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(54) **HEAT-EXCHANGING FLAT TUBE**

(57) To provide a flat tube for heat exchange that can ensure a target pressure-resisting strength and in which thinning is achieved. A flat tube (1) for heat exchange is a flat tube (1) for heat exchange in which plural through holes (3) with circular cross-sections through which refrigerant passes are arranged in one row. If $t1/R$ is a value in which a thickness $t1$ of partition portions (4) partitioning adjacent two of the through holes (3) has been made

dimensionless by a radius R of the through holes (3) and $t2/R$ is a value in which an outer peripheral thickness $t2$ that is a thickness from a flat surface of an outer periphery of the flat tube (1) to the through holes (3) has been made dimensionless by the radius R , in a case where the internal pressure of the through holes (3) is 10.0 to 90.0 MPa, the relationship of $0.28 < (t2/R)/(t1/R) < 0.42$ holds true.

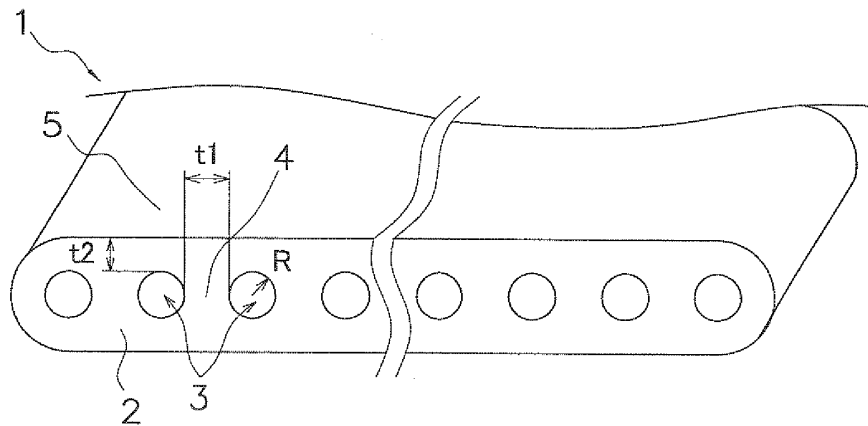


FIG. 1

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Description**TECHNICAL FIELD**

5 **[0001]** The present invention relates to a flat tube for heat exchange in which plural through holes are formed.

BACKGROUND ART

10 **[0002]** Conventionally, flat tubes for heat exchange such as the one described in patent citation 1 (JP-ANo. 10-132424) have been used in evaporators of air conditioners and so forth. The flat tube is integrally molded by, for example, extrusion-molding an aluminum alloy or the like, and plural through holes with circular cross-sections are arranged side-by-side in one row or plural rows. Heat exchange is performed between refrigerant that passes through the insides of the through holes and a medium such as air that passes over the outer periphery of the flat tube.

15 **[0003]** In recent years, carbon dioxide (CO₂) refrigerant (which has a working pressure equal to or greater than 10 MPa), whose working pressure is much higher than that of HFC refrigerant, has come to be used, and a variety of flat tubes that can withstand the high pressure of CO₂ refrigerant have been proposed.

SUMMARY OF INVENTION

20 <Technical Problem>

[0004] However, in the case of designing a flat tube that withstands high-pressure refrigerant such as CO₂, making the thickness of the areas surrounding the through holes thicker so as to satisfy a pressure-resisting strength is required, making the outer peripheral thickness that is the thickness from the flat surface of the outer periphery of the flat tube to the through holes thinner is difficult, and as a result it has been difficult to achieve thinning of the flat tube overall.

[0005] It is a problem of the present invention to provide a flat tube for heat exchange that can ensure the target pressure-resisting strength and in which thinning is achieved.

30 <Solution to Problem>

[0006] A flat tube for heat exchange of a first invention is a flat tube for heat exchange in which plural through holes with circular cross-sections through which refrigerant passes are arranged in one row.

35 **[0007]** If $t1/R$ is a value in which a thickness $t1$ of partition portions partitioning adjacent two of the through holes has been made dimensionless by a radius R of the through holes and $t2/R$ is a value in which an outer peripheral thickness $t2$ that is a thickness from a flat surface of an outer periphery of the flat tube to the through holes has been made dimensionless by the radius R , in a case where the internal pressure of the through holes is 10.0 to 90.0 MPa, the relationship of

$$40 \quad 0.28 < (t2/R)/(t1/R) < 0.42 \quad (\text{Expression 1})$$

holds true.

[0008] Here, the above relational expression (expression 1) holds true, so the flat tube for heat exchange can ensure the target pressure-resisting strength and it becomes possible to make the thickness of the flat tube thinnest.

45 **[0009]** A flat tube for heat exchange of a second invention is the flat tube for heat exchange of the first invention, wherein in a case where the internal pressure of the through holes is 20.0 to 80.0 MPa, the relationship of

$$50 \quad 0.30 \leq (t2/R)/(t1/R) \leq 0.41 \quad (\text{Expression 2})$$

holds true.

[0010] Here, depending on the type of refrigerant, even in a case where the internal pressure of the through holes becomes 20.0 to 80.0 MPa, the above relational expression (expression 2) holds true, so the flat tube for heat exchange can ensure the target pressure-resisting strength and it becomes possible to make the thickness of the flat tube thinnest.

55 **[0011]** A flat tube for heat exchange of a third invention is the flat tube for heat exchange of the first invention or the second invention, wherein in a case where the internal pressure of the through holes is 30.0 to 80.0 MPa, the relationship of

$$0.32 \leq (t_2/R)/(t_1/R) \leq 0.41 \quad (\text{Expression 3})$$

holds true.

[0012] Here, depending on the type of refrigerant, even in a case where the internal pressure of the through holes becomes 30.0 to 80.0 MPa, the above relational expression (expression 3) holds true, so the flat tube for heat exchange can ensure the target pressure-resisting strength and it becomes possible to make the thickness of the flat tube thinnest.

[0013] Further, a flat tube for heat exchange of a fourth invention is the flat tube for heat exchange of any of the first invention to the third invention, wherein the flat tube is manufactured from an elasto-plastically deformable material.

[0014] Here, the flat tube for heat exchange is manufactured from an elasto-plastically deformable material, so in a case where the above relational expression holds true, the target pressure-resisting strength can be ensured more reliably and it becomes possible to make the thickness of the flat tube thinnest.

<advantageous Effects of Invention>

[0015] According to the first invention, the flat tube for heat exchange can ensure the target pressure-resisting strength and the thickness of the flat tube becomes thinnest; because of this, downsizing of the flat tube for heat exchange and a reduction in cost can be achieved.

[0016] According to the second invention, depending on the type of refrigerant, even in a case where the internal pressure of the through holes becomes 20.0 to 80.0 MPa, the above relational expression (expression 2) holds true, so the flat tube for heat exchange can ensure the target pressure-resisting strength and it becomes possible to make the thickness of the flat tube thinnest.

[0017] According to the third invention, depending on the type of refrigerant, even in a case where the internal pressure of the through holes becomes 30.0 to 80.0 MPa, the above relational expression (expression 3) holds true, so the flat tube for heat exchange can ensure the target pressure-resisting strength and it becomes possible to make the thickness of the flat tube thinnest.

[0018] According to the fourth invention, the target pressure-resisting strength can be ensured more reliably and the thickness of the flat tube becomes thinnest, so downsizing and a reduction in cost can be achieved.

BRIEF DESCRIPTION OF DRAWINGS

[0019]

FIG. 1 is a partial front view of a flat tube for heat exchange pertaining to an embodiment of the present invention.

FIG. 2 is a schematic view of an analysis object corresponding to the flat tube for heat exchange of FIG. 1.

FIG. 3 is a graph showing isobars of the pressure-resisting strength of the flat tube for heat exchange of FIG. 1 in a case where the radius of the through holes is 0.2 mm (a case using aluminum alloy A3003-O).

FIG. 4 is a graph showing isobars of the pressure-resisting strength of the flat tube for heat exchange of FIG. 1 in a case where the radius of the through holes is 0.3 mm (a case using aluminum alloy A3003-O).

FIG. 5 is a graph showing isobars of the pressure-resisting strength of the flat tube for heat exchange of FIG. 1 in a case where the radius of the through holes is 0.4 mm (a case using aluminum alloy A3003-O).

FIG. 6 is a graph showing isobars of the pressure-resisting strength of the flat tube for heat exchange of FIG. 1 in a case where the radius of the through holes is 0.5 mm (a case using aluminum alloy A3003-O).

FIG. 7 is a graph showing isobars of the pressure-resisting strength of the flat tube for heat exchange of FIG. 1 in a case where the radius of the through holes is 0.6 mm (a case using aluminum alloy A3003-O).

FIG. 8 is a graph in which the plural graphs in the cases where the radius of the through holes was changed are superimposed on each other and shows isobars of the pressure-resisting strength of the flat tube for heat exchange of FIG. 1 (cases using aluminum alloy A3003-O).

FIG. 9 is a graph in which the graph of FIG. 8 is approximated and shows isobars of the pressure-resisting strength of the flat tube for heat exchange of FIG. 1 (cases using aluminum alloy A3003-O).

FIG. 10 is a graph corresponding to FIG. 9 in a case using aluminum alloy A1050-O.

DESCRIPTION OF EMBODIMENT

[0020] An embodiment of a flat tube for heat exchange of the present invention will be described with reference to the drawings.

Embodiment

[0021] A flat tube 1 for heat exchange shown in FIG. 1 is a multi-hole tube having a flat elliptical cross-section in which plural through holes 3 with circular cross-sections through which refrigerant passes are arranged laterally in one row inside a body 2 of the flat tube 1. The through holes 3 have completely round circular cross-sections.

[0022] The flat tube 1 for heat exchange is manufactured by integral molding by extrusion-molding an elasto-plastically deformable material such as an aluminum alloy.

[0023] In this flat tube 1 for heat exchange, if $t1/R$ is a value in which a thickness $t1$ of partition portions 4 partitioning adjacent two of the through holes 3 has been made dimensionless by a radius R of the through holes 3 and $t2/R$ is a value in which an outer peripheral thickness $t2$ that is a thickness from a flat surface 5 of an outer periphery of the flat tube 1 to the through holes 3 has been made dimensionless by the radius R , in a case where the internal pressure of the through holes 3 is 10.0 to 90.0 MPa, the thickness $t1$ of the partition portions 4, the outer peripheral thickness $t2$, and the radius R of the through holes 3 are set in such a way that the relationship of

$$0.28 < (t2/R)/(t1/R) < 0.42 \quad (\text{Expression 1})$$

holds true (it is preferred that the relationship of $0.30 \leq (t2/R)/(t1/R) < 0.42$ holds true).

[0024] By setting $t1$, $t2$, and R in such a way that this relational expression (expression 1) holds true, the flat tube 1 for heat exchange can ensure the targeted pressure-resisting strength (that is, the target pressure-resisting strength) and the thickness of the flat tube 1 becomes thinnest; because of this, downsizing of the flat tube 1 for heat exchange and a reduction in cost can be achieved.

[0025] Although it will be described in detail in Example below, when $(t2/R)/(t1/R)$ becomes equal to or less than 0.28, the flat tube 1 becomes unable to withstand the minimum pressure-resisting strength (10 MPa) that stands up to actual use, and when $(t2/R)/(t1/R)$ becomes equal to or greater than 0.42, a strength sufficient for withstanding the maximum pressure-resisting strength (90 MPa) assumed in actual use is obtained, but as the value of $(t2/R)/(t1/R)$ becomes larger, the dimensions of the flat tube 1 end up becoming larger than necessary and downsizing becomes difficult. Consequently, if the relationship is such that the relational expression (expression 1) holds true, designing a pressure-resisting strength that stands up to actual use is possible and downsizing can be achieved.

[0026] As will be described in detail in the Examples below, the present invention is designed considering tensile strength which greatly exceeds yield stress in aluminum materials and the like, assumes that $t1$, $t2$, and R are set in such a way that the value of $(t2/R)/(t1/R)$ falls around a central value of 0.35 within the range of 0.28 to 0.42, and differs from settings that greatly deviate from this range (e.g., designs that consider only yield stress).

[0027] Further, in the case of using low-pressure refrigerant such as HFC, considering that it is necessary for the pressure-resisting strength of the flat tube 1 to be equal to or greater than 20.0 MPa, in a case where the internal pressure of the through holes 3 in the flat tube 1 is 20.0 to 80.0 MPa, it is preferred that the relationship of

$$0.30 \leq (t2/R)/(t1/R) \leq 0.41 \quad (\text{Expression 2})$$

holds true. Because of this, even in a case where low-pressure refrigerant such as HFC is used and the internal pressure of the through holes 3 becomes 20.0 to 80.0 MPa, the above (expression 2) holds true, so the flat tube 1 can ensure the target pressure-resisting strength and it becomes possible to make the thickness of the flat tube 1 thinnest.

[0028] Moreover, in the case of using high-pressure refrigerant such as carbon dioxide (CO_2) considering that it is necessary for the pressure-resisting strength of the flat tube 1 to be equal to or greater than 30.0 MPa, in a case where the internal pressure of the through holes 3 in the flat tube 1 is 30.0 to 80.0 MPa, it is preferred that the relationship of

$$0.32 \leq (t2/R)/(t1/R) \leq 0.41 \quad (\text{Expression 3})$$

holds true. Because of this, even in a case where high-pressure refrigerant such as CO_2 is used and the internal pressure of the through holes 3 becomes 30.0 to 80.0 MPa, the above (expression 3) holds true, so the flat tube 1 can ensure the target pressure-resisting strength and it becomes possible to make the thickness of the flat tube 1 thinnest.

Examples

[0029] FIGS. 3 to 7 show graphs in which the radius R of the through holes 3 is fixed at 0.2 mm, 0.3 mm, 0.4 mm, 0.5 mm, and 0.6 mm, isobars of pressure resistance P when t_1/R is taken on the horizontal axis and t_2/R is taken on the vertical axis are numerically analyzed and found by computer simulation, and the isobars are shown. Aluminum alloy A3003-O is used in the analyses of the graphs shown in FIGS. 3 to 7. The material properties of aluminum alloy A3003-O are shown in Table 1 below.

<Table 1>

Table 1. Material Properties of Aluminum Alloy A3003-O

Elastic Modulus (MPa)	Poisson's Ratio	Yield Stress (MPa)	Tensile Strength (MPa)	Elongation at Break (%)
70000.0	0.33	40.0	110.0	29.0

[0030] In this way, in an elasto-plastically deformable material such as aluminum or an aluminum alloy, tensile strength at the time when the material eventually plastically fractures after elasto-plastic deformation is much larger compared to yield stress which is an elastic limit, so by devising a pressure-resistant design that considers elasto-plastic deformation, the dimensions of the flat tube 1 can be made much more compact and further thinning also becomes possible. This technique is particularly effective for pressure-resistant designs in cases using high-pressure refrigerant such as CO₂.

[0031] Moreover, when the graphs showing the isobars of FIG. 3 to FIG. 7 are superimposed on each other, the graph of FIG. 8 is obtained. Further, FIG. 9 shows a graph in which, in order to make them easier to see, the isobars in the graph of FIG. 8 are approximated in order to consolidate the isobars into single lines per pressure resistance P in 10 MPa intervals.

[0032] Looking at the graphs shown in FIGS. 8 and 9, it will be understood that the isobars, which have shapes in which the relationship between t_1/R and t_2/R that have been made dimensionless abruptly curves on curve C1, are regularly arranged.

[0033] Additionally, the combinations of t_1/R and t_2/R on curve C1 become combinations with which the thicknesses of t_1 and t_2 can be made smallest.

[0034] Consequently, by using the graphs in FIGS. 8 and 9, optimum combinations of t_1/R and t_2/R at a given pressure resistance P can be easily obtained.

[0035] Here, P, t_1/R , t_2/R , and the relationships of $(t_2/R)/(t_1/R)$ found from these in a case where the thicknesses of t_1 and t_2 can be made smallest are summarized in Table 2.

<Table 2>

Table 2. P, t_1/R , t_2/R , and Relationships of $(t_2/R)/(t_1/R)$ in Case Using Aluminum Alloy A3003-O

Pressure Resistance P (MPa)	t_1/R	t_2/R	$(t_2/R)/(t_1/R)$
10.0	0.26	0.08	0.308
20.0	0.47	0.15	0.319
30.0	0.68	0.23	0.338
40.0	0.94	0.32	0.341
50.0	1.24	0.43	0.347
60.0	1.62	0.58	0.358
70.0	2.02	0.75	0.371
80.0	2.47	0.96	0.389
90.0	2.97	1.24	0.418

[0036] Looking at Table 2, it is confirmed that $(t_2/R)/(t_1/R)$ where the pressure resistance P that stands up to actual use conforms to the range of 10.0 to 90.0 MPa is in a range greater than 0.28 (preferably equal to or greater than 0.30) and smaller than 0.42—that is, a range that satisfies the above relational expression (expression 1). Further, it is confirmed that $(t_2/R)/(t_1/R)$ where the pressure resistance P conforms to the range of 20.0 to 80.0 MPa is in a range equal to or greater than 0.30 and equal to or less than 0.41—that is, a range that satisfies the above relational expression (expression

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2). Further, it is confirmed that $(t_2/R)/(t_1/R)$ where the pressure resistance P conforms to the range of 30.0 to 80.0 MPa is in a range equal to or greater than 0.32 and equal to or less than 0.41—that is, a range that satisfies the above relational expression (expression 3).

[0037] Further, using Table 3 below, for example, in a case where the target pressure resistance is 70 MPa or 80 MPa, the optimum thicknesses of t1 and t2 when the diameter (2R) of the through holes 3 is 0.9, 1.0, 1.1, and 1.2 mm can be quickly found.

<Table 3>

Pressure Resistance P (MPa)	Partition Portion Thickness	Diameter of Through Holes (mm)			
	Outer Peripheral Thickness	0.9	1.0	1.1	1.2
70	t1	0.9	1.0	1.1	1.2
	t2	0.36	0.4	0.44	0.48
80	t1	1.125	1.25	1.375	1.5
	t2	0.45	0.5	0.55	0.6

[0038] Further, the present inventors performed the same analysis as that of aluminum alloy A3003-O also in regard to another aluminum alloy A1050-O other than aluminum alloy A3003-O (that is, in which the radius R of the through holes 3 is fixed at 0.2 mm, 0.3 mm, 0.4 mm, 0.5 mm, and 0.6 mm, and isobars of pressure resistance P when t1/R is taken on the horizontal axis and t2/R is taken on the vertical axis are numerically analyzed and found by computer simulation). The material properties of aluminum alloy A1050-O are shown in Table 4 below.

<Table 4>

Table 4. Material Properties of Aluminum Alloy A1050-O

Elastic Modulus (MPa)	Poisson's Ratio	Yield Stress (MPa)	Tensile Strength (MPa)	Elongation at Break (%)
70000.0	0.33	30.0	70.0	35.0

[0039] FIG. 10 shows analysis results in a case where the same analysis as that of aluminum alloy A3003-O is performed using aluminum alloy A1050-O. FIG. 10 corresponds to FIG. 9 and shows analysis results of aluminum alloy A1050-O.

[0040] In the case using aluminum alloy A1050-O also, like in the case using A3003-O, the combinations of t1/R and t2/R when they are on curve C2 become combinations with which the thicknesses of t1 and t2 can be made smallest. P, t1/R, t2/R, and the relationships of $(t_2/R)/(t_1/R)$ found from these in a case where the thicknesses of t1 and t2 can be made smallest in a case using aluminum alloy A1050-O are summarized in Table 5 below.

<Table 5>

Table 5. P, t1/R, t2/R, and Relationships of $(t_2/R)/(t_1/R)$ in Case Using Aluminum Alloy A1050-O

Pressure Resistance P (MPa)	t1/R	t2/R	$(t_2/R)/(t_1/R)$
10.0	0.33	0.10	0.303
20.0	0.80	0.25	0.313
30.0	1.30	0.42	0.323
40.0	1.95	0.65	0.333
50.0	2.75	0.95	0.345
60.0	3.76	1.37	0.364
70.0	5.00	1.92	0.384
80.0	6.70	2.70	0.403
90.0	8.90	3.70	0.416

[0041] As described above, even in a case using a different aluminum alloy, it is confirmed that $(t2/R)/(t1/R)$ where the pressure resistance P that stands up to actual use conforms to the range of 10.0 to 90.0 MPa is in a range greater than 0.28 (preferably equal to or greater than 0.30) and smaller than 0.42—that is, a range that satisfies the above relational expression (expression 1). Further, even in a case using a different aluminum alloy, it is confirmed that $(t2/R)/(t1/R)$ where the pressure resistance P conforms to the range of 20.0 to 80.0 MPa is in a range equal to or greater than 0.30 and equal to or less than 0.41—that is, a range that satisfies the above relational expression (expression 2). Further, even in a case using a different aluminum alloy, it is confirmed that $(t2/R)/(t1/R)$ where the pressure resistance P conforms to the range of 30.0 to 80.0 MPa is in a range equal to or greater than 0.32 and equal to or less than 0.41—that is, a range that satisfies the above relational expression (expression 3).

<Characteristics of Embodiment>

(1)

[0042] The flat tube 1 for heat exchange of the embodiment is a flat tube for heat exchange in which plural through holes 3 with circular cross-sections through which refrigerant passes are arranged in one row, wherein if $t1/R$ is a value in which a thickness $t1$ of partition portions 4 partitioning adjacent two of the through holes 3 has been made dimensionless by a radius R of the through holes 3 and $t2/R$ is a value in which an outer peripheral thickness $t2$ that is a thickness from a flat surface of an outer periphery of the flat tube 1 to the through holes 3 has been made dimensionless by the radius R, in a case where the internal pressure of the through holes 3 is 10.0 to 90.0 MPa, the thickness $t1$ of the partition portions 4, the outer peripheral thickness $t2$, and the radius R of the through holes 3 are set in such a way that the relationship of

$$0.28 < (t2/R)/(t1/R) < 0.42 \quad (\text{Expression 1})$$

holds true.

[0043] The relational expression (expression 1) holds true, so the flat tube 1 for heat exchange can ensure the target pressure-resisting strength and the thickness of the flat tube 1 becomes thinnest; because of this, downsizing of the flat tube 1 for heat exchange and a significant reduction in its manufacturing cost can be achieved.

(2)

[0044] Moreover, as shown in FIGS. 8 and 9, the above relational expression (expression 1) makes $t1$ and $t2$ dimensionless by the radius R of the through holes 3 with circular cross-sections, so specific values of $t1$ and $t2$ can be easily calculated in cases where the radius R is different.

(3)

[0045] Further, in a case where the internal pressure of the through holes 3 in the flat tube 1 is 20.0 to 80.0 MPa, by ensuring that the relationship of

$$0.30 \leq (t2/R)/(t1/R) \leq 0.41 \quad (\text{Expression 2})$$

holds true, even in a case where low-pressure refrigerant such as HFC is used and the internal pressure of the through holes 3 becomes 20.0 to 80.0 MPa, the above (expression 2) holds true, so the flat tube 1 can ensure the target pressure-resisting strength and it becomes possible to make the thickness of the flat tube 1 thinnest.

(4)

[0046] Moreover, in a case where the internal pressure of the through holes 3 in the flat tube 1 is 30.0 to 80.0 MPa, by ensuring that the relationship of

$$0.32 \leq (t2/R)/(t1/R) \leq 0.41 \quad (\text{Expression 3})$$

holds true, even in a case where high-pressure refrigerant such as CO₂ is used and the internal pressure of the through holes 3 becomes 30.0 to 80.0 MPa, the above (expression 3) holds true, so the flat tube 1 can ensure the target pressure-resisting strength and it becomes possible to make the thickness of the flat tube 1 thinnest.

5 (5)

[0047] The flat tube 1 for heat exchange of the embodiment is manufactured from an elasto-plastically deformable material such as an aluminum alloy, so the target pressure-resisting strength can be ensured more reliably and the thickness of the flat tube becomes thinnest, so downsizing and a reduction in cost can be achieved.

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(6)

[0048] As described above, in an elasto-plastically deformable material such as an aluminum alloy, tensile strength at the time when the material eventually plastically fractures after elasto-plastic deformation is much larger compared to yield stress which is an elastic limit, so by devising a pressure-resistant design that considers elasto-plastic deformation like the flat tube 1 of the present embodiment, the dimensions of the flat tube 1 can be made much more compact and further thinning also becomes possible. This technique is particularly effective for pressure-resistant designs in cases using high-pressure refrigerant such as CO₂.

15

20 <Modification>

[0049] An example where the flat tube 1 for heat exchange of the embodiment is manufactured by extrusion-molding an aluminum alloy has been described, but the present invention is not limited to this, it suffices for the material to be an elasto-plastically deformable material, and in addition to aluminum and aluminum alloys, the present invention is widely applicable to materials ranging from metals such as copper and iron to resins.

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INDUSTRIAL APPLICABILITY

[0050] The present invention can be applied to a variety of flat tubes for heat exchange equipped with plural through holes.

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REFERENCE SIGNS LIST

[0051]

35

- 1 Flat Tube for Heat Exchange
- 3 Through Holes
- 4 Partition Portions

40

CITATION LIST

<Patent Literature>

[0052]

45

Patent Citation 1: JP-A No. 10-132424

Claims

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1. A flat tube (1) for heat exchange in which plural through holes (3) with circular cross-sections through which refrigerant passes are arranged in one row, wherein
if $t1/R$ is a value in which a thickness $t1$ of partition portions (4) partitioning adjacent two of the through holes (3) has been made dimensionless by a radius R of the through holes (3) and $t2/R$ is a value in which an outer peripheral thickness $t2$ that is a thickness from a flat surface of an outer periphery of the flat tube (1) to the through holes (3) has been made dimensionless by the radius R ,
in a case where the internal pressure of the through holes (3) is 10.0 to 90.0 MPa, the relationship of

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$$0.28 < (t2/R)/(t1/R) < 0.42 \quad (\text{Expression 1})$$

holds true.

- 5
2. The flat tube (1) for heat exchange according to claim 1, wherein in a case where the internal pressure of the through holes (3) is 20.0 to 80.0 MPa, the relationship of

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$$0.30 \leq (t2/R)/(t1/R) \leq 0.41 \quad (\text{Expression 2})$$

holds true.

- 15
3. The flat tube (1) for heat exchange according to claim 1 or 2, wherein in a case where the internal pressure of the through holes (3) is 30.0 to 80.0 MPa, the relationship of

$$0.32 \leq (t2/R)/(t1/R) \leq 0.41 \quad (\text{Expression 3})$$

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holds true.

4. The flat tube (1) for heat exchange according to any of claims 1 to 3, wherein the flat tube is manufactured from an elasto-plastically deformable material.

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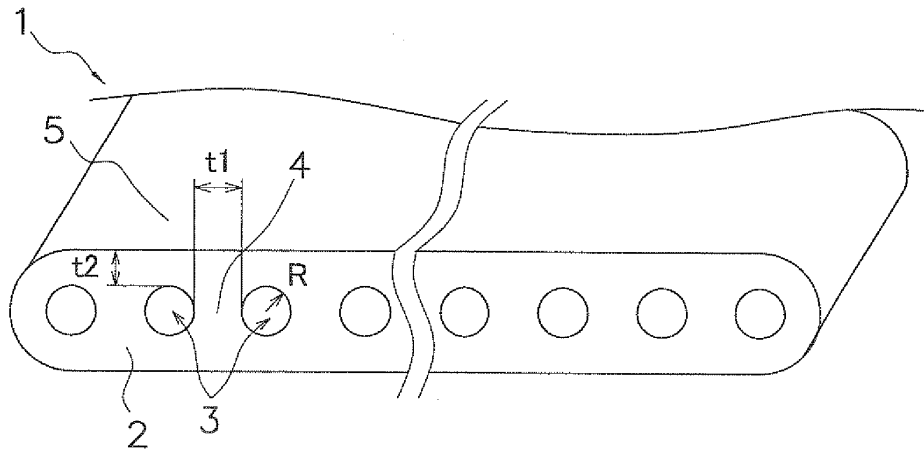


FIG. 1

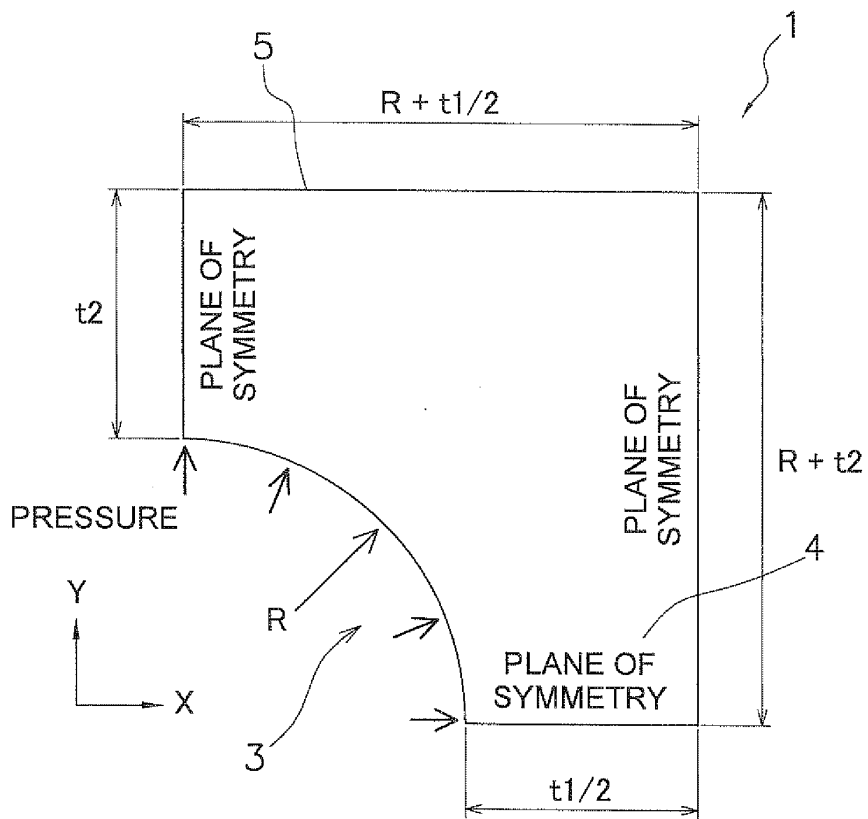


FIG. 2

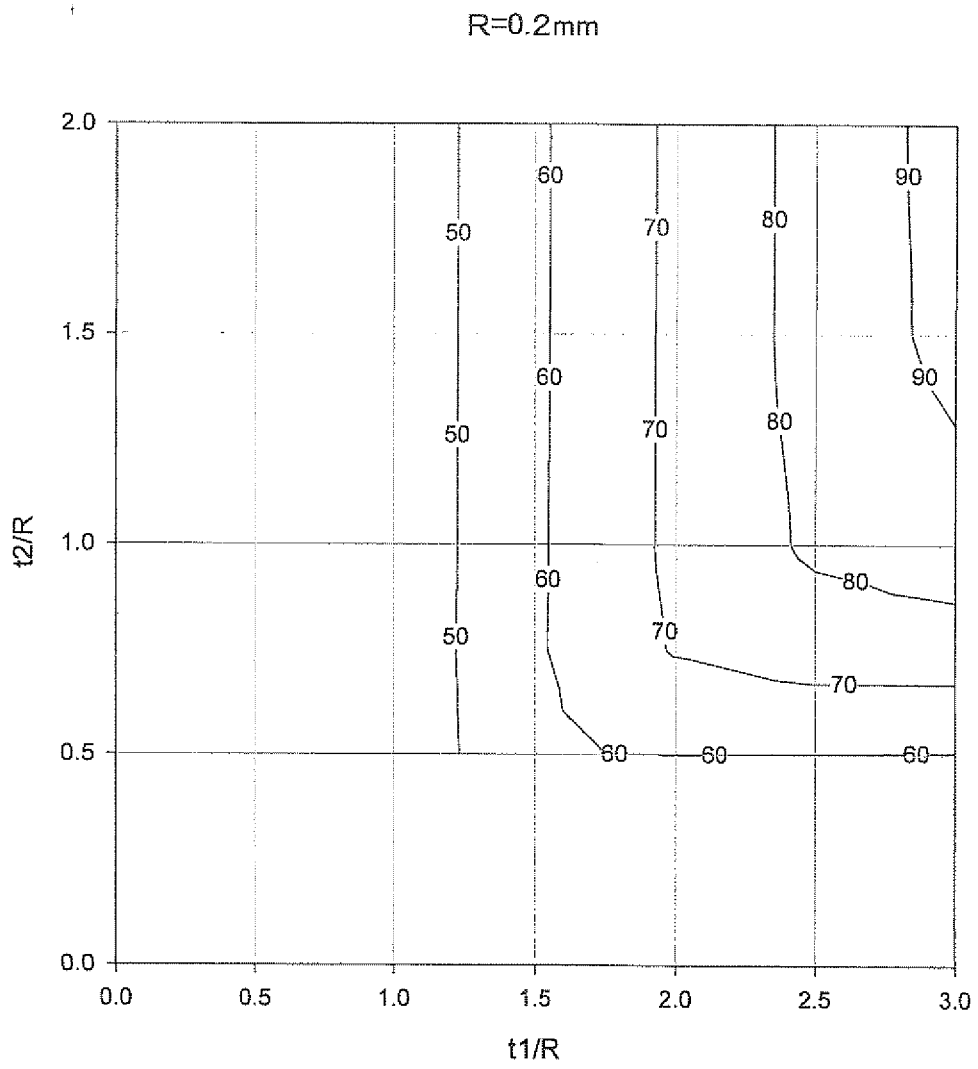


FIG. 3

R=0.3mm

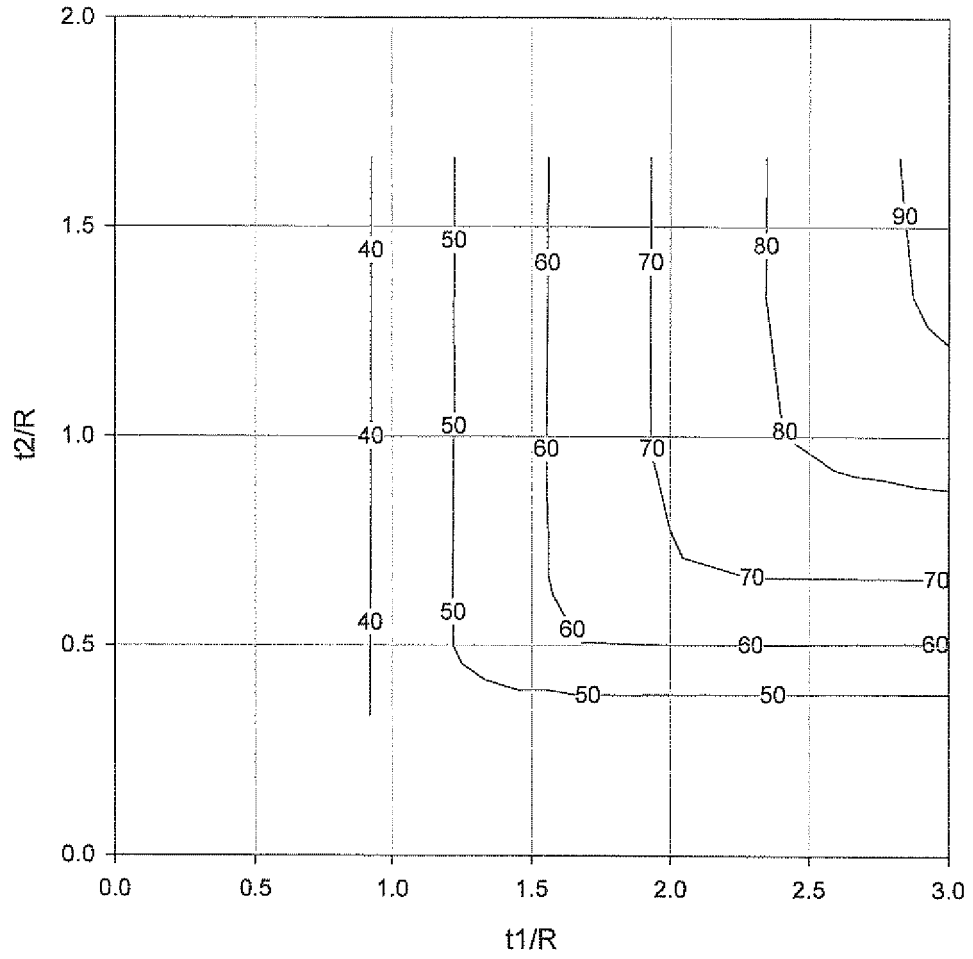


FIG. 4

R=0.4mm

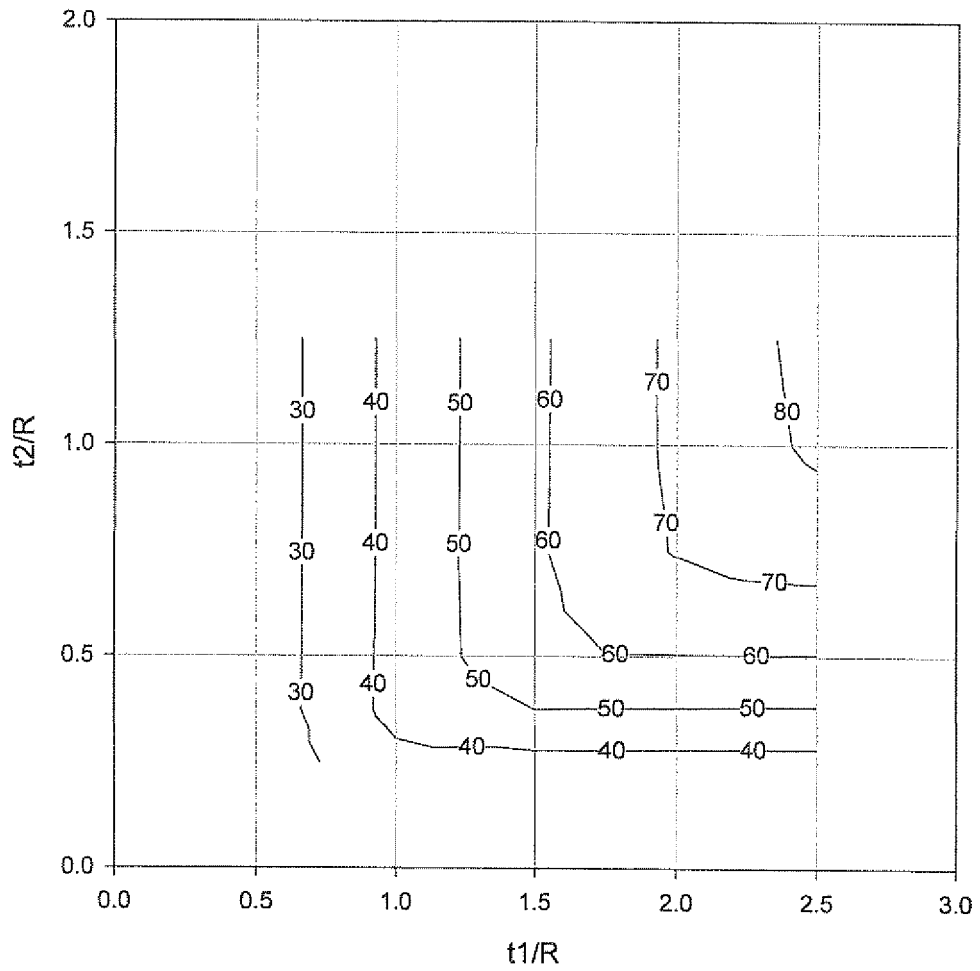


FIG. 5

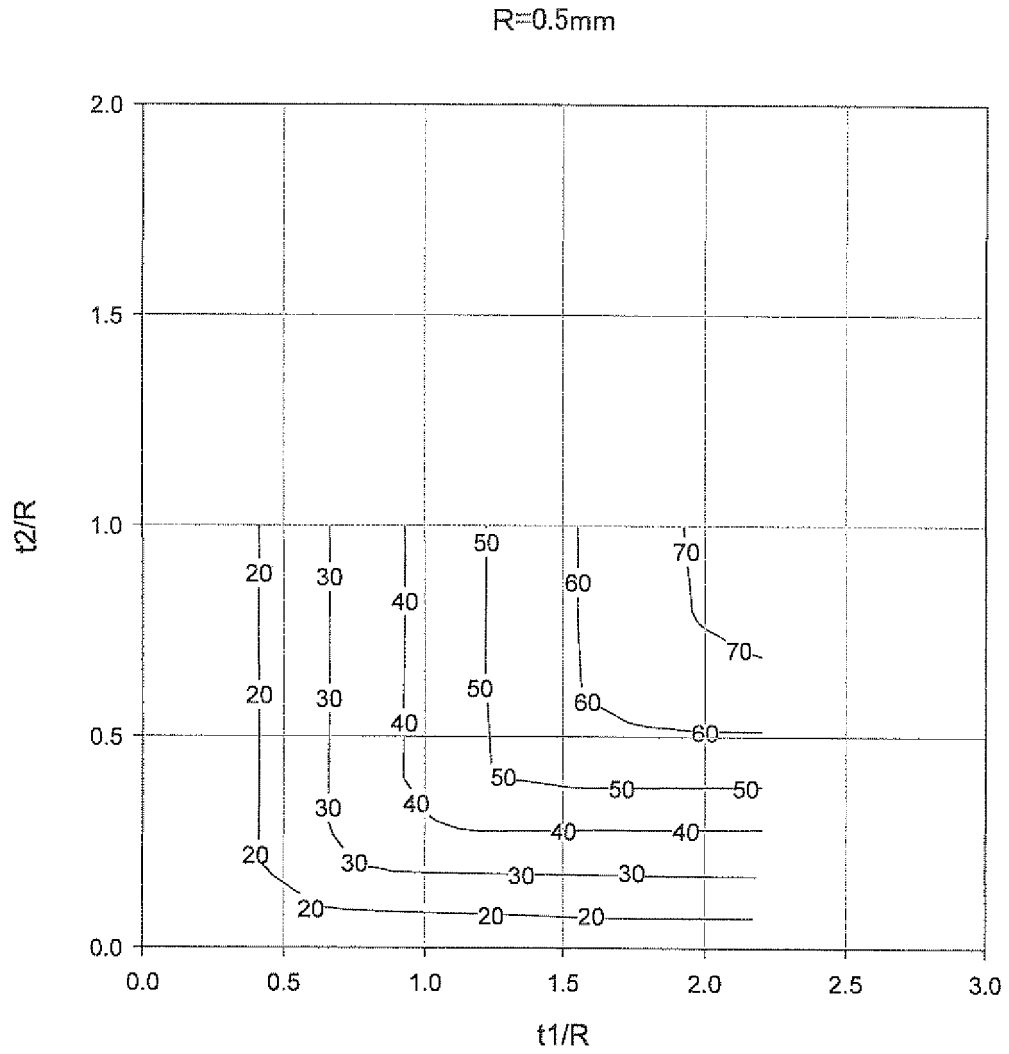


FIG. 6

R=0.6mm

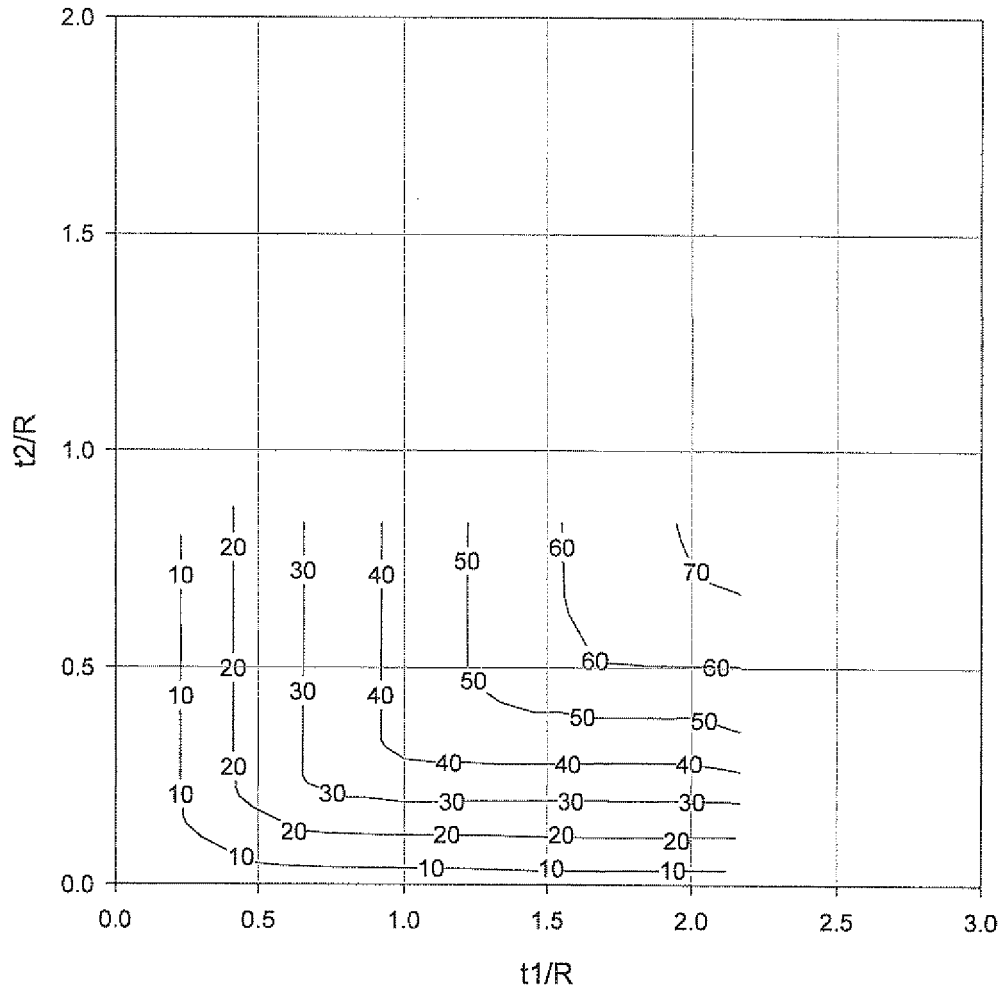


FIG. 7

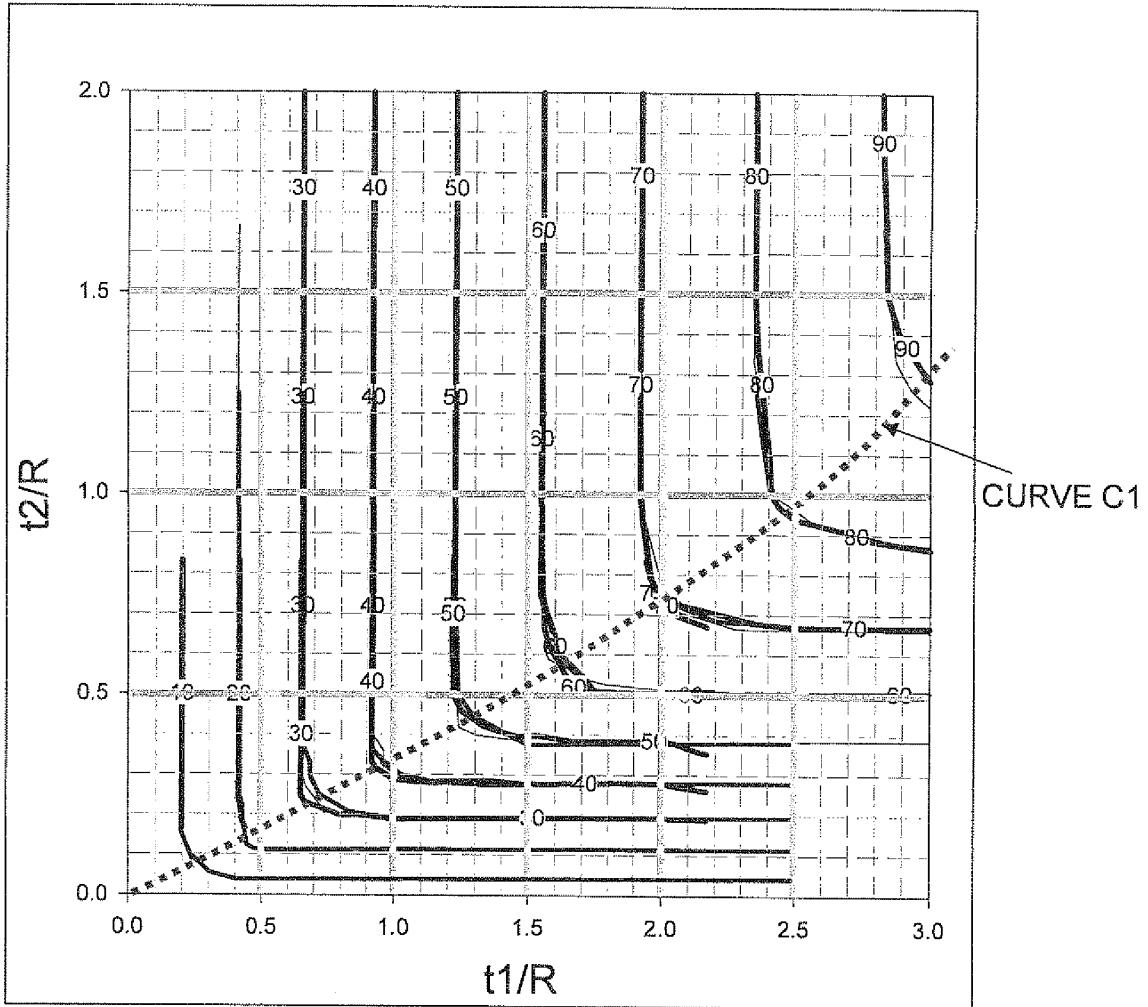


FIG. 8

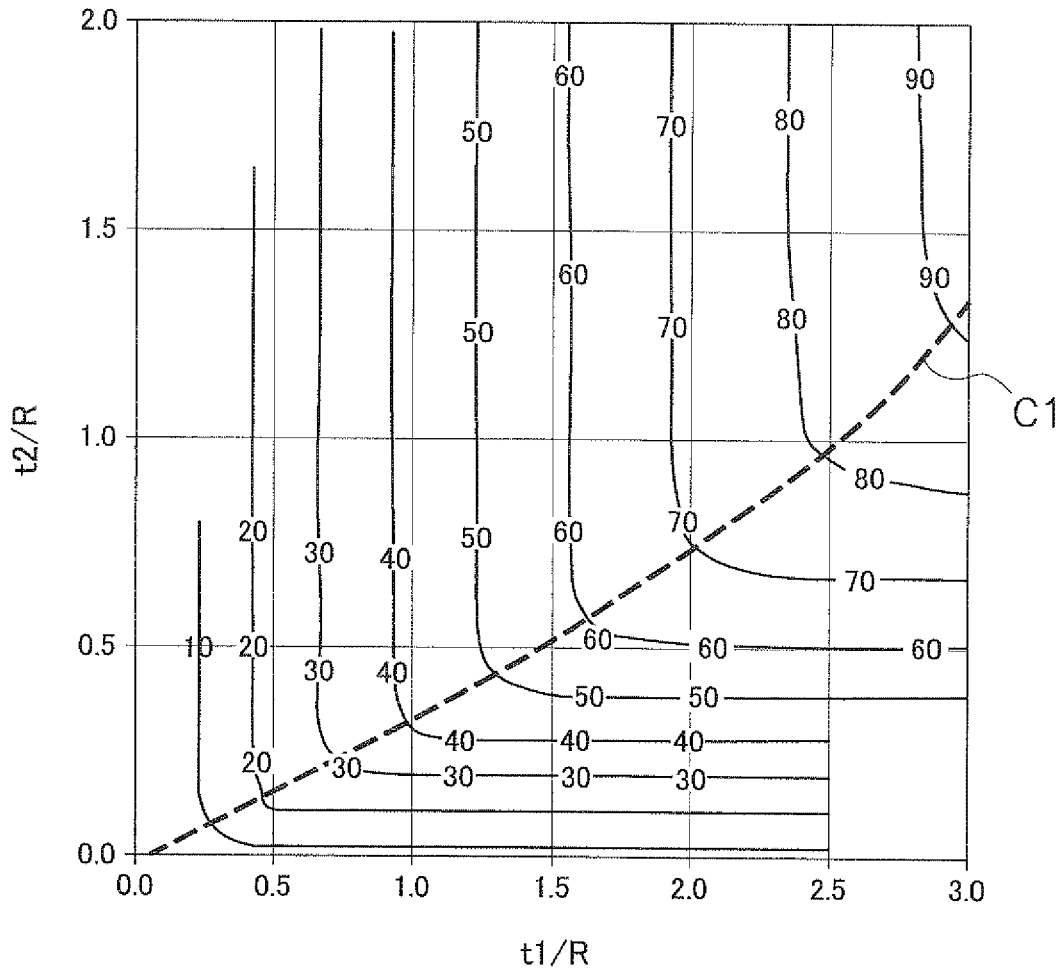


FIG. 9

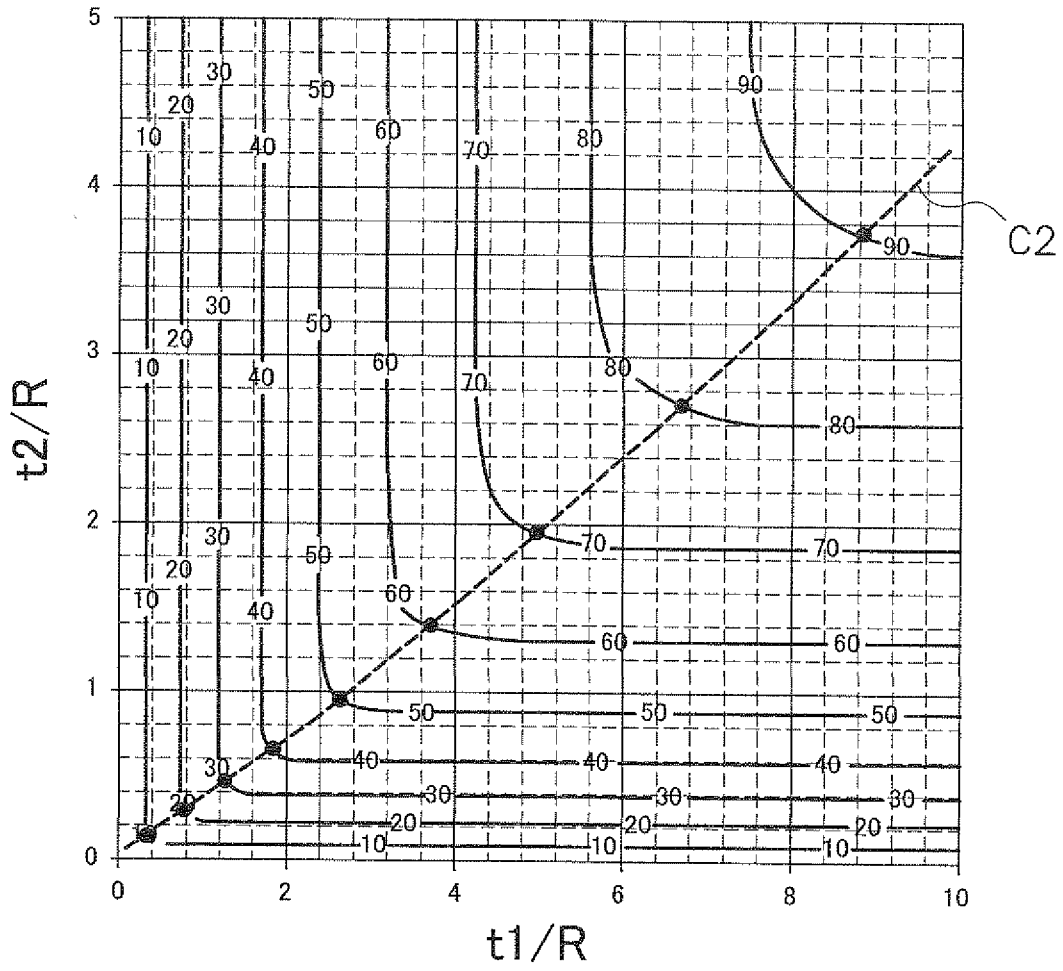


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/067068

<p>A. CLASSIFICATION OF SUBJECT MATTER F28F1/02(2006.01) i, F28F21/08(2006.01) i</p> <p>According to International Patent Classification (IPC) or to both national classification and IPC</p>														
<p>B. FIELDS SEARCHED</p> <p>Minimum documentation searched (classification system followed by classification symbols) F28F1/02, F28F21/08</p> <p>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 1996-2010 Kokai Jitsuyo Shinan Koho 1971-2010 Toroku Jitsuyo Shinan Koho 1994-2010</p> <p>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)</p>														
<p>C. DOCUMENTS CONSIDERED TO BE RELEVANT</p> <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X</td> <td>JP 2004-347267 A (Denso Corp.), 09 December 2004 (09.12.2004), entire text; all drawings (particularly, paragraphs [0006], [0031] to [0035], [0042]; fig. 1 to 4) & US 2004/0251013 6A1 & DE 102004024825 A</td> <td>1-4</td> </tr> </tbody> </table> <p><input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.</p> <p>* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family</p> <table border="1"> <tr> <td>Date of the actual completion of the international search 18 November, 2010 (18.11.10)</td> <td>Date of mailing of the international search report 30 November, 2010 (30.11.10)</td> </tr> <tr> <td>Name and mailing address of the ISA/ Japanese Patent Office</td> <td>Authorized officer</td> </tr> <tr> <td>Facsimile No.</td> <td>Telephone No.</td> </tr> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	JP 2004-347267 A (Denso Corp.), 09 December 2004 (09.12.2004), entire text; all drawings (particularly, paragraphs [0006], [0031] to [0035], [0042]; fig. 1 to 4) & US 2004/0251013 6A1 & DE 102004024825 A	1-4	Date of the actual completion of the international search 18 November, 2010 (18.11.10)	Date of mailing of the international search report 30 November, 2010 (30.11.10)	Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer	Facsimile No.	Telephone No.
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- JP 10132424 A [0002] [0052]