US 20250164192A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2025/0164192 A1
SHIMMURA et al.
(43) Pub. Date: May 22, 2025

(54) **HEAT EXCHANGER, AND METHOD FOR MANUFACTURING HEAT EXCHANGER**

(71) Applicant: **Mitsubishi Electric Corporation**, Chiyoda-ku, Tokyo (JP)

(72) Inventors: **Takanori SHIMMURA**, Chiyoda-ku, Tokyo (JP); **Takashi NAKAJIMA**, Chiyoda-ku, Tokyo (JP); **Yuriko OKUMA**, Chiyoda-ku, Tokyo (JP); **Yoshinori ITO**, Chiyoda-ku, Tokyo (JP); **Kodai MIYAKAWA**, Chiyoda-ku, Tokyo (JP); **Norio KATSUMA**, Chiyoda-ku, Tokyo (JP)

(73) Assignee: **Mitsubishi Electric Corporation**, Chiyoda-ku, Tokyo (JP)

(21) Appl. No.: **18/838,266**

(22) PCT Filed: **Mar. 15, 2023**

(86) PCT No.: **PCT/JP2023/010041**

§ 371 (c)(1),
(2) Date: **Aug. 14, 2024**

(30) **Foreign Application Priority Data**

Mar. 17, 2022 (JP) 2022-042358

Publication Classification

(51) **Int. Cl.**
F28D 7/08 (2006.01)
F28F 9/02 (2006.01)

(52) **U.S. Cl.**
CPC . ***F28D 7/08*** (2013.01); ***F28F 9/02*** (2013.01)

(57) **ABSTRACT**

A heat exchanger includes a first header having a first bent section and a first linear section extending from the first bent section, a second header having a second bent section bent in the same direction as the first bent section and opposed to the first bent section and a second linear section extending from the second bent section, first heat transfer pipes arranged along the first bent section and connecting the first bent section and the second bent section, and fins that each disposed between two adjacent first heat transfer pipes and that transfer heat from the first heat transfer pipes. At least one of the fins has a weak portions having a lower rigidity than the other portions of the fin, and being more readily deformed than the other portions in response to a change in the distance between the two adjacent first heat transfer pipes.

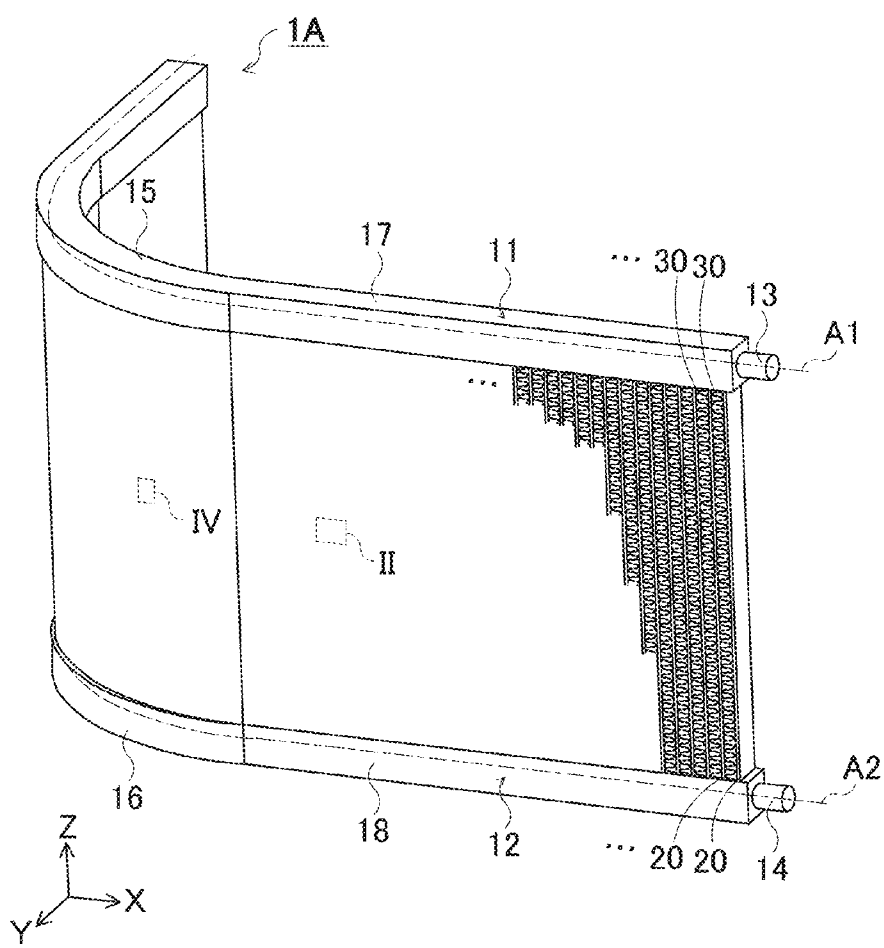


FIG. 1

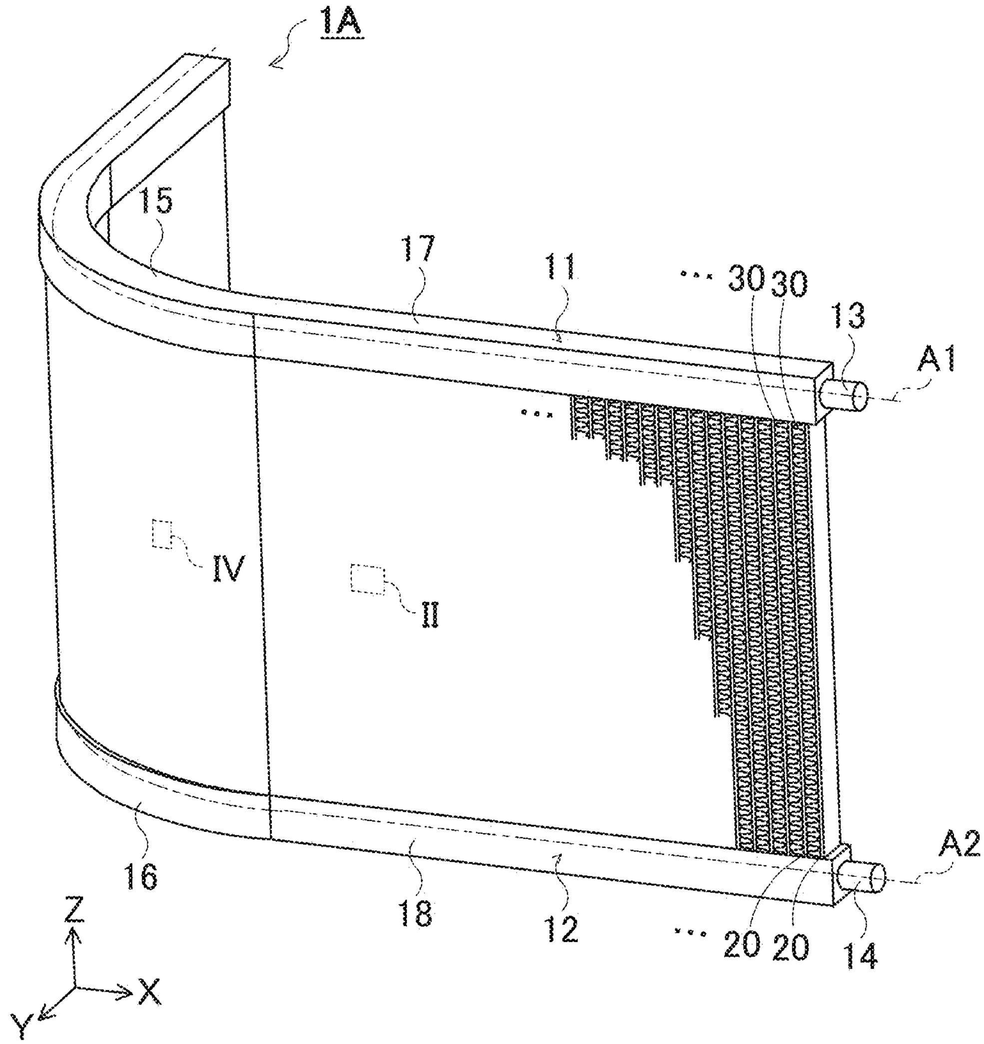


FIG. 2

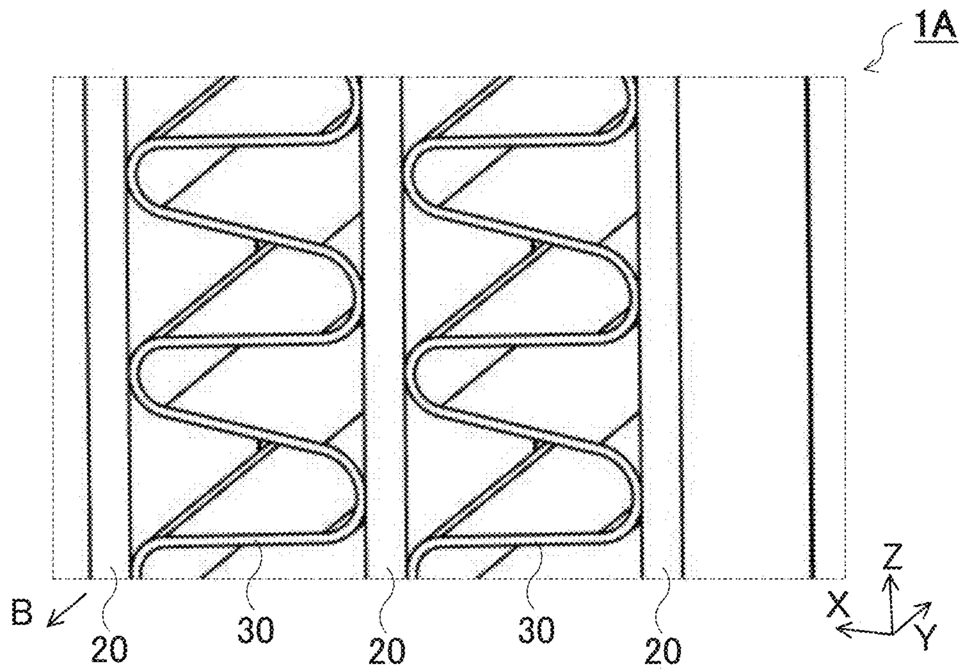


FIG. 3

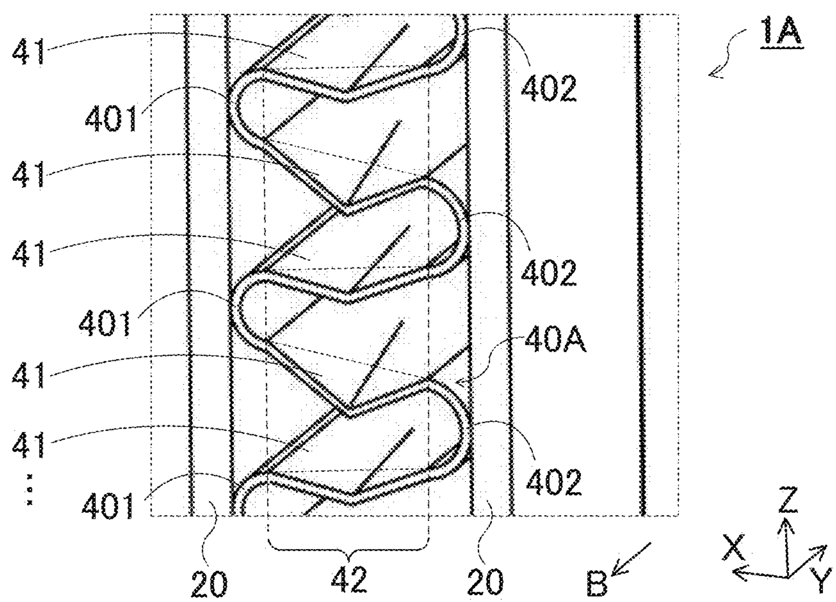


FIG. 4

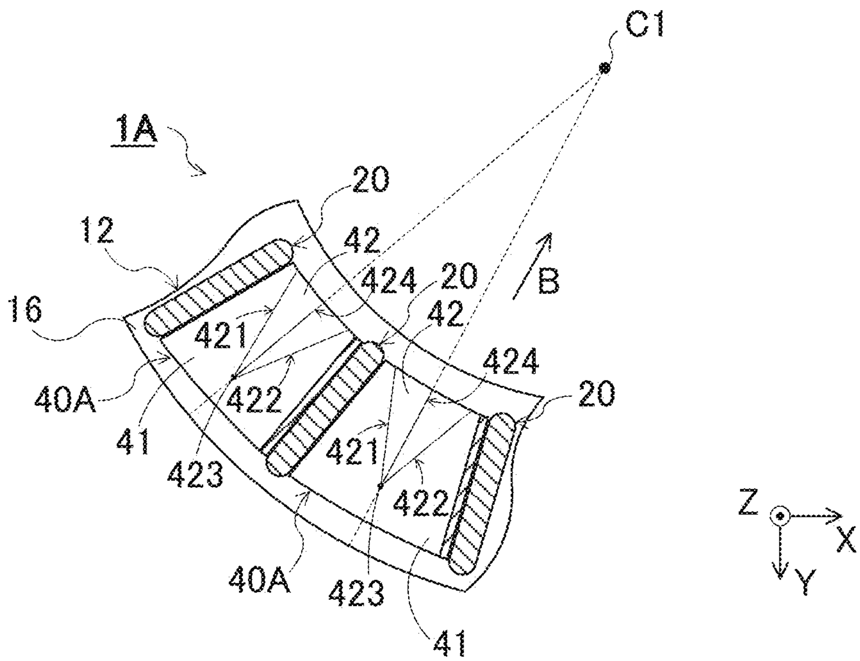

C1
1A
20
12
42
424
20
B
16
421
42
40A
424
422
20
41
423
421
422
Z
X
Y
40A
423
41

FIG. 5

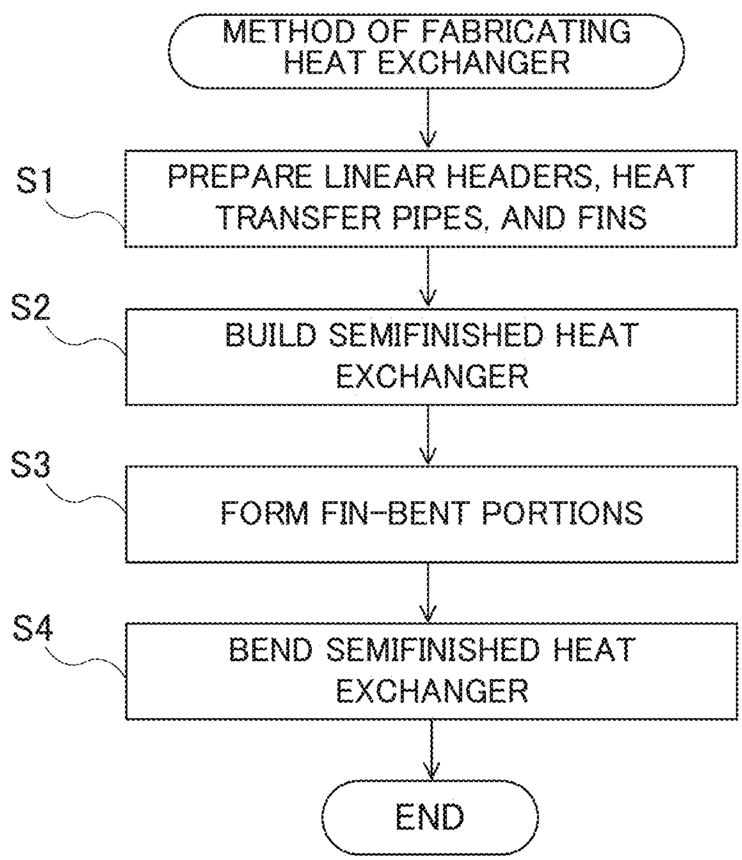

METHOD OF FABRICATING HEAT EXCHANGER
S1
PREPARE LINEAR HEADERS, HEAT TRANSFER PIPES, AND FINS
S2
BUILD SEMIFINISHED HEAT EXCHANGER
S3
FORM FIN-BENT PORTIONS
S4
BEND SEMIFINISHED HEAT EXCHANGER
END

FIG. 6

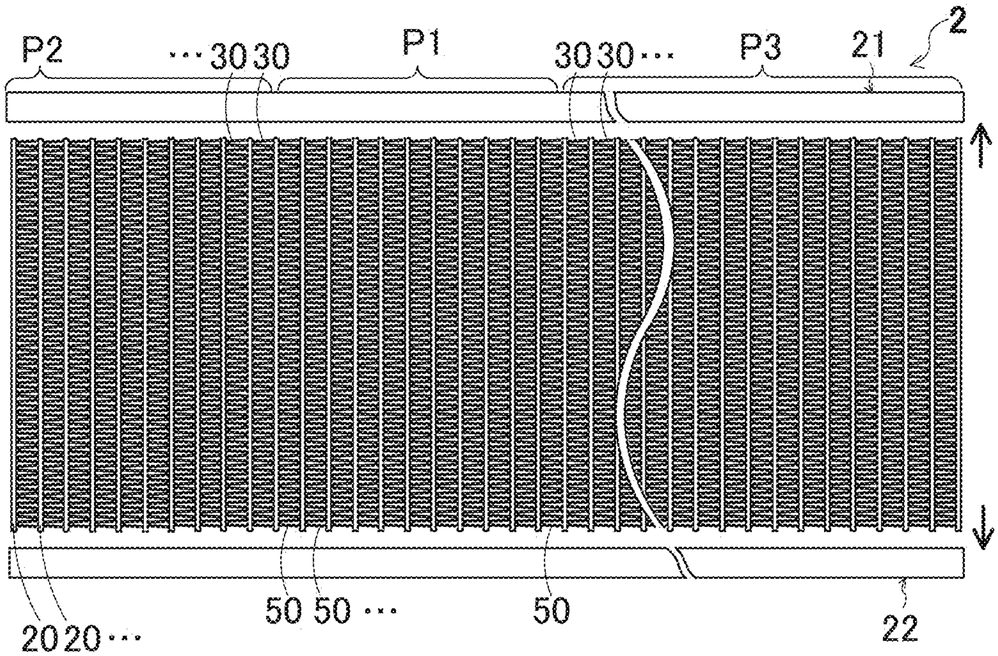


FIG. 7

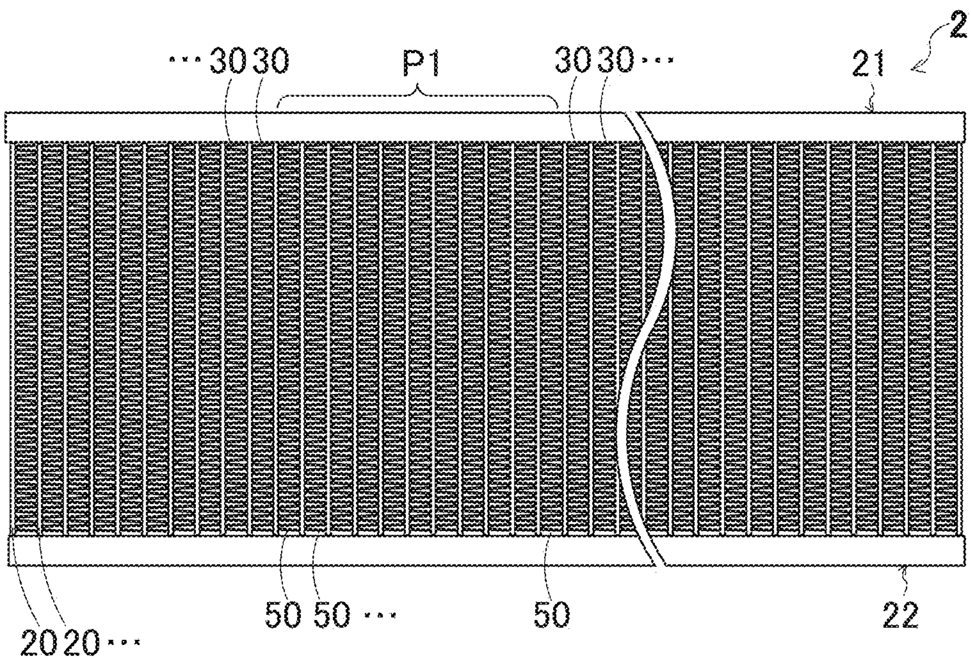


FIG. 8

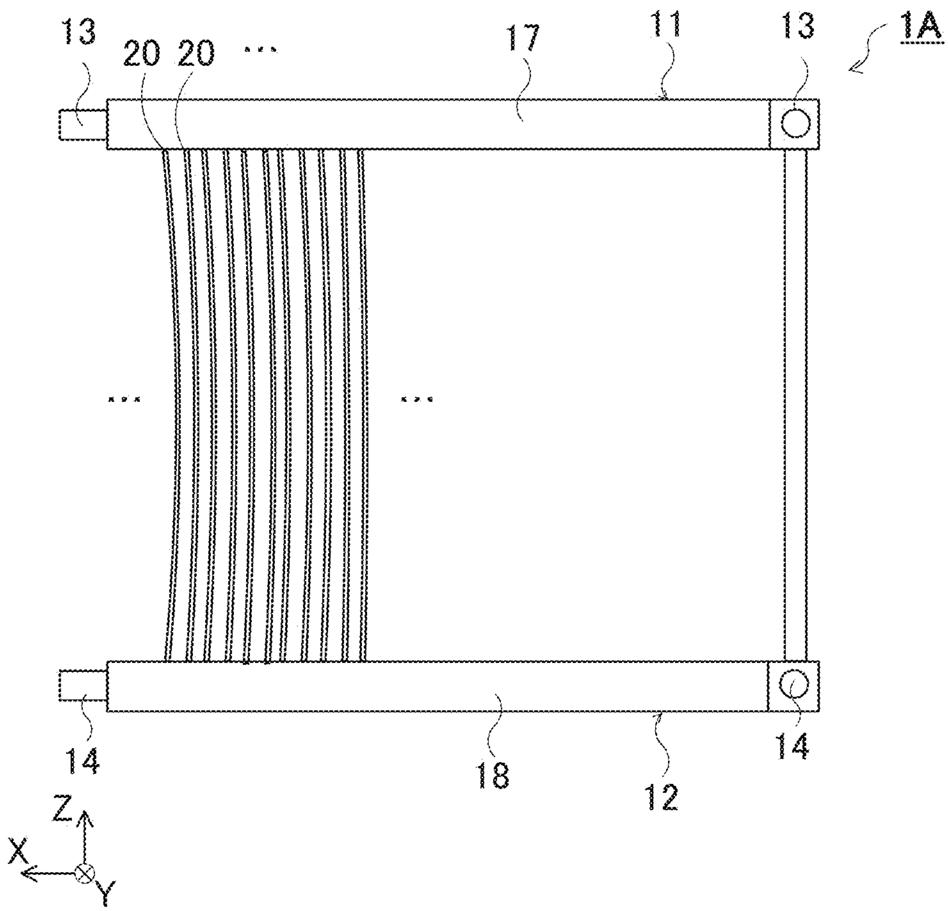


FIG. 9

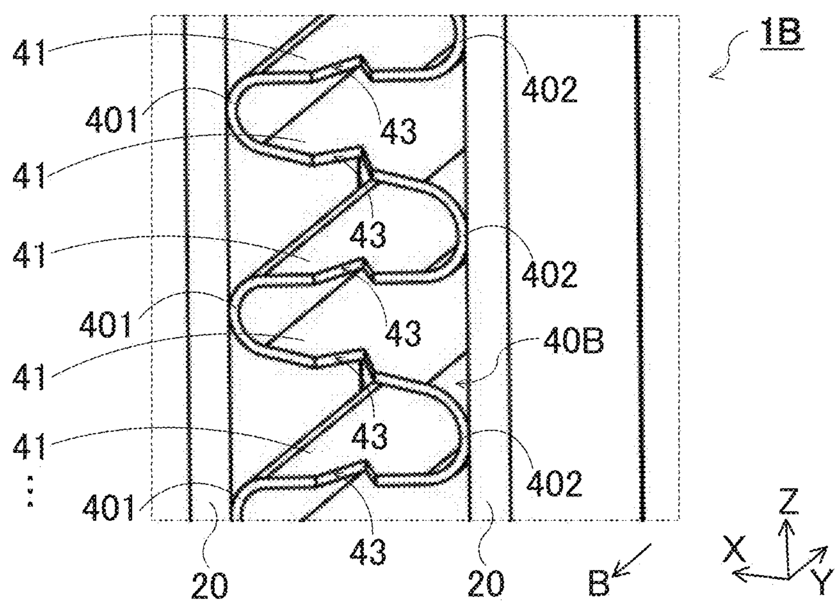

41
401
41
41
401
41
41
401
43
43
43
43
43
402
402
40B
402
20
20
B
1B
X
Z
Y

FIG. 10

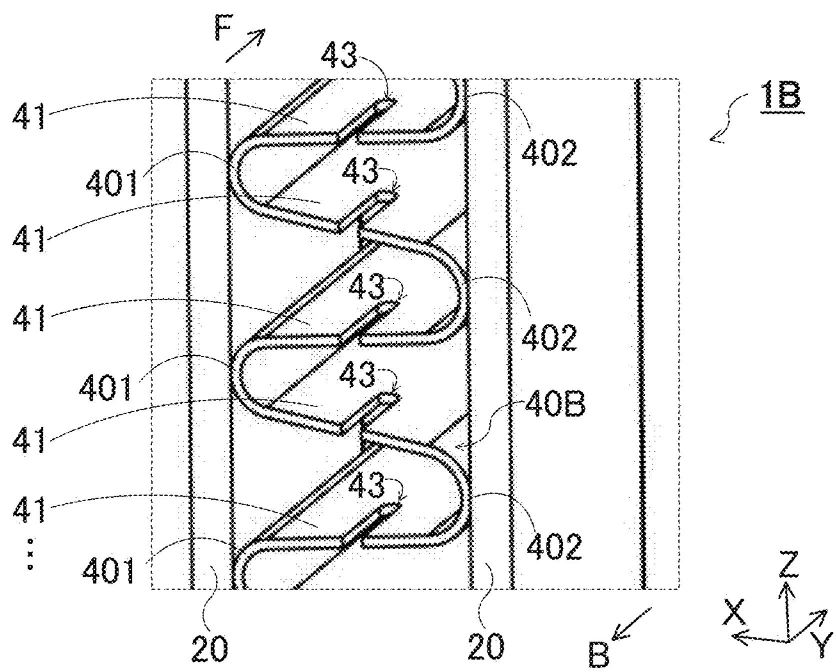

F
43
41
401
402
1B
43
41
43
41
402
401
43
40B
41
43
41
402
401
20
20
B
Z
X
Y

FIG. 11

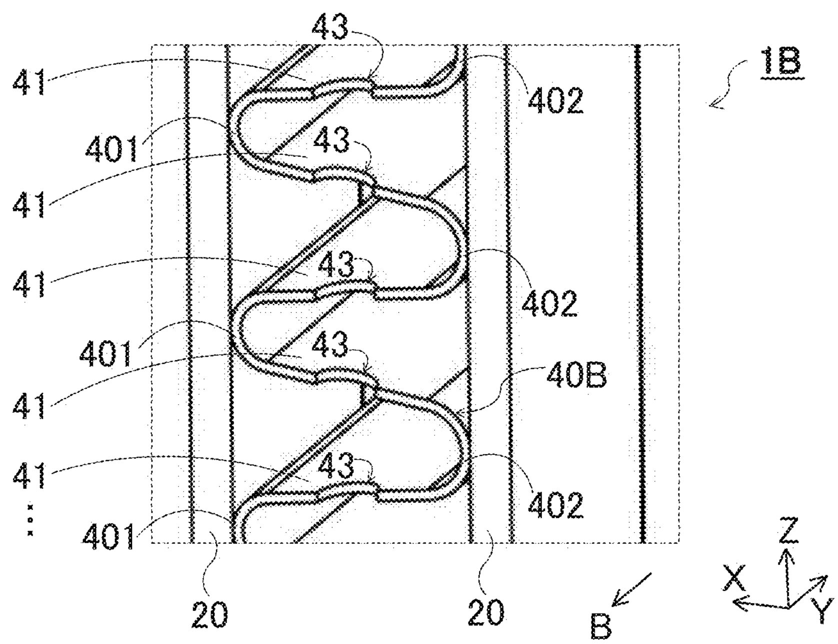
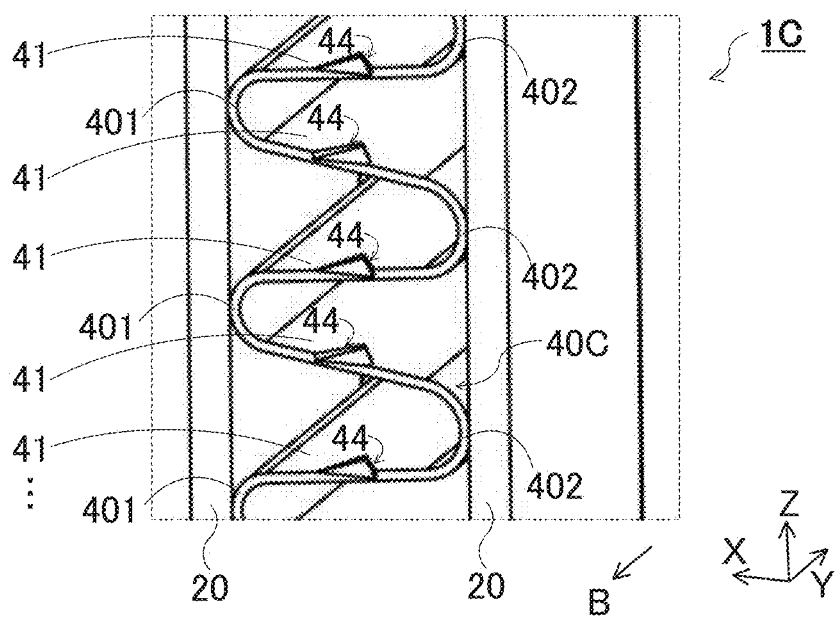

43
41
402
1B
401
43
41
41
43
402
401
43
40B
41
41
43
402
401
20
20
B
Z
X
Y

FIG. 12



41
401
41
41
401
41
41
401
44
44
44
44
44
402
402
40C
402
1C
20
20
B
Z
X
Y

FIG. 13

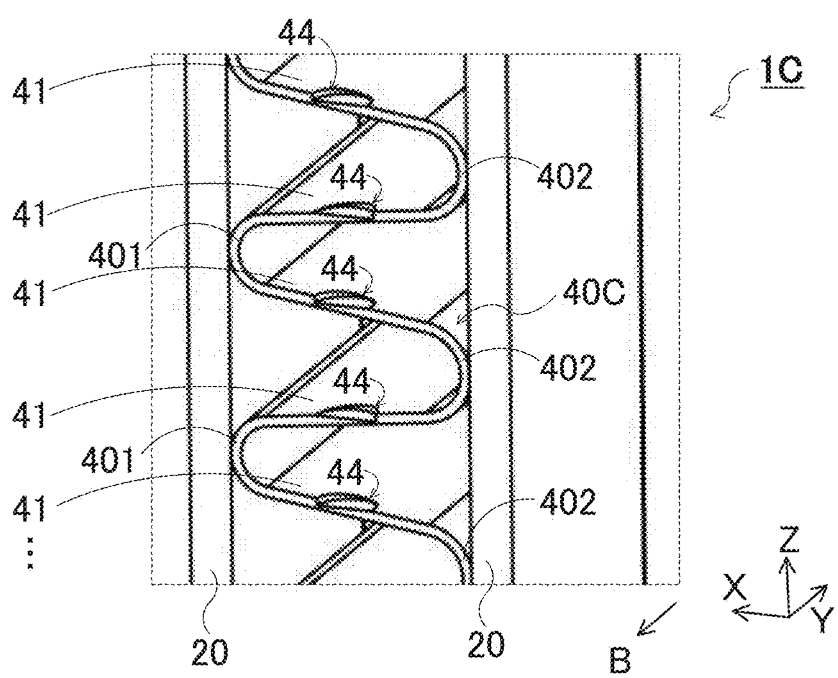


FIG. 14

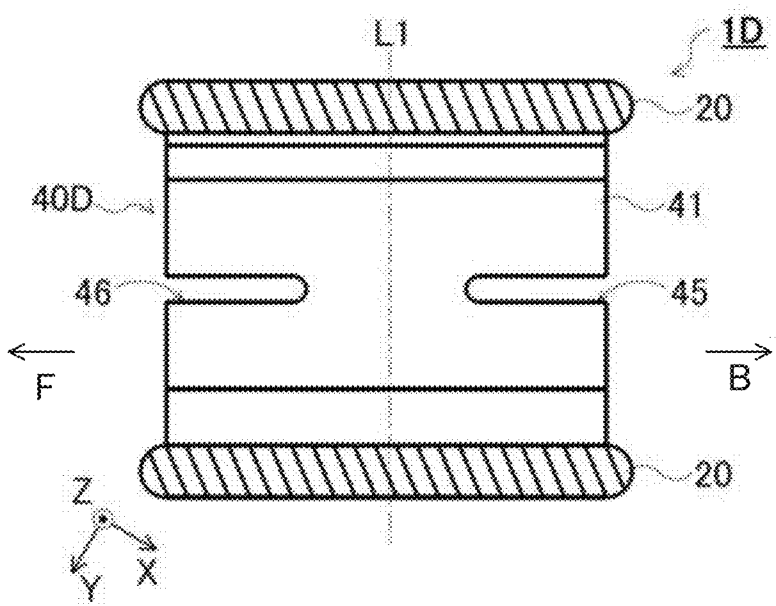
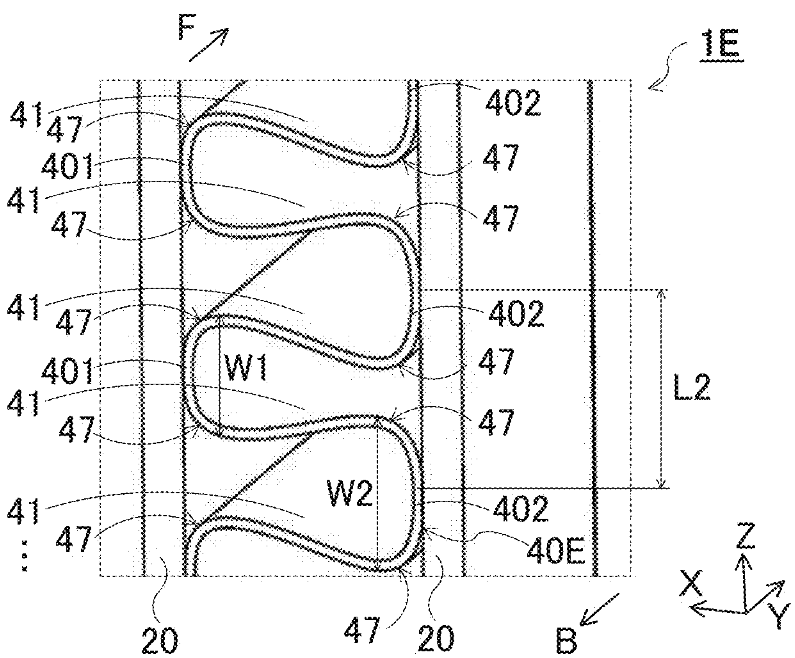


FIG. 15



F
1E
41
47
401
41
47
402
47
47
41
47
402
401
W1
47
41
47
47
L2
W2
41
47
402
40E
Z
X
Y
20
47
20
B

FIG. 16

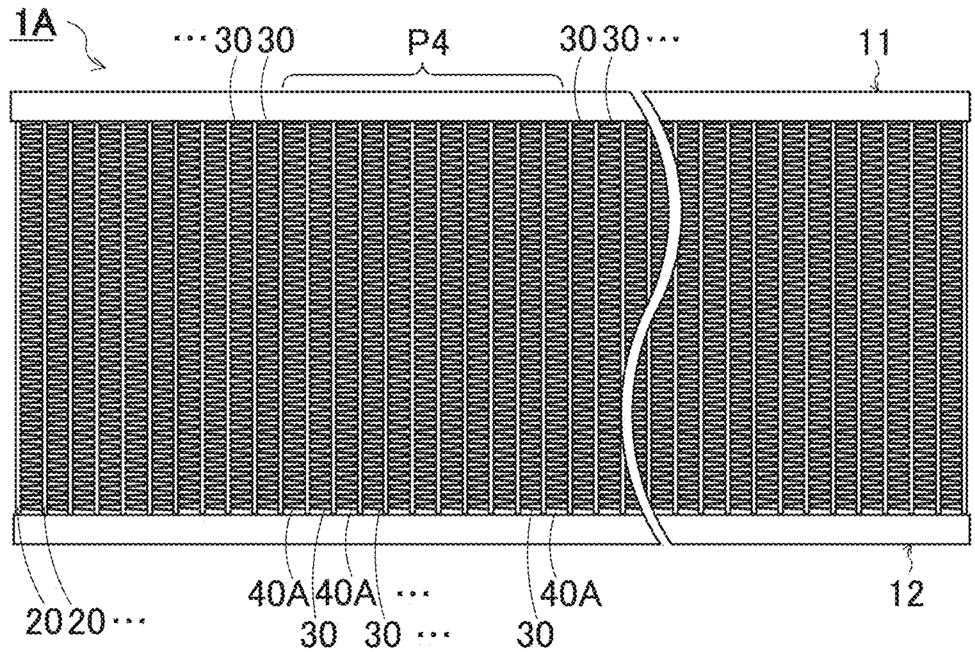


FIG. 17

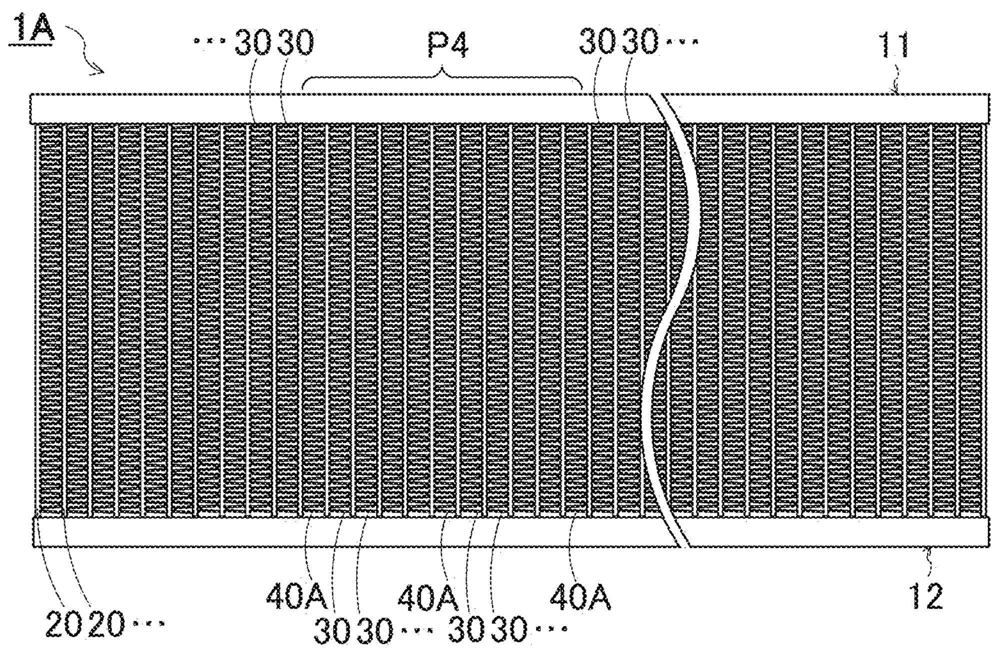
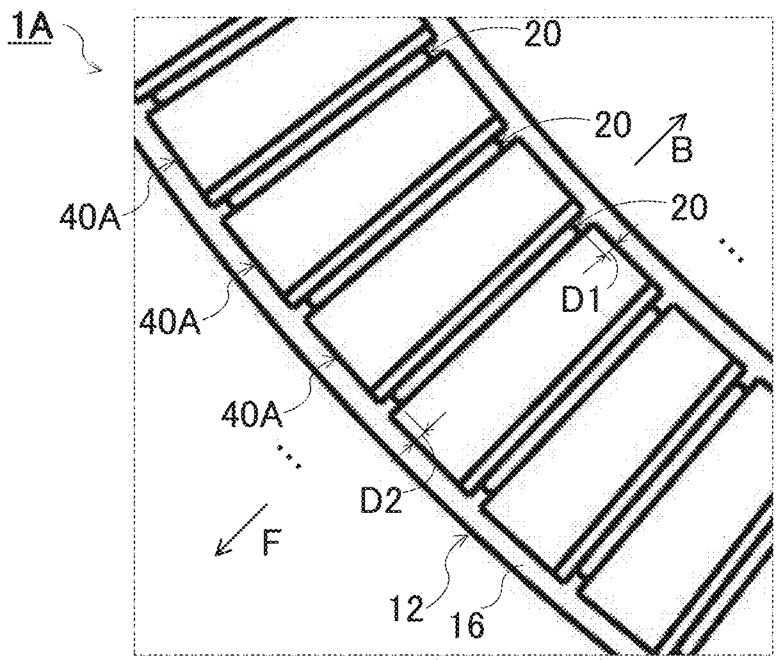


FIG. 18



HEAT EXCHANGER, AND METHOD FOR MANUFACTURING HEAT EXCHANGER

TECHNICAL FIELD

[0001] The present disclosure relates to a heat exchanger and a method of fabricating a heat exchanger.

BACKGROUND ART

[0002] Some heat exchangers include partially bent headers for distributing or gathering refrigerant to or from heat transfer pipes. The partially bent headers can be readily installed in apparatuses. Such a heat exchanger is fabricated by providing heat transfer pipes and fins to linearly extending headers, and then bending these headers. The step of bending the headers may unintentionally deform the fins in this heat exchanger. To avoid deformation of the fins, heat exchangers capable of avoiding deformation of the fins have been developed.

[0003] For example, Patent Literature 1 discloses a heat exchanger including two types of fins having different depths, in the gaps between heat transfer pipes arranged adjacent to the bent sections of headers. The two types of fins are alternately arranged in the arrangement direction of the heat transfer pipes.

[0004] Patent Literature 1 describes that the two types of fins having different depths can avoid significant deformation and breakage of fins in the bending step of the process of fabricating the heat exchanger.

CITATION LIST

Patent Literature

[0005] Patent Literature 1: International Publication No. WO 2015/027680

SUMMARY OF INVENTION

Technical Problem

[0006] The bending step, however, applies a compressive force to the inner side of bending of the headers, regardless of avoidance of deformation of the fins. The bending step may thus cause deformation of the heat transfer pipes disposed adjacent to the bent sections of the headers.

[0007] The deformation of the heat transfer pipes may narrow or close the internal flow paths of the heat transfer pipes. This phenomenon may lead to a decrease in the heat exchange efficiency.

[0008] An objective of the present disclosure, which has been accomplished to solve the above problem, is to provide a heat exchanger and a method of fabricating a heat exchanger that can avoid deformation of heat transfer pipes disposed adjacent to bent sections of headers and avoid a decrease in the heat exchange efficiency.

Solution to Problem

[0009] In order to achieve the above objective, a heat exchanger according to the present disclosure includes: a first header having a first bent section; a second header having a second bent section bent in the same direction as the first bent section and opposed to the first bent section; first heat transfer pipes arranged along the first bent section and connecting the first bent section and the second bent section; and fins that are to transfer heat from the first heat transfer pipes and that are each disposed between adjacent two of the first heat transfer pipes. At least one fin of the fins has a weak portion, the weak portion of each of the at least one fin has a lower rigidity than other portions of the fin, and the weak portion is more readily deformed than the other portions in response to a change in the distance between the adjacent two of the first heat transfer pipes.

Advantageous Effects of Invention

[0010] In the heat exchanger according to the present disclosure, at least one fin of the fins has a weak portion, the weak portion of each of the at least one fin has a lower rigidity than the other portions of the fin, and the weak portion is more readily deformed than the other portions in response to a change in the distance between the adjacent two of the first heat transfer pipes. That is, when the distance between the first heat transfer pipes changes in a bending step of providing the first bent section and the second bent section to the first header and the second header, the weak portion of the fin is deformed earlier than the other portions of the fin. These features can avoid deformation of the first heat transfer pipes. The avoidance of deformation of the first heat transfer pipes leads to avoidance of a decrease in the heat exchange efficiency of the heat exchanger.

BRIEF DESCRIPTION OF DRAWINGS

[0011] FIG. **1** is a perspective view of a heat exchanger according to Embodiment 1 of the present disclosure;

[0012] FIG. **2** is an enlarged perspective view of an area II illustrated in FIG. **1** when the area II is viewed from the rear side;

[0013] FIG. **3** is an enlarged perspective view of a fin fixed to heat transfer pipes coupled to bent sections of headers included in the heat exchanger according to Embodiment 1 of the present disclosure;

[0014] FIG. **4** is a sectional view of the fins vertically overlapping with the bent sections of the heat exchanger according to Embodiment 1 of the present disclosure;

[0015] FIG. **5** is a flowchart illustrating a method of fabricating a heat exchanger according to Embodiment 1 of the present disclosure;

[0016] FIG. **6** is a front view of multiple heat transfer pipes that hold fins and unprocessed fins therebetween in a step of building a semifinished heat exchanger involved in the method of fabricating a heat exchanger according to Embodiment 1 of the present disclosure;

[0017] FIG. **7** is a front view of a semifinished heat exchanger fabricated in the step of building a semifinished heat exchanger involved in the method of fabricating a heat exchanger according to Embodiment 1 of the present disclosure;

[0018] FIG. **8** is an enlarged rear view illustrating a part of a modification of the heat exchanger according to Embodiment 1 of the present disclosure, which includes warped heat transfer pipes;

[0019] FIG. **9** is an enlarged perspective view illustrating a part of heat transfer pipes and a fin included in a heat exchanger according to Embodiment 2 of the present disclosure;

[0020] FIG. **10** is an enlarged perspective view illustrating a part of a modification of the heat exchanger according to Embodiment 2 of the present disclosure;

[0021] FIG. **11** is an enlarged perspective view illustrating a part of another modification of the heat exchanger according to Embodiment 2 of the present disclosure;

[0022] FIG. **12** is an enlarged perspective view illustrating a part of heat transfer pipes and a fin included in a heat exchanger according to Embodiment 3 of the present disclosure;

[0023] FIG. **13** is an enlarged perspective view illustrating a part of a modification of the heat exchanger according to Embodiment 3 of the present disclosure;

[0024] FIG. **14** is an enlarged sectional view illustrating a part of a fin included in a heat exchanger according to Embodiment 4 of the present disclosure;

[0025] FIG. **15** is an enlarged perspective view illustrating a part of heat transfer pipes and a fin included in a heat exchanger according to Embodiment 5 of the present disclosure;

[0026] FIG. **16** is a development view of a modification of the heat exchanger according to Embodiment 1 of the present disclosure;

[0027] FIG. **17** is a development view of another modification of the heat exchanger according to Embodiment 1 of the present disclosure; and

[0028] FIG. **18** is a sectional view of fins included in still another modification of the heat exchanger according to Embodiment 1 of the present disclosure.

DESCRIPTION OF EMBODIMENTS

[0029] A heat exchanger and a method of fabricating a heat exchanger according to embodiments of the present disclosure are described in detail below with reference to the accompanying drawings. In the drawings, the components identical or corresponding to each other are provided with the same reference symbol. The drawings are provided with an orthogonal coordinate system XYZ. In this coordinate system, the Z axis corresponds to the vertical direction in which the pipe axes of multiple heat transfer pipes included in the heat exchanger extend. The X axis corresponds to the horizontal direction in which the heat transfer pipes are arranged. The Y axis is orthogonal to the Z and X axes. The following description refers to this coordinate system as required.

Embodiment 1

[0030] A heat exchanger according to Embodiment 1 includes fins that are coupled to bent sections of headers and have weak portions, in order to avoid deformation of heat transfer pipes. The following describes a structure of the heat exchanger, focusing on an example in which this heat exchanger is applied to an outdoor unit of an air-conditioning apparatus. The entire structure of the heat exchanger is described below with reference to FIGS. **1** and **2**.

[0031] FIG. **1** is a perspective view of a heat exchanger **1**A according to Embodiment 1. FIG. **2** is an enlarged perspective view of an area II illustrated in FIG. **1** when the area II is viewed from a rear side B. FIG. **1** illustrates only heat transfer pipes **20** and fins **30** located in a part of the heat exchanger **1**A, without the heat transfer pipes **20** and the fins **30** located in other parts, in order to facilitate an understanding. FIG. **2** illustrates only three heat transfer pipes **20** adjacent in the horizontal direction and two fins **30** disposed therebetween.

[0032] As illustrated in FIG. **1**, the heat exchanger **1**A includes headers **11** and **12** for distributing and gathering refrigerant, multiple heat transfer pipes **20** that are coupled to the headers **11** and **12** and allow the refrigerant to flow therein, and multiple fins **30** fixed to the heat transfer pipes **20**.

[0033] The headers **11** and **12** have a shape of rectangular tube. The headers **11** and **12** define internal flow paths, which are not illustrated. The headers **11** and **12** respectively have joint sections **13** and **14** having a shape of circular pipe, which are illustrated in FIG. **1**. The joint sections **13** and **14** are coupled to connecting tubes of external apparatuses, which are not illustrated, for feeding or discharging refrigerant. The headers **11** and **12**, which are connected to the external apparatuses, allow refrigerant to flow in the internal flow paths.

[0034] The headers **11** and **12** are arranged apart from each other in the vertical direction, such that the pipe axes A**1** and A**2** extend in the horizontal direction, as illustrated in FIG. **1**. The headers **11** and **12** are coupled to the heat transfer pipes **20** to allow refrigerant to circulate therebetween.

[0035] The heat transfer pipes **20** have a tubular shape in which refrigerant flows. The heat transfer pipes **20** extend in the vertical direction. The upper and lower ends of the heat transfer pipes **20** are inserted in insertion holes, which are not illustrated, on the walls of the rectangular cylinders of the headers **11** and **12**. The heat transfer pipes **20** are thus coupled to the headers **11** and **12**. The heat transfer pipes **20** having this structure allow the refrigerant flowing in the headers **11** and **12** to circulate in the heat transfer pipes **20**.

[0036] The heat transfer pipes **20** are made of a metal having a high thermal conductivity, such as pure aluminum or aluminum alloy, so as to facilitate heat conduction of the refrigerant circulating in the heat transfer pipes **20**. The heat transfer pipes **20** have a flattened circular section, which also contributes to heat conduction of the refrigerant. That is, the heat transfer pipes **20** are flat pipes. The heat transfer pipes **20** are arranged with a certain pitch along the pipe axes of the headers **11** and **12**, as illustrated in FIG. **1**. The heat transfer pipes **20** have gaps therebetween. These gaps accommodate the fins **30** for radiating, to the ambient air, the heat transferred to the heat transfer pipes **20**.

[0037] The fins **30** are made of a metal having a high thermal conductivity, for example, the metal identical to the material of the heat transfer pipes **20**, so as to facilitate heat conduction from the heat transfer pipes **20**. The fins **30** have a plate shape, as illustrated in FIG. **2**, which contributes to radiation of the heat to the ambient air. These plate-like fins **30** are repetitively bent into a shape of corrugation. The fins **30** are each held between adjacent heat transfer pipes **20** such that the mountain portions and the valley portions of the corrugation are oriented toward the flat surfaces of the heat transfer pipes **20**. The mountain portions and the valley portions of the corrugation defined by the fin **30** are bonded to the corresponding heat transfer pipes **20**. The fins **30** are thus fixed to the heat transfer pipes **20**. The fins **30** having this structure radiate the heat transferred from the heat transfer pipes **20**, from the surfaces of the corrugated plate to the ambient air.

[0038] Referring back to FIG. **1**, the headers **11** and **12** are bent into an L-shape suitable for being accommodated in a rectangular parallelepiped housing of the outdoor unit. In detail, the headers **11** and **12** respectively have L-shaped bent sections **15** and **16** bent at a right angle, and linear sections **17** and **18** linearly extending from the bent sections **15** and **16**.

[0039] The bent sections **15** and **16** are formed by, after building a semifinished heat exchanger including linearly extending headers **11** and **12**, bending this semifinished heat exchanger. This bending step applies a compressive force to the inner side of bending of the semifinished heat exchanger, which may unintentionally deform the fins **30** into irregular shapes. These fins **30** having irregular shapes have different ventilation resistances, and may lead to a decrease in the heat exchange efficiency of the heat exchanger **1**A.

[0040] The compressive force applied in the bending step may also deform the heat transfer pipes **20** and thus narrow or close the internal flow paths of the heat transfer pipes **20**. Such deformation may lead to a decrease in the heat exchange efficiency of the heat exchanger **1**A.

[0041] To avoid irregular deformation of the fins **30**, and to avoid deformation of the heat transfer pipes **20** with higher propriety than that of deformation of the fins **30**, the method of fabricating the heat exchanger **1**A involves a step of bending the fins **30** at certain sites. Specifically, the fins **30** disposed adjacent to the bent sections **15** and **16** have weak portions at certain sites, which have a lower rigidity and are more readily deformed in response to bending than the other portions.

[0042] The following describes structures of fins **40**A and weak portions, with reference to FIGS. **3** and **4**. The fins **40**A hereinafter indicate the fins **30** disposed adjacent to the bent sections **15** and **16**, in order to facilitate an understanding.

[0043] FIG. **3** is an enlarged perspective view of a fin **40**A fixed to the heat transfer pipes **20** coupled to the bent sections **15** and **16** of the headers **11** and **12**. FIG. **4** is a sectional view of the fins **40**A vertically overlapping with the bent sections **15** and **16** of the heat exchanger **1**A. FIG. **3** is an enlarged perspective view of an area IV illustrated in FIG. **1** when the area IV is viewed from the rear side B. FIG. **4** does not illustrate the internal structures of the heat transfer pipes **20**, in order to facilitate an understanding.

[0044] As illustrated in FIG. **3**, the fin **40**A is repetitively bent into a corrugated plate having a shape of vertically arranged waves, like the fin **30**. The mountain portions **401** of the corrugation in contact with the heat transfer pipe **20** on the +X side, and valley portions **402** in contact with the heat transfer pipe **20** on the −X side. The mountain portions **401** and the valley portions **402** are connected to each other with plate segments **41**. In other words, the fin **40**A has multiple plate segments **41** that extend from one to the other of two adjacent heat transfer pipes **20** across the gap between the heat transfer pipes **20**.

[0045] Such fins **40**A are fixed to the heat transfer pipes **20** disposed adjacent to the bent sections **15** and **16** of the headers **11** and **12**. The fins **40**A are each provided with weak portions in the plate segments **41**.

[0046] This specification defines the weak portions as portions of the plate segments **41** of the fin **40**A that have a lower rigidity than the other portions of the plate segments **41**. In detail, the weak portions are more readily deformed than the other portions of the plate segments **41** when any change occurs in the gap between the adjacent heat transfer pipes **20**, for example, when the bending step reduces the distance between the heat transfer pipes **20** on the inner side of bending. Being more readily deformed than the other portions means being more readily bent than the other portions, in an exemplary case of the heat exchanger **1**A.

[0047] In detail, the weak portions are made of fin-bent portions **42** formed by bending the plate segments **41** so as to protrude downward.

[0048] The fin-bent portions **42** are formed by bending, into a V-shape, the plate segments **41** at the center in the arrangement direction of the heat transfer pipes **20**. That is, the fin-bent portions **42** are V-shaped bent portions of the plate segments **41** located at the center of the gap between the adjacent heat transfer pipes **20**. These fin-bent portions **42**, when the bending step of the fabrication process changes the distance between the adjacent heat transfer pipes **20**, are more readily deformed or bent than the other portions of the plate segments **41**. In response to a change in the distance between the heat transfer pipes **20**, the fin-bent portions **42** are deformed such that the angle defined by the V-shape is increased or decreased. In other words, the fin-bent portions **42** extend or contract while maintaining the fold lines and cause the fin **40**A to deform regularly, like bellows, in the bending step of the fabrication process. The fin-bent portions **42** can thus prevent the bending step from causing irregular deformation of the fin **40**A and impairment of the ventilation performance. The fin-bent portions **42** can ensure the ventilation performance of the fin **40**A at a sufficiently high level. In addition, the fin-bent portions **42**, which extend or contract like bellows in response to a compressive force applied in a step of bending the headers **11** and **12**, can prevent the compressive force from being concentrated at the heat transfer pipes **20**. The fin-bent portions **42** can therefore avoid deformation of the heat transfer pipes **20**.

[0049] Each of the fin-bent portions **42** defines a V-shape of which the tip is oriented downward. The fin-bent portion **42** having this shape guides water drops adhering on the fin **40**A to the tip of the V-shape and facilitates drainage of the water drops. The fin-bent portion **42** can therefore improve the drainage performance of the fin **40**A.

[0050] The fin-bent portions **42** are located at the end faces of the plate segments **41** that face the inner side of bending, so as to achieve deformation depending on a compressive force applied in the bending step of the fabrication process.

[0051] In detail, as illustrated in FIG. **4**, the bent section **16** of the header **12** is bent toward the rear side B when viewed from the right. The rear side B thus corresponds to the inner side of bending of the bent section **16**. The rear side B of the bent section **16** is likely to receive a large compressive force in the bending step of the fabrication process. The fin-bent portions **42** are thus provided to the portions encompassing the end faces of the plate segments **41** on the rear side B, that is, the end faces on the rear side B and the portions therearound. The end face means a side surface of the plate segment **41** of which the main surfaces are vertically directed.

[0052] Each of the fin-bent portions **42** defines an isosceles triangular shape having the base located adjacent to the end face of the plate segment **41** on the rear side B, when the plate segment **41** is viewed in the direction orthogonal to the main surfaces. The fin-bent portion **42** is formed by bending the plate segment **41** along the equal sides, serving as mountain fold lines **421** and **422**, of the isosceles triangle, and along the perpendicular line, serving as a valley fold line **424**, from a vertex **423** of the isosceles triangle to the base. The fin-bent portion **42** formed by bending the plate segment **41** thus has an area expanding toward the rear side B. The bending step of the fabrication process applies a compressive force increasing from the neutral plane toward rear side. The fin-bent portion **42** having an area expanding toward the rear side B can be deformed in accordance with a compressive force. This fin-bent portion **42** is more readily deformed than the heat transfer pipes **20** by a compressive force applied in the bending step, and can suppress the compressive force in the bending step from being applied to the heat transfer pipes **20**.

[0053] The fin-bent portion **42**, formed by bending the plate segment **41** in the above-described manner, has a V-shape becoming deeper toward the rear side B. The fin-bent portion **42** thus defines a V-shaped groove on the upper surface of the plate segment **41**, of which the depth increases toward the rear side B, as illustrated in FIG. **3**. The fin-bent portion **42** having this structure can facilitate effective drainage of water drops adhering on the fin **40**A to the outside of the fin **40**A.

[0054] The above-mentioned fold line **424** of the fin-bent portion **42**, when being extended, preferably intersects the center C**1** of bending, which is illustrated in FIG. **4**. This fold line **424** can achieve uniform application of a compressive force to the individual sites of the fin-bent portion **42** in the bending step of the fabrication process, which is likely to result in regular deformation of the fin-bent portion **42**. This structure can thus prevent the compressive force from being concentrated at some of the heat transfer pipes **20**.

[0055] The vertex **423**, corresponding to the intersection of the fold lines **421** and **422**, is preferably located on or near the neutral plane of the plate segment **41**. This structure can effectively place the fin-bent portion **42** to the site expected to receive a compressive force in the bending step of the fabrication process.

[0056] The following describes a method of fabricating the heat exchanger **1**A including such fins **40**A, with reference to FIGS. **5** to **7**.

[0057] FIG. **5** is a flowchart illustrating the method of fabricating the heat exchanger **1**A. FIG. **6** is a front view of multiple heat transfer pipes **20** that hold fins **30** and unprocessed fins **50** therebetween in a step of building a semifinished heat exchanger **2** involved in the method of fabricating the heat exchanger **1**A. FIG. **7** is a front view of the semifinished heat exchanger **2** fabricated in the step of building the semifinished heat exchanger **2** involved in the method of fabricating the heat exchanger **1**A.

[0058] As illustrated in FIG. **5**, the method first involves preparing linear headers, heat transfer pipes **20**, and fins **30** (Step S**1**). The linear headers mean headers having linearly extending pipe axes without the bent sections **15** and **16**, before being bent into the headers **11** and **12**. Two linear headers are prepared through press working of metal plates made of the above-mentioned material, for example.

[0059] The fins **30** having the above-described shape are prepared through press working of metal plates made of the above-mentioned material, for example. Also prepared are other fins, which have a larger length from the mountain portions **401** to the valley portions **402** of the corrugation than that of the fins **30**, and from which the fins **40**A are yielded. The other fins are hereinafter referred to as "unprocessed fins".

[0060] The heat transfer pipes **20** having the above-described shape are also prepared through extrusion processing of a metal member made of the above-mentioned material.

[0061] The preparation step is followed by a step of building the semifinished heat exchanger **2** with the prepared linear headers, heat transfer pipes **20**, fins **30**, and unprocessed fins (Step S**2**).

[0062] This building step first involves arranging the heat transfer pipes **20** such that the pipe axes are oriented in the same direction and the flat surfaces face each other. Each adjacent two of the heat transfer pipes **20** hold the fin **30** or the unprocessed fin such that the mountain portions **401** and the valley portions **402** of the corrugation face the flat surfaces of the heat transfer pipes **20**. As illustrated in FIG. **6**, unprocessed fins **50** are held between the heat transfer pipes **20** coupled to a section P**1** of linear headers **21** and **22**, which corresponds to the bent sections **15** and **16** to be formed in Step S**3** described below. In contrast, the fins **30** are held between the heat transfer pipes **20** coupled to the other sections P**2** and P**3** of the linear headers **21** and **22**.

[0063] One and the other ends of the heat transfer pipes **20** holding the fins or unprocessed fins therebetween are inserted into the insertion holes, which are not illustrated, of the linear headers **21** and **22**, thereby building a core. The individual parts of the built core are then brazed to each other, and thus produce the semifinished heat exchanger **2** illustrated in FIG. **7**.

[0064] The building step is followed by a step of forming fin-bent portions **42**, as illustrated in FIG. **5** (Step S**3**). In detail, each of the unprocessed fins **50** of the resulting semifinished heat exchanger **2** has multiple plate segments **41** disposed between the mountain portions **401** and the valley portions **402** of the corrugated shape, as in FIG. **3**. These plate segments **41** extend across the gap between the heat transfer pipes **20**. After producing the semifinished heat exchanger **2**, the teeth of a comb-like tool, which is not illustrated, are introduced into the gap between the heat transfer pipes **20** from the rear side B. The teeth are urged onto the individual plate segments **41**, and thus bend the plate segments **41** into the above-described V-shape. This step forms fin-bent portions **42** on the rear side of the plate segments **41**. The fin-bent portions **42** each define a V-shaped groove shallower than that described above with reference to FIG. **3**. The angle formed between the V-shaped groove is almost 180°. The above-described steps yield the fins **40**A having the fin-bent portions **42**.

[0065] The resulting semifinished heat exchanger **2** is then bent, as illustrated in FIG. **5** (Step S**4**).

[0066] This bending step involves urging a punch, which is not illustrated, onto the section P**1** illustrated in FIG. **7**, which corresponds to the above-described bent sections **15** and **16**, from the rear side B adjacent to the fin-bent portions **42**. This step thus bends the semifinished heat exchanger **2** into an L-shape.

[0067] The fin-bent portions **42**, which are located on the inner side of bending, receive a compressive force. The compressive force further bends the fin-bent portions **42**, and thus deepens the V-shaped grooves defined by the fin-bent portions **42** into a depth equal to the depth illustrated in FIG. **3**. The V-shaped grooves defined by the fin-bent portions **42** form a narrowed angle therebetween, which is equal to the angle illustrated in FIG. **3**. The fin-bent portions **42** can thus prevent the compressive force from being concentrated at the heat transfer pipes **20** in the bending step. This structure can avoid deformation of the heat transfer pipes **20**, and thus avoid a decrease in the heat exchange efficiency of the heat exchanger **1**A.

[0068] Such changes in the V-shaped grooves defined by the fin-bent portions **42** are mere regular deformation of the fins **40**A. The fins **30** thus tend to have similar ventilation resistances, and are less likely to decrease the heat exchange efficiency of the heat exchanger **1**A.

[0069] The bending of the semifinished heat exchanger **2** into an L-shape deepens the above-described V-shaped grooves defined by the fin-bent portions **42**. The bending step also forms the L-shaped bent sections **15** and **16** in the linear headers. This step thus produces the heat exchanger **1**A including the headers **11** and **12** having the bent sections **15** and **16**. The above-described steps complete the heat exchanger **1**A.

[0070] Step S**2** is also called a step of building the semifinished heat exchanger **2** in the present disclosure. Step S**4** is also called a step of producing the heat exchanger **1**A or a bending step. The fin-bent portions **42**, which are the portions of the plate segments **41** hung downward, are also called hung portions.

[0071] The linear header **21** and the linear header **22** prepared in Step S**1** are examples of a first header having a first linear pipe section and a second header having a second linear pipe section in the present disclosure. The headers **11** and **12** are examples of the first header and the second header in the present disclosure. The bent sections **15** and **16** are examples of a first bent section and a second bent section in the present disclosure. The linear sections **17** and **18** are examples of the first linear section and the second linear section in the present disclosure. The fins **40**A and the fins **30** are examples of first fins and second fins in the present disclosure. The heat transfer pipes **20** disposed adjacent to the bent sections **15** and **16** are examples of first heat transfer pipes in the present disclosure. The heat transfer pipes **20** disposed adjacent to the linear sections **17** and **18** are examples of second heat transfer pipes in the present disclosure.

[0072] As described above, the heat exchanger **1**A according to Embodiment 1 includes the heat transfer pipes **20** disposed adjacent to the bent sections **15** and **16**, and the fins **40**A fixed to the heat transfer pipes **20**. These fins **40**A have the fin-bent portions **42** serving as the weak portions. Since the fin-bent portions **42** have a lower rigidity than the other portions, and are more readily deformed than the other portions in response to a change in the distance between the adjacent heat transfer pipes, the fin-bent portions **42** of the fins **40**A located between the heat transfer pipes **20** are deformed earlier than the other portions when the bending step of the process of fabricating the heat exchanger **1**A changes the distance between the heat transfer pipes **20**. These features can suppress a compressive force from being concentrated at the heat transfer pipes **20**, and avoid deformation of the heat transfer pipes **20**. The avoidance of deformation of the heat transfer pipes **20** leads to avoidance of a decrease in the heat exchange efficiency of the heat exchanger **1**A.

[0073] The fin-bent portions **42** are located at the end faces of the plate segments **41** of the fins **40**A that face the inner side of bending, and thus readily receive a compressive force in the bending step. That is, the compressive force, applied to the heat transfer pipes **20** in the bending step, is likely to be concentrated at the fin-bent portions **42** and less likely to be concentrated at the heat transfer pipes **20**. The heat exchanger **1**A can avoid deformation of the heat transfer pipes **20**, just by providing the fin-bent portions **42** at the end faces of the plate segments **41** that face the inner side of bending. The heat exchanger **1**A capable of avoiding deformation of the heat transfer pipes **20** can thus be readily fabricated.

[0074] The fin-bent portions **42** are each bent such that the plate segment **41** of the fin **40**A protrudes from one of the main surfaces. The fin-bent portion **42** can adjust the amount of protrusion depending on a compressive force applied in the bending step, and thus prevent the compressive force from being concentrated at the heat transfer pipes **20**.

[0075] The fin-bent portions **42** are each formed by bending the plate segment **41** of the fin **40**A into a V-shape of which the tip is oriented downward. The fin-bent portion **42** can thus guide water drops adhering on the plate segment **41** to the tip of the V-shape, and facilitate highly efficient drainage of the water drops.

[0076] The fin-bent portions **42** can maintain the bent V-shapes of the plate segments **41**, regardless of a compressive force applied in the bending step. The fins **40**A are thus less likely to suffer from increased ventilation resistances, in comparison to the fins **30** irregularly deformed by a compressive force applied in the bending step. These fins **40**A can maintain the ventilation resistance within a certain low range, and thus avoid a decrease in the heat exchange efficiency of the heat exchanger **1**A.

[0077] The bending step may warp the heat transfer pipes **20**. The heat transfer pipes **20** may be warped provided that the heat transfer pipes **20** are not buckled. FIG. **8** illustrates such warped heat transfer pipes **20**.

[0078] FIG. **8** is an enlarged rear view illustrating a part of a modification of the heat exchanger **1**A according to Embodiment 1, which includes warped heat transfer pipes **20** of the heat exchanger **1**A. FIG. **8** illustrates the linear sections **17** and **18** of the headers **11** and **12** of the heat exchanger **1**A after the bending step when viewed from the inner side of bending.

[0079] As illustrated in FIG. **8**, the heat transfer pipes **20** coupled to the linear sections **17** and **18** of the headers **11** and **12** may be warped so as to be in a shape of the convex curves oriented toward the −X side, that is, toward the bent sections **15** and **16**. The heat transfer pipes **20** disposed adjacent to the linear sections **17** and **18** are warped because of being drawn and deformed toward the bent sections **15** and **16**, when the bending step changes the distance between the heat transfer pipes **20** disposed adjacent to the bent sections **15** and **16**.

[0080] This phenomenon of warpage of the heat transfer pipes **20** occurs in a uniform bending process, which involves applying a load at the center of a linear-pipe header and thus bending the linear-pipe header while holding the lateral parts on both sides of the center in the longitudinal direction. This uniform bending process may warp the heat transfer pipes **20** disposed adjacent to the linear sections **17** and **18** on both sides of the bent sections **15** and **16**. These heat transfer pipes **20** disposed adjacent to the linear sections **17** and **18** on both sides may be warped.

[0081] In the case of a rotary draw bending process, while no warpage occurs in some heat transfer pipes **20** disposed adjacent to the linear sections **17** and **18** located in the direction of rotation of a clamp used in this process, some warpage occurs in other heat transfer pipes **20** disposed adjacent to the linear sections **17** and **18** located in the direction opposite to the direction of rotation of the clamp. The heat transfer pipes **20** located at such positions may be warped. The rotary draw bending process involves holding parts of the linear headers **21** and **22** between the clamp and a columnar bending die, shifting the clamp in the circumferential direction of the bending die and thus rotating the clamp about the central axis of the bending die, and thereby yielding bent sections **15** and **16**.

[0082] In the case of a bending process, while warpage occurs in some heat transfer pipes **20** disposed adjacent to the linear sections **17** and **18** located on one side of the bent sections **15** and **16**, no warpage occurs in other heat transfer pipes **20** disposed adjacent to the linear sections **17** and **18** located on the other side of the bent sections **15** and **16**. The heat transfer pipes **20** may be deformed into such shapes.

[0083] This phenomenon of warpage of the heat transfer pipes **20** occurs not only in the linear sections **17** and **18** but also in the bent sections **15** and **16**. The warpage of the heat transfer pipes **20** disposed adjacent to the bent sections **15** and **16** is not as large as the warpage of the heat transfer pipes **20** disposed adjacent to the linear sections **17** and **18**. That is, the warpage of the heat transfer pipes **20** disposed adjacent to the bent sections **15** and **16** may be smaller than the warpage of the heat transfer pipes **20** disposed adjacent to the linear sections **17** and **18**.

Embodiment 2

[0084] In Embodiment 1, the weak portions of the plate segments **41** of the fins **40**A are made of the fin-bent portions **42**. These weak portions, however, are mere examples. The weak portions are only required to have a lower rigidity than the other portions of the plate segments **41**, and be more readily deformed than the other portions in response to a change in the distance between the adjacent heat transfer pipes **20**.

[0085] In a heat exchanger **1**B according to Embodiment 2, each of the weak portions of the plate segments **41** is made of a portion encompassing a notch cut out from the end face of the plate segment **41** toward the central part. The following describes a structure of the heat exchanger **1**B with reference to FIG. **9**. The description of Embodiment 2 is mainly directed to the differences from Embodiment 1.

[0086] FIG. **9** is an enlarged perspective view illustrating a part of heat transfer pipes **20** and a fin **40**B included in the heat exchanger **1**B according to Embodiment 2. FIG. **9** illustrates the heat transfer pipes **20** coupled to the bent sections **15** and **16** of the headers **11** and **12**, and the fin **40**B fixed to the heat transfer pipes **20**, as in FIG. **3**. FIG. **9** illustrates the fin **40**B having substantially no deformation, in order to facilitate an understanding, although the fin **40**B is expected to be deformed by a compressive force applied in the bending step.

[0087] In the heat exchanger **1**B, the weak portions are made of portions encompassing notches **43** illustrated in FIG. **9** cut out from the end faces of the plate segments **41**. That is, the weak portions are made of the notches **43** and the portions of the plate segments **41** around the notches **43**.

[0088] The notches **43** are each cut out from the end face of the plate segment **41** on the rear side B toward the central part of the plate segment **41**. The notch **43** extends through the plate segment **41**. The notch **43** has a shape of wedge of which the tip is oriented toward the central part of the plate segment **41**. That is, the notch **43** has a triangular shape of which the vertex is located adjacent to the central part of the plate segment **41** and the opposite side of the vertex is located at the end face of the plate segment **41**, when viewed in the direction orthogonal to the main surfaces of the plate segment **41**.

[0089] In detail, the notches **43** each have a shape of isosceles triangle of which the base is oriented toward the inner side of bending of the bent sections **15** and **16** illustrated in FIG. **1**, that is, toward the rear side B, when the plate segment **41** is viewed in the direction orthogonal to the main surfaces. The compressive force applied in the bending step increases from the neutral plane toward rear side B. The notches **43** having such a shape allow the fin **40**B to be deformed in accordance with a compressive force. The notches **43** can thus achieve deformation by a compressive force applied in the bending step, and suppress the compressive force from being applied to the heat transfer pipes **20**.

[0090] Even if the notches **43** having the above-described shape are deformed by a compressive force, the end faces of the notches **43** of the plate segments **41** are less likely to overlap with each other or protrude outward. These notches **43** are less likely to suffer from increased ventilation resistances.

[0091] The notches **43** cut the plate segments **41** into the above-described shape. That is, the notches **43** extend completely through the plate segments **41** in the thickness direction. The notches **43** can thus facilitate the fin **40**B to be deformed by a compressive force applied in the bending step.

[0092] This specification defines the notch as a cut-out hole ranging from the end face toward the central part of the plate segment **41**. The notches **43** are thus also called cut-out holes.

[0093] The method of fabricating the heat exchanger **1**B is identical to the method of fabricating the heat exchanger **1**A according to Embodiment 1, except for that: (1) the fins **40**B are prepared in Step S**1** described above in Embodiment 1, as in the preparation of the fins **30**; (2) The notches **43** are formed through press working, for example, simultaneously with the formation of the fins **40**B; and (3) Step S**3** described above in Embodiment 1 is accordingly skipped. The fabrication method is thus not redundantly described. The notches **43** each have a triangular shape, which is formed by punching a hole in the plate segment **41** through press working.

[0094] The above-described notches **43** are examples of first notches in the present disclosure. The end faces of the plate segments **41** on the rear side B provided with the notches **43** are examples of one of an end face of the plate segment **41** that faces the inner side of bending of the first bent section or an end face that faces the outer side of bending of the first bent section in the present disclosure. The fins **40**B are examples of first fins in the present disclosure. The shape of the notches **43** may also be called a V-shape.

[0095] As described above, in the heat exchanger **1**B according to Embodiment 2, the plate segments **41** of the fins **40**B have the notches **43**, and the portions of the plate segments **41** encompassing the notches **43** serve as the weak portions. The portions of the plate segments **41** encompassing the notches **43** are thus deformed earlier than the other portions of the plate segments **41**, when the bending step of the fabrication process applies a compressive force to the heat transfer pipes **20**. These features of the heat exchanger **1**B can prevent the compressive force from being concentrated at the heat transfer pipes **20**. The heat exchanger **1**B can also avoid deformation of the heat transfer pipes **20**.

[0096] The method of fabricating the heat exchanger **1**B can achieve formation of the notches **43** through press working, for example, simultaneously with the formation of the fins **40**B. The heat exchanger **1**B can therefore be fabricated by the same number of steps as those of a normal heat exchanger including fins without the notches **43**.

Modifications

[0097] Although the heat exchanger **1**B according to Embodiment 2 has the triangular notches **43**, these notches **43** are mere examples. The notches **43** are only required to be designed such that the portions of the plate segments **41** encompassing the notches **43** have a lower rigidity than the other portions of the plate segments **41** and are more readily deformed than the other portions of the plate segments **41** in response to a change in the gap between the adjacent heat transfer pipes **20**. The notches **43** may have any shape provided that these requirements are satisfied.

[0098] FIG. **10** is an enlarged perspective view illustrating a part of a modification of the heat exchanger **1**B according to Embodiment 2. FIG. **11** is an enlarged perspective view illustrating a part of another modification of the heat exchanger **1**B according to Embodiment 2. FIGS. **10** and **11** each illustrate the area of the heat exchanger **1**B identical to the area illustrated in FIG. **9**.

[0099] As illustrated in FIG. **10**, the notches **43** may have a rectangular shape. In detail, the notches **43** may have a rectangular shape, which is cut out from the end face of the plate segment **41** on the rear side B toward the front side F and of which the longitudinal direction is oriented toward the front. In other words, the notches **43** may have an I-shape having the longitudinal direction oriented toward the front.

[0100] These notches **43** preferably have a width in the transverse direction smaller than that of the base of the isosceles triangle defined by each of the notches **43** described above in Embodiment 2. This structure can achieve a smaller cut-out area of the plate segment **41** than that in Embodiment 2, and make the heat exchange performance of the fins **40**B as high as possible.

[0101] As illustrated in FIG. **11**, the notches **43** may also have a semicircular shape. In detail, the notches **43** may have a semicircular shape, of which the center is located adjacent to the end face of the plate segment **41** and the convex arc is oriented toward the central part of the plate segment **41**. This structure can suppress stresses from being concentrated at the inner angles of the notches **43** in the bending step, and prevent the fins **40**B from being broken or deformed into an unintended shape. The arc of a semicircle may be an arc of a true circle or an arc of an ellipse.

[0102] The mode illustrated in FIG. **11** may also be applied to Embodiment 2 or the mode illustrated in FIG. **10**, although this modification is not illustrated. That is, the inner angles of the triangular or rectangular notches **43** may be rounded into a semicircular shape. In this case, the arc of the semicircle preferably has a shape depending on the inner angle.

[0103] Embodiment 2 and the modes illustrated in FIGS. **10** and **11** may also be applied to Embodiment 1. That is, the fin-bent portions **42** may be provided with the notches **43**.

Embodiment 3

[0104] In Embodiment 1, the weak portions of the plate segments **41** of the fins **40**A are made of the fin-bent portions **42**. In Embodiment 2, the weak portions are made of the portions of the plate segments **41** encompassing the notches **43**. These weak portions, however, are mere examples. As described above in Embodiment 2, the weak portions are only required to have a lower rigidity than the other portions of the plate segments **41**, and be more readily deformed than the other portions in response to a change in the distance between the adjacent heat transfer pipes **20**.

[0105] In a heat exchanger **1**C according to Embodiment 3, the plate segments **41** each have a weak portion made of a thin portion. The following describes a structure of the heat exchanger **1**C with reference to FIG. **12**. The description of Embodiment 3 is mainly directed to the differences from Embodiments 1 and 2.

[0106] FIG. **12** is an enlarged perspective view illustrating a part of heat transfer pipes **20** and a fin **40**C included in the heat exchanger **1**C according to Embodiment 3. FIG. **12** illustrates the heat transfer pipes **20** coupled to the bent sections **15** and **16** of the headers **11** and **12**, and the fin **40**C fixed to the heat transfer pipes **20**, as in FIG. **3**. FIG. **12** illustrates the fin **40**C having substantially no deformation, in order to facilitate an understanding as in FIG. **9**, although the fin **40**C is expected to be deformed by a compressive force applied in the bending step.

[0107] As illustrated in FIG. **12**, the weak portions in the heat exchanger **1**C are made of thin portions **44** having a smaller thickness than the other portions of the plate segments **41**.

[0108] The thin portions **44** have a triangular shape, of which the vertex is located adjacent to the central part of the plate segment **41** and the opposite side of the vertex is located at the end face of the plate segment **41**, when viewed in the direction orthogonal to the main surfaces of the plate segment **41**. That is, the thin portions **44** have the same flat shape as the notches **43** described above with reference to FIG. **9**. The thin portions **44** thus each have the same contour as that of the notches **43** illustrated in FIG. **9** when the plate segment **41** is viewed in the direction orthogonal to the main surfaces of the plate segment **41**. The following description thus excludes a specific description of the contour of the thin portion **44**. The thin portions **44** having such a shape are deformed by a compressive force applied in the bending step, and can suppress the compressive force from being applied to the heat transfer pipes **20**.

[0109] The thin portions **44** have a smaller thickness than the other portions of the plate segments **41**, as described above. This thickness of the thin portions **44** is constant. The thin portions **44** receive heat from the heat transfer pipes **20** and thus contribute to heat exchange, unlike the notches **43** described above in Embodiment 2. The fins **40**C can therefore achieve higher heat exchange efficiency than the fins **40**B described above in Embodiment 2.

[0110] The thin portions **44** may each be embossed on one of the main surfaces of the plate segment **41**, although this modification is not illustrated in FIG. **12**. In this case, the embossment of the thin portions **44** is preferably oriented toward the gravity direction, that is, the downward direction. Although the thin portions **44** symmetric about the X axis are adjacent to each other in the vertical direction in FIG. **12**, the thin portions **44** having the identical shape may be adjacent to each other in the vertical direction.

[0111] The method of fabricating the heat exchanger **1**C is identical to the method of fabricating the heat exchanger **1**A according to Embodiment 1, except for that: (1) the fins **40**C are prepared in Step S**1** described above in Embodiment 1, as in the preparation of the fins **30**, and the thin portions **44** are formed through press working, for example, simultaneously with the formation of the fins **40**C; and (2) Step S**3** described above in Embodiment 1 is accordingly skipped. The fabrication method is thus not redundantly described.

[0112] The above-described thin portions **44** are examples of first thin portions in the present disclosure. The end faces of the plate segments **41** on the rear side B provided with the thin portions **44** are examples of one of an end face of the plate segment **41** that faces the inner side of bending of the first bent section, or an end face that faces the outer side of bending of the first bent section in the present disclosure. The fins **40**C are examples of first fins in the present disclosure.

[0113] As described above, in the heat exchanger **1**C according to Embodiment 3, the fins **40**C have the thin portions **44** serving as the weak portions. The thin portions **44** are thus deformed earlier than the other portions of the plate segments **41**, when the bending step of the fabrication process applies a compressive force to the heat transfer pipes **20**. These features can prevent the compressive force from being concentrated at the heat transfer pipes **20**. The heat exchanger **1**C can also avoid deformation of the heat transfer pipes **20**.

[0114] The method of fabricating the heat exchanger **1**C can achieve formation of the thin portions **44** through press working, for example, simultaneously with the formation of the fins **40**C, as in Embodiment 2. The heat exchanger **1**C can therefore be fabricated by the same number of steps as those of a normal heat exchanger including fins without the thin portions **44**.

Modification

[0115] Although the heat exchanger **1**C according to Embodiment 3 has the thin portions **44** having a triangular shape in a plan view, these thin portions **44** are mere examples. The thin portions **44** may have any shape provided that the requirements for weak portions are satisfied, for the same reason as that described above in Embodiment 2.

[0116] FIG. **13** is an enlarged perspective view illustrating a part of a modification of the heat exchanger **1**C according to Embodiment 3. FIG. **13** illustrates the area of the heat exchanger **1**C identical to the area illustrated in FIG. **12**.

[0117] As illustrated in FIG. **13**, the thin portions **44** may have a semicircular shape. In detail, the thin portions **44** may have a semicircular shape, of which the center is located adjacent to the end face of the plate segment **41** and the convex arc is oriented toward the central part of the plate segment **41**, as in the mode illustrated in FIG. **11**. This structure can suppress stresses from being concentrated in the bending step, as in the mode illustrated in FIG. **11**. The arc of a semicircle in this structure may be an arc of an ellipse.

[0118] The thin portions **44** in Embodiment 3 may also be applied to the fin-bent portions **42** of the fins **40**A described above in Embodiment 1. For example, the fin-bent portions **42**, each having a shape of isosceles triangle of which the base is located adjacent to the end face of the plate segment **41** on the rear side B when the plate segment **41** is viewed in the direction orthogonal to the main surfaces, may be formed as the thin portions **44** having a smaller thickness than that of the other portions of the plate segments **41**. The thin portions **44** can be more readily bent, and thus facilitate deformation of the fin-bent portions **42**.

Embodiment 4

[0119] In Embodiment 2, the notches **43** are located at the end faces of the plate segments **41** that face the inner side of bending. This structure including the notches **43** is a mere example. Notches may also be provided to the other portions of the plate segments **41**.

[0120] In a heat exchanger **1**D according to Embodiment 4, each of the plate segments **41** has notches **45** and **46**. The following describes a structure of the heat exchanger **1**D with reference to FIG. **14**. The description of Embodiment 4 is mainly directed to the differences from Embodiments 1 to 3.

[0121] FIG. **14** is an enlarged sectional view illustrating a part of a fin **40**D included in the heat exchanger **1**D according to Embodiment 4. The fin **40**D illustrated in FIG. **14** is one of the fins to be coupled to the bent sections **15** and **16** of the headers **11** and **12** included in the heat exchanger **1**D. FIG. **14** illustrates the fin **40**D before being deformed in accordance with the bending of the headers **11** and **12**, in order to facilitate an understanding.

[0122] As illustrated in FIG. **14**, in the heat exchanger **1**D, each of the plate segments **41** of the fin **40**D has the notch **45** corresponding to the notch **43** in Embodiment 2, and the notch **46** disposed at a position different from the notch **45**. These notches **45** and **46** both correspond to the weak portions described above in Embodiments 1 to 3.

[0123] The notches **45** are disposed at the end faces of the plate segments **41** that face the rear side B, as in Embodiment 2. The notches **45** have a rectangular shape, which is cut out from the end face of the plate segment **41** on the rear side B toward the front side F and of which the longitudinal direction is oriented toward the front, like the notches **43** according to the modification of Embodiment 2. The bottoms of the notches **45** adjacent to the front side F are rounded into a semicircular shape. The notches **45** are disposed at the end faces of the plate segments **41** that face the rear side B and have the above-described shape. The notches **45** can thus facilitate the plate segments **41** to be deformed by a compressive force applied in the bending step, and suppress the compressive force from being applied to the heat transfer pipes **20**, as in Embodiment 2.

[0124] In contrast, the notches **46** are disposed at the end faces of the plate segments **41** that face the front side F. That is, the notches **46** are disposed at the end faces opposite to the end faces of the plate segments **41** provided with the notches **45**. The notches **46** each have a shape defined by inverting the notch **45** into the frontward direction. In other words, the notch **46** is symmetric to the notch **45** about the line L1 representing the neutral plane.

[0125] The heat exchanger **1**D is fabricated through Steps S1, S**2**, and S**4** except for Step S**3** described above in Embodiment 2. The fabrication method in Embodiment 2 requires alignment of the end faces of the fins **40**B provided with the notches **43** to one side before holding the fins **40**B between the heat transfer pipes **20** in Step S**2**. In contrast, the method of fabricating the heat exchanger **1**D according to Embodiment 4 does not require alignment of the end faces of the fins **40**D provided with the notches **45** to one side in

Step S2, because the opposite end surfaces of each plate segment **41** both have the notches **45** and **46**. That is, the end faces provided with the notches **45** and the end faces provided with the notches **46** may exist on the same side. The method of fabricating the heat exchanger **1**D can thus achieve improved efficiency.

[0126] When the semifinished heat exchanger **2** is bent in Step S**4** of the method of fabricating the heat exchanger **1**D, while the end faces of the plate segments **41** that face the inner side of bending receive a compressive force, the end faces of the plate segments **41** on the outer side of bending receive a tensile force. In the heat exchanger **1**D, while the end faces of the plate segments **41** that face the inner side of bending have the notches **45**, the end faces of the plate segments **41** on the outer side of bending have the notches **46**. When the semifinished heat exchanger **2** is bent in Step S4, the plate segments **41** are deformed such that the notches **45** are compressed and the notches **46** are stretched. The method of fabricating the heat exchanger **1**D is thus less likely to apply a compressive force and a tensile force to the heat transfer pipes **20**. These features can avoid deformation of the heat transfer pipes **20**, and avoid a decrease in the heat exchange efficiency of the heat exchanger **1**D.

[0127] The above-described notches **45** and **46** are examples of first notches and second notches in the present disclosure. The end faces of the plate segments **41** that face the rear side B and are provided with the notches **45** are examples of one of an end face of the plate segment **41** that faces the inner side of bending of the first bent section, or an end face that faces the outer side of bending of the first bent section in the present disclosure. The end faces of the plate segments **41** that face the front side F and are provided with the notches **46** are examples of the other of the end face of the plate segment **41** that faces the inner side of bending of the first bent section, or the end face that faces the outer side of bending of the first bent section in the present disclosure.

[0128] As described above, in the heat exchanger **1**D according to Embodiment 4, each of the plate segments **41** of the fins **40**D has the notch **45** and the notch **46** having a shape and a position symmetric to the notch **45**. Such fins **40**D may be inversed in the step of building the heat exchanger **1**D with the fins **40**D. The method of fabricating the heat exchanger **1**D can thus exclude the alignment of the fins **40**D to one side, and can therefore achieve improved efficiency of the building step.

[0129] The heat exchanger **1**D can also avoid deformation of the heat transfer pipes **20**, as in Embodiment 2.

Modifications

[0130] In Embodiment 4, the notches **45** and **46** have a rectangular shape. The notches **45** and **46**, however, may have another shape. The notches **45** and **46** may have any shape provided that the requirements for weak portions are satisfied for the same reason as that described above in Embodiment 2. The shapes of the notches **45** and **46** are only required to be symmetric about the neutral plane. For example, the notches **45** and **46** may have a triangular shape or semicircular shape described above in Embodiment 2 and the modification of Embodiment 2.

[0131] Although Embodiment 4 is applied to the case of the weak portions made of the notches **45** and **46**, Embodiment 4 can also be applied to the case of the weak portions made of the thin portions **44**. In detail, the notches **45** may be replaced with the thin portions **44**, and the notches **46** may be replaced with thin portions **44** symmetric to the original thin portions **44** about the neutral plane. The thin portions **44** symmetric about the neutral plane in this case are examples of second thin portions in the present disclosure.

[0132] Embodiment 4 may also be applied to the case of the weak portions made of the fin-bent portions **42**. In detail, the notches **45** may be replaced with the fin-bent portions **42**, and the notches **46** may be replaced with fin-bent portions **42** symmetric to the original fin-bent portions **42** about the neutral plane.

Embodiment 5

[0133] In Embodiment 1, the weak portions of the plate segments **41** of the fins **40**A are made of the fin-bent portions **42**. In Embodiment 2, the weak portions are made of the portions of the plate segments **41** encompassing the notches **43**. In Embodiment 3, the weak portions are made of the thin portions **44**. These weak portions, however, are mere examples. The weak portions are only required to have a lower rigidity than the other portions of the plate segments **41**, and be more readily deformed than the other portions in response to a change in the distance between the adjacent heat transfer pipes **20**, as described above.

[0134] In a heat exchanger **1**E according to Embodiment 5, each of the plate segments **41** has a weak portion made of a warped portion **47**. The following describes a structure of the heat exchanger **1**E with reference to FIG. **15**. The description of Embodiment 5 is mainly directed to the differences from Embodiments 1 to 4.

[0135] FIG. **15** is an enlarged perspective view illustrating a part of heat transfer pipes **20** and a fin **40**E included in the heat exchanger **1**E according to Embodiment 5. FIG. **15** illustrates the heat transfer pipes **20** coupled to the bent sections **15** and **16** of the headers **11** and **12**, and the fin **40**E fixed to the heat transfer pipes **20**, as in FIG. **3**. FIG. **15** illustrates the fin **40**E having no deformation in the bending step, in order to facilitate an understanding as in FIGS. **9** and **12**, although the fin **40**E is expected to be deformed by a compressive force applied in the bending step.

[0136] As illustrated in FIG. **15**, the weak portions in the heat exchanger **1**E are made of the warped portions **47** having a larger amount of warpage than the other portions of the plate segments **41**.

[0137] The mountain portions **401** and the valley portions **402** of the corrugated shape defined by each fin **40**E are brazed to the heat transfer pipes **20**. Each of the mountain portions **401** and the valley portions **402** has two warped portions **47** on both sides of the site to be brazed of the mountain portion **401** or the valley portion **402**. The warped portions **47** located at these positions make the widths W1 and W2 of the mountain portions **401** and the valley portions **402** of the corrugated shape, larger than the half of the wavelength L2 of the corrugated shape. Although FIG. **15** illustrates the warped portions **47** on the rear side B, the warped portions **47** extend from the rear side B to the front side F, which is not illustrated. The warped portions **47** having this shape and positions are deformed by a compressive force and a tensile force applied in the bending step, and can prevent the fins **40**E themselves from being broken. The warped portions **47** can also suppress a compressive force and a tensile force from being applied to the heat transfer pipes **20**.

[0138] The method of fabricating the heat exchanger **1**E is identical to the method of fabricating the heat exchanger **1**A according to Embodiment 1, except for that: (1) the fins **40**E having the warped portions **47** are prepared in Step S**1** described above in Embodiment 1; and (2) Step S**3** described above in Embodiment 1 is accordingly skipped. The fabrication method is thus not redundantly described.

[0139] As described above, in the heat exchanger **1**E according to Embodiment 5, the fins **40**E have the warped portions **47** serving as the weak portions. The warped portions **47** are deformed earlier than the other portions of the plate segments **41**, when the bending step of the fabrication process applies a compressive force or a tensile force to the heat transfer pipes **20**. These features can prevent the compressive force or tensile force from being concentrated at the heat transfer pipes **20**. The features can thus avoid deformation of the heat transfer pipes **20**.

[0140] In particular, a plate segment **41** may be broken by being stretched by a tensile force exceeding the tolerance. The warped portions **47** of the heat exchanger **1**E have larger rooms to be stretched and can thus prevent the fins **40**E themselves from being broken.

[0141] The above-described heat exchangers **1**A to **1**E and the methods of fabricating the heat exchangers **1**A to **1**E according to the embodiments of the present disclosure are mere examples.

[0142] In Embodiments 1 to 5, the fins **40**A to **40**E having the weak portions are fixed to each of the heat transfer pipes **20** coupled to the bent sections **15** and **16** of the headers **11** and **12**. In other words, the fins **40**A to **40**E are fixed to all of the heat transfer pipes **20** disposed adjacent to the bent sections **15** and **16**. These heat exchangers **1**A to **1**E, however, are mere examples. In the heat exchangers **1**A to **1**E, the weak portions are only required to be provided to at least one of the fins fixed to the heat transfer pipes **20** coupled to the bent sections **15** and **16**. In short, the fins **40**A to **40**E correspond to at least one of the fins.

[0143] FIG. **16** is a development view of a modification of the heat exchanger **1**A according to Embodiment 1. FIG. **17** is a development view of another modification of the heat exchanger **1**A according to Embodiment 1. FIGS. **16** and **17** each illustrate the heat exchanger **1**A in which the bent sections **15** and **16** of the modification or the other modification of the heat exchanger **1**A are developed into a linear shape. The section corresponding to the bent sections **15** and **16** developed into a linear shape is provided with a reference symbol P**4**.

[0144] As illustrated in FIG. **16**, in the section P**4** corresponding to the bent sections **15** and **16** of the headers **11** and **12**, the fins **40**A having weak portions and the fins **30** having no weak portions are alternately arranged in the arrangement direction of the heat transfer pipes **20**. That is, the fins **30**, which are less likely to be deformed than the fins **40**A in the bending step and can thus readily maintain the ventilation performance, are disposed adjacent to the bent sections **15** and **16**, and can therefore improve the ventilation performance of the heat exchanger **1**A.

[0145] Alternatively, as illustrated in FIG. **17**, in the section P**4** corresponding to the bent sections **15** and **16** of the headers **11** and **12**, the fins **30** having no weak portions may constitute fin arrays successively aligned in the arrangement direction of the heat transfer pipes **20**. The fins **40**A may each be disposed between adjacent two of the fin arrays. The fins **30** are less likely to be deformed than the fins **40**A in the bending step and can thus readily maintain the ventilation performance, as described above. This modification can therefore achieve higher ventilation performance of the heat exchanger **1**A than that in Embodiment 1.

[0146] That is, the bent sections **15** and **16** are only required to be provided with at least one of the fins **40**A to **40**E. The heat exchangers **1**A to **1**E satisfying this requirement can avoid deformation of the heat transfer pipes **20** and avoid a decrease in the heat exchange efficiency.

[0147] In Embodiments 1 to 4, the weak portions are provided to the end faces of the plate segments **41** of the fins **40**A that face the inner side of bending. These positions of the weak portions, however, are mere examples. The weak portions are each only required to be provided to at least one of the end face of the plate segment **41** that faces the inner side of bending of the bent section **15**, or the end face that faces the outer side of bending of the bent section **15**. The weak portions disposed at these positions are deformed with higher priority, when the bending step of the process of fabricating the heat exchangers **1**A to **1**D changes the distance between the heat transfer pipes **20**, for example, when the bending step narrows or widens the distance between the heat transfer pipes **20**. The weak portions can thus prevent a compressive force or a tensile force from being concentrated at the heat transfer pipes **20**.

[0148] In Embodiments 1 to 5, the fins **40**A to **40**E do not protrude further than the heat transfer pipes **20** toward the rear side B, or further than the heat transfer pipes **20** toward the front side F. These shapes of the fins **40**A to **40**E, however, are mere examples. The fins **40**A to **40**E may protrude further than the heat transfer pipes **20** toward the rear side B. Alternatively, the fins **40**A to **40**E may protrude further than the heat transfer pipes **20** toward the front side F.

[0149] FIG. **18** is a sectional view of the fins **40**A included in still another modification of the heat exchanger **1**A according to Embodiment 1. FIG. **18** illustrates sections of the heat transfer pipes **20** and the modified fins **40**A vertically overlapping with the bent sections **15** and **16**. FIG. **18** illustrates the components without hatching, in order to facilitate an understanding.

[0150] As illustrated in FIG. **18**, the fins **40**A may protrude further toward the front side F, than the distal ends of the flat-shaped sections of the heat transfer pipes **20** on the front side F. That is, the fins **40**A may protrude toward the outer side of bending of the bent sections **15** and **16**. The front side F of the fins **40**A illustrated in FIG. **18** corresponds to the outer side of bending, into which the ambient air is introduced during a heating operation of the outdoor unit. The parts of the fins **40**A adjacent to the front side F are readily subject to frost adhering thereon. The fins **40**A, which protrude further than the heat transfer pipes **20** toward the front side F, can expand the area of the parts readily subject to frost, and thus avoid a decrease in the heat exchange performance. The fins **40**A having such a shape can expand the heat transfer area, and thus improve the heat exchange performance.

[0151] As illustrated in FIG. **18**, the fins **40**A may protrude further toward the rear side B, than the proximal ends of the flat-shaped sections of the heat transfer pipes **20** on the rear side B. That is, the fins **40**A may protrude toward the inner side of bending of the bent sections **15** and **16**. The fins **40**A protrude by a distance D**1**, which may be equal to the distance D**2** of protrusion of the fins **40**A toward the front side F, or shorter than the distance D**2**, for example. The fins **40**A having such a shape can expand the area of the parts readily subject to frost, and avoid a decrease in the heat exchange performance. The fins **40**A can also expand the heat transfer area, and improve the heat exchange performance.

[0152] Although the fins **40**A protrude toward both of the inner and outer sides of bending of the bent sections **15** and **16** in the mode illustrated in FIG. **18**, the fins **40**A may protrude toward at least one of the inner and outer sides of bending of the bent sections **15** and **16**.

[0153] Although the fins **30** and **40**A to **40**E have a corrugated shape in Embodiments 1 to 5, these fins **30** and **40**A to **40**E are mere examples. The fins **30** and **40**A to **40**E are only required to be disposed between the adjacent heat transfer pipes **20** and transfer heat from the heat transfer pipes **20**.

[0154] Although the heat transfer pipes **20** are flat pipes in Embodiments 1 to 5, these heat transfer pipes **20** are mere examples. The heat transfer pipes **20** are only required to at least connect the bent sections **15** and **16** to each other. The heat transfer pipes **20** may also be circular pipes, for example.

[0155] Although the heat exchangers **1**A to **1**E are each installed in the outdoor unit of the air-conditioning apparatus in the examples described above in Embodiments 1 to 5, these heat exchangers **1**A to **1**E are mere examples. The heat exchangers **1**A to **1**E may also be applied to general apparatuses and machines that require heat exchange. For example, the heat exchanger **1**A may also be installed in an indoor unit of an air-conditioning apparatus.

[0156] The above descriptions of Embodiments 1 to 5 refer to the directions of the heat exchangers **1**A to **1**E, such as vertical direction and horizontal direction, which are provided for descriptive purposes as a matter of convenience. These directions may be varied provided that the components of the heat exchangers **1**A to **1**E have the same positional relationship.

[0157] The foregoing describes some example embodiments for explanatory purposes. Although the foregoing discussion has presented specific embodiments, persons skilled in the art will recognize that changes may be made in form and detail without departing from the broader spirit and scope of the invention. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. This detailed description, therefore, is not to be taken in a limiting sense, and the scope of the invention is defined only by the included claims, along with the full range of equivalents to which such claims are entitled.

[0158] This application claims the benefit of Japanese Patent Application No. 2022-42358, filed on Mar. 17, 2022, the entire disclosure of which is incorporated by reference herein.

Reference Signs List

[0159] **1**A, **1**B, **1**C, **1**D, **1**E Heat exchanger
[0160] **2** Semifinished heat exchanger
[0161] **11**, **12** Header
[0162] **13**, **14** Joint section
[0163] **15**, **16** Bent section
[0164] **17**, **18** Linear section
[0165] **20** Heat transfer pipe
[0166] **21**, **22** Linear header
[0167] **30** Fin
[0168] **40**A, **40**B, **40**C, **40**D, **40**E Fin
[0169] **41** Plate segment
[0170] **42** fin-bent portion
[0171] **43** Notch
[0172] **44** Thin portion
[0173] **45**, **46** Notch
[0174] **47** Warped portion
[0175] **50** Unprocessed fin
[0176] **401** Mountain portion
[0177] **402** Valley portion
[0178] **421**, **422**, **424** Fold line
[0179] **423** Vertex
[0180] A**1**, A**2** Pipe axis
[0181] B Rear side
[0182] C**1** Center
[0183] D**1**, D**2** Distance
[0184] F Front side
[0185] L**1** Line
[0186] L**2** Wavelength
[0187] P**1**, P**2**, P**3**, P**4** Section
[0188] W**1**, W**2** Width

1. A heat exchanger, comprising:
a first header having
a first bent section, and
a first linear section extending from the first bent section;
a second header having
a second bent section bent in a same direction as the first bent section, and opposed to the first bent section, and
a second linear section extending from the second bent section;
first heat transfer pipes arranged along the first bent section and connecting the first bent section and the second bent section;
second heat transfer pipes arranged along the first linear section and connecting the first linear section and the second linear section; and
fins to transfer heat from the first heat transfer pipes and the second heat transfer pipes, the fins each being disposed between adjacent two of the first heat transfer pipes or between adjacent two of the second heat transfer pipes, wherein
at least one fin of the fins has a weak portion, the weak portion of each of the at least one fin having a lower rigidity than other portions of the fin, the weak portion being more readily deformed than the other portions in response to a change in a distance between the adjacent two of the first heat transfer pipes, and
at least one of the second heat transfer pipes is warped so as to be in a shape of a convex curve oriented toward the first bent section and the second bent section.

2. The heat exchanger according to claim **1**, wherein
each of the fins has a plate segment extending from one to the other of the adjacent two of the first heat transfer pipes, and
the weak portion is disposed in a part encompassing at least one of an end face of the plate segment that faces an inner side of bending of the first bent section, or an end face that faces an outer side of bending of the first bent section.

3. The heat exchanger according to claim **2**, wherein the weak portion has a fin-bent portion formed by bending the plate segment so as to protrude from one main surface of the plate segment.

4. The heat exchanger according to claim **3**, wherein the one main surface of the plate segment faces a gravity direction, and the fin-bent portion protrudes in the gravity direction.

5. The heat exchanger according to claim **2**, wherein the weak portion has a first notch cut out, toward a central part of the plate segment, from one of the end face of the plate segment that faces the inner side of bending of the first bent section, or the end face that faces the outer side of bending of the first bent section.

6. The heat exchanger according to claim **5**, wherein each of the first notches has any of a triangular, rectangular, or semicircular shape when viewed in a direction orthogonal to main surfaces of the plate segment.

7. The heat exchanger according to claim **5**, wherein the weak portion has

the first notch, and

a second notch cut out, toward the central part of the plate segment, from the other of the end face of the plate segment that faces the inner side of bending of the first bent section, or the end face that faces the outer side of bending of the first bent section.

8. The heat exchanger according to claim **2**, wherein the weak portion has a first thin portion at a position adjoining one of the end face of the plate segment that faces the inner side of bending of the first bent section, or the end face that faces the outer side of bending of the first bent section, the first thin portion having a smaller thickness than other portions of the plate segment.

9. The heat exchanger according to claim **8**, wherein the first thin portion has, when viewed in a direction orthogonal to main surfaces of the plate segment,

a triangular shape having

a vertex located adjacent to a central part of the plate segment, and

an opposite side of the vertex located at the end face of the plate segment, or

a semicircular shape having

a center located adjacent to the end face of the plate segment, and

a convex arc oriented toward the central part of the plate segment.

10. The heat exchanger according to claim **8**, wherein the weak portion has

the first thin portion, and

a second thin portion at a position adjoining the other of the end face of the plate segment that faces the inner side of bending of the first bent section, or the end face that faces the outer side of bending of the first bent section, the second thin portion having a smaller thickness than other portions of the plate segment.

11. The heat exchanger according to claim **1**, wherein

each of the fins has a plate segment having a shape of corrugation between one and another of the adjacent two of the first heat transfer pipes, and

the weak portion is disposed in the plate segment and has warped portions making a width of mountain portions or valley portions of the corrugation larger than a half of a wavelength of the corrugation.

12. The heat exchanger according to claim **1**, wherein the fins protrude further than the first heat transfer pipes, toward at least one of an inner side or an outer side of bending of the first bent section.

13. The heat exchanger according to claim **1**, wherein all of the fins have the weak portion.

14. The heat exchanger according to claim **1**, wherein the fins include

first fins each having the weak portion, and

second fins each not having the weak portion.

15. The heat exchanger according to claim **14**, wherein the first fins and the second fins are alternately arranged in gaps between the first heat transfer pipes, the gaps being aligned in an arrangement direction of the first heat transfer pipes.

16. The heat exchanger according to claim **14**, wherein

the second fins are arranged in gaps between the first heat transfer pipes, the gaps being aligned in an arrangement direction of the first heat transfer pipes, the second fins constituting fin arrays successively aligned in the arrangement direction of the first heat transfer pipes, each of the fin arrays including two or more of the second fins successively aligned in the arrangement direction, and

the first fins are each disposed between adjacent two of the fin arrays.

17. (canceled)

18. A method of fabricating a heat exchanger, the method comprising:

building a semifinished heat exchanger including

a first header having a first linear pipe section,

a second header having a second linear pipe section in parallel to the first linear pipe section,

heat transfer pipes arranged along the first linear pipe section and connecting the first linear pipe section and the second linear pipe section, and

fins to transfer heat from the heat transfer pipes, the fins each being disposed between adjacent two of the heat transfer pipes, at least one fin of the fins having a weak portion, the weak portion of each of the at least one fin having a lower rigidity than other portions of the fin, the weak portion being more readily deformed than the other portions in response to a change in a distance between the adjacent two of the heat transfer pipes; and

producing a heat exchanger including the first header having a first bent section and a first linear section extending from the first bent section and the second header having a second bent section bent in a same direction as the first bent section and opposed to the first bent section and a second linear section extending from the second bent section, the heat exchanger being produced by bending, in a same direction, the first linear pipe section of the first header included in the semifinished heat exchanger and the second linear pipe section of the second header included in the semifinished heat exchanger, wherein

in the producing of the heat exchanger, the bending of the first linear pipe section of the first header and the second linear pipe section of the second header changes the distance between the adjacent two of the heat transfer pipes and deforms the weak portion,

the heat transfer pipes include heat transfer pipes connecting the first linear section and the second linear section, and at least one of the heat transfer pipes connecting the first linear section and the second linear section is warped so as to be in a shape of a convex curve oriented toward the first bent section and the second bent section.

* * * * *