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(54) INNER GROOVED PIPE FOR FLARE PROCESSING AND HEAT EXCHANGER PROVIDED WITH SAME

(57) The present invention addresses the problem of providing an inner grooved pipe for flare processing in which cracking due to tube expansion from flare processing is unlikely to occur. The problem is solved by an inner grooved pipe for flare processing, which is a seamless pipe, that has grooves in the inner surface thereof, and flare processing applied to an end thereof, wherein: the outer diameter D is 2.0-5.5 mm; the ratio T/D between the wall thickness T and the outer diameter D is 0.057-0.005 D to 0.075-0.005 D; the twist angle θ of the inner groove is 15-27 degrees; the tip radius of curvature r of fins constituting the inner grooves and the number N of the fins in the circumferential direction satisfy a specific formula; and the tip radius of curvature r and the twist angle θ satisfy a specific formula.

FIG.1A

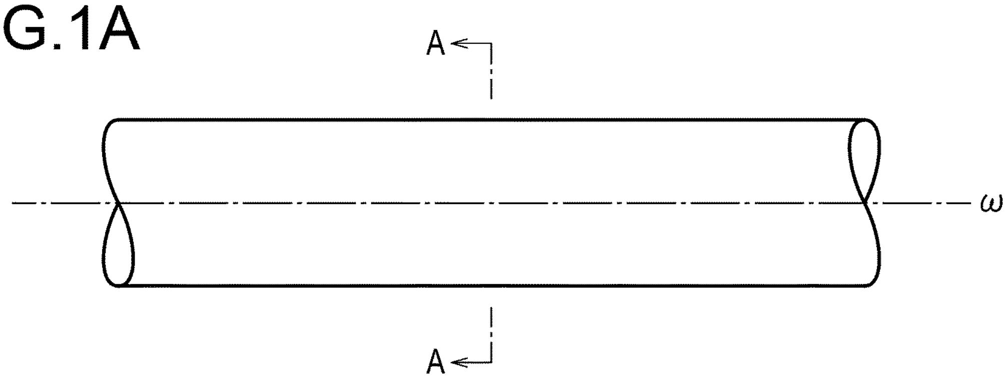

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FIG.1B

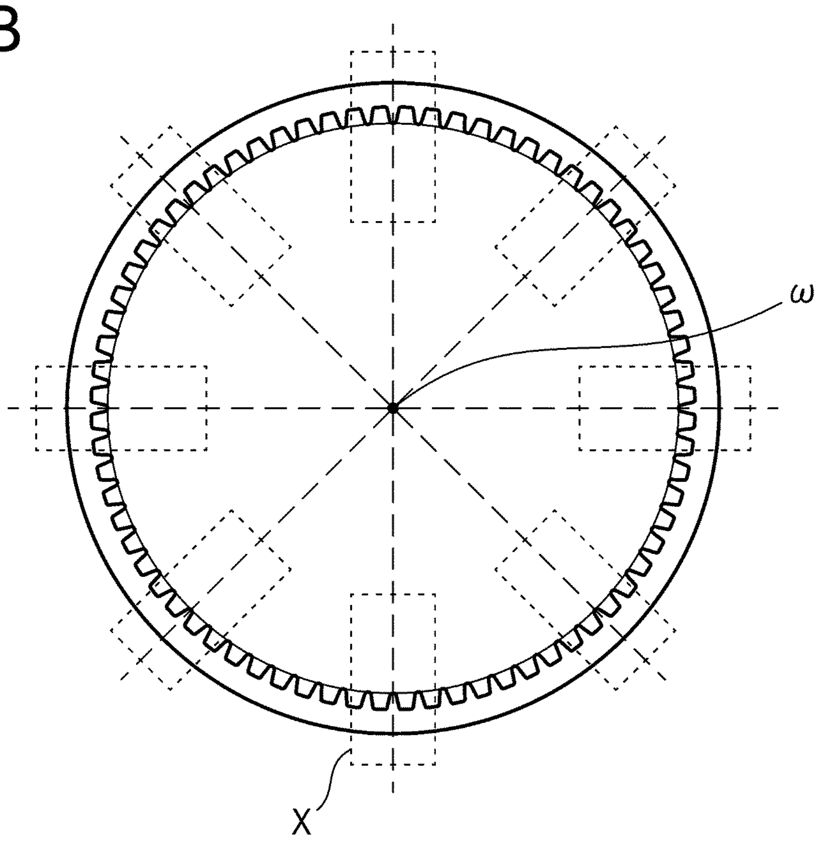
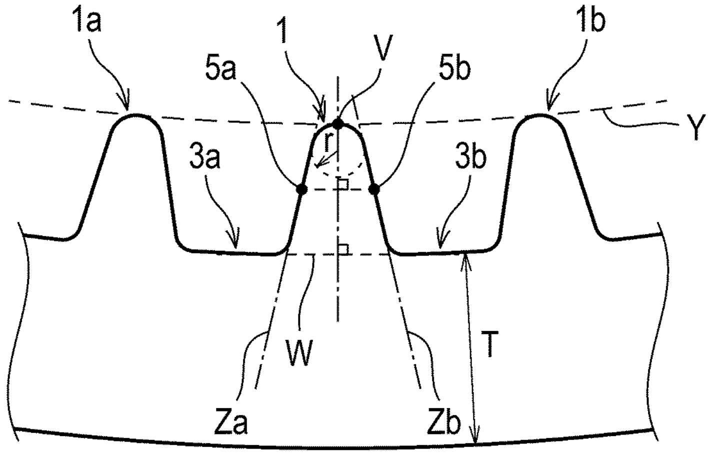


FIG.1C



Description

TECHNICAL FIELD

[0001] The present invention relates to an internally grooved pipe for flare processing and a heat exchanger including the same.

BACKGROUND ART

[0002] Copper pipes which circulate a heating medium in their interiors for heat exchange have heretofore been incorporated into heat exchangers of room air conditioners (RAC), packaged air conditioners (PAC), refrigerators, water heaters and the like, and electronic devices such as personal computers, smartphones, and game consoles.

[0003] For instance, in the process of assembling a room air conditioner, a plurality of copper pipes having the shape of a straight pipe are first prepared and each of them is bended at a central part in its longitudinal direction to form a U-shaped hairpin pipe. Then, each of the copper pipes is made to pass through through-holes of aluminum fins made up of a large number of aluminum plates stacked on top of each other, and straight pipe parts of each copper pipe are enlarged to closely attach the outer surfaces of the straight pipe parts to the inner peripheral surfaces of the through-holes of the aluminum fins. After that, pipe end parts of each copper pipe projecting from the aluminum fins are connected to other ones adjacent thereto with U-shaped bend pipes or branched pipes. In this way, the connected copper pipes form one or more flow paths within which a heat medium circulates. Then, heat of the heat medium inside the copper pipes is transmitted to the aluminum fins and room air or the like is made to flow through gaps between the aluminum plates in the aluminum fins, whereby the temperature of the air or the like can be adjusted.

[0004] Enlarging the straight pipe parts of the copper pipes so that they are closely attached to the inner peripheral surfaces of the through-holes of the aluminum fins is called primary pipe enlargement. Enlarging the pipe end parts of each copper pipe to insert U-shaped bend pipes thereinto is called secondary pipe enlargement, and parts obtained by the secondary pipe enlargement are also called secondarily enlarged pipe parts.

[0005] Edges of ends of the secondarily enlarged pipe parts are further enlarged. This enlargement is called tertiary pipe enlargement or flare processing. Parts obtained by the tertiary pipe enlargement or the flare processing are called flare-processed parts.

[0006] Bend pipes are inserted through the flare-processed parts into the secondarily enlarged pipe parts, and ring-shaped brazing filler metal is inserted into gaps between outer surfaces of the bend pipes and inner surfaces of the flare-processed parts. After that, the brazing filler metal is melted by heating and solidified to join the bend pipes to pipe end parts of their corresponding copper pipes. The flare-processed parts are formed to ensure the gaps for inserting the brazing filler metal thereinto.

[0007] Conventionally, such flare processing often caused cracking of copper pipes at their edges of ends. Flare processing often caused cracking particularly when copper pipes were small in external diameter and had an external diameter of, for example, 6 mm or less. This was considered to be mainly due to the fact that a gap for inserting brazing filler metal is required to have a certain size even if the copper pipe external diameter is small, and therefore a copper pipe having a small external diameter has a relatively large pipe enlargement ratio compared to a copper pipe having a large external diameter.

[0008] In contrast, Patent Document 1 proposed a copper or copper alloy pipe for flare processing which is used to perform flare processing of seamless pipes at their ends, the tube having an external diameter D of 2.0 to 5.5 mm, a ratio T/D of a thickness T to the external diameter D of at least (0.057-0.005D) but up to (0.075-0.005D), an average grain size of 30 μm or less, and an elongation in its circumferential direction of 35% or more. Patent Document 1 describes that in such a copper or copper alloy pipe for flare processing, the seamless copper pipe thickness, the average grain size, and the elongation are appropriately set and therefore, when a thin copper pipe with an external diameter of 2.0 to 5.5 mm is used to perform flare processing, cracking can be prevented from occurring at an enlarged pipe portion of a flare-processed part.

CITATION LIST

PATENT DOCUMENTS

[0009] Patent Document 1: JP 2017-20063 A

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0010] The present invention provides an internally grooved pipe for flare processing which is less likely to cause cracking due to pipe enlargement using flare processing and a heat exchanger including the same.

MEANS FOR SOLVING THE PROBLEM

[0011] The inventors of the present invention have made an intensive study to solve the problem described above and completed the present invention.

[0012] The present invention provides the following (I) to (IV).

(I) An internally grooved pipe for flare processing which is a seamless pipe having grooves at its inner surface, flare processing being applied to its end portions, wherein:

an external diameter D is 2.0 mm or more but 5.5 mm or less;
a ratio T/D of a thickness T to the external diameter D is 0.057-0.005D or more but 0.075-0.005D or less;
the grooves at its inner surface have an angle of torsion θ of 15° or more but 27° or less;
a tip radius of curvature r of fins making up the grooves at the inner surface and a number N of the fins in a circumferential direction satisfy formula (1) shown below:

$$\text{formula (1):}\quad 0.32 \leq 1/(r \times N) \leq 0.61$$

and
the tip radius of curvature r and the angle of torsion θ satisfy formula (2) shown below:

$$\text{formula (2):}\quad 0.04 \leq r \times (1/\cos\theta) \leq 0.051.$$

(II) The internally grooved pipe for flare processing according to (I) above, wherein the tip radius of curvature r and the number N of the fins satisfy formula (1') shown below:

$$\text{formula (1'):}\quad 0.52 \leq 1/(r \times N) \leq 0.61.$$

(III) The internally grooved pipe for flare processing according to (I) or (II) above, wherein the internally grooved pipe is made of copper or a copper alloy.

(IV) A heat exchanger including the internally grooved pipe for flare processing according to any one of (I) to (III) above.

EFFECT OF THE INVENTION

[0013] The present invention can provide an internally grooved pipe for flare processing which is less likely to cause cracking due to pipe enlargement using flare processing and a heat exchanger including the same.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

[FIGS. 1] FIG. 1A is a schematic view showing a lateral surface of a grooved pipe of the invention which has the shape of a straight pipe; FIG. 1B is a cross-sectional view taken along line A-A in FIG. 1A; and FIG. 1C is an enlarged view of one of eight dotted portions in FIG. 1B (portion denoted by X).

[FIGS. 2] FIG. 2A is a schematic side view showing a specimen 10 obtained by cutting out a part (portion having a length L in a longitudinal direction) from the grooved pipe of the invention; and FIG. 2B and FIG. 2C are a schematic side view and a schematic end view, respectively, which show the state in which a load P is applied from above to the specimen 10 put on a surface of a metallic substrate 20.

[FIGS. 3] FIG. 3A is a schematic side view showing the state in which the specimen 10 is completely crushed due to the applied load P to be formed into overlapping two plates; FIG. 3B is a schematic side view showing the state in which the two plates are separated from each other; and FIG. 3C is a schematic view (schematic front view) in which an upper plate (10b) of the two plates is removed and a lower plate (10a) is seen from above.

[FIG. 4] As with FIG. 1C, FIG. 4 is an enlarged view of one of the eight dotted portions in FIG. 1B (portion denoted by X) and is a view (schematic view) for illustrating a fin height, a vertex angle and a radius of curvature R at a fin base.

[FIG. 5] As with FIG. 1C, FIG. 5 is an enlarged view of one of the eight dotted portions in FIG. 1B (portion denoted by X) and a view (schematic view) for illustrating the radius of curvature R at a fin base.

[FIG. 6] FIG. 6 is a view showing an example of a manufacturing device for use in manufacturing the grooved pipe of the invention.

[FIG. 7] FIG. 7 is a partially cutaway front view illustrating a heat exchanger 60 of the invention that is a fin- and-tube heat exchanger into which the grooved pipes of the invention are incorporated.

[FIG. 8] FIG. 8 is a partially enlarged view (schematic perspective view) of FIG. 7.

DESCRIPTION OF EMBODIMENTS

[0015] The present invention will be described.

[0016] The present invention provides an internally grooved pipe for flare processing which is a seamless pipe having grooves at its inner surface, flare processing being applied to its end portions, wherein: an external diameter D is 2.0 mm or more but 5.5 mm or less; a ratio T/D of a thickness T to the external diameter D is 0.057-0.005D or more but 0.075-0.005D or less; the grooves at its inner surface have an angle of torsion θ of 15° or more but 27° or less; a tip radius of curvature r of fins making up the grooves at the inner surface and a number N of the fins in a circumferential direction satisfy formula (1) shown below:

$$\text{formula (1):}\quad 0.32 \leq 1/(r \times N) \leq 0.61$$

and

the tip radius of curvature r and the angle of torsion θ satisfy formula (2) shown below:

$$\text{formula (2):}\quad 0.04 \leq r \times (1/\cos\theta) \leq 0.051.$$

[0017] The internally grooved pipe for flare processing as described above is hereinafter referred to also as the "grooved pipe of the invention."

[0018] The present invention also provides a heat exchanger including the grooved pipe of the invention.

[0019] The heat exchanger as described above is hereinafter referred to also as the "heat exchanger of the invention."

<Grooved Pipe of the Invention>

[0020] The grooved pipe of the invention will be described.

[0021] The grooved pipe of the invention is an internally grooved pipe for flare processing which is a seamless pipe having grooves at its inner surface, flare processing being applied to its end portions.

[0022] The grooved pipe of the invention may be a pipe before undergoing flare processing or a pipe after having undergone flare processing. The grooved pipe of the invention included in the heat exchanger of the invention is usually a pipe having undergone flare processing.

[0023] The shape of the grooved pipe of the invention is not particularly limited. It may have the shape of a straight pipe, or may be a straight pipe wound into a coil shape or formed into a U-shape through bending (hairpin-shaped pipe).

[0024] The cross-sectional shape is also not particularly limited. A cross-section in a direction perpendicular to a longitudinal direction of the pipe may have the shape of an ellipse, a triangle, a quadrangle, or another polygon but preferably has a circular shape.

[0025] The material of the grooved pipe of the invention is not particularly limited and is preferably copper or a copper alloy.

[0026] Examples of the copper or the copper alloy include those specified in JIS H 3300, such as C1220 (phosphorus deoxidized copper), C1201 (low phosphorus deoxidized copper), C1020 (oxygen-free copper), and C5010, C1862, and C1565 (high-strength copper) .

[0027] The grooved pipe of the invention has grooves at its inner surface.

[0028] The grooves formed at the inner surface of the grooved pipe of the invention will be described with reference to FIGS. 1.

[0029] FIG. 1A is a schematic view showing a lateral surface of a grooved pipe of the invention in a case where it has the shape of a straight pipe and is circular in cross-section. In FIG. 1A, the central axis of the grooved pipe of the invention is denoted by ω.

[0030] FIG. 1B is a view (schematic cross-sectional view) showing a cross-section taken along line A-A in FIG. 1A, in other words, a cross-section in a direction perpendicular to a longitudinal direction (direction parallel to the central axis ω) of the pipe. Eight dotted rectangular portions in FIG. 1B show portions where the external diameter D, the thickness T, the radius of curvature r at fin tips are to be measured by methods to be described below, and these portions are circumferentially positioned at substantially regular intervals (at intervals of approximately 45 degrees) on the cross-section shown in FIG. 1B. As will be described later, these values of the grooved pipe of the invention mean simple average values of measurement results at the eight portions.

[0031] FIG. 1C is an enlarged view of one of the eight dotted portions in FIG. 1B (portion denoted by X).

[External Diameter D]

[0032] The grooved pipe of the invention has an external diameter D of 2.0 mm or more but 5.5 mm or less, and preferably 3.5 mm or more but 5.0 mm or less.

[0033] The external diameter D is measured at the eight dotted portions in FIG. 1B. Specifically, in FIG. 1B, these eight portions make up four pairs, portions of each pair facing each other with respect to a point showing the central axis ω as the point of symmetry. Four external diameter measurement values are obtained at the eight portions (of the four pairs) circumferentially positioned at substantially regular intervals and their simple average value is then obtained and taken as the external diameter D of the grooved pipe of the invention.

[0034] The external diameter is measured using a digital caliper.

[0035] Copper pipes having an external diameter of 7 to 9.52 mm have heretofore been mainly used as those for flare processing. However, diameter reduction has been desired recently for weight reduction and performance improvement of heat-transfer pipes. For the sake of reduction of the global warming potential, heat media (refrigerants or the like) circulating in pipes are switching to R32. However, reducing its amount of use is required because of mild flammability of R32 and diameter reduction has also been desired to achieve this point.

[0036] The external diameter D of the grooved pipe of the invention falls within the above-defined range and hence satisfies the recent desire for diameter reduction.

[Thickness T]

[0037] In the grooved pipe of the invention, the ratio (T/D) of the thickness T to the external diameter D is 0.057-0.005D or more but 0.075-0.005D or less, and preferably 0.059-0.005D or more but 0.071-0.005D or less.

[0038] The thickness T is preferably 0.09 to 0.27 mm, more preferably 0.13 to 0.25 mm, even more preferably 0.17 to 0.23 mm, and still more preferably 0.18 to 0.21 mm.

[0039] Against a backdrop of recent increases in the price of copper, in addition to satisfied pressure capacity, weight reduction is desired for the internally grooved pipe for use in heat exchangers or the like. The grooved pipe of the invention has the external diameter D and thickness T as described above and satisfies the desires.

[0040] The method of measuring the thickness T will be described.

[0041] First of all, each of the eight dotted portions in FIG. 1B is magnified ten times with the use of a laser microscope (for example, VK-8500 manufactured by Keyence Corporation) to obtain an image or photo as shown in FIG. 1C. Next, the thickness of the thinnest part in a radial direction having the central axis ω as its center is measured at each of the eight portions shown in FIG. 1C. Then, a value obtained by simple average of the measurement values at the eight portions is taken as the thickness T of the grooved pipe of the invention.

[Tip Radius of Curvature r]

[0042] The tip radius of curvature r of fins making up grooves that the grooved pipe of the invention has at its inner surface is preferably 0.030 to 0.045 mm, and preferably 0.030 to 0.040 mm in view of heat-transfer performance. Further, it is more preferably 0.036 to 0.040 mm in view of productivity.

[0043] The method of measuring the tip radius of curvature r of the fins will be described with reference to FIG. 1B and FIG. 1C.

[0044] First of all, each of the eight dotted portions in FIG. 1B is magnified ten times with the use of a laser microscope (for example, VK-8500 manufactured by Keyence Corporation) to obtain an image or photo as shown in FIG. 1C.

[0045] Next, on the image or photo as shown in FIG. 1C, a curve Y which touches three fins including a fin 1 to be measured and two fins 1a and 1b present adjacent thereto at their tips is drawn. The curve Y and the circumference of a circle having ω shown in FIG. 1B as its center usually overlap each other.

[0046] Next, a groove bottom 3a present between the fin 1 to be measured and the fin 1a present adjacent thereto is specified, and a groove bottom 3b present between the fin 1 to be measured and the fin 1b present adjacent thereto is specified in the same manner, and then a straight line W which is tangent to both of them is drawn.

[0047] Next, in FIG. 1C, when a line which connects the outline of the fin 1 to a point on the straight line W and is perpendicular to the straight line W has the largest length, a point on the outline of the fin 1 is denoted by tip V. Usually, the tip V substantially coincides with the point of contact between the outline of the fin 1 and the curve Y. Then, the line perpendicular to the straight line W is drawn from the tip V of the fin 1.

[0048] Next, a point at which the perpendicular line drawn from the tip V toward the straight line W is bisected is specified, a line which passes through this point and is parallel to the straight line W is drawn, and points where the line and the outline of the fin 1 intersect are denoted by 5a and 5b, respectively. Then, a tangent line which passes through the point 5a and touches the outline of the fin 1 is denoted by Za, and a tangent line which passes through the point 5b and touches the outline of the fin 1 in the same manner is denoted by Zb.

[0049] Next, a circle which passes through the tip V and touches the tangent lines Za and Zb is drawn on the outer peripheral side of the tip V.

[0050] The radius of the thus drawn circle is called the fin tip radius of curvature r**.**

[Number N of Fins]

[0051] The number N of the fins making up the grooves that the grooved pipe of the invention has at its inner surface is preferably 36 to 69 and more preferably 37 to 52.

[0052] The number N of the fins making up the grooves that the grooved pipe of the invention has at its inner surface is measured on the cross-section as in FIG. 1B. In other words, the number N of the fins present in the circumferential direction on the cross-section in the direction perpendicular to the longitudinal direction (direction parallel to the central axis ω) of the pipe is visually counted.

[Angle of Torsion θ]

[0053] The grooves that the grooved pipe of the invention has at its inner surface preferably have an angle of torsion θ of 15° or more but 27° or less, and preferably 20° or more but 27° or less.

[0054] Too large an angle of torsion θ increases the internal pressure loss of a heat medium (refrigerant or the like) flowing in the pipe, which may increase the power of a compressor in an air conditioner unit or the like. In this case, the coefficient of performance (COP) of the device is reduced. Further, the fins may be crushed in the primary pipe enlargement.

[0055] Too small an angle of torsion θ may easily cause cracking due to pipe enlargement using flare processing. It is caused that the heat transfer coefficient inside the pipe is reduced, and then, the heat exchange performance may be reduced.

[0056] The method of measuring the angle of torsion θ will be described with reference to FIGS. 2 and FIGS. 3.

[0057] FIG. 2A is a schematic side view showing a specimen 10 obtained by cutting out a part (portion having a length L in the longitudinal direction) from the grooved pipe of the invention. FIG. 2B and FIG. 2C are a schematic side view and a schematic end view, respectively, which show the state in which a load P is applied from above to the specimen 10 put on a surface of a metallic substrate 20. FIG. 3A is a schematic side view showing the state in which the specimen 10 is completely crushed by the applied load P to be formed into overlapping two plates. FIG. 3B is a schematic side view showing the state in which the two plates are separated from each other. FIG. 3C shows a schematic view (schematic front view) in which an upper plate (10b) of the two plates is removed and a lower plate (10a) is seen from above.

[0058] First of all, as shown in FIG. 2A, a part is cut out from the grooved pipe of the invention to obtain the specimen 10. Specifically, a portion having a length L of 15 to 30 mm in the longitudinal direction is cut out.

[0059] Next, as shown in FIG. 2B and FIG. 2C, the specimen 10 is put on the surface of the metallic substrate 20 and the load P is applied to the specimen 10 from above. The load P is set to about 0.14 to 0.20 kN.

[0060] The metallic substrate 20 is not limited as long as it has such a hardness that it does not dent when the load P is applied to the specimen 10. For example, a stainless steel plate may be used.

[0061] When the load P is applied to the specimen 10 as described above, the specimen 10 is completely crushed into the state in which the two plates (10a and 10b) overlap each other as shown in FIG. 3A. Then, the two plates are separated from each other as shown in FIG. 3B.

[0062] There are cases where the two plates (10a and 10b) are joined together at their both ends (both ends in a direction parallel to the main surface of the substrate 20 in FIG. 3A) in the state shown in FIG. 3A. In such a case, the two plates can be separated from each other by grinding the joined portions with the use of abrasive paper.

[0063] In this way, grooves formed (transferred) by pressing the fins of the upper plate 10b appear at the fins 15 of the lower plate 10a. When the grooves are connected together by lines, the lines (lines indicated by dotted lines in FIG. 3C) mean positions where the fins 16 of the upper plate 10b were present in the state in which the two plates (10a and 10b) overlapped each other as in FIG. 3A.

[0064] Then, an angle formed by the fin 15 and the fin 16 as described above is measured and denoted by 2θ. A value obtained by dividing the angle by two is taken as the angle of torsion (θ).

[Formula 1]

[0065] In the grooved pipe of the invention, the above-mentioned fin tip radius of curvature r and number N of the fins in the circumferential direction satisfy the following formula (1):

$$\text{formula (1): } 0.32 \leq 1/(r \times N) \leq 0.61.$$

[0066] Further, they preferably satisfy the following formula (1'):

$$\text{formula (1'): } 0.52 \leq 1/(r \times N) \leq 0.61.$$

[0067] When formula (1) shown above is satisfied, cracking due to pipe enlargement using flare processing is less likely to occur.

[0068] When formula (1') is satisfied, this tendency becomes further noticeable.

[0069] As shown in FIG. 1B and FIG. 1C, portions where the grooves are present and portions where the fins are present appear alternately in the circumferential direction on the cross-section in the direction perpendicular to the longitudinal direction (direction parallel to the central axis ω) of the grooved pipe of the invention. The latter portions and the former portions are denoted by (i) groove bottom thick portion + fin, and (ii) groove bottom thick portion, respectively. When flare processing is performed, the portions (i) have smaller amount of material elongation compared to (ii). In short, the portions (ii) are more elongated. Therefore, it is necessary to increase the width of the portions (ii) (groove bottom width shown in FIG. 4 to be described later) in order to suppress breakage at the portions (ii). When the number N of the fins is reduced or the tip radius of curvature r of the fins is reduced to satisfy the above formula (1), the width of the portions (ii) can be increased, thus making it possible to suppress cracking during flare processing.

[0070] When the ratio of the groove bottom width to the fin height (groove bottom width/fin height) is not more than a certain value by increasing the number N of the fins or the tip radius of curvature r of the fins, a grooved plug tends to be more easily broken during the manufacturing process. When the grooved plug is broken, fins are formed incompletely at the broken portion or the broken portion serves as resistance to cause fracture of the grooved pipe. In other words, commercialization is not possible. If the number N of the fins and the tip radius of curvature r of the fins are determined so as to satisfy the above formula (1), breakage of the grooved plug is less likely to occur during the manufacturing process.

[0071] When the tip radius of curvature r of the fins or the number N of the fins is too large, the unit mass of the internally grooved pipe is increased, thus leading to cost increases. When the tip radius of curvature r of the fins is too large, the surface area of the internally grooved pipe contributing to heat-transfer effect is reduced, thus causing a decrease in heat-transfer performance. If the number N of the fins and the tip radius of curvature r of the fins are determined so as to satisfy the above formula (1), such problems are less likely to occur.

[Formula 2]

[0072] In the grooved pipe of the invention, the above-mentioned tip radius of curvature r of the fins and angle of torsion θ satisfy the following formula (2):

$$\text{formula (2): } 0.04 \leq r \times (1/\cos\theta) \leq 0.051.$$

[0073] cosθ indicates the interval between an arbitrary fin within the internally grooved pipe and another fin adjacent thereto in the longitudinal direction (direction parallel to the central axis ω) of the pipe.

[0074] In cases where the angle of torsion θ is small and cosθ has a large value, the interval between an arbitrary fin and another fin adjacent thereto in the longitudinal direction of the pipe is large. When performing flare processing, the above-mentioned groove bottom thick portions (ii) which have the smallest thickness should withstand cracking due to flare processing, and the tensile strength in the circumferential direction of the pipe is the lowest at the groove bottom thick portions (ii). Therefore, the larger the interval between an arbitrary fin and another fin adjacent thereto in the longitudinal direction of the pipe is, the more cracking is likely to occur at the groove bottom thick portions (ii) due to flare processing.

[0075] On the other hands, in cases where the angle of torsion θ is large and cosθ is small, the interval between an arbitrary fin and another fin adjacent thereto in the longitudinal direction of the pipe is small and the groove bottom thick portions (ii) are hence reduced in thickness. In this case, when a tool for flare processing is inserted, as it advances, it reaches the portions denoted by (i) groove bottom thick portion + fin before cracking due to pipe enlargement using flare processing occurs at the groove bottom thick portions (ii). In other words, the groove bottom thick portions (ii) are supported by the fins before being broken and cracking due to flare processing can be suppressed.

[0076] The productivity as well as the heat-transfer performance tend to be reduced when $r \times (1/\cos\theta)$ has too large a value.

[0077] In view of this, the grooved pipe of the invention satisfying the above formula (2) is less likely to cause cracking due to pipe enlargement using flare processing.

[Internal Area]

[0078] The internal area (mm^2) which is a surface area of the inner surface of the grooved pipe of the invention is preferably 94 to 335 mm^2 and more preferably 243 to 255 mm^2.

[0079] This is because when the internal area is within the above range, the heat-transfer performance is excellent and cracking due to flare processing is less likely to occur. When the internal area is too large, thread rolling tends to be more difficult.

[0080] The internal area is determined by calculating from numerical values of the external diameter D, thickness T, angle of torsion θ, fin tip radius of curvature r, and number N of the fins that were measured as described above as well as those of the fin height, vertex angle and fin base radius of curvature.

[0081] The fin height and the vertex angle mean the length and the angle shown in FIG. 4, respectively. The fin base radius of curvature R means the radius R of a circle which touches a fin base at a position shown in FIG. 4. As with FIG. 1C, FIG. 4 is an enlarged view of one of the eight dotted portions in FIG. 1B (portion denoted by X).

[0082] On the cross-section shown in FIG. 1C, the fin height is a value obtained by subtracting the distance between the central axis ω and the tip V of a fin and the thickness T from 1/2D which is a half of the external diameter D.

[0083] The vertex angle means an angle formed by the tangent line Za and the tangent line Zb shown in FIG. 1C.

[0084] The method of measuring the fin base radius of curvature R will be described with reference to FIG. 5.

[0085] As with FIG. 1C, FIG. 5 is an enlarged view (schematic view) of one of the eight dotted portions in FIG. 1B (portion denoted by X). In FIG. 5 and FIG. 1C, the same parts are denoted by the same signs.

[0086] First of all, a point of contact between the straight line W explained using FIG. 1C and the outline of the fin 1 is denoted by a point Q.

[0087] Next, the point of intersection between the tangent line Za and the straight line W is denoted by a point O. Then, a circle which has the point O as its center and touches the outline of the fin 1 is drawn and a point of contact between the circle and the outline of the fin 1 is denoted by a point S.

[0088] Next, a circle having the point O as its center and passing through the point Q is drawn and one of points of intersection between the circle and the tangent line Za which is on the side closer to 5a of the fin 1 is denoted by a point P.

[0089] Then, a circle passing through three points including the point P, the point Q and the point S is drawn, and the radius of the circle is called the "fin base radius of curvature R."

[0090] The grooved pipe of the invention as described above is less likely to cause cracking due to pipe enlargement using flare processing.

[Manufacturing Method]

[0091] The manufacturing method of the grooved pipe of the invention is not particularly limited. The grooved pipe of the invention can be manufactured using, for example, a manufacturing device shown in FIG. 6.

[0092] The manufacturing device shown in FIG. 6 will be described.

[0093] FIG. 6 is a schematic cross-sectional view of a manufacturing device 30 capable of manufacturing the grooved pipe of the invention.

[0094] The manufacturing device 30 has a holding plug 32 to be inserted into the inside of a pipe blank 31. The holding plug 32 is in the shape of a truncated cone, and is inserted so that a side having a smaller diameter is on the downstream side in a direction in which the pipe blank 31 is drawn.

[0095] A holding die 33 is provided at a position on the outer peripheral side of the holding plug 32, and is positioned so that the pipe blank 31 is sandwiched between the holding plug 32 and the holding die 33 from inside and outside, respectively. The pipe blank 31 is sandwiched between the holding plug 32 and the holding die 33 to be subjected to diameter reduction processing.

[0096] A grooved plug 35 is connected to the holding plug 32 via a rod-shaped plug shaft 34. The grooved plug 35 has grooves formed at its outer peripheral surface, the grooves having a shape of those to be formed at the inner peripheral surface of the pipe blank 31. The grooved plug 35 is rotatable about the plug shaft 34.

[0097] A plurality of rolling balls 36 are provided at positions on the outer peripheral side of the grooved plug 35, and the pipe blank 31 is sandwiched between the grooved plug 35 and the rolling balls 36 from inside and outside, respectively. The rolling balls 36 are positioned so as to be revolvable in a pipe circumferential direction about the pipe axis (identical to the central axis ω) of the pipe blank 31. The rolling balls 36 are held by a processing ring 40. Each rolling ball 36 can rotate and is capable of planetary rotation within the processing ring 40 while being in contact with the outer surface of the pipe blank 31. The grooved plug 35 and the rolling balls 36 make up a rolling portion 37. Further, a shaping die (not shown) for reducing the external diameter of the pipe blank 31 having grooves formed at its inner surface to a predetermined size is provided on the downstream side of the rolling portion 37 in the drawing direction of the pipe blank 31.

[0098] Next, the method of manufacturing the grooved pipe of the invention using the above-mentioned manufacturing device will be described.

[0099] First of all, the pipe blank 31 is subjected to diameter reduction processing using the holding plug 32 and the holding die 33.

[0100] Next, the pipe blank 31 having undergone the diameter reduction processing is pressed by the rolling balls 36 rotating in a planetary manner outside the pipe blank 31 to be reduced in diameter while the inner surface of the pipe blank 31 is simultaneously pressed against the grooved plug 35. In this way, the grooves of the grooved plug 35 are transferred to the inner surface of the pipe blank 31, whereby fins 39 extending helically are formed. Then, the grooved plug 35 is rotated by the fins 39 which were formed by the grooved plug at the inner surface of the pipe blank 31.

[0101] The grooved plug 35 is connected to the holding plug 32 via the plug shaft 34. The holding plug 32 remains at a position on the inner peripheral side of the holding die 33 by the frictional force due to drawing of the pipe blank 31 and the drag from the holding die 33, and therefore the grooved plug 35 also stops at a position on the inner peripheral side of the rolling balls 36.

[0102] Next, the pipe blank 31 having passed through the rolling portion 37 to have the grooves formed at its inner surface is further reduced in diameter by a shaping die (not shown), whereby the grooved pipe of the invention is obtained.

[0103] The internally grooved pipe having undergone rolling processing in this way is usually wound up to thereby obtain wound coils. The wound coils are annealed and then shipped to air conditioner manufactures or the like.

<Heat Exchanger of the Invention>

[0104] The heat exchanger of the invention will be described.

[0105] The heat exchanger of the invention is not particularly limited as long as it is a heat exchanger including the grooved pipes of the invention.

[0106] For example, FIG. 7 is a partially cutaway front view illustrating a heat exchanger 60 of the invention that is a fin-and-tube heat exchanger into which the grooved pipes of the invention are incorporated; and FIG. 8 is a partially enlarged view (schematic perspective view) thereof.

[0107] As shown in FIG. 7 and FIG. 8, in the heat exchanger 60 of the invention, the grooved pipes 52 of the invention are processed into a hairpin pipe shape. Then, the heat exchanger has a plurality of aluminum fins 50 stacked on one another in parallel, and the grooved pipes 52 of the invention. The grooved pipes 52 of the invention are made to pass through their corresponding holes formed in the aluminum fins 50 and fixed by primary pipe enlargement. A return bend pipe 54 is interposed between two grooved pipes 52 of the invention to connect them together. The grooved pipes 52 of the invention form a long flow path through which a heat medium flows. A smooth pipe is usually used for the return bend pipe 54 but the grooved pipe of the invention processed into a return bend pipe may be used. Air or the like flows between the aluminum fins 50 and a heat medium such as a chlorofluorocarbon refrigerant is made to flow inside the grooved pipes 52 of the invention, whereby heat exchange is performed between the heat medium and the air or the like.

EXAMPLES

[0108] The present invention will be described by way of examples. The present invention should not be construed as being limited to the examples illustrated below.

[0109] Internally grooved pipes for flare processing according to Examples 1 to 7 and Comparative Examples 1 to 8 which had the features shown in Table 1 were fabricated. Each of them is a seamless copper pipe made of C1020 (oxygen-free copper specified in JIS H 3300).

[0110] The external diameter D, the thickness T, the fin tip radius of curvature r, and the number N of fins in each of the internally grooved pipes for flare processing shown in Table 1 have values obtained by performing measurement using the above-mentioned methods on a ring-shaped section obtained by cutting each internally grooved pipe for flare processing in a direction perpendicular to the pipe axis. The internal area (mm^2) also has values obtained by calculating after measurement using the above-mentioned methods.

[0111] Further, the angle of torsion (θ) in Table 1 also has values obtained by performing measurement using the above-mentioned method.

[0112] Each of the above-mentioned internally grooved pipes for flare processing according to Examples 1 to 7 and Comparative Examples 1 to 8 was subjected to a flaring test.

[0113] The flaring test is a test in which a tool for flare processing having a cone angle of 60° is used to gradually enlarge an end of each internally grooved pipe for flare processing until cracking due to flare processing occurs.

[0114] Five samples were prepared for each internally grooved pipe for flare processing, and an end of each sample was gradually enlarged with the tool for flare processing to determine the external diameter at a time when cracking due to flare processing occurred in the same method as in the case of the measurement of the above-mentioned external diameter D. Specifically, the external diameter at the time when cracking due to flare processing occurred (external diameter at an edge having an increased diameter) was measured with a digital caliper at eight portions (of four pairs) circumferentially positioned at substantially regular intervals, and a simple average value was determined from four measurement values. Then, the external diameters (simple average values) of the five samples of the same internally grooved pipe for flare processing were further simply averaged, and the resulting value was taken as the external diameter D' after the internally grooved pipes for flare processing were enlarged.

[0115] The performance of the internally grooved pipes for flare processing were evaluated from the relationship between the resulting external diameter D' and the external diameter D before enlargement.

[0116] Specifically, the internally grooved pipes for flare processing were rated failed (Poor) when $D' - D \geq 2$ was not satisfied and were rated passed (Good) when $D' - D \geq 2$ was satisfied. The internally grooved pipes for flare processing having been rated passed were further rated particularly good (Excellent) when $D' - D \geq 2.32$ was satisfied.

[0117] The grounds for which an internally grooved pipe is rated passed when $D' - D \geq 2$ is satisfied will be given below.

[0118] A brazing ring usually has a wire diameter of 1.4 mm. This is because, when a U-shaped bend pipe is fitted into an internally grooved pipe for flare processing with an external diameter D of 5.00 mm, a portion to be subjected to flare processing needs to be enlarged by about 1.0 mm per side corresponding to about 72% of the wire diameter of the brazing ring, that is to say, to an external diameter of 7.0 mm in order to prevent filler metal leakage.

[Table 1]

	Features											Test results		
	External diameter D(mm) (before enlargement)	Thickness T (mm)	T/D (Calculation result)	0.057-0.005D (Calculation result)	0.075-0.005D (Calculation result)	Angle of torsion θ (°)	**Fin** tip radius of curvature r (mm)	Number of fins N(pcs)	$1/(r \times N)$ (Calculation result)	$r \times (1/\cos\theta)$ (Calculation result)	Internal area (mm^2)	External diameter after enlargement D'(mm)	D'- D (mm)	Flaring test result
EX1	4.999	0.21	0.042	0.032	0.050	25	0.039	45	0.570	0.043	252	7.341	2.342	Excellent
EX 2	5.030	0.19	0.038	0.032	0.050	25	0.040	45	0.556	0.044	250	7.430	2.400	Excellent
EX3	5.001	0.20	0.040	0.032	0.050	25	0.044	45	0.505	0.049	245	7.208	2.207	Good
EX4	5.002	0.20	0.040	0.032	0.050	25	0.042	45	0.529	0.046	250	7.616	2.614	Excellent
EX5	5.000	0.20	0.040	0.032	0.050	25	0.043	45	0.517	0.047	244	7.317	2.317	Good
EX6	5.000	0.18	0.036	0.032	0.050	25	0.043	45	0.517	0.047	248	7.042	2.042	Good
EX7	5.000	0.20	0.040	0.032	0.050	16	0.040	50	0.500	0.042	252	7.012	2.012	Good
CE 1	5.005	0.19	0.038	0.032	0.050	5	0.035	42	0.680	0.035	233	6.494	1.489	Poor
CE 2	5.006	0.20	0.040	0.032	0.050	5	0.033	42	0.722	0.033	239	6.681	1.675	Poor
CE 3	5.011	0.18	0.036	0.032	0.050	5	0.030	42	0.794	0.030	242	6.872	1.861	Poor
CE 4	5.028	0.20	0.040	0.032	0.050	5	0.031	42	0.768	0.031	232	6.843	1.815	Poor
CE 5	5.015	0.20	0.040	0.032	0.050	5	0.038	42	0.627	0.038	228	6.839	1.824	Poor
CE 6	4.995	0.20	0.040	0.032	0.050	5	0.038	42	0.627	0.038	229	6.552	1.557	Poor
CE 7	4.990	0.18	0.036	0.032	0.050	5	0.039	42	0.611	0.039	229	6.713	1.723	Poor
CE 8	5.000	0.20	0.040	0.032	0.050	14	0.038	40	0.658	0.039	227	6.970	1.970	Poor

EX: Example
CE: Comparative Example

REFERENCE SIGNS LIST

[0119]

1, 1a, 1b fin
3a, 3b groove bottom
5a, 5b point
10, 10a, 10b specimen
15 fins the specimen (plate) 10a has
16 fins the specimen (plate) 10b has
20 substrate
30 manufacturing device
31 pipe blank
32 holding plug
33 holding die
34 plug shaft
35 grooved plug
36 rolling ball
37 rolling portion
39 fin
40 processing ring
50 aluminum fin
52 grooved pipe of the invention
54 return bend pipe
60 heat exchanger of the invention

[0120] This application claims priority based on Japanese Patent Application No. 2022-107073 filed on July 1, 2022, the entire disclosure of which is incorporated herein by reference.

Claims

1. An internally grooved pipe for flare processing which is a seamless pipe having grooves at its inner surface, flare processing being applied to its end portions, wherein:

an external diameter D is 2.0 mm or more but 5.5 mm or less;
a ratio T/D of a thickness T to the external diameter D is 0.057-0.005D or more but 0.075-0.005D or less;
the grooves at its inner surface have an angle of torsion θ of 15° or more but 27° or less;
a tip radius of curvature r of fins making up the grooves at the inner surface and a number N of the fins in a circumferential direction satisfy formula (1) shown below:

$$\text{formula (1):}\quad 0.32 \leq 1/(r\times N) \leq 0.61$$

and
the tip radius of curvature r and the angle of torsion θ satisfy formula (2) shown below:

$$\text{formula (2):}\quad 0.04 \leq r \times (1/\cos\theta) \leq 0.051.$$

2. The internally grooved pipe for flare processing according to claim 1, wherein the tip radius of curvature r and the number N of the fins satisfy formula (1') shown below:

$$\text{formula (1'):}\quad 0.52 \leq 1/(r\times N) \leq 0.61.$$

3. The internally grooved pipe for flare processing according to claim 1 or 2, wherein the internally grooved pipe is made of copper or a copper alloy.

4. A heat exchanger comprising the internally grooved pipe for flare processing according to any one of claims 1 to 3.

FIG.1A

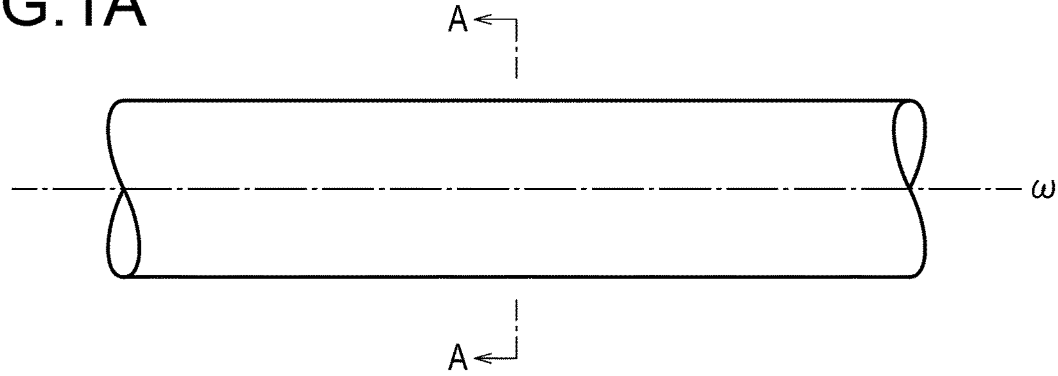


FIG.1B

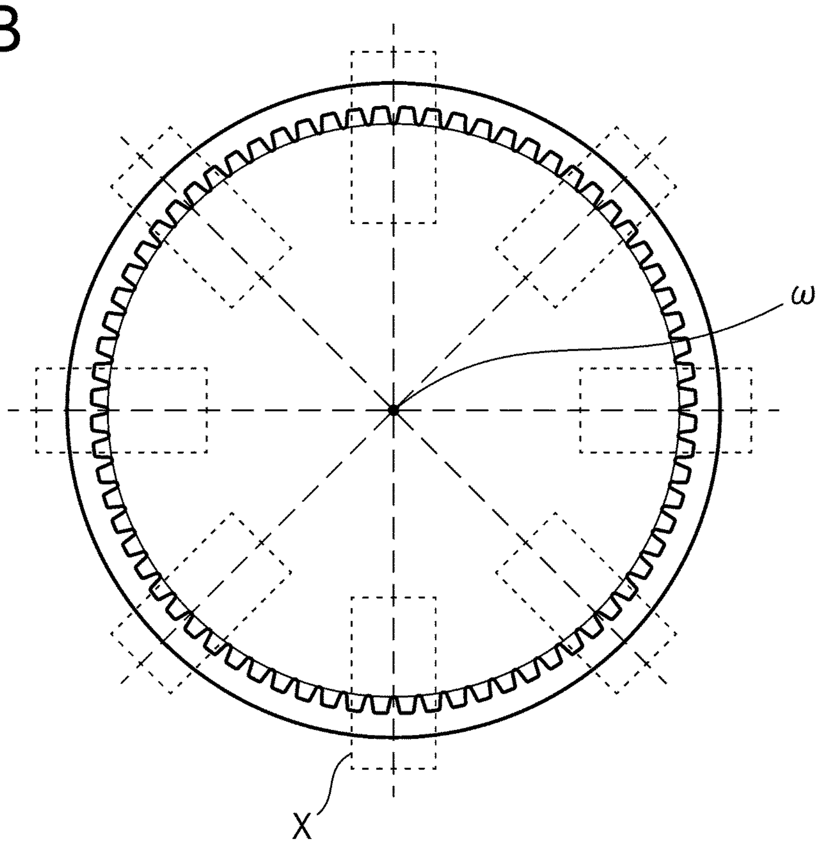


FIG.1C

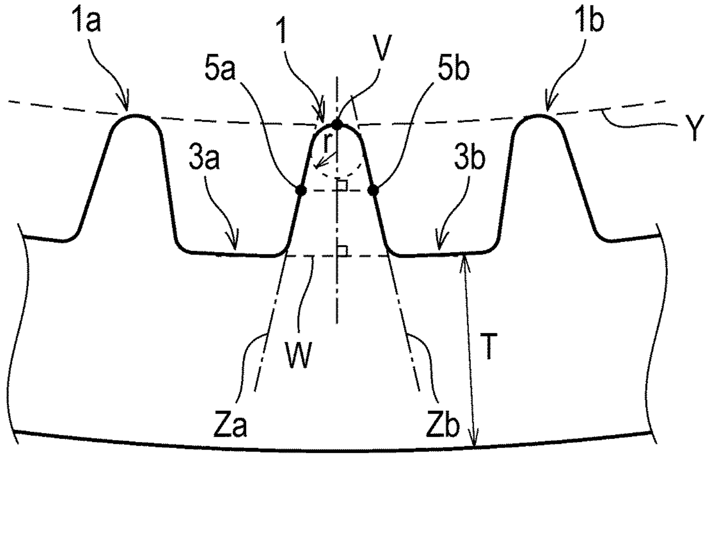


FIG.2A

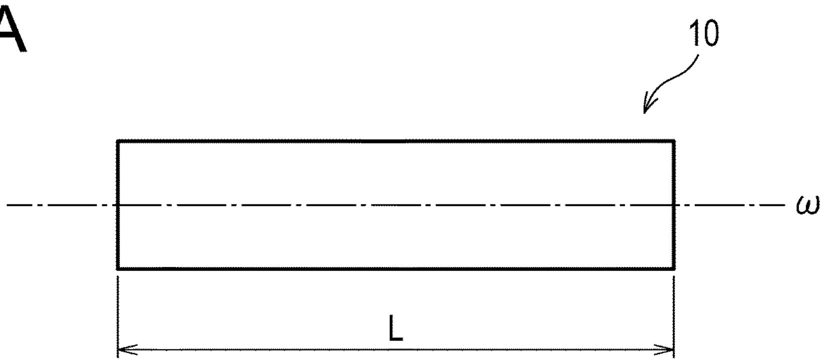


FIG.2B

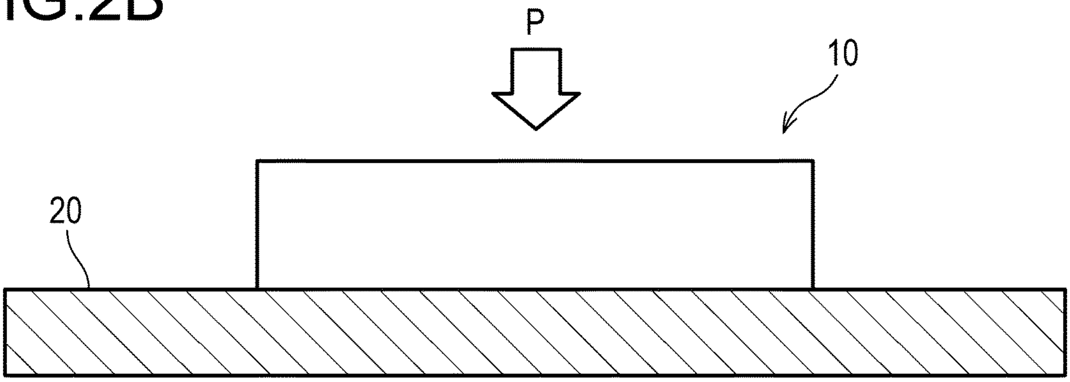


FIG.2C

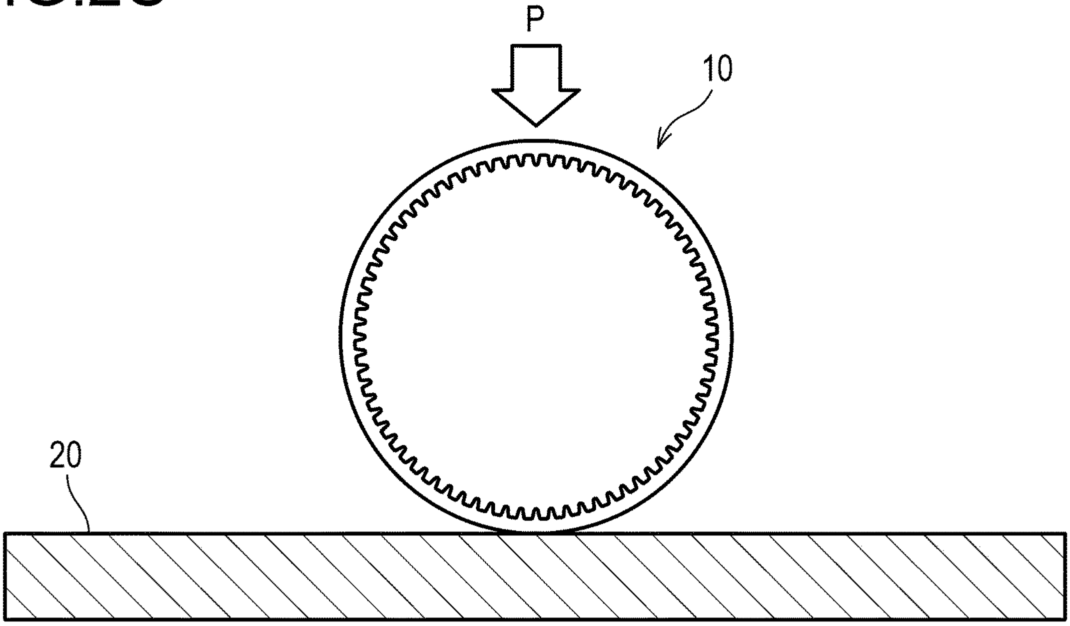


FIG.3A

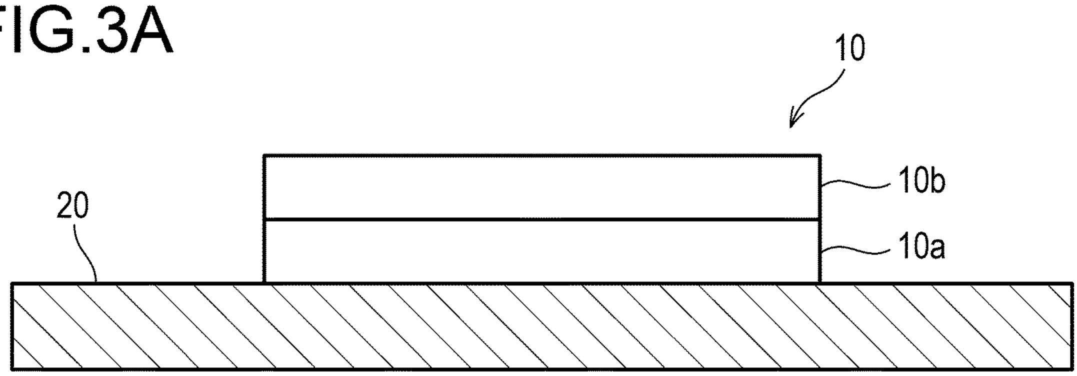


FIG.3B

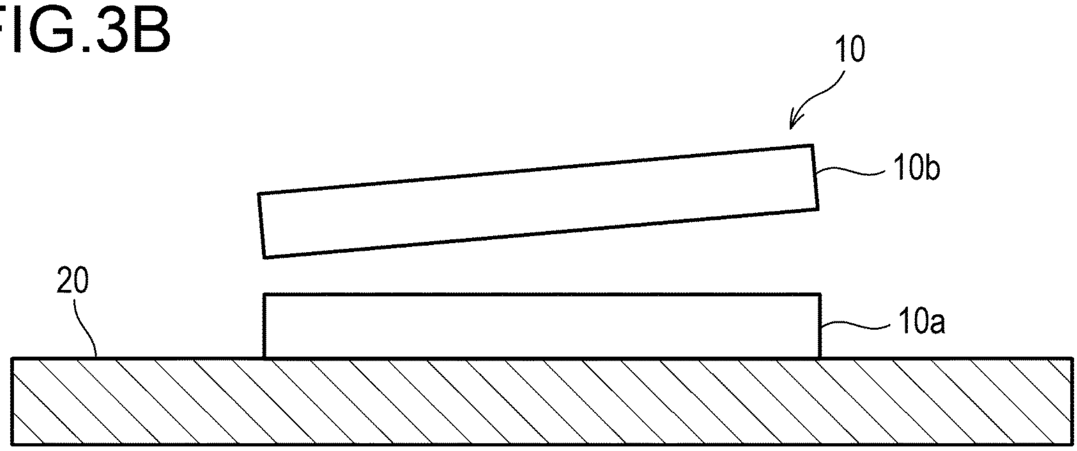


FIG.3C

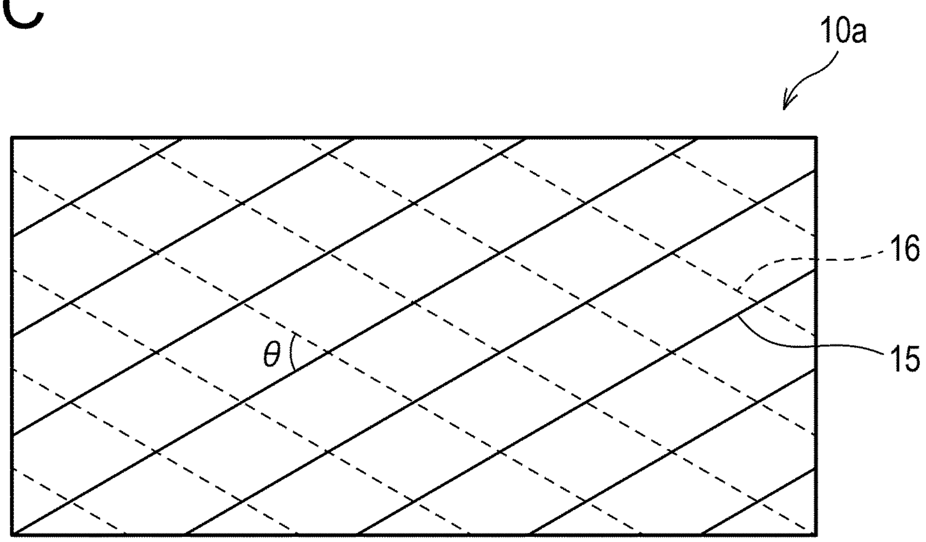


FIG.4

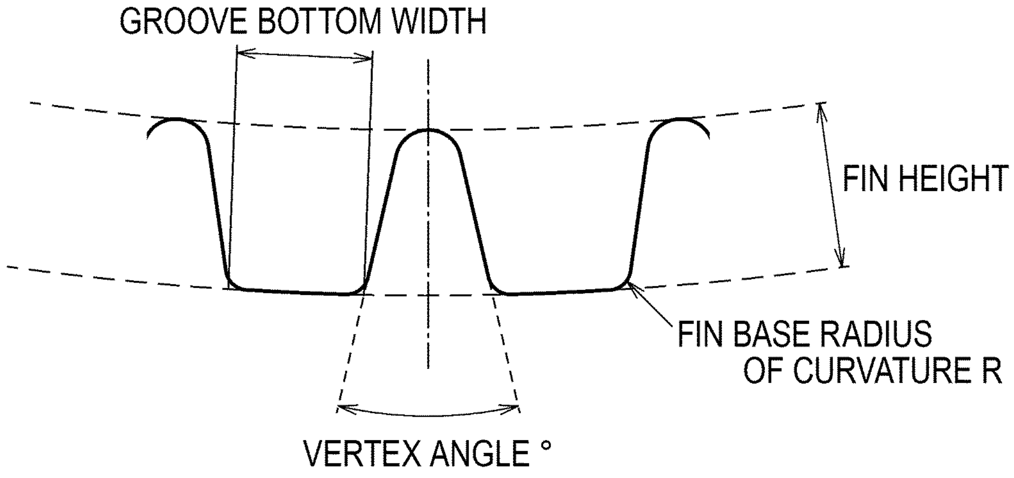

GROOVE BOTTOM WIDTH
FIN HEIGHT
FIN BASE RADIUS
OF CURVATURE R
VERTEX ANGLE °

FIG.5

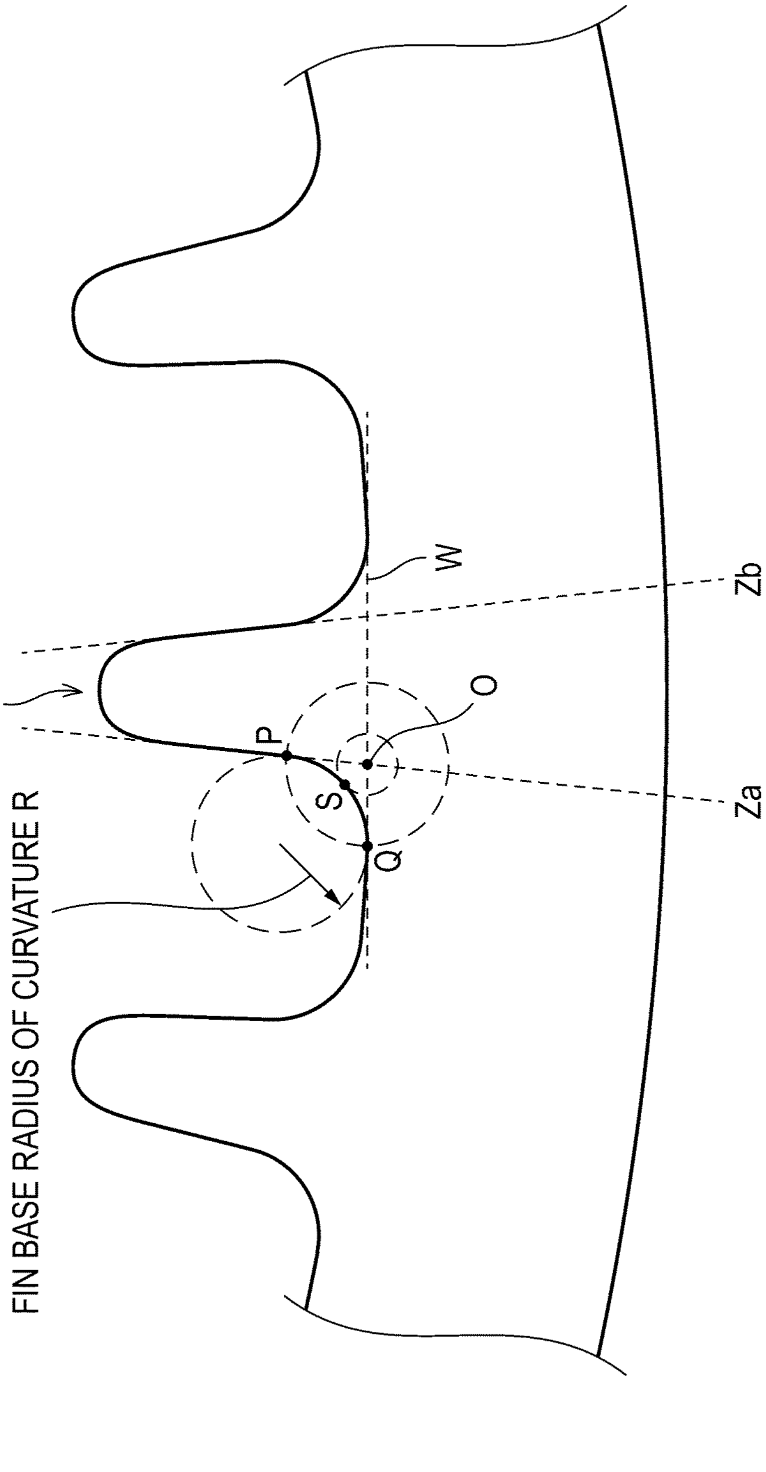


FIG.6

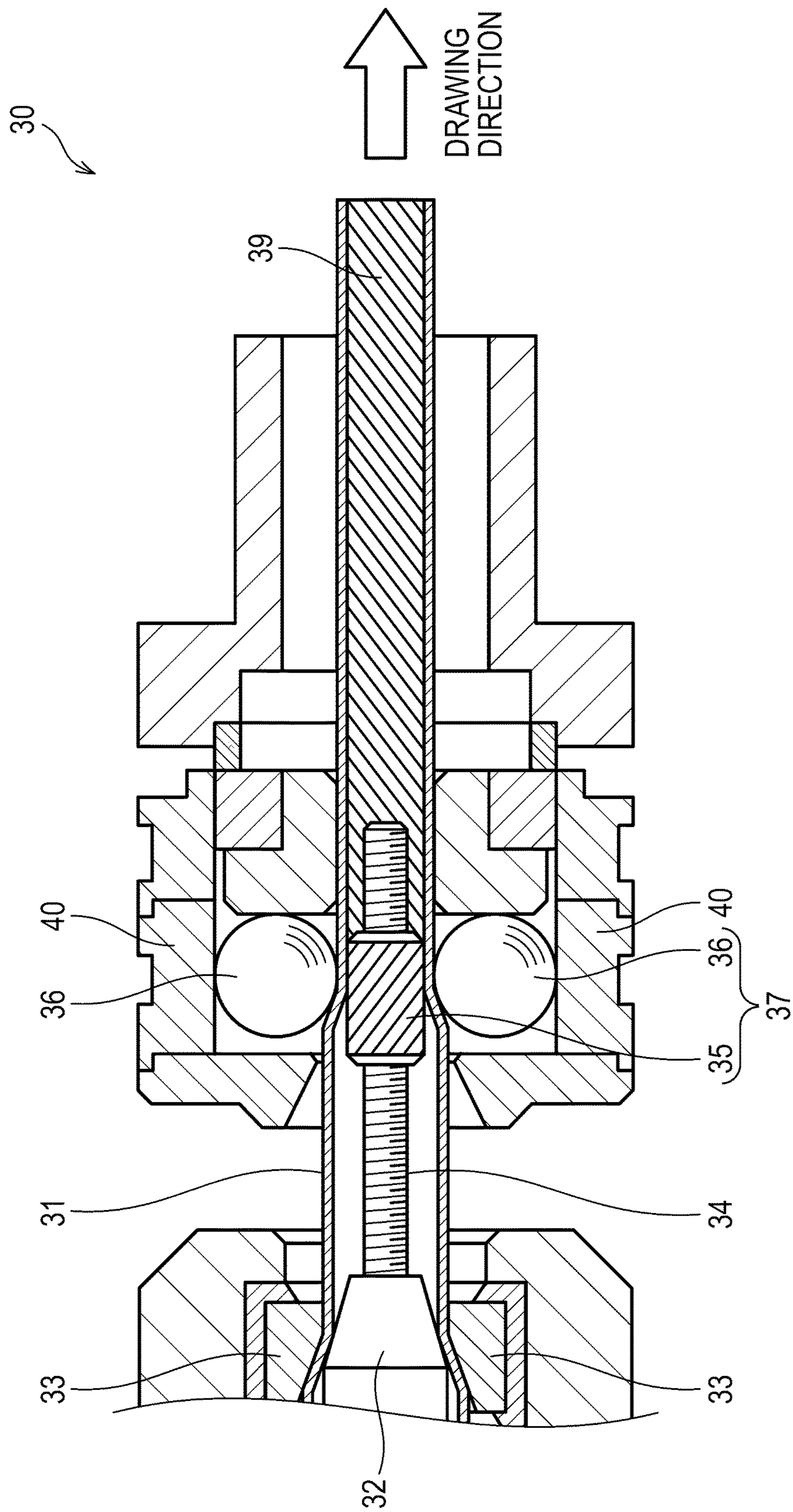


FIG.7

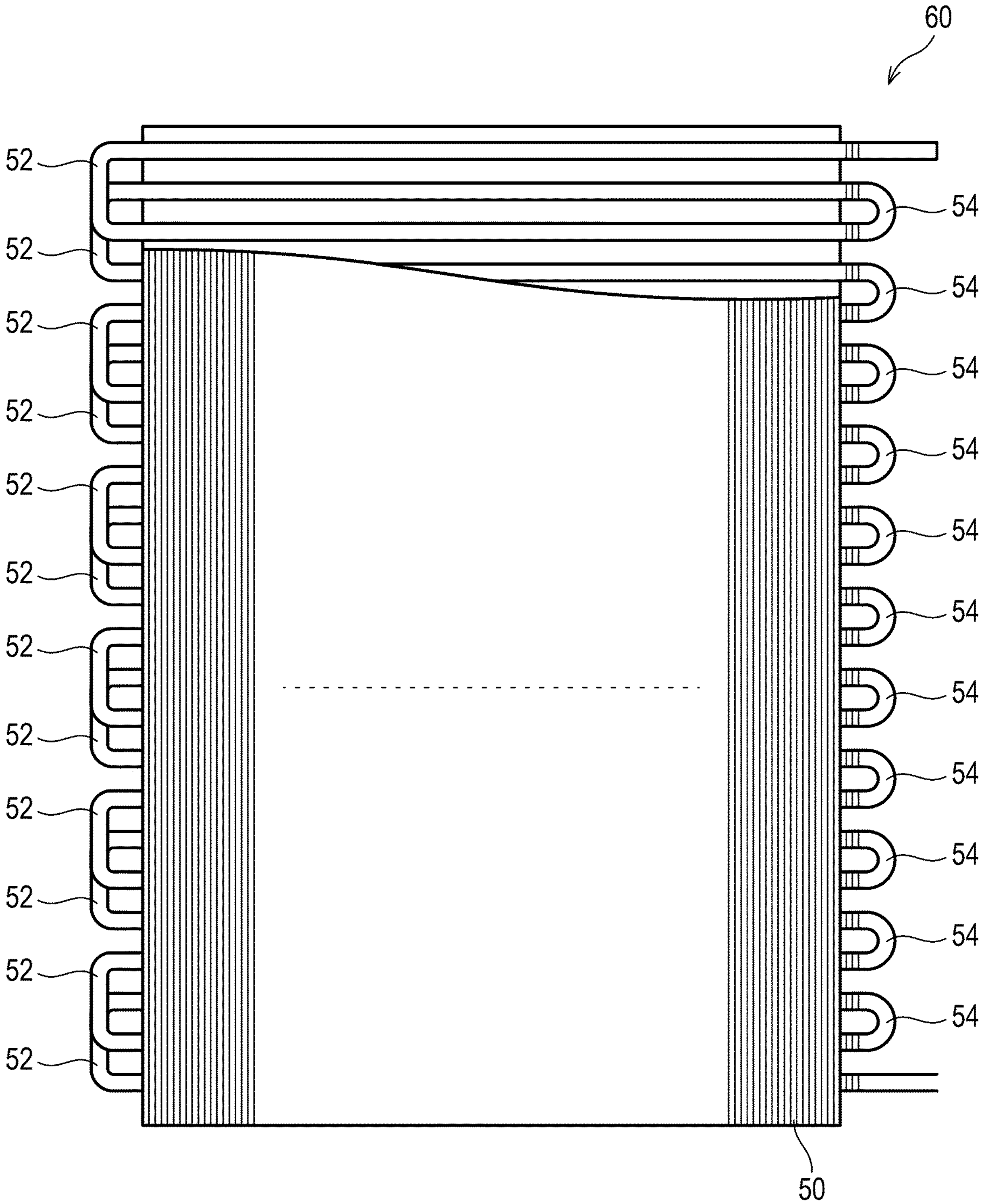

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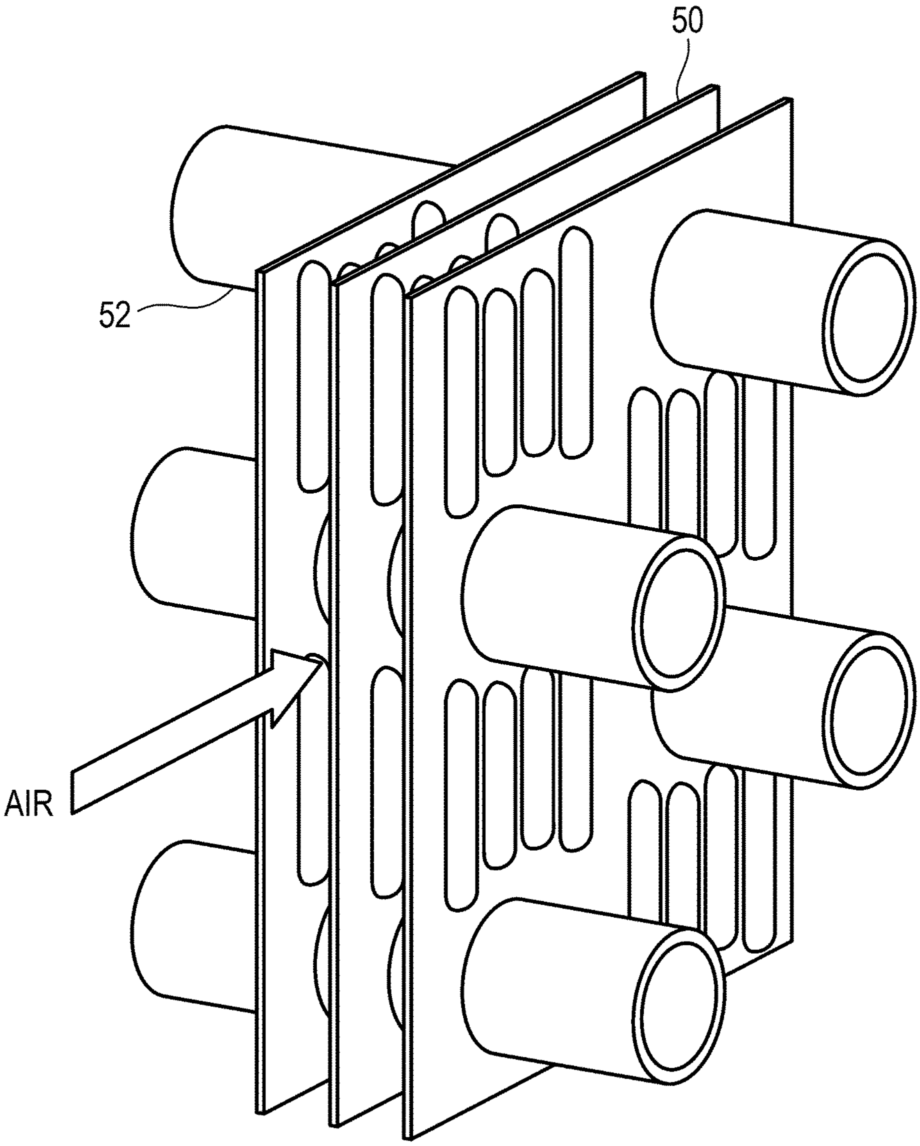
FIG.8



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/020057

A. CLASSIFICATION OF SUBJECT MATTER

F28F 1/40(2006.01)i; ***B21D 53/06***(2006.01)i; ***C22F 1/00***(2006.01)i
FI: F28F1/40 D; B21D53/06 D; C22F1/00 626

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)

F28F1/40; B21D53/06; C22F1/00

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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 2017-20063 A (KOBELCO & MAT COPPER TUBE INC) 26 January 2017 (2017-01-26) paragraphs [0014]-[0016], [0032], fig. 1	1-4
Y	JP 2009-243722 A (KOBELCO & MAT COPPER TUBE INC) 22 October 2009 (2009-10-22) paragraphs [0022]-[0023], [0065], fig. 1-9	1-4

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

* Special categories of cited documents:
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"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	Date of mailing of the international search report
08 August 2023	**15 August 2023**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/020057

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2017-20063 A	26 January 2017	(Family: none)	
JP 2009-243722 A	22 October 2009	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2017020063 A **[0009]**
- JP 2022107073 A **[0120]**