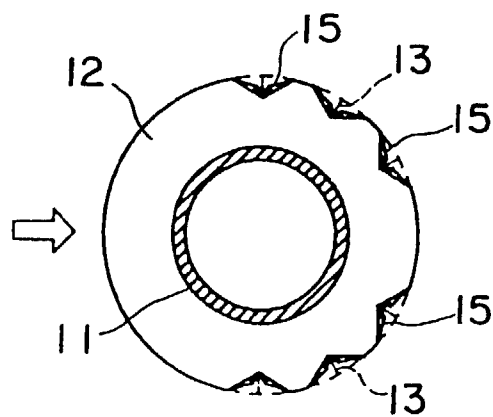


FIG. 16

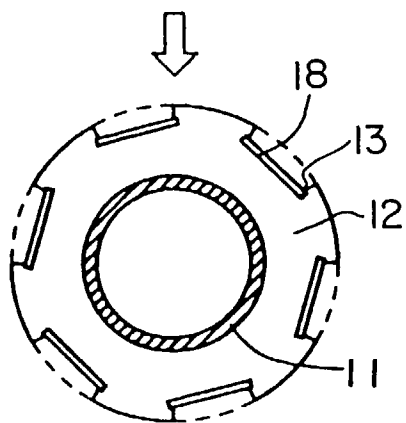


FIG. 17a

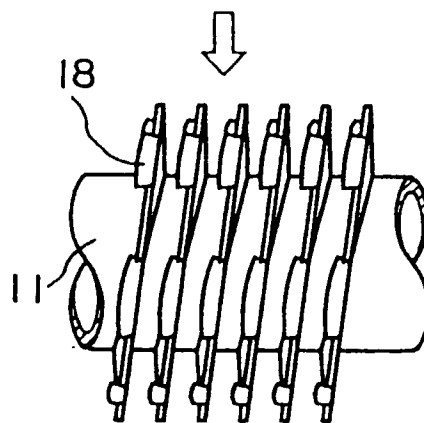


FIG. 17b

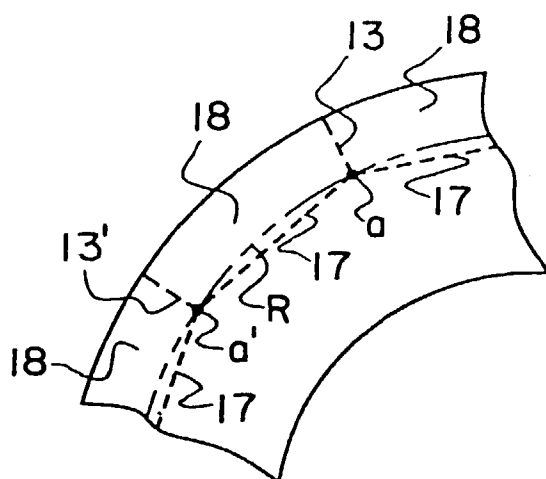


FIG. 18

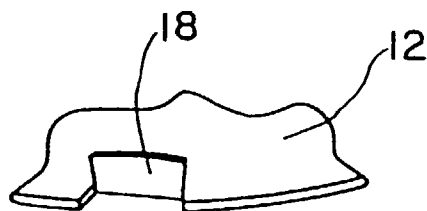


FIG. 19

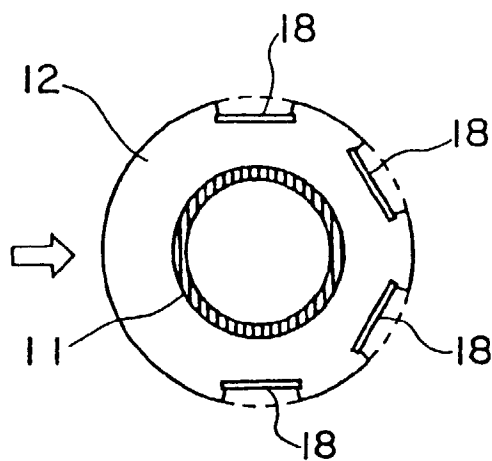


FIG. 20

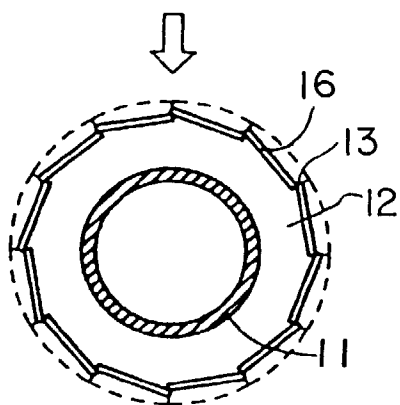


FIG. 21a

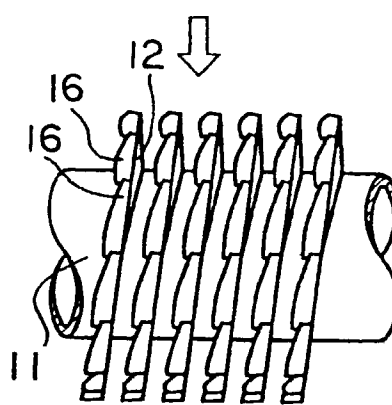


FIG. 21b

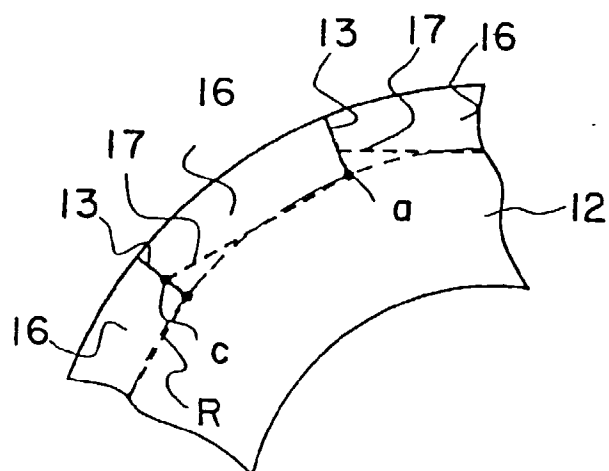


FIG. 22

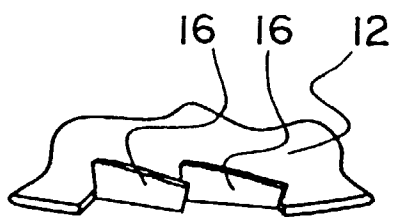


FIG. 23

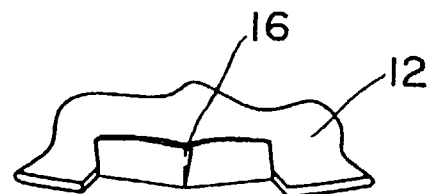


FIG. 24

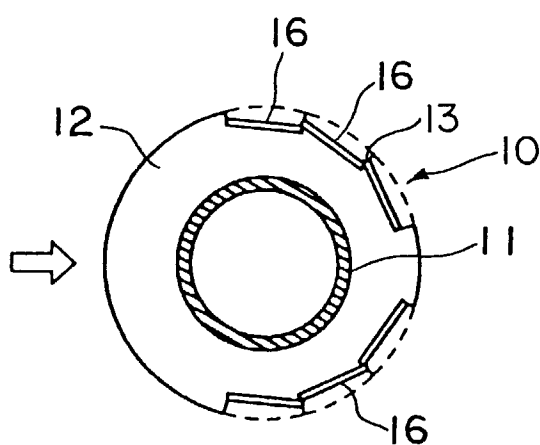


FIG. 25

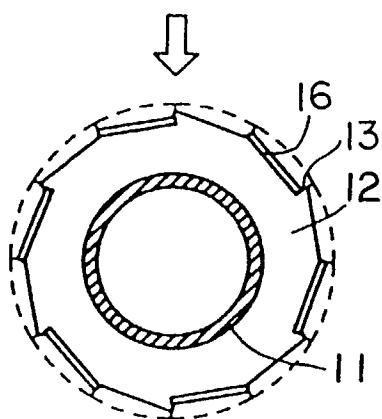


FIG. 26a

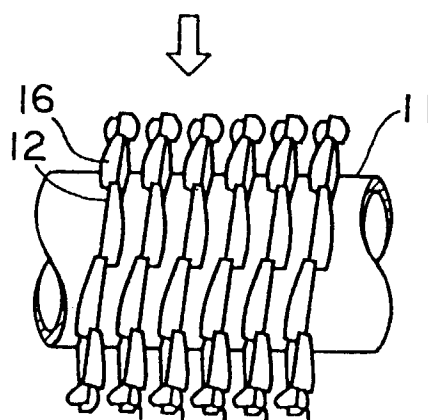


FIG. 26b

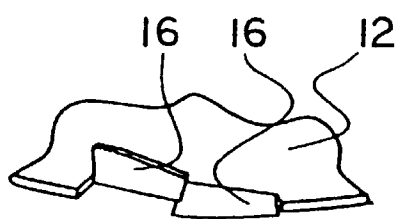


FIG. 27

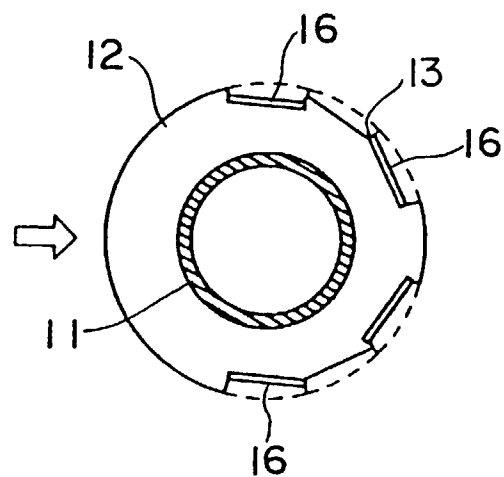


FIG. 28

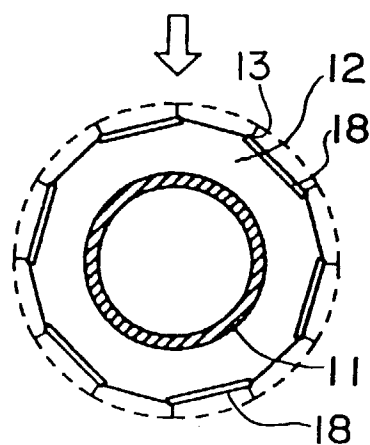


FIG. 29a

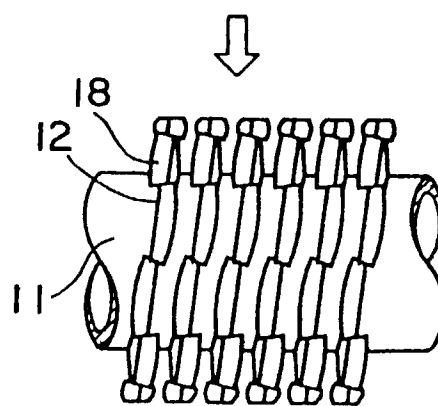


FIG. 29b

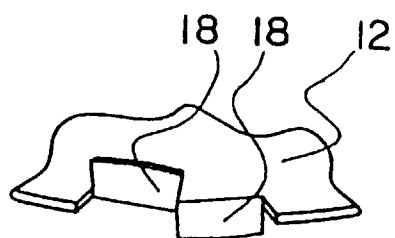


FIG. 30

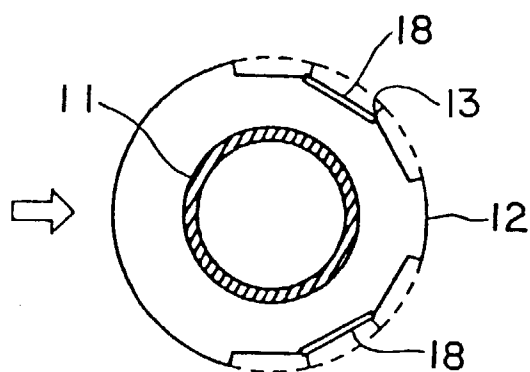


FIG. 31

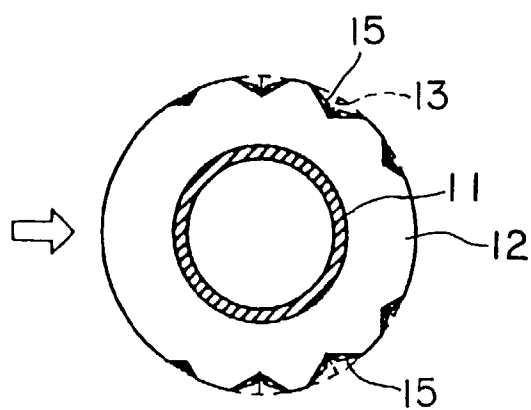


FIG. 32

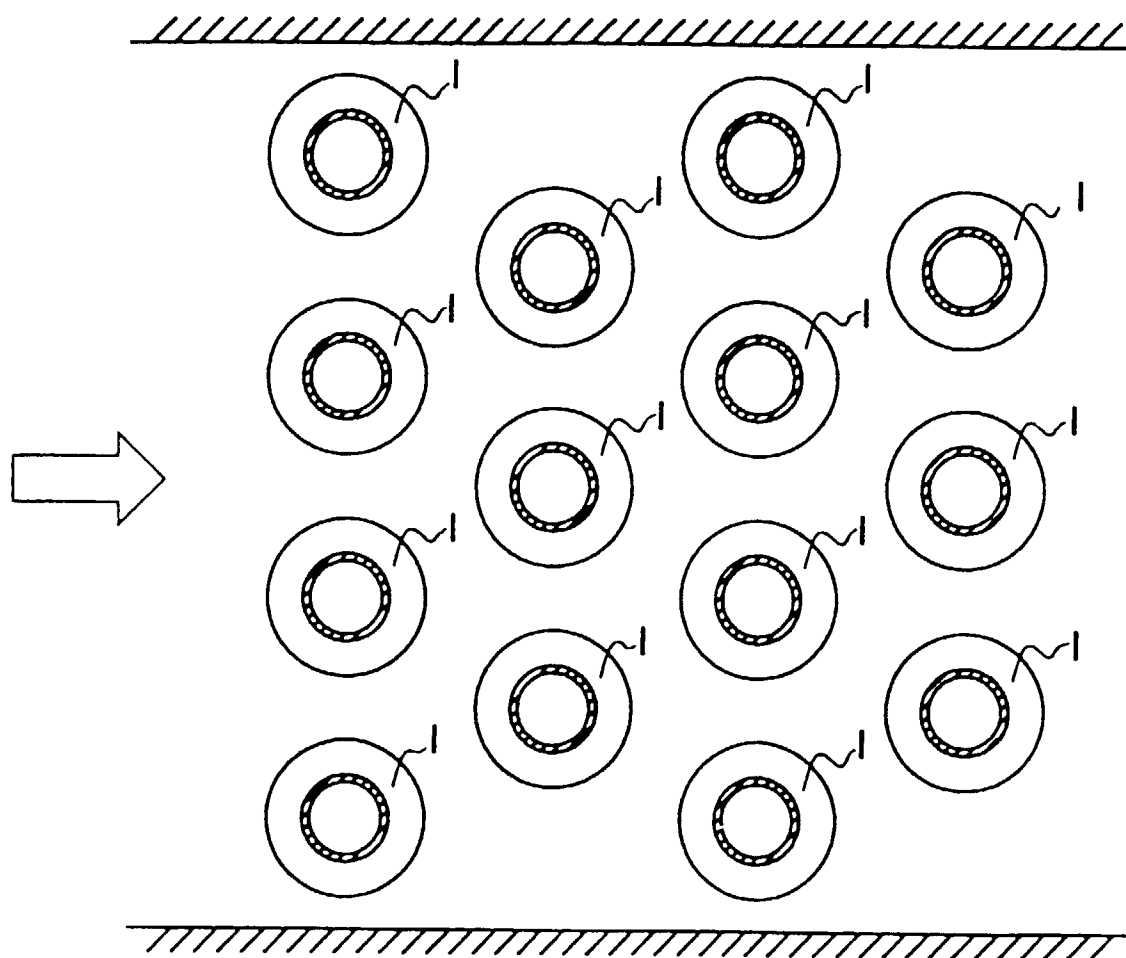


FIG. 33

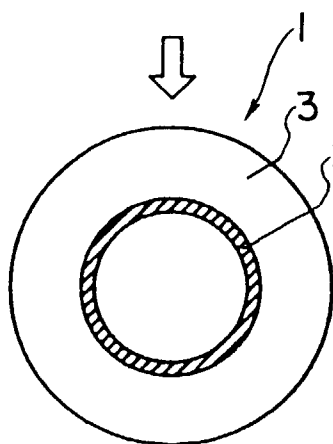


FIG. 34a

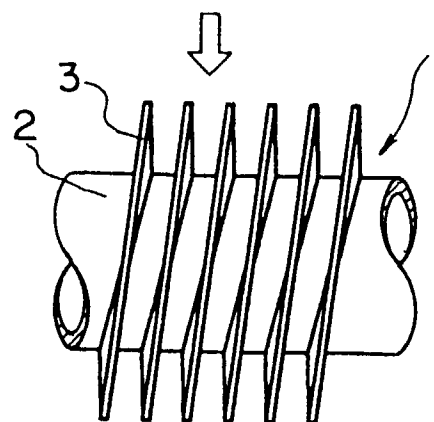


FIG. 34b

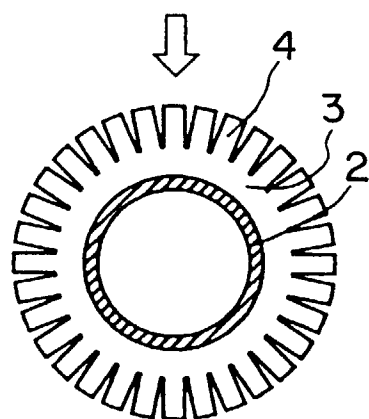


FIG. 35a

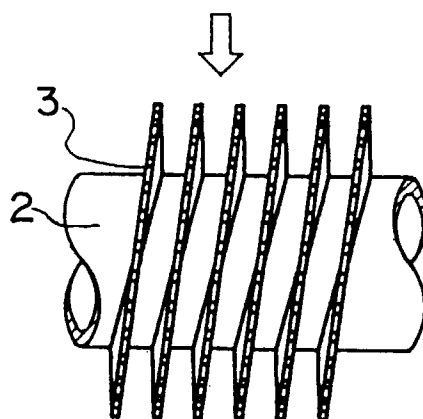


FIG. 35b

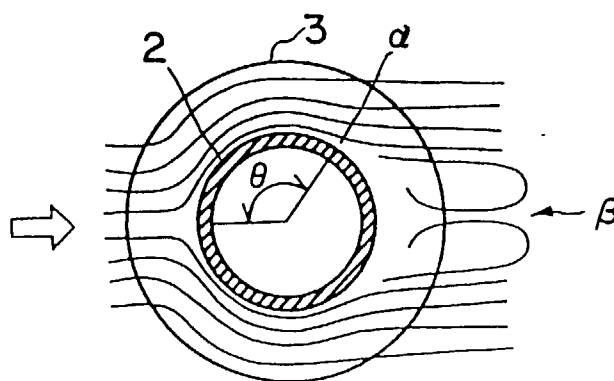


FIG. 36

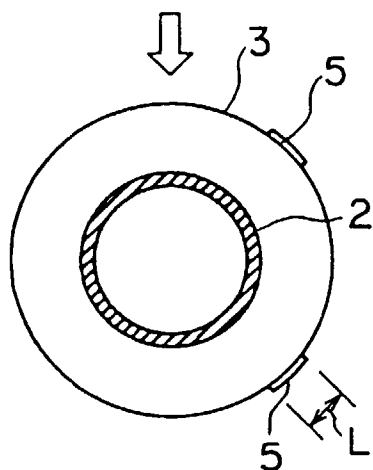


FIG. 37a

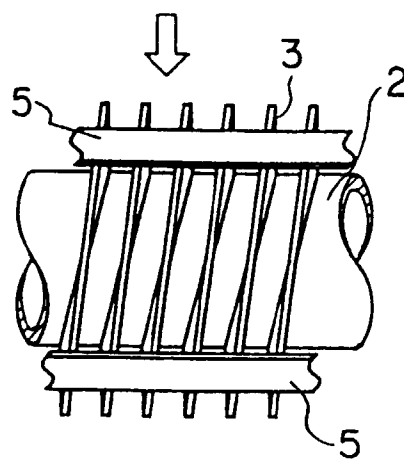


FIG. 37b

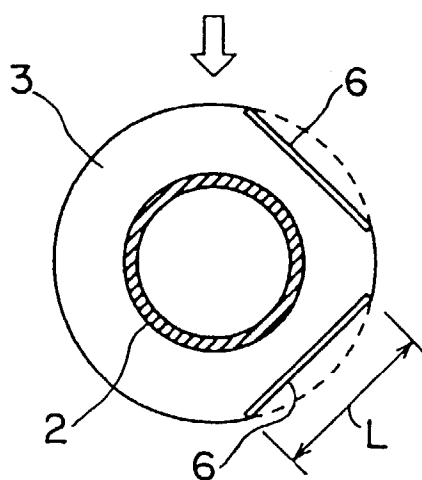


FIG. 38a

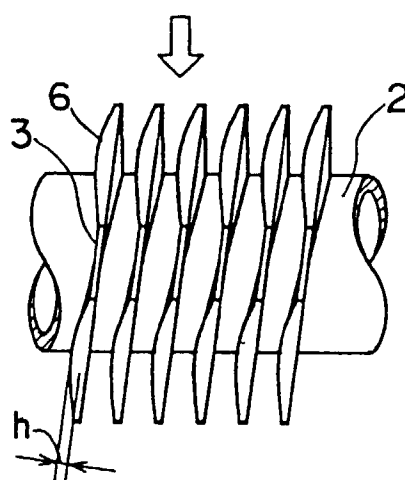


FIG. 38b