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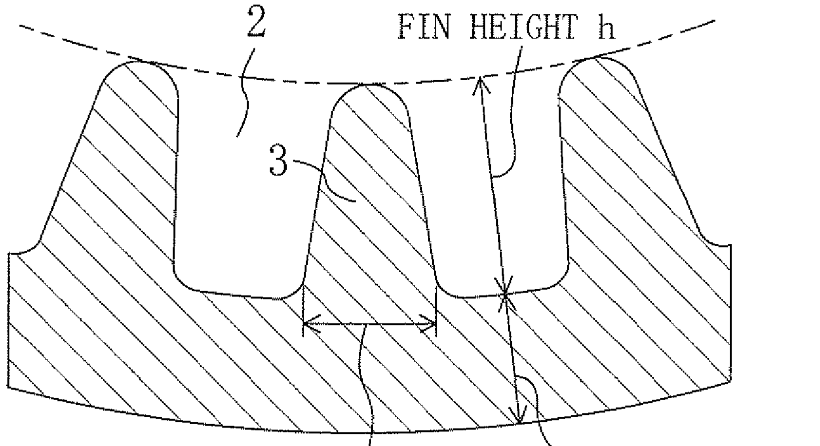
(54) GROOVED TUBE FOR HEAT EXCHANGER

(57) A heat exchanger grooved tube is made of a copper alloy having a 0.2% proof stress of greater than or equal to 40 N/mm^2, and the relationship among the fin width b, the number N of fins (3), and the root thickness t is represented by $8 < bN/t < 20$.

FIG. 3



EP 2 320 188 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to heat exchanger grooved tubes, and more particularly relates to a measure for reducing collapse of grooves during tube expansion.

BACKGROUND ART

[0002] Conventionally, internally grooved tubes each having an internal surface including many grooves to increase the heat transfer performance have been often used as heat transfer tubes for heat exchangers (so-called finned-tube heat exchangers) of refrigeration systems, etc. For example, the internal surface of an internally grooved tube of PATENT DOCUMENT 1 includes many fins helically extending along the tube axial direction, and a groove is formed between each adjacent pair of the fins. This allows the internal surface area of the tube to be larger than that of a so-called smooth tube which does not include fins and grooves, thereby accelerating the heat transfer action.

CITATION LIST

PATENT DOCUMENT

[0003]

PATENT DOCUMENT 1: Japanese Patent Publication No. H08-174044

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0004] Incidentally, in the assembly of a heat exchanger, in order to adhere an internally grooved tube having been passed through a plurality of fin plates to the fin plates, the internally grooved tube is expanded by inserting a tube expanding tool into the internally grooved tube. In this case, the distal ends of fins forming the internal surface of the tube are pressed by the tube expanding tool, and thus, are crushed to some extent.

[0005] Here, the operating pressure of an internally grooved tube for use in a so-called supercritical refrigeration cycle in which the high pressure exceeds the critical pressure of refrigerant is higher than that for use in a subcritical refrigeration cycle, and thus, the tube thickness needs to be increased in order to ensure the tube strength. However, the tube expanding force for expanding the tube must also be increased with an increase in the tube thickness, thereby causing the fins forming the internal surface of the tube to be significantly crushed. As a result, the heat transfer performance is significantly impaired.

[0006] The present invention has been made in view of the foregoing point, and it is an object of the present invention to reduce collapse of fins arising from expansion of heat exchanger grooved tubes (infernally grooved tubes).

SOLUTION TO THE PROBLEM

[0007] A first aspect of the invention is directed to a heat exchanger grooved tube having an internal surface including a plurality of grooves and a plurality of projections adjacent to the grooves. The heat exchanger grooved tube of the present invention is made of a copper alloy having a 0.2% proof stress of greater than or equal to 40 N/mm^2, and the relationship among a width b of a root end of each of the projections, a number N of the projections, and a bottom thickness t of each of the grooves is represented by $8 < bN/t < 20$.

[0008] According to the above-described invention, a copper alloy having a higher proof stress than a conventional material, i.e., phosphorus-deoxidized copper, is used as a material. This can reduce the bottom thickness t of each of the grooves (the root thickness t illustrated in FIG. 3) while maintaining the same design pressure (the fluid pressure in the tube). Furthermore, in the present invention, the tube is formed such that the relationship bN/t among the width b of the root end of each of the projections before the tube expansion, the number N of the projections (i.e., the number of the grooves), and the bottom thickness t of each of the grooves is greater than 8 and less than 20. This relationship allows the ratio (h/h_0) of the projection (fin) height after the tube expansion to that before the tube expansion to be greater than or equal to approximately 0.8 as illustrated in FIG. 6. Specifically, the degree of collapse of the projections arising from the tube expansion is reduced.

[0009] A second aspect of the invention is the heat exchanger grooved tube of the first aspect of the invention, wherein the heat exchanger grooved tube is used for a refrigeration circuit through which carbon dioxide serving as refrigerant circulates and which operates in a vapor compression refrigeration cycle such that a high pressure is greater than or equal to a critical pressure of carbon dioxide.

[0010] According to the above-described invention, a so-called supercritical cycle in which the high pressure corresponds to a supercritical pressure is performed in the refrigeration circuit. This increases the design pressure of the heat exchanger grooved tube. Even in this case, the bottom thickness t of each of the grooves of the grooved tube can be reduced, thereby facilitating satisfying the relationship of $8 < bN/t < 20$.

ADVANTAGES OF THE INVENTION

[0011] Therefore, according to the present invention, the tube is made of a copper alloy having a 0.2% proof stress of greater than or equal to 40 N/mm^2, thereby reducing the bottom thickness t of each of the grooves. Furthermore, the relationship among the width b of the root end of each of the projections, the number N of the projections, and the bottom thickness t of each of the grooves is represented by $8 < bN/t < 20$, thereby reliably reducing collapse of the projections (fins) arising from expansion of tubes of any size.

[0012] Here, referring to FIG. 6, in order to reduce collapse of the projections in the height direction, the above-described value bN/t may be as large as possible. In order to increase the value bN/t, the width b of the root end of each of the projections and the number N of the projections may be increased because the bottom thickness t is determined by the design pressure. However, with an increase in the width b of the root end of each of the projections, the internal surface area of the tube is reduced, thereby reducing the heat transfer performance. An increase in the number N of the projections causes an increase in the tube weight and an increase in the pressure loss while increasing the internal surface area of the tube. Therefore, in the present invention, the value bN/t is set greater than 8 in order to reduce collapse of the projections in the height direction, and the value bN/t is set less than 20 in order to reduce an increase in the tube weight and an increase in the pressure loss while ensuring an appropriate internal surface area of the tube. Therefore, according to the present invention, while an appropriate internal surface area of the tube is ensured, collapse of the projections can be reliably reduced without increasing the tube weight and pressure loss. As a result, a grooved tube exhibiting high heat transfer performance, and a heat exchanger using the grooved tube can be provided.

[0013] When, as described in the second aspect of the invention, the tube is used for a refrigeration circuit operating in a supercritical refrigeration cycle by circulating carbon dioxide therethrough, the high pressure of the cycle is higher than that of a normal subcritical refrigeration cycle, thereby increasing the design pressure. However, an increase in the root thickness t can be reduced, and the relationship of $8 < bN/t < 20$ is reliably satisfied. This can reduce collapse of the projections. As a result, high heat transfer performance can be achieved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

[FIG. 1] FIG. 1 is a longitudinal cross-sectional view illustrating a heat transfer tube according to an embodiment.

[FIG. 2] FIG. 2 is a cross-sectional view illustrating the heat transfer tube according to the embodiment.

[FIG. 3] FIG. 3 is a cross-sectional view illustrating an essential portion of the heat transfer tube according to the embodiment.

[FIG. 4] FIG. 4 is a graph illustrating the relationship between the area increase rate and the rate of acceleration of heat transfer of an evaporator.

[FIG. 5] FIG. 5 is a graph illustrating the relationship between the area increase rate and the rate of acceleration of heat transfer of a radiator.

[FIG. 6] FIG. 6 is a graph illustrating the relationship between the value bN/t and the ratio of variation in the fin height.

DESCRIPTION OF EMBODIMENT

[0015] An embodiment of the present invention will be described hereinafter in detail with reference to the drawings. The following embodiment is set forth merely for the purposes of preferred examples in nature, and is not intended to limit the scope, applications, and use of the invention.

[0016] A heat exchanger grooved tube according to this embodiment is used as a heat transfer tube for a heat exchanger (a so-called finned tube heat exchanger) provided for a refrigeration system, etc., and refrigerant flows through the interior of the grooved tube. The refrigerant flowing through the heat exchanger grooved tube (hereinafter referred to as the heat transfer tube (1)) is evaporated or condensed by exchanging heat with air or water circulating around the tube. The heat transfer tube (1) of this embodiment is for use in a radiator or an evaporator of a refrigeration circuit operating in a vapor compression refrigeration cycle by circulating carbon dioxide serving as refrigerant therethrough. The refrigeration circuit operates in a supercritical refrigeration cycle in which the high pressure is increased to greater than or equal to the critical pressure of carbon dioxide by compressing carbon dioxide.

[0017] As illustrated in FIGS. 1-3, the internal surface of the heat transfer tube (1) includes a plurality of fins (3) helically extending along the tube axial direction. The fins (3) form projections each having a cross section formed in a tapered chevron shape. Adjacent grooves (2) are formed between adjacent ones of the fins (3). The grooves (2) each have an inverted trapezoidal cross section. The grooves (2) and the fins (3) are formed in parallel, and are inclined at a predetermined lead angle α to the tube axial direction.

[0018] Here, in the assembly of a heat exchanger, such as a radiator or an evaporator, in order to adhere the heat transfer tube (1) having been passed through a plurality of fin plates to the fin plates, the heat transfer tube (1) is expanded using a tube expanding tool. The expansion of the tube causes the fins (3) forming the internal surface of the heat transfer tube (1) to be crushed to some extent. In particular, in the supercritical cycle, the high pressure is very high, and thus, the root thickness t (see FIG. 3) needs to be greater than that in a normal subcritical cycle in order to ensure the strength of the heat transfer tube (1). This increases the tube expanding force needed to expand the tube, thereby causing the fins (3) to be further crushed. As a result, the heat transfer performance is significantly impaired.

[0019] Therefore, the heat transfer tube (1) of this embodiment is made of a copper alloy having a 0.2% proof stress of greater than or equal to 40 N/mm^2. Specifically, a material having a higher proof stress than a conventional material, i.e., phosphorus-deoxidized copper (C1220-OL), is used as a material of the heat transfer tube (1) of this embodiment. This can reduce the root thickness t while maintaining the same design pressure (the design pressure of refrigerant flowing through the heat transfer tube (1)).

[0020] The heat transfer tube (1) of this embodiment is configured such that the relationship among the fin width b, the number N of the fins (3), and the root thickness t of the grooves (2) is represented by 8 < bN/t < 20. The fin width b corresponds to the width of the root end of each of the projections according to the present invention. The number N of the fins (3) corresponds to the number of the projections according to the present invention. The root thickness t corresponds to the bottom thickness according to the present invention.

[0021] With the above configuration, as illustrated in FIG. 6, the ratio of variation in the fin height h arising from the tube expansion is greater than or equal to approximately 0.8. The ratio of variation denotes the ratio (h/h_0) of the fin height h after the tube expansion to the fin height h_0 before the tube expansion. With an increase in the ratio of variation, i.e., as the ratio of variation is closer to "1," collapse of the fins in the height direction is reduced. The ratio of variation (h/h_0) proportionally increases until the value bN/t reaches approximately 10, and thereafter, is substantially fixed. Thus, when the value bN/t is set greater than 8, this can appropriately reduce collapse of the fins (3) arising from the tube expansion. This can reduce the loss of the internal surface area of the tube and the loss of the heat transfer performance.

[0022] Consequently, as illustrated in FIGS. 4 and 5, the rate η of acceleration of heat transfer can be increased as compared with a conventional heat transfer tube made of phosphorus-deoxidized copper. Specifically, in either an evaporator (FIG. 4) or a radiator (FIG. 5), the area increase rate σ (illustrated by the black triangle in each of the figures) of the heat transfer tube (1) after the tube expansion is not reduced as much as that of the conventional heat transfer tube (illustrated by the black circle in each of the figures) while being less than the area increase rate σ (illustrated by the white circle in each of the figures) before the tube expansion. In other words, the loss of the area increase rate σ can be reduced as compared with the conventional art. This can reduce the loss of the rate η of acceleration of heat transfer. The area increase rate σ denotes the rate of increase in the internal surface area of the tube with respect to the internal surface area of a smooth tube without grooves. Therefore, the area increase rate σ before the tube expansion is highest. The rate η of acceleration of heat transfer of the heat transfer tube (1) represents the heat transfer performance, and is basically proportional to the area increase rate σ.

[0023] The reason why the value bN/t is set less than 20 is as follows. In order to reduce collapse of the fins in the height direction, the value bN/t may be set as large as possible as seen from FIG. 6. In order to increase the value bN/t, the fin width b and the fin number N may be substantially increased because the root thickness t is determined by the design pressure. However, with an increase in the fin width b, the internal surface area of the tube is reduced, thereby reducing the heat transfer performance. An increase in the fin number N causes an increase in the tube weight and an increase in the pressure loss while increasing the internal surface area of the tube. Therefore, in this embodiment, in order to reduce an increase in the tube weight and an increase in the pressure loss while ensuring an appropriate internal surface area of the tube, the value bN/t is set less than 20. In the conventional heat transfer tube made of phosphorus-deoxidized copper, the value bN/t has been set greater than or equal to 20.

-Advantages of Embodiment-

[0024] As described above, according to this embodiment, the heat transfer tube is made of a copper alloy having a 0.2% proof stress of greater than or equal to 40 N/mm^2, thereby reducing the root thickness t. Furthermore, the relationship among the fin width b, the fin number N, and the root thickness t is represented by 8 < bN/t < 20, and thus, while an appropriate internal surface area of the tube is ensured, collapse of the fins (3) is reliably reduced without increasing the tube weight and pressure loss. As a result, a heat transfer tube (1) and a heat exchanger, such as an evaporator or a radiator, both exhibiting high heat transfer performance can be provided.

[0025] The heat transfer tube is used for a refrigeration circuit operating in a supercritical refrigeration cycle by circulating carbon dioxide therethrough, and the high pressure of the cycle is higher than that of a normal subcritical refrigeration cycle, thereby increasing the design pressure of the heat transfer tube (1). However, an increase in the root thickness t can be reduced. This can advantageously reduce collapse of the fins (3). As a result, high heat transfer performance can be achieved.

INDUSTRIAL APPLICABILITY

[0026] As described above, the present invention is useful for heat exchanger grooved tubes each having an internal surface including a plurality of grooves.

DESCRIPTION OF REFERENCE CHARACTERS

[0027]

1 HEAT TRANSFER TUBE (HEAT EXCHANGER GROOVED TUBE)
2 GROOVE

3 FIN (PROJECTION)

Claims

1. A heat exchanger grooved tube having an internal surface including a plurality of grooves and a plurality of projections adjacent to the grooves,
wherein the heat exchanger grooved tube is made of a copper alloy having a 0.2% proof stress of greater than or equal to 40 N/mm^2, and
the relationship among a width b of a root end of each of the projections, a number N of the projections, and a bottom thickness t of each of the grooves is represented by $8 < bN/t < 20$.

2. The heat exchanger grooved tube of claim 1, wherein the heat exchanger grooved tube is used for a refrigeration circuit through which carbon dioxide serving as refrigerant circulates and which operates in a vapor compression refrigeration cycle such that a high pressure is greater than or equal to a critical pressure of carbon dioxide.

FIG. 1

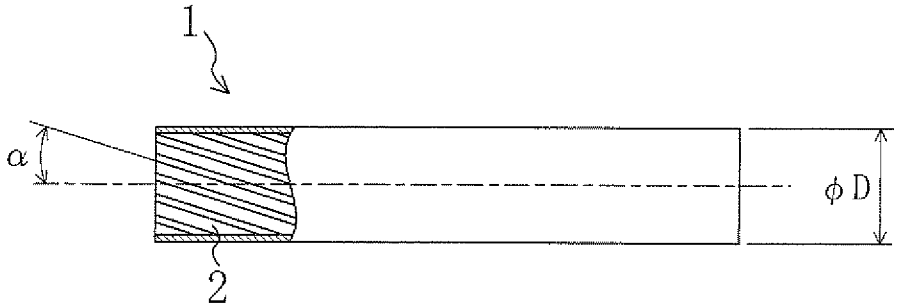


FIG. 2

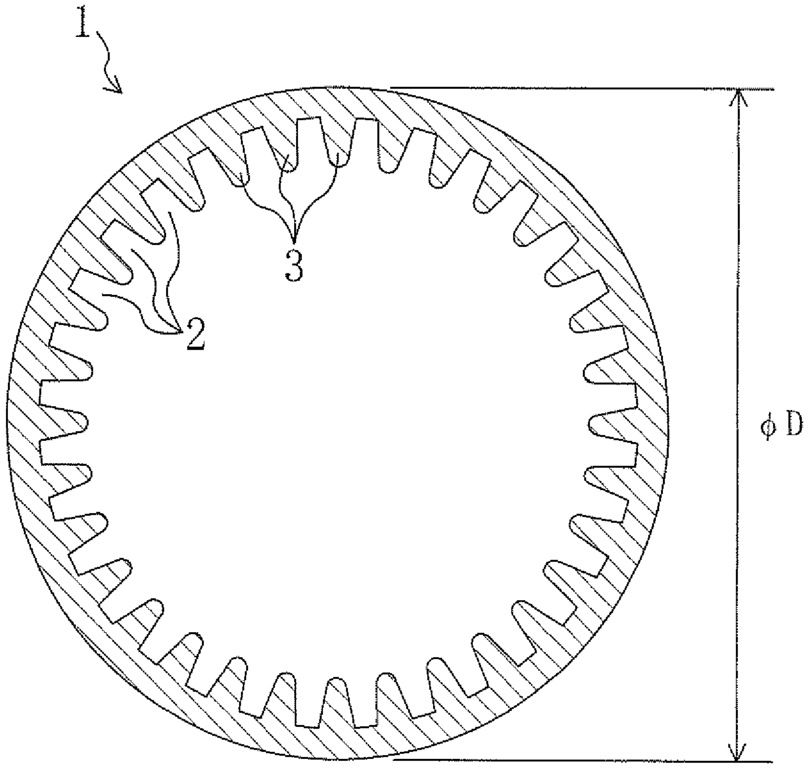


FIG. 3

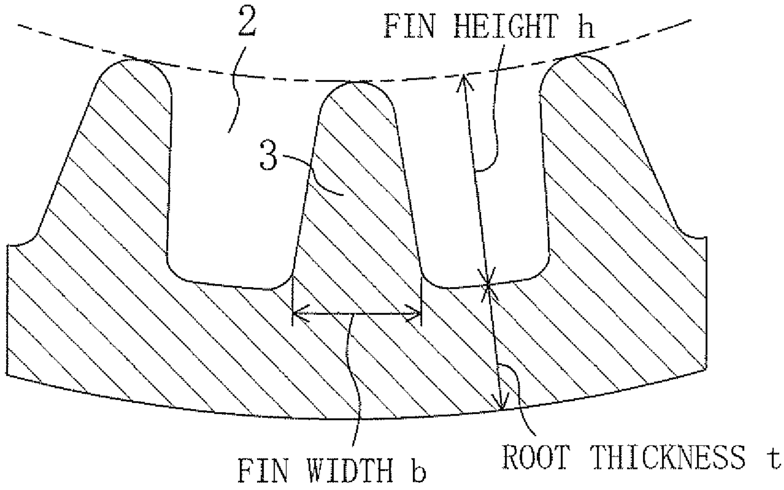

2
FIN HEIGHT h
3
FIN WIDTH b
ROOT THICKNESS t

FIG. 4

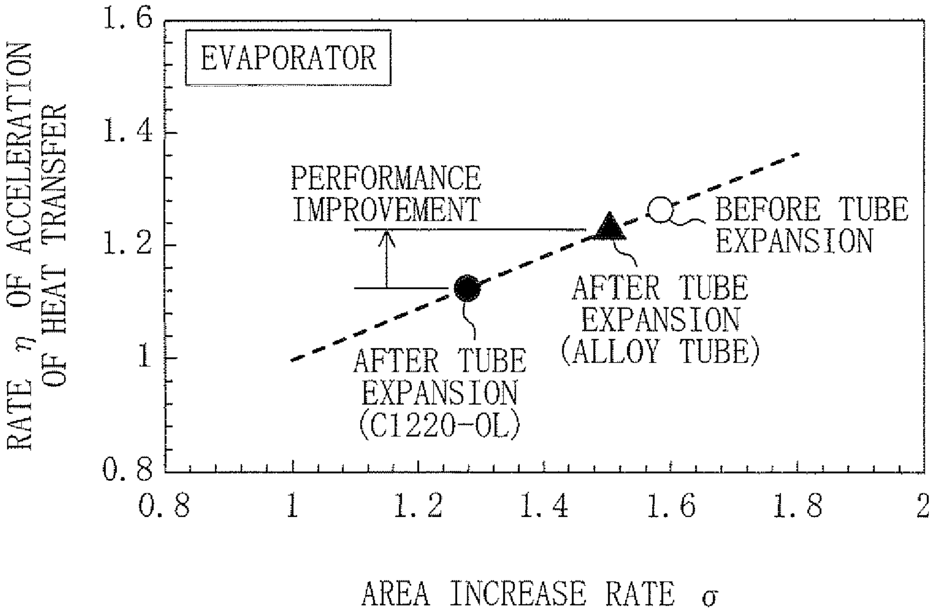

EVAPORATOR
PERFORMANCE IMPROVEMENT
BEFORE TUBE EXPANSION
AFTER TUBE EXPANSION (ALLOY TUBE)
AFTER TUBE EXPANSION (C1220-OL)
RATE η OF ACCELERATION OF HEAT TRANSFER
AREA INCREASE RATE σ
1.6
1.4
1.2
1
0.8
0.8
1
1.2
1.4
1.6
1.8
2

FIG. 5

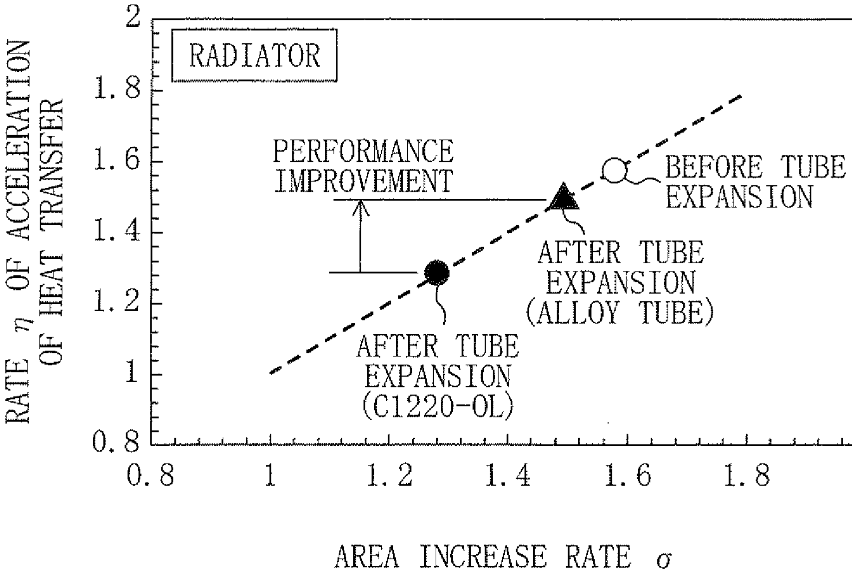
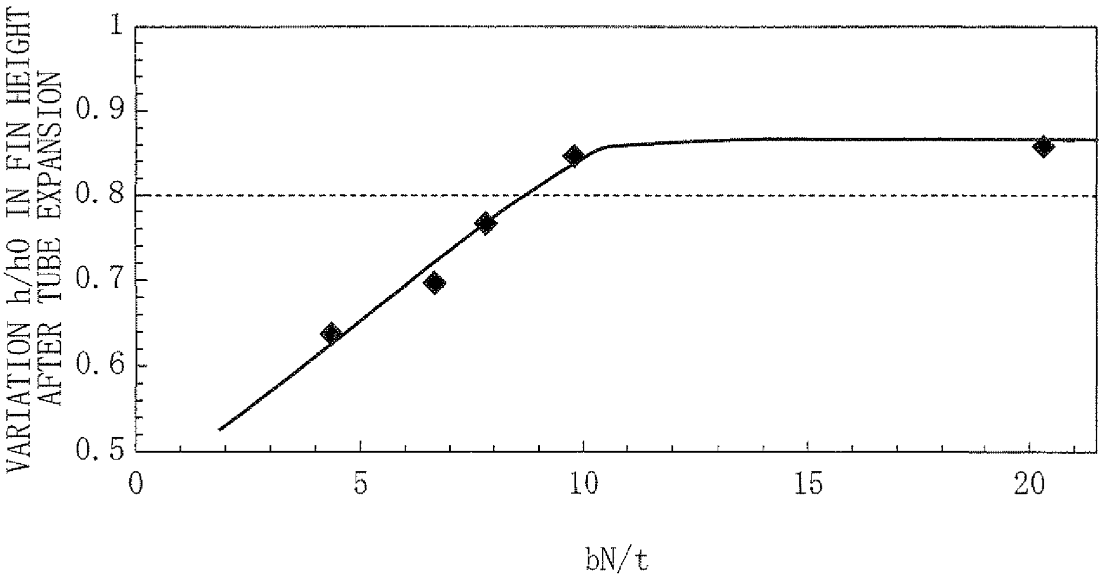

RADIATOR
PERFORMANCE IMPROVEMENT
BEFORE TUBE EXPANSION
AFTER TUBE EXPANSION (ALLOY TUBE)
AFTER TUBE EXPANSION (C1220-OL)
RATE η OF ACCELERATION OF HEAT TRANSFER
AREA INCREASE RATE σ
2
1.8
1.6
1.4
1.2
1
0.8
0.8
1
1.2
1.4
1.6
1.8
2

FIG. 6


VARIATION h/h0 IN FIN HEIGHT AFTER TUBE EXPANSION
bN/t
1
0.9
0.8
0.7
0.6
0.5
0
5
10
15
20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/003554

A. CLASSIFICATION OF SUBJECT MATTER
F28F1/40(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28F1/40

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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 2007-271123 A (Kobelco & Materials Copper Tube, Ltd.), 18 October, 2007 (18.10.07), Par. Nos. [0008], [0013] to [0044]; Figs. 1, 2 (Family: none)	1,2
Y	JP 8-5278 A (Mitsubishi Shindoh Co., Ltd.), 12 January, 1996 (12.01.96), Par. Nos. [0012], [0016], [0024]; Figs. 1 to 3 (Family: none)	1,2

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

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
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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
02 September, 2009 (02.09.09)	15 September, 2009 (15.09.09)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H08174044 B **[0003]**