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(54) **PLATE FIN-AND-TUBE HEAT EXCHANGER, AND REFRIGERATION AND AIR-CONDITIONING SYSTEM WITH SAME**

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Description

Technical Field

[0001] The present invention relates to a plate fin-tube heat exchanger in which heat transfer tubes are fitted in a plurality of plate-like fins arranged at predetermined intervals, and a refrigeration-and-air-conditioning system including the same.

[0002] GB 2466687 A discloses a plate fin-tube heat exchanger as defined in the preamble of claim 1.

Background Art

[0003] A hitherto known plate fin-tube heat exchanger includes, for example, heat transfer tubes each having a flat cross-sectional shape (hereinafter referred to as flat tubes) and being fitted in plate-like fins that are arranged at predetermined intervals. The plate-like fins each have notches that are provided in the same number and at the same intervals as the flat tubes in a plate-long-axis direction. Meanwhile, a corrugated fin-tube heat exchanger that includes plate-like fins each having a wavy shape and flat tubes being in contact with the fins at peaks and troughs of the wavy shape of the fins is in general used in, for example, an automobile and so forth (see Patent Literature 1, for example).

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2001-296088 (Figs. 1 and 2 and others)

Summary of Invention

Technical Problem

[0005] The corrugated fin-tube heat exchanger is suitable for use as a condenser included in a refrigeration cycle, but is not suitable for use as an evaporator. Specifically, in a case where the corrugated fin-tube heat exchanger is used as an evaporator, if the temperature of a refrigerant flowing in the flat tubes drops below the dew point of air with which the refrigerant exchanges heat, moisture in the air forms dew on surfaces of the heat exchanger and condenses into dew water (drain water). The dew water generated on the surfaces of the heat exchanger does not cause any problems if it is quickly drained from end facets of the fins and surfaces of the flat tubes.

[0006] The corrugated fin-tube heat exchanger, however, has two factors that deteriorate the drainability: (1) dew water tends to accumulate in trough portions of the wavy-shaped fins, and (2) dew water tends to accumulate on upper surfaces of the flat tubes (surfaces extending

in the long-side direction of the flat tubes). If the drainability is poor and dew water accumulates, the stack loss on the surfaces of the heat exchanger increases, whereby the volume of airflow passing through the heat exchanger is reduced significantly. Accordingly, the ability as a heat exchanger is reduced significantly. Consequently, a vicious cycle occurs in which the evaporating temperature is further lowered, the dew water is transformed and grows into frost, the stack loss further increases, the volume of airflow is reduced, and the ability is lowered.

[0007] The present invention is to solve the above problems and to provide a plate fin-tube heat exchanger including fins and flat tubes having improved drainability, and a refrigeration-and-air-conditioning system including the same.

Solution to Problem

[0008] In a plate fin-tube heat exchanger according to the present invention, flat tubes each having a flat cross-sectional shape whose long sides are linear and whose short sides are curved in a semicircular manner are fitted in notches provided in fins. A surface of at least one of each of the flat tubes and each of the fins has a plurality of concavities and convexities in which a length between one of peak portions that has the smallest height and one of trough portions that has the smallest depth is 10 μm or larger.

[0009] In a refrigeration-and-air-conditioning system according to the present invention, the above plate fin-tube heat exchanger is used as an evaporator. **Advantageous Effects of Invention**

[0010] In the plate fin-tube heat exchanger according to the present invention, since the surface of at least one of each of the fins and each of the flat tubes has the plurality of concavities and convexities, an effect of hydrophilicity is produced on the surface of the fin or the flat tube, whereby the drainability is improved significantly.

[0011] The refrigeration-and-air-conditioning system according to the present invention includes the above plate fin-tube heat exchanger. Therefore, even if the plate fin-tube heat exchanger is used as an evaporator, the increase in stack loss due to dew water is reduced significantly, and the heat exchangeability is maintained.

Brief Description of Drawings

[0012]

[Fig. 1] Fig. 1 is a diagram schematically illustrating welding steps employed for a heat exchanger according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a diagram illustrating a weld material used for welding flat tubes and fins included in the heat exchanger according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 is an enlarged schematic perspective view illustrating a part of an existing corrugated fin-

tube heat exchanger.

[Fig. 4] Fig. 4 is a graph illustrating the relationship between the water contact angle on and the hydrophilicity of a surface of each flat tube or each fin included in the heat exchanger according to Embodiment 1 of the present invention before and after the welding.

[Fig. 5] Fig. 5 includes schematic diagrams illustrating the relationship between the water contact angle and the hydrophilicity.

[Fig. 6] Fig. 6 includes observation diagrams schematically illustrating the surface of the flat tube or the fin included in the heat exchanger according to Embodiment 1 of the present invention before and after the welding.

[Fig. 7] Fig. 7 is a schematic cross-sectional view illustrating the cross-sectional shape of a part of the fin or the flat tube included in the heat exchanger according to Embodiment 1 of the present invention and having concavities and convexities.

[Fig. 8] Fig. 8 includes diagrams illustrating an effect produced in the heat exchanger according to Embodiment 1 of the present invention.

[Fig. 9] Fig. 9 is a diagram illustrating a weld material used for welding flat tubes and fins included in a heat exchanger according to Embodiment 2 of the present invention.

[Fig. 10] Fig. 10 includes diagrams illustrating a heat exchanger according to Embodiment 3 of the present invention.

[Fig. 11] Fig. 11 is a graph illustrating the thickness of each of fins and flat tubes included in the heat exchanger according to Embodiment 3 of the present invention.

[Fig. 12] Fig. 12 is a circuit diagram schematically illustrating a basic configuration of a refrigeration-and-air-conditioning system according to Embodiment 4 of the present invention.

Description of Embodiments

[0013] Embodiments of the present invention will now be described with reference to the drawings.

Embodiment 1

[0014] Fig. 1 is a diagram schematically illustrating welding steps employed for a heat exchanger 50 according to Embodiment 1 of the present invention. Referring to Fig. 1, the heat exchanger 50 according to Embodiment 1 of the present invention will be described. In the drawings including Fig. 1 to be referred to below, individual elements are not necessarily scaled in accordance with their actual sizes.

[0015] As illustrated in Fig. 1, the heat exchanger 50 includes a plurality of flat tubes 51 made of aluminum or the like and each having a flat cross-sectional shape whose long sides are linear and whose short sides are

curved in, for example, a semicircular manner or the like.

The plurality of flat tubes 51 are arranged parallel to one another at arbitrary intervals in a direction orthogonal to a direction of a passage of a refrigerant that is made to flow in the tubes. The heat exchanger 50 further includes a plurality of flat-plate-like (rectangular) fins 52 made of aluminum or the like. The fins 52 are arranged parallel to one another at predetermined arbitrary intervals in the direction of the passage of the refrigerant (a direction orthogonal to the direction in which the flat tubes 51 are arranged side by side). The fins 52 each have a rectangular shape with a larger length in the direction in which the flat tubes 51 are arranged side by side than in the width direction of the flat tubes 51 (the horizontal direction in Fig. 1). Therefore, in the following description, the width direction of the flat tubes 51 is referred to as short-side direction, and the direction in which the flat tubes 51 are arranged side by side is referred to as long-side direction.

[0016] The flat tubes 51 each have thereinside a plurality of holes 53 arranged side by side in the width direction. A refrigerant, for example, is made to flow in the holes 53. The refrigerant exchanges heat with air flowing through the heat exchanger 50. The fins 52 each have a plurality of U-shaped notches 54 in the long-side direction. The notches 54 are provided in correspondence with the flat tubes 51. That is, for example, the notches 54 are provided in the same number and at the same arbitrary intervals (excluding the ones at both ends) as the flat tubes 51. Furthermore, the notches 54 each have substantially the same length as a corresponding one of the flat tubes 51 in the long-side direction of the fin 52. The notches 54 are provided such that one end of the fin 52 is open. That is, the notches 54 are arranged side by side in a comb-like pattern in the long-side direction of the fin 52.

[0017] Steps of manufacturing the heat exchanger 50 will now be described.

[0018] First, the flat tubes 51 are each fitted into a corresponding one of the notches 54 of each of the fins 52 from a secondary side of the airflow (the right side in Fig. 1) and with a predetermined clearance 52A interposed between an end facet of the fin 52 that is on a primary side of the airflow (the left side in Fig. 1) and an end of the flat tube 51 (the end on the left side in Fig. 1). Subsequently, the fin 52 and the flat tube 51 are welded to each other with a weld material such as a solder material. In this manner, a core portion (main portion) of the heat exchanger 50 is manufactured. In addition, although not illustrated in Fig. 1, the fin 52 may have gate-type (bridge-type) cut-raised portions formed by cutting and raising portions of the fin 52 between the notches 54. In such a case, the cut-raised portions promote the heat exchange between the air and the refrigerant.

[0019] Fig. 2 is a diagram illustrating the weld material used for welding the flat tube 51 and the fin 52. Referring to Fig. 2, the welding of the fin 52 and the flat tube 51 will be described briefly. The fin 52 and the flat tube 51 are welded to each other with a weld material such as a solder

material. When performing the welding, another material prepared separately from a base material 55 may be used as the weld material. Alternatively, as illustrated in Fig. 2, a surface of the base material 55 that is to form the fin 52 and the flat tube 51 may be covered (cladded) with the weld material as a cladding layer 56 in advance. The base material 55 is a material for the flat tube 51 and the fin 52.

[0020] Fig. 3 is an enlarged schematic perspective view illustrating a part of an existing corrugated fin-tube heat exchanger (hereinafter denoted as heat exchanger 50'). Referring to Fig. 3, the heat exchanger 50' will be described briefly. Fig. 3 also illustrates dew water 59.

[0021] As illustrated in Fig. 3, the heat exchanger 50' includes flat tubes (hereinafter denoted as flat tubes 51'), as with the heat exchanger 50. As with the flat tube 51, the flat tubes 51' are heat transfer tubes each having several holes, specifically, a plurality of holes 53' each having a flat contour. The heat exchanger 50' further includes wavy-shaped fins (hereinafter denoted as fins 52'). In the heat exchanger 50', the fins 52' are in contact with the flat tubes 51' at peaks and troughs thereof. The heat exchanger 50 is in general used in an automobile and so forth.

[0022] As described above, however, the heat exchanger 50' has two factors that deteriorate the drainability: a fact that dew water tends to accumulate in trough portions of the fins 52', and a fact that dew water tends to accumulate on upper surfaces of the flat tubes 51' (surfaces extending in the long-side direction of the flat tubes 51').

[0023] In contrast, unlike that the heat exchanger 50', the heat exchanger 50 including the fins 52 each having a flat-plate-like shape does not have the factor of dew water tending to accumulate in trough portions of the fins 52'. Moreover, in the heat exchanger 50, since a predetermined clearance (the clearance 52A illustrated in Fig. 1) is interposed between the end facet of each fin 52 that is on the primary side of the airflow and each flat tube 51, dew water is quickly drained along the end facet of the fin 52. That is, since the end facet of the fin 52 that is on the primary side of the airflow is not sectioned by the notches 54, nothing prevents dew water from flowing. Accordingly, smooth drainage is realized. This solves the first one of the factors that deteriorate the drainability.

[0024] Now, a mechanism of improving the hydrophilicity of the surfaces of the heat exchanger 50 will be described.

[0025] Fig. 4 is a graph illustrating the relationship between the water contact angle on and the hydrophilicity of the surface of the flat tube 51 or the fin 52 before and after the welding. Fig. 4 illustrates the hydrophilicity of the surface of the flat tube 51 or the fin 52 for different water contact angles (degrees) obtained before the welding, after the welding, and after a reliability test conducted after the welding.

[0026] The water contact angle is an index indicating the "wettability" of the surface of the flat tube 51 or the

fin 52. Herein, the water contact angle is defined as an angle θ formed between the surface of the flat tube 51 or the fin 52 and a line tangent to a dewdrop produced by dropping water onto the surface of the flat tube 51 or the fin 52, the line being tangent to an end of a portion of the dewdrop that is in contact with the surface of the flat tube 51 or the fin 52. The water contact angle is determined by the relationship of interfacial energy acting among the gas, the liquid, and the solid. In general, the smaller the water contact angle, the higher the hydrophilicity; the larger the water contact angle, the lower the hydrophilicity.

[0027] As illustrated in Fig. 4, the water contact angle before the welding of the flat tube 51 and the fin 52 is about 90degrees, whereas the water contact angle after the welding is reduced to 40degrees to 50degrees. This shows that the hydrophilicity is improved after the welding. This is because the surfaces of the fin 52 and the flat tube 51 are oxidized by heat generated in the welding, and the resulting oxide forms microscopic concavities and convexities in the surfaces. With the microscopic concavities and convexities formed in the surfaces of the fin 52 and the flat tube 51, the water contact angle on each of the surfaces is reduced, improving the flowability and the drainability of the water (dew water or drain water, for example) on the surfaces. This solves the second one of the factors that deteriorate the drainability. Note that, if the water contact angle is 60 degrees or smaller, the flowability of water on the surfaces of the fin 52 and the flat tube 51 is improved.

[0028] Fig. 5 includes schematic diagrams illustrating the relationship between the water contact angle and the hydrophilicity. Fig. 5(a) illustrates a case where dewdrops each have a shape forming a large water contact angle. Fig. 5(b) illustrates a case where dewdrops each have a shape forming a small water contact angle.

[0029] As illustrated in Fig. 5(a), if the water contact angle is large, the dewdrops each have a nearly spherical shape in side view. Hence, the surface tension of the dewdrops is high. That is, the larger the water contact angle, the lower the hydrophilicity. In contrast, as illustrated in Fig. 5(b), if the water contact angle is small, the dewdrops each have a nearly flat shape in side view. Hence, the surface tension of the dewdrops is low. Low hydrophilicity means poor drainability. That is, if the water contact angle is large, dewdrops tend to remain on the fins as illustrated in Fig. 5(a); if the water contact angle is small, dewdrops do not tend to remain on the fins as illustrated in Fig. 5(b).

[0030] If any coating material such as a post-coat is applied so as to provide hydrophilicity, the coating material is deteriorated with age and accordingly the effect of its hydrophilicity is eventually reduced. Specifically, since the aluminum base having low hydrophilicity is exposed with the deterioration of the post-coating, the hydrophilicity is deteriorated. In contrast, in the heat exchanger 50 according to Embodiment 1, the contact angle tends to be reduced even after an accelerated test

(after the reliability test in Fig. 4) conducted for checking the aging deterioration of the heat exchanger 50, whereby the effect of hydrophilicity is maintained or further improved. This is because oxidation gradually progresses after the accelerated test, and more concavities and convexities are formed in the surfaces with finer sizes and at a higher density. Such a fact shows the superiority in terms of maintenance of hydrophilicity.

[0031] Fig. 6 includes observation diagrams schematically illustrating the surface of the flat tube 51 or the fin 52 before and after the welding. Fig. 6(a) illustrates the surface of the flat tube 51 or the fin 52 before the welding. Fig. 6(b) illustrates the surface of the flat tube 51 or the fin 52 after the welding. Fig. 6(c) illustrates the surface of the flat tube 51 or the fin 52 after the reliability test conducted after the welding.

[0032] As can be seen from Fig. 6, there are differences in surface roughness between the states observed before the welding, after the welding, and after the accelerated test. That is, Fig. 6 shows that the surface roughness before the welding is low, the surface roughness after the welding is high, and the surface roughness after the accelerated test is much higher. This means that the concavities and convexities are formed with finer sizes and at a higher density in order of that before the welding, that after the welding, and that after the accelerated test. Furthermore, as described above, if the surface of the base material is covered (cladded) with a weld material in advance, concavities and convexities tend to be formed uniformly in the surfaces of the fin 52 and the flat tube 51. Accordingly, the uniformity in the effect of hydrophilicity is further promoted.

[0033] Fig. 7 is a schematic cross-sectional view illustrating the cross-sectional shape of a part of the fin 52 or the flat tube 51 having concavities and convexities. To obtain the above effect of hydrophilicity, in the concavities and convexities formed in the fin 52 and the flat tube 51, the length between one of peak portions that has the smallest height and one of trough portions that has the smallest depth may be 10 μm or larger. If this value is taken as the minimum value for forming concavities and convexities, a small water contact angle and high hydrophilicity are obtained. The concavities and convexities are desirably to be formed uniformly but are not necessarily uniform, as long as the length between the peak portion having the smallest height and the trough portion having the smallest depth is 10 μm or larger.

[0034] Fig. 8 includes diagrams illustrating an effect produced in the heat exchanger 50. Fig. 8(a) is a perspective view of the heat exchanger 50. Fig. 8(b) is a side view of the heat exchanger 50 seen from a side from which the flat tubes 51 are fitted into the fins 52. White arrows illustrated in Fig. 8 represent the flow of air. In Fig. 8, the flows of dewdrops are represented by arrow (1) and arrow (2). In each of Figs. 8(a) and 8(b), the flat tubes 51 are illustrated in cross-sectional view.

[0035] As described above, the fins 52 of the heat exchanger 50 each have a flat-plate-like shape. Therefore,

unlike the heat exchanger 50', the heat exchanger 50 does not have the factor of dew water tending to accumulate in trough portions of the fins 52'. Moreover, in the heat exchanger 50, since a predetermined clearance (the clearance 52A illustrated in Fig. 1) is interposed between the end facet of each fin 52 that is on the primary side of the airflow and each flat tube 51, dew water is quickly drained along the end facet of the fin 52 (arrow (1)). This solves the first one of the factors that deteriorate the drainability.

[0036] Furthermore, in the heat exchanger 50, the surfaces of the fin 52 and the flat tube 51 are oxidized by heat generated when the flat tube 51 and the fin 52 are welded to each other, and the resulting oxide forms microscopic concavities and convexities in the surfaces. With the concavities and convexities, the hydrophilicity of the surfaces of the fin 52 and the flat tube 51 is improved, the flowability of water (dew water or drain water, for example) on the surfaces is improved, and the drainability is improved (arrow (2)). This solves the second one of the factors that deteriorate the drainability.

[0037] To summarize, in the heat exchanger 50, since the surface roughness of the fin 52 and the flat tube 51 is increased and an effect of hydrophilicity is produced, the drainability is improved. Furthermore, in the heat exchanger 50, since the hydrophilicity of the surfaces of the fin 52 and the flat tube 51 is provided only by performing welding, no hydrophilic treatment with a post-coat or the like is necessary. This is also expected to contribute to the ease of production and the cost reduction. Furthermore, since no hydrophilic treatment with a post-coat or the like is necessary, the heat exchanger 50 does not have problems such as aging deterioration of a coating material such as a post-coat. Hence, the hydrophilicity of the surfaces of the fin 52 and the flat tube 51 is maintained at a highly reliable level.

Embodiment 2

[0038] Fig. 9 is a diagram illustrating a weld material used for welding flat tubes and fins included in a heat exchanger according to Embodiment 2 of the present invention. Referring to Fig. 9, the weld material used for welding the flat tubes and the fins included in the heat exchanger according to Embodiment 2 of the present invention will now be described. Description of Embodiment 2 focuses on differences from Embodiment 1. Elements that are the same as those of Embodiment 1 are denoted by corresponding reference numerals, and description thereof is thus omitted.

[0039] In Embodiment 1, the surface roughness is changed by utilizing an oxide formed on the surfaces of the fins 52 and the flat tubes 51 with heat generated in the welding, whereby an effect of hydrophilicity is produced. On the other hand, in Embodiment 2, a foreign substance is added to the weld material in advance, and the surface roughness of the fins and the flat tubes is increased by utilizing the weld material. Consequently,

an effect of hydrophilicity is produced while the oxidation of the fins and the flat tubes themselves is suppressed.

[0040] In Embodiment 2 also, as described in Embodiment 1 referring to Fig. 2, the fins and the flat tubes are welded to each other with a weld material such as a solder material. In Embodiment 2 also, as in Embodiment 1, the welding may be performed by using a weld material prepared separately from the base material 55 or by using a weld material that has been added to the surface of the base material 55. Note that, as illustrated in Fig. 9, Embodiment 2 concerns a case where the fins and the flat tubes that have been covered (cladded) with a weld material to which a foreign substance 57 has been added in advance are welded to each other.

[0041] As illustrated in Fig. 9, a cladding layer 56A as a weld material is provided in advance on a surface of the base material 55. The cladding layer 56A contains particles of the foreign substance 57 whose melting point is higher than that of the weld material forming the cladding layer 56A. The foreign substance 57 may be selected from any materials having higher melting points than the weld material forming the cladding layer 56A: for example, alumina and so forth. Furthermore, the foreign substance 57 may be selected from any materials having such particle sizes as to form concavities and convexities in the surfaces of the fins and the flat tubes after the welding. Furthermore, the foreign substance 57 may be selected from any materials having intentionally lower potentials than the materials forming the fins and the flat tubes. In such a case, if any moisture is added to the heat exchanger with age, the surfaces of the fins and the flat tubes are electrolytically oxidized and corroded. Hence, the formation of concavities and convexities in the surfaces of the fins and the flat tubes is further promoted.

[0042] To summarize, in the heat exchanger according to Embodiment 2, the surface roughness of the fins and the flat tubes is increased while the oxidation of the fins and the flat tubes themselves is suppressed, whereby an effect of hydrophilicity is produced. Hence, in the heat exchanger according to Embodiment 2, the fins and the flat tubes themselves can be made thinner correspondingly, and a cost reduction is thus realized. Moreover, if the foreign substance 57 having a lower potential than the material of the fins and the flat tubes is added, hydrophilicity as a countermeasure for aging deterioration is maintained at a highly reliable level.

[0043] Furthermore, in the heat exchanger according to Embodiment 2, since an oxide layer is made of a weld material, which is originally necessary, no hydrophilic treatment with a post-coat or the like is necessary. This is also expected to contribute to the ease of production and the cost reduction. Furthermore, since no hydrophilic treatment with a post-coat or the like is necessary, the heat exchanger according to Embodiment 2 does not have problems such as aging deterioration of a coating material such as a post-coat. Hence, the hydrophilicity of the surfaces of the fins and the flat tubes is maintained

at a highly reliable level.

Embodiment 3

[0044] Fig. 10 includes diagrams illustrating a heat exchanger 50B according to Embodiment 3 of the present invention. Referring to Fig. 10, the heat exchanger 50B according to Embodiment 3 of the present invention will now be described.

[0045] Fig. 10(a) is a side view of the heat exchanger 50B seen from a side from which flat tubes 51 are fitted into fins 52. Fig. 10(b) is a top view of the heat exchanger 50B. Description of Embodiment 3 focuses on differences from Embodiment 1 and Embodiment 2. Elements that are the same as those of Embodiment 1 and Embodiment 2 are denoted by corresponding reference numerals, and description thereof is thus omitted. In Fig. 10(a), the flat tubes 51 are illustrated in cross-sectional view.

[0046] In Embodiment 2, the foreign substance 57 is added to the weld material forming the cladding layer 56A, and the surface roughness of the fins and the flat tubes is increased while the oxidation of the fins and the flat tubes themselves is suppressed. On the other hand, in Embodiment 3, the foreign substance 57 is added to a flux 58 provided on the surface of the base material 55, and the surface roughness of the fins 52 and the flat tubes 51 is increased while the oxidation of the fins 52 and the flat tubes 51 themselves is suppressed. The flux 58 protects the surface of the base material 55. The foreign substance 57 is the same as that described in Embodiment 2.

[0047] If the flux 58 containing the foreign substance 57 is provided on the surface of the base material 55 that is to form the fins 52, the flux 58 is diffused over the entirety of the surface of each of the fins 52 as illustrated in Fig. 10(a) (as represented by arrows in Fig. 10(a)). If the flux 58 containing the foreign substance 57 is provided on the surface of the base material 55 that is to form the flat tubes 51, the flux 58 is diffused over the entirety of the surface of each of the flat tubes 51 as illustrated in Fig. 10(b) (as represented by arrows in Fig. 10(b)).

[0048] Fig. 11 is a graph illustrating the thickness of each fin 52 or each flat tube 51. Referring to Fig. 11, the thickness of the fin 52 or the flat tube 51 will now be described. In Fig. 11, the horizontal axis represents the thickness of the base material 55 that is to form the fin 52 or the flat tube 51, and the vertical axis represents the residual thickness of the base material 55 that is to form the fin 52 or the flat tube 51 excluding the oxide layer.

[0049] The base material 55 that is to form the fin 52 or the flat tube 51 needs to have at least a minimum thickness with which heat transferability and compressive strength are assuredly provided, with an oxide layer having concavities and convexities that are required for providing hydrophilicity. Accordingly, as illustrated in Fig. 11, the minimum thickness of the base material 55 may be determined within a thickness range in which the welding temperature, time, and the oxygen concentration are

controllable. This also applies to Embodiments 1 and 2. Note that the graph in Fig. 11 varies with the characteristics of the base material, the characteristics of the weld material, the characteristics of the flux, and the characteristics of the foreign substance, and therefore values of the welding temperature, time, and the oxygen concentration do not necessarily fall within predetermined ranges.

[0050] To summarize, in Embodiment 3, manufacturing the heat exchanger increases the surface roughness of the fins and the flat tubes while suppressing the oxidation of the fins and the flat tubes themselves, whereby an effect of hydrophilicity is produced. Hence, in the heat exchanger according to Embodiment 3, the fins and the flat tubes themselves can be made thinner correspondingly, and a cost reduction is thus realized. Moreover, if the foreign substance 57 having a lower potential than the material of the fins and the flat tubes is added, hydrophilicity as a countermeasure for aging deterioration is maintained at a highly reliable level.

[0051] Furthermore, in the heat exchanger according to Embodiment 3, since an oxide layer is made of a flux, which is originally necessary, no hydrophilic treatment with a post-coat or the like is necessary. This is also expected to contribute to the ease of production and the cost reduction. Furthermore, since no hydrophilic treatment with a post-coat or the like is necessary, the heat exchanger according to Embodiment 3 does not have problems such as aging deterioration of a coating material such as a post-coat. Hence, the hydrophilicity of the surfaces of the fins and the flat tubes is maintained at a highly reliable level.

[0052] While the present invention has been described above in three Embodiments, this does not deny any combinations of features described in different Embodiments. Moreover, while each of Embodiments concerns a case where the surfaces of both the fins 52 and the flat tubes 51 have concavities and convexities, the above effect is also produced by forming concavities and convexities in the surfaces of one of the fins 52 and the flat tubes 51, needless to say.

Embodiment 4

[0053] Fig. 12 is a circuit diagram schematically illustrating a basic configuration of a refrigeration-and-air-conditioning system 100 according to Embodiment 4 of the present invention. Referring to Fig. 12, the configuration and operations of the refrigeration-and-air-conditioning system 100 will now be described. The refrigeration-and-air-conditioning system 100 performs a cooling operation or a heating operation by causing a refrigerant to circulate through devices that form a refrigeration cycle. The refrigeration-and-air-conditioning system 100 according to Embodiment 4 includes any of the heat exchangers according to Embodiments 1 to 3. In Fig. 12, solid lines represent the flow of the refrigerant when cooling is performed, and dotted lines represent the flow of

the refrigerant when heating is performed.

[0054] As described above, corrugated fin-tube heat exchangers are suitable for use as condensers but are not suitable for use as evaporators. In contrast, the heat exchangers according to Embodiments 1 to 3 are much superior in drainability. Therefore, the increase in stack loss due to dew water is reduced significantly, and heat exchangeability is maintained. Hence, the heat exchangers according to Embodiments 1 to 3 are also suitable for use as evaporators. Therefore, the refrigeration-and-air-conditioning system 100 employs any of the heat exchangers according to Embodiments 1 to 3 as a heat-source-side heat exchanger and load-side heat exchangers that are each required to function as both a condenser and an evaporator.

[0055] The refrigeration-and-air-conditioning system 100 includes the following devices: a compressor 1, a heat-source-side heat exchanger 3, expansion devices 102, and load-side heat exchangers 101 that are connected to one another by pipes. Among the foregoing devices, the compressor 1 and the heat-source-side heat exchanger 3 are included in an outdoor unit, while the expansion devices 102 and the load-side heat exchangers 101 are included in indoor units. The expansion devices 102 may be included in the outdoor unit 101, not in the indoor units. Furthermore, a four-way valve 2 configured to switch the flow of the refrigerant in accordance with the operation requested is provided on a discharge side of the compressor 1.

[0056] The compressor 1 sucks the refrigerant and compresses the refrigerant, whereby the refrigerant has a high temperature and a high pressure. The compressor 1 is, for example, an inverter compressor or the like whose capacity is controllable. The heat-source-side heat exchanger 3 allows the refrigerant and air that is forcibly supplied thereto from a non-illustrated fan to exchange heat therebetween. Any of the heat exchangers according to Embodiments 1 to 3 is employed as the heat-source-side heat exchanger 3. The expansion devices 102 each expand the refrigerant by reducing the pressure of the refrigerant and each include, for example, an electronic expansion valve or the like whose opening degree is variably controllable. The load-side heat exchangers 101 each allow the refrigerant and air that is forcibly supplied thereto from a non-illustrated air-sending device such as a fan to exchange heat therebetween. Any of the heat exchangers according to Embodiments 1 to 3 is employed as each of the load-side heat exchangers 101.

[0057] The cooling operation and the heating operation performed by the refrigeration-and-air-conditioning system 100 will now be described briefly.

[Cooling Operation]

[0058] When the compressor 1 is driven, the compressor 1 raises the pressure of the refrigerant, whereby the refrigerant has a high temperature and a high pressure

and is discharged. The resulting high-temperature, high-pressure gas refrigerant discharged from the compressor 1 flows into the heat-source-side heat exchanger 3 via the four-way valve 2 and is cooled while exchanging heat with air, whereby the refrigerant falls into a low-temperature, high-pressure liquid state and is discharged from the heat-source-side heat exchanger 3. The liquid refrigerant then undergoes pressure reduction by being expanded by the expansion devices 102, and turns into a low-temperature, low-pressure two-phase refrigerant. The two-phase refrigerant flows into the load-side heat exchangers 101 and evaporates while exchanging heat with air, thereby turning into a low-temperature, low-pressure gas refrigerant. In this step, cooling air is provided from the indoor units, whereby air-conditioned spaces are cooled. The low-pressure gas refrigerant discharged from the load-side heat exchangers 101 flows into the compressor 1 again.

[0059] In each of the load-side heat exchangers 101, if the temperature of the refrigerant flowing in the flat tubes (flat tubes 51) drops below the dew point of the air, the moisture contained in the air forms dew on the surfaces of the heat exchanger, whereby dew water (drain water) is generated. There is no problem if the dew water generated on the surfaces of the heat exchanger is quickly drained from the end facets of the fins or the surfaces of the flat tubes. However, dew water may form bridges between the fins or accumulate on the upper surfaces of the flat tubes because of surface tension. If dew water accumulates, the stack loss on the surfaces of the heat exchanger increases, whereby the volume of airflow passing through the heat exchanger is reduced significantly. Accordingly, the ability as a heat exchanger is reduced significantly. Consequently, a vicious cycle may occur in which the evaporating temperature is further lowered, the dew water is transformed and grows into frost, the stack loss further increases, the volume of airflow is reduced, and the ability is lowered.

[0060] To address such a problem, the refrigeration-and-air-conditioning system 100 employs any of the heat exchangers according to Embodiments 1 to 3 as each of the load-side heat exchangers 101. Therefore, even if moisture forms dew on the surfaces of the heat exchanger, good drainability efficiently suppresses the accumulation of dew water. Hence, the refrigeration-and-air-conditioning system 100 does not have problems of the increase in the stack loss on the surfaces of each of the heat exchangers and the reduction in the volume of airflow passing through the heat exchanger that may occur with the accumulation of dew water. Thus, the reduction in the ability as a heat exchanger is suppressed.

[Heating Operation]

[0061] When the compressor 1 is driven, the compressor 1 raises the pressure of the refrigerant, whereby the refrigerant has a high temperature and a high pressure and is discharged. The resulting high-temperature, high-

pressure gas refrigerant discharged from the compressor 1 flows into the load-side heat exchangers 101 via the four-way valve 2 and is cooled while exchanging heat with air, whereby the refrigerant falls into a low-temperature, high-pressure liquid state and is discharged from the load-side heat exchangers 101. In this step, heating air is provided from the indoor units, whereby the air-conditioned spaces are heated. The liquid refrigerant then undergoes pressure reduction by being expanded by the expansion devices 102, and turns into a low-temperature, low-pressure two-phase refrigerant. The two-phase refrigerant flows into the heat-source-side heat exchanger 3 and evaporates while exchanging heat with air, thereby turning into a low-temperature, low-pressure gas refrigerant. The low-pressure gas refrigerant discharged from the heat-source-side heat exchanger 3 flows into the compressor 1 again.

[0062] In the heat-source-side heat exchanger 3, if the temperature of the refrigerant flowing in the flat tubes (flat tubes 51) drops below the dew point of the air, the moisture contained in the air forms dew on the surfaces of the heat exchanger, whereby dew water (drain water) is generated. There is no problem if the dew water generated on the surfaces of the heat exchanger is quickly drained from the end facets of the fins or the surfaces of the flat tubes. However, dew water may form bridges between the fins or accumulate on the upper surfaces of the flat tubes because of surface tension. If dew water accumulates, the stack loss on the surfaces of the heat exchanger increases, whereby the volume of airflow passing through the heat exchanger is reduced significantly. Accordingly, the ability as a heat exchanger is reduced significantly. Consequently, a vicious cycle may occur in which the evaporating temperature is further lowered, the dew water is transformed and grows into frost, the stack loss further increases, the volume of airflow is reduced, and the ability is lowered.

[0063] To address such a problem, the refrigeration-and-air-conditioning system 100 employs any of the heat exchangers according to Embodiments 1 to 3 as the heat-source-side heat exchanger 3. Therefore, even if moisture forms dew on the surfaces of the heat exchanger, good drainability efficiently suppresses the accumulation of dew water. Hence, the refrigeration-and-air-conditioning system 100 does not have problems of the increase in the stack loss on the surfaces of the heat exchanger and the reduction in the volume of airflow passing through the heat exchanger that may occur with the accumulation of dew water. Thus, the reduction in the ability as a heat exchanger is suppressed.

[0064] To summarize, since the refrigeration-and-air-conditioning system 100 includes any of the heat exchangers according to Embodiments 1 to 3, the increase in the stack loss due to dew water is reduced significantly even if the heat exchangers are used as evaporators. Thus, the refrigeration-and-air-conditioning system 100 maintains its heat exchangeability.

Reference Signs List

[0065]

1 compressor 2 four-way valve 3 heat-source-side
heat exchanger 50 heat exchanger 50' heat ex-
changer 50B heat exchanger 51 flat tube 51' flat tube
52 fin 52A clearance between fin and flat tube 52'
fin 53 hole 53' hole 54 notch 55
base material 56 cladding layer 56A cladding layer
57
foreign substance 58 flux 59 dew water 100 refrig-
eration-and-air-conditioning system 101 load-side
heat exchanger 102 expansion device

Claims

1. A plate fin-tube heat exchanger (50) in which flat tubes (51) each having a flat cross-sectional shape whose long sides are linear and whose short sides are curved in a semicircular manner are fitted in notches (54) provided in fins (52), **characterized in that** a surface of at least either one of each of the flat tubes (51) and each of the fins (52) has a plurality of concavities and convexities in which a difference in height between one of peak portions that has a smallest height and one of trough portions that has a smallest depth is 10 μm or larger, which is achieved by either a foreign substance having a higher melting point than a weld material used for welding the flat tubes (51) and the fins (52) added to the weld material in advance, or a foreign substance having a higher melting point than a flux (58) used for surfaces of the flat tubes (51) and the fins (52) added to the flux (58) in advance.
2. The plate fin-tube heat exchanger (50, 50B) of claim 1, wherein the concavities and convexities are formed such that an angle formed between the surface of at least either one of each of the flat tubes (51) and each of the fins (52) and a line is 60 degrees or smaller, the line being tangent to an end of a portion of a dewdrop being present in contact with the surface of at least either one of each of the flat tubes (51) and each of the fins (52).
3. The plate fin-tube heat exchanger (50, 50B) of any one of claims 1 or 2, wherein the concavities and convexities are provided in an oxide film that is formed by heat generated when the flat tubes (51) and the fins (52) are welded to each other.
4. A refrigeration-and-air-conditioning system (100), wherein the plate fin-tube heat exchanger (50, 50B)

of any one of claims 1 to 3 is used as an evaporator.

Patentansprüche

1. Plattenrippen-Rohr-Wärmetauscher (50), in welchem Flachrohre (51), jeweils aufweisend eine flache Querschnittsform, deren lange Seiten linear sind und deren kurze Seiten in einer halbkreisförmigen Weise gekrümmt sind, in Aussparungen (54) eingepasst sind, die in Rippen (52) bereitgestellt sind, **dadurch gekennzeichnet, dass** eine Oberfläche von zumindest einem von jedem der Flachrohre (51) und jeder der Rippen (52) aufweist:

eine Vielzahl von Konkavitäten und Konvexitäten, in welchen eine Höhendifferenz zwischen einem der Erhebungsabschnitte, der eine kleinste Höhe aufweist, und einem der Vertiefungsabschnitte, der eine kleinste Tiefe aufweist, 10 μm oder größer ist, wobei dies erreicht wird, indem entweder eine Fremdschmelzsubstanz, aufweisend einen höheren Schmelzpunkt als ein Schweißmaterial, das zum Schweißen der Flachrohre (51) und der Rippen (52) eingesetzt wird, dem Schweißmaterial zuvor zugesetzt wird, oder eine Fremdschmelzsubstanz, aufweisend einen höheren Schmelzpunkt als ein Fließmittel (58), das für Oberflächen der Flachrohre (51) und der Rippen (52) eingesetzt wird, dem Fließmittel zuvor zugesetzt wird.

2. Plattenrippen-Rohr-Wärmetauscher (50, 50B) nach Anspruch 1, wobei die Konkavitäten und Konvexitäten derart ausgebildet sind, dass ein Winkel, der zwischen der Oberfläche von zumindest einem von jedem der Flachrohre (51) und jeder der Rippen (52) und einer Linie gebildet ist, 60 Grad oder kleiner ist, wobei die Linie tangential ist zu einem Ende eines Abschnittes eines Tautropfens, der in Kontakt mit der Oberfläche von zumindest einem von jedem der Flachrohre (51) und jeder der Rippen (52) vorhanden ist.
3. Plattenrippen-Rohr-Wärmetauscher (50, 50B) nach einem der Ansprüche 1 oder 2, wobei die Konkavitäten und Konvexitäten in einem Oxidfilm bereitgestellt werden, der durch Wärme gebildet ist, die erzeugt wird, wenn die Flachrohre (51) und die Rippen (52) miteinander verschweißt werden.
4. Kühl- und Klimatisierungssystem (100), wobei der Plattenrippen-Rohr-Wärmetauscher (50, 50B) nach einem der Ansprüche 1 bis 3 als ein Verdampfer eingesetzt wird.

Revendications

1. Échangeur de chaleur à tubes et plaques ailettes (50) dans lequel des tubes plats (51), chacun d'eux présentant une forme en coupe transversale plate dont les côtés longs sont linéaires et dont les côtés courts sont incurvés d'une manière semi-circulaire, sont disposés dans des encoches (54) prévues dans les ailettes (52) ;
caractérisé en ce que :
 une surface de chacun des tubes plats (51) ou de chacune des ailettes (52) au moins présente une pluralité de concavités et de convexités dans lesquelles la différence de hauteur entre l'une des parties crêtes qui présente la plus petite hauteur, et l'une des parties creux qui présente la plus petite profondeur, est égale ou supérieure à 10 μm , ce qui est réalisé par une substance étrangère qui présente un point de fusion plus élevé que celui d'un matériau de brasage utilisé de façon à braser les tubes plats (51) et les ailettes (52), ajoutée à l'avance au matériau de brasage, ou par une substance étrangère qui présente un point de fusion plus élevé que celui d'un flux (58) utilisé pour les surfaces des tubes plats (51) et des ailettes (52), ajoutée à l'avance au flux (58).
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2. Échangeur de chaleur à tubes et plaques ailettes (50, 50B) selon la revendication 1, dans lequel les concavités et les convexités sont formées de telle sorte que l'angle formé entre la surface de chacun des tubes plats (51) et de chacune des ailettes (52) au moins, et une ligne, soit égal ou inférieur à 60 degrés, la ligne étant tangente à une extrémité d'une partie d'une goutte de rosée présente en contact avec la surface de chacun des tubes plats (51) et de chacune des ailettes (52) au moins.
 30
35
3. Échangeur de chaleur à tubes et plaques ailettes (50, 50B) selon la revendication 1 ou la revendication 2, dans lequel les concavités et les convexités sont prévues dans une couche d'oxyde qui est formée par la chaleur dégagée lorsque les tubes plats (51) et les ailettes (52) sont brasés les uns aux autres.
 40
45
4. Système de réfrigération et de climatisation (100), dans lequel l'échangeur de chaleur à tubes et plaques ailettes (50, 50B) selon l'une quelconque des revendications 1 à 3, est utilisé en tant qu'évaporateur.
 50

55

FIG. 1

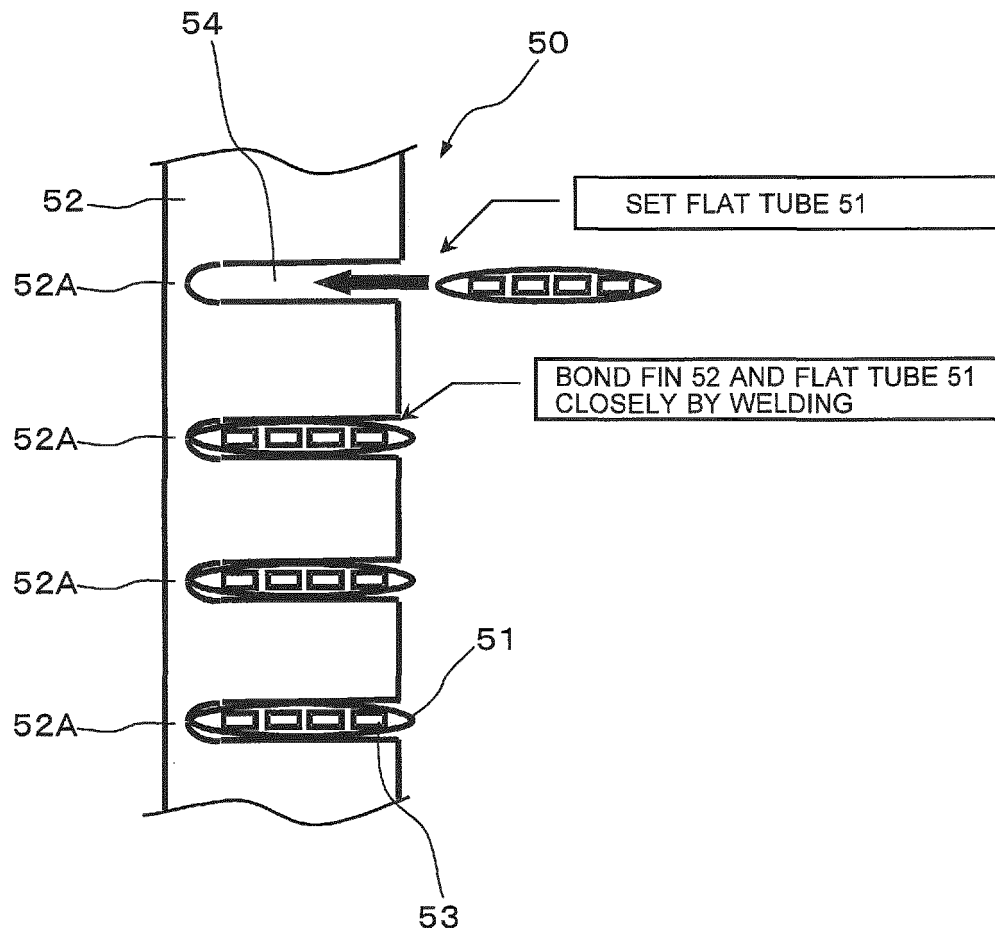


FIG. 2

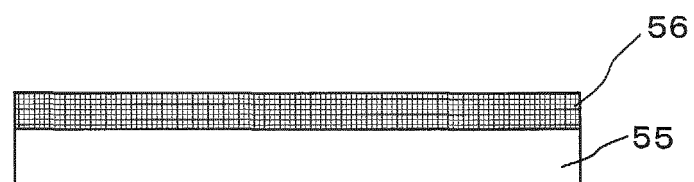


FIG. 3

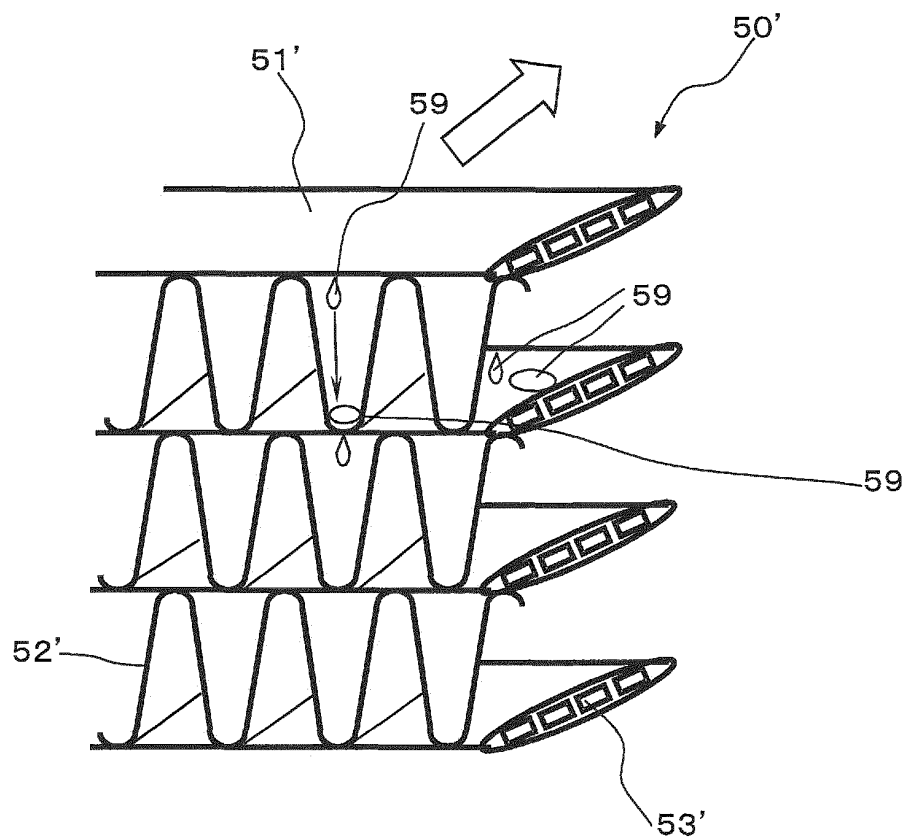


FIG. 4

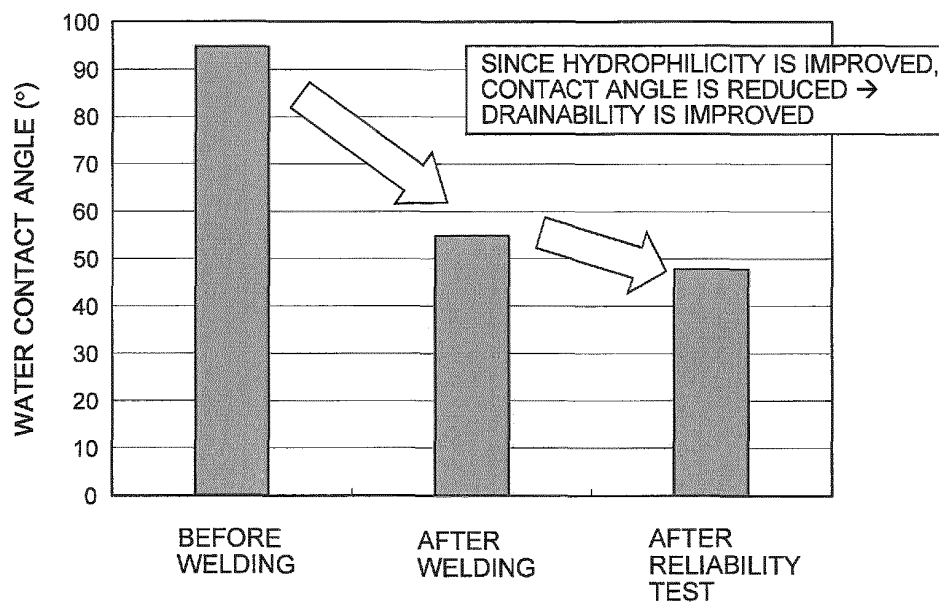


FIG. 5

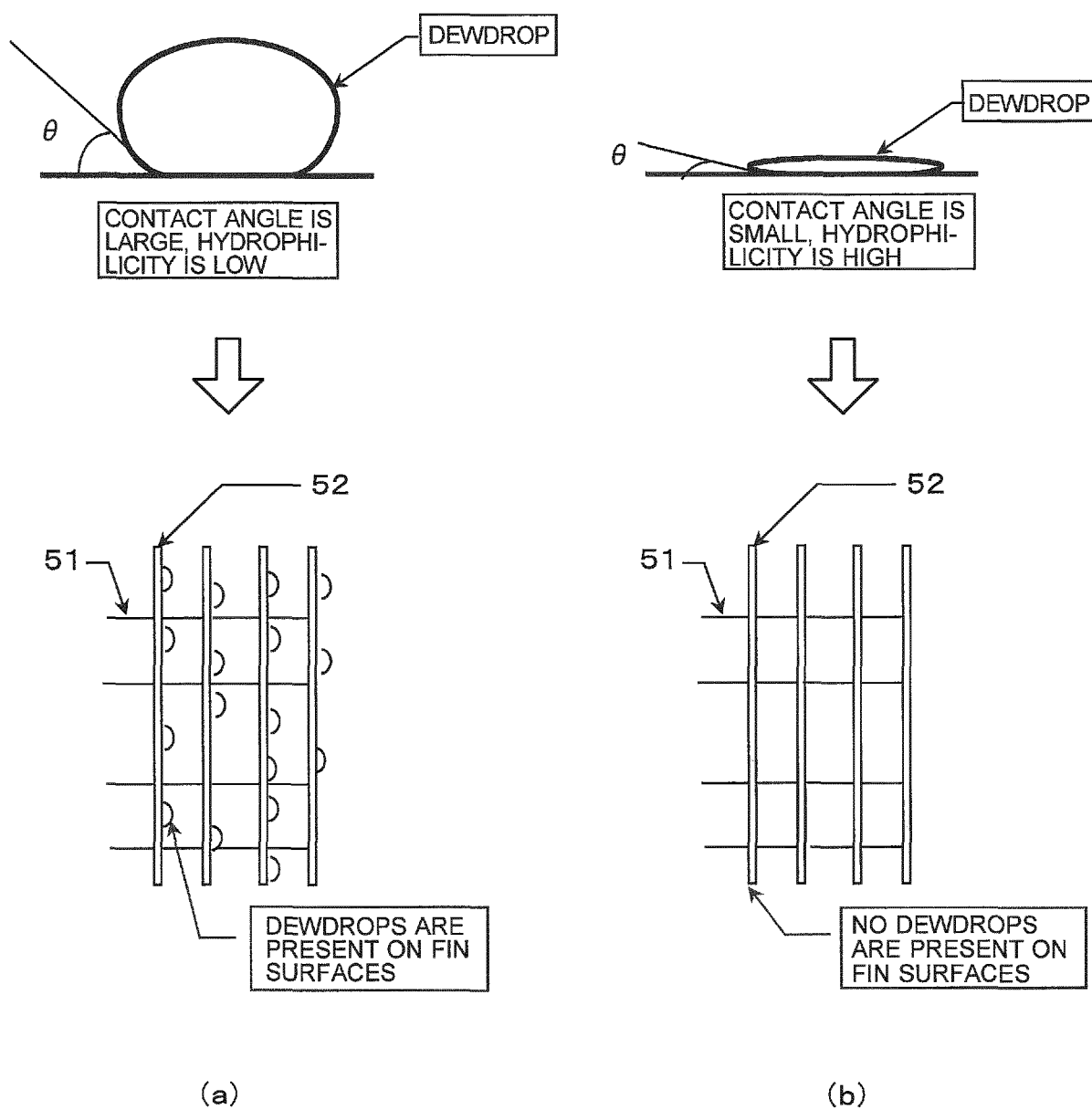


FIG. 6

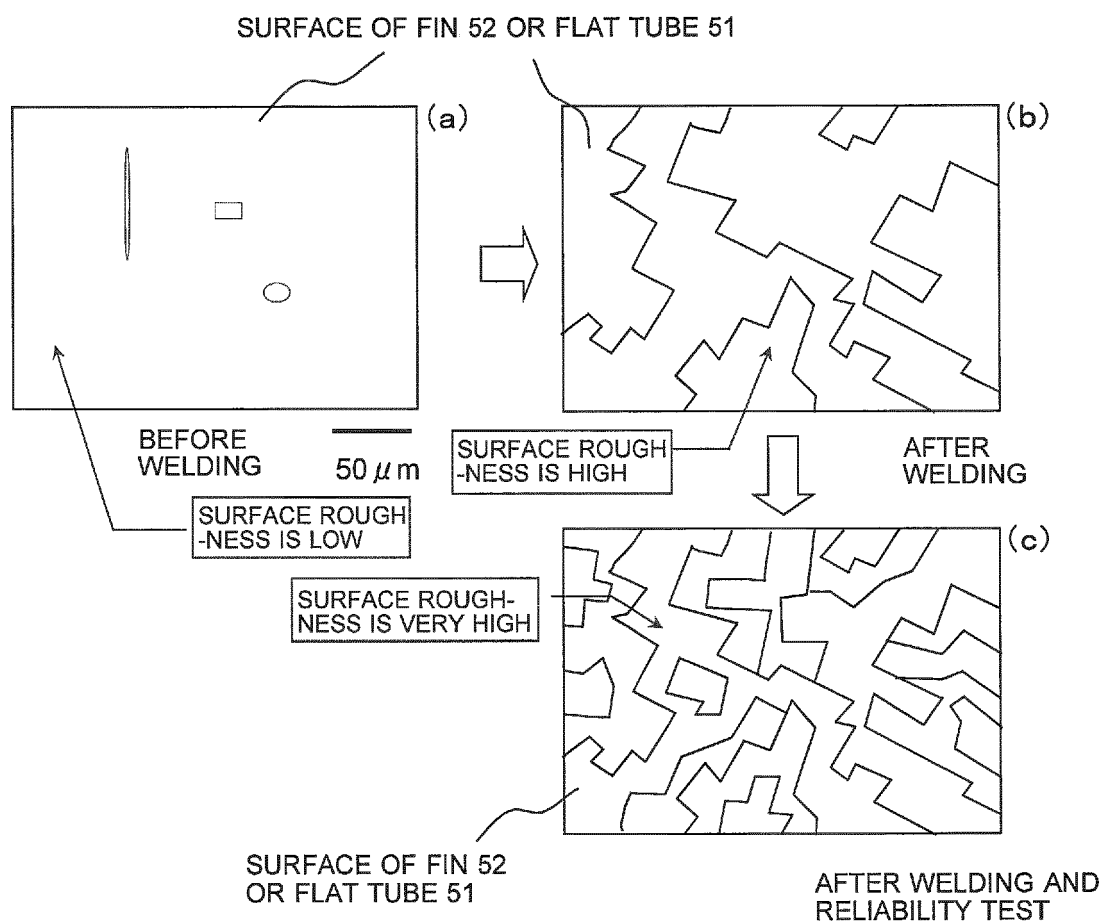


FIG. 7

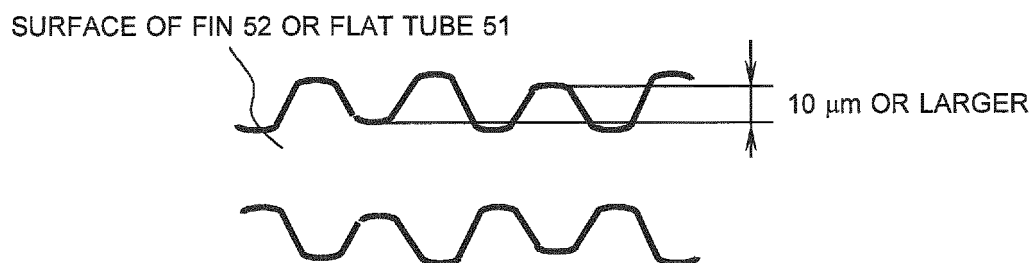


FIG. 8

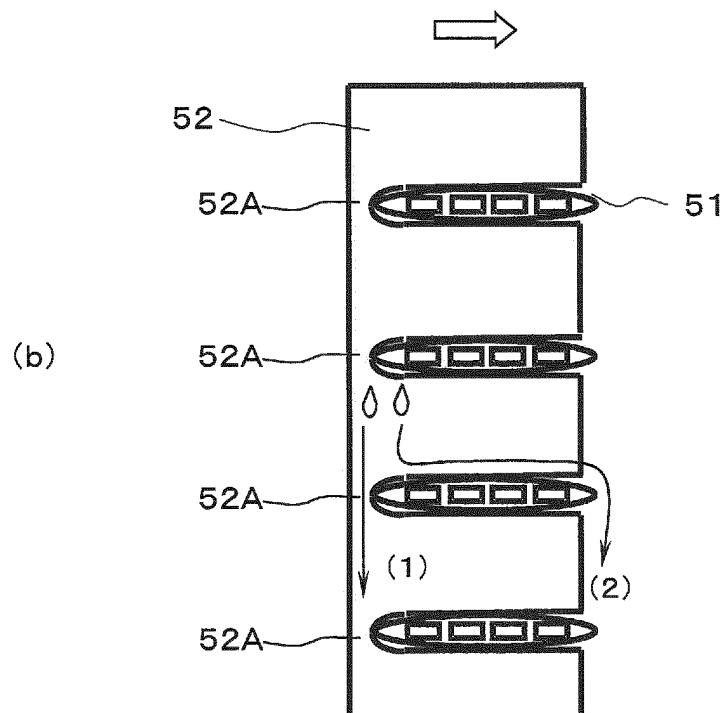
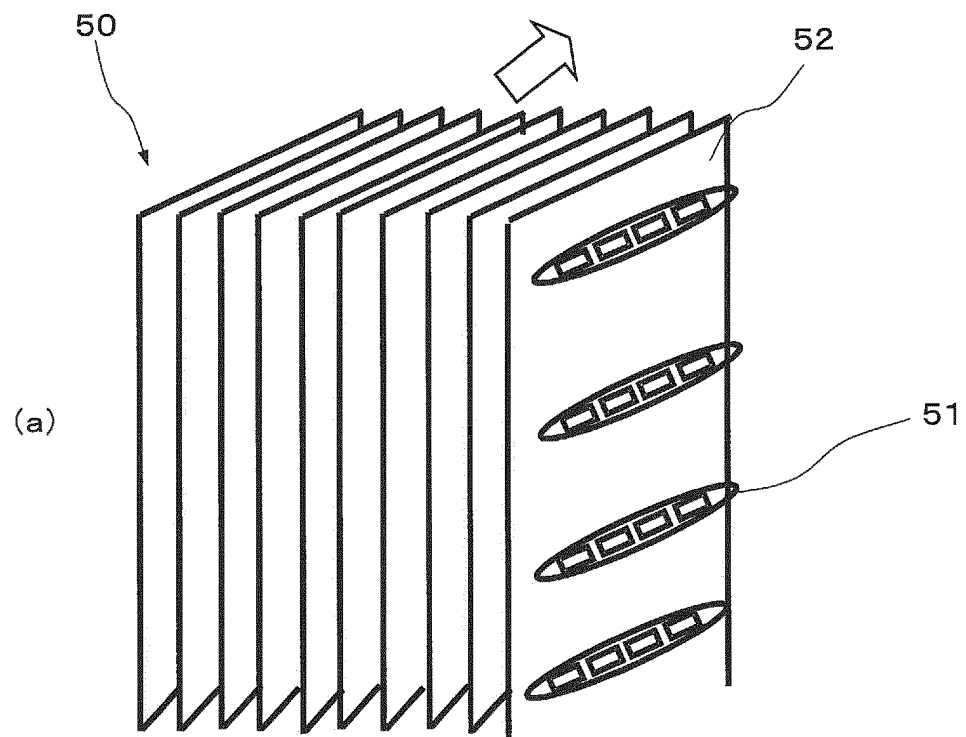


FIG. 9

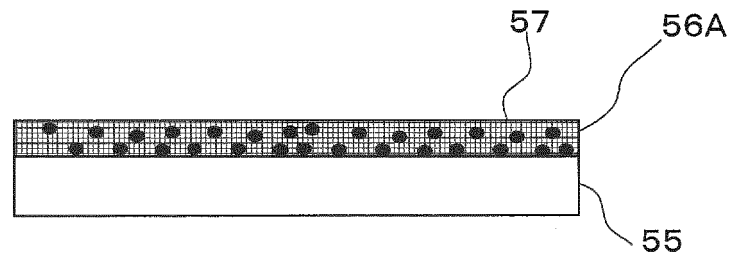


FIG. 10

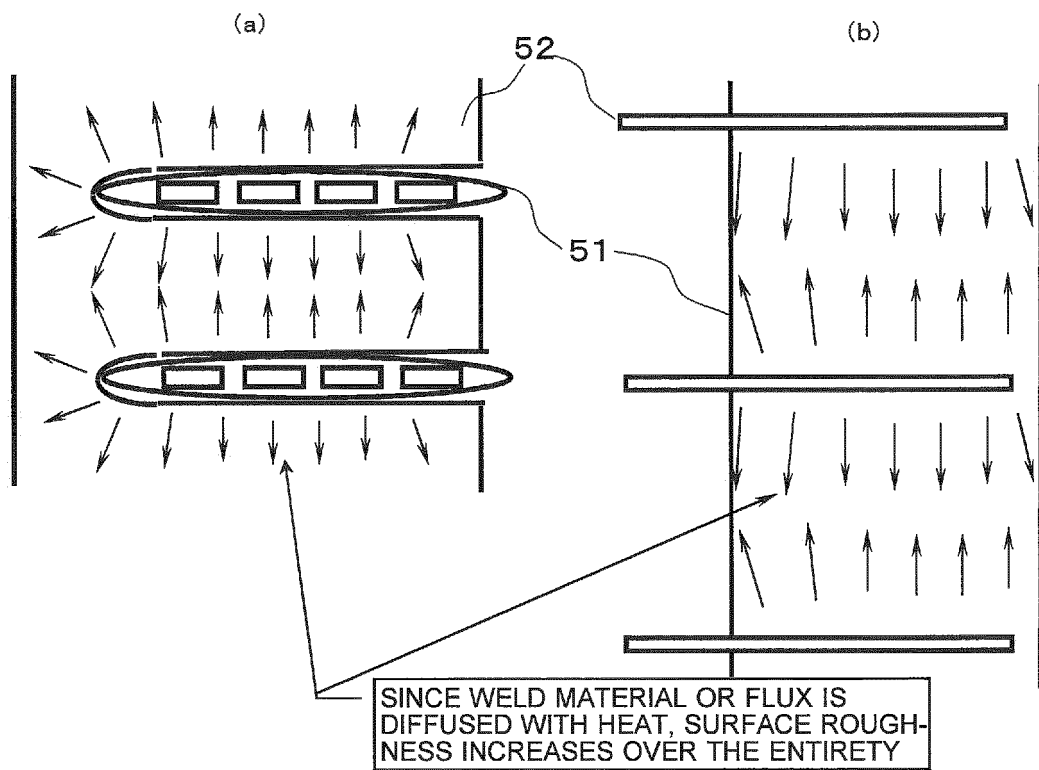


FIG. 11

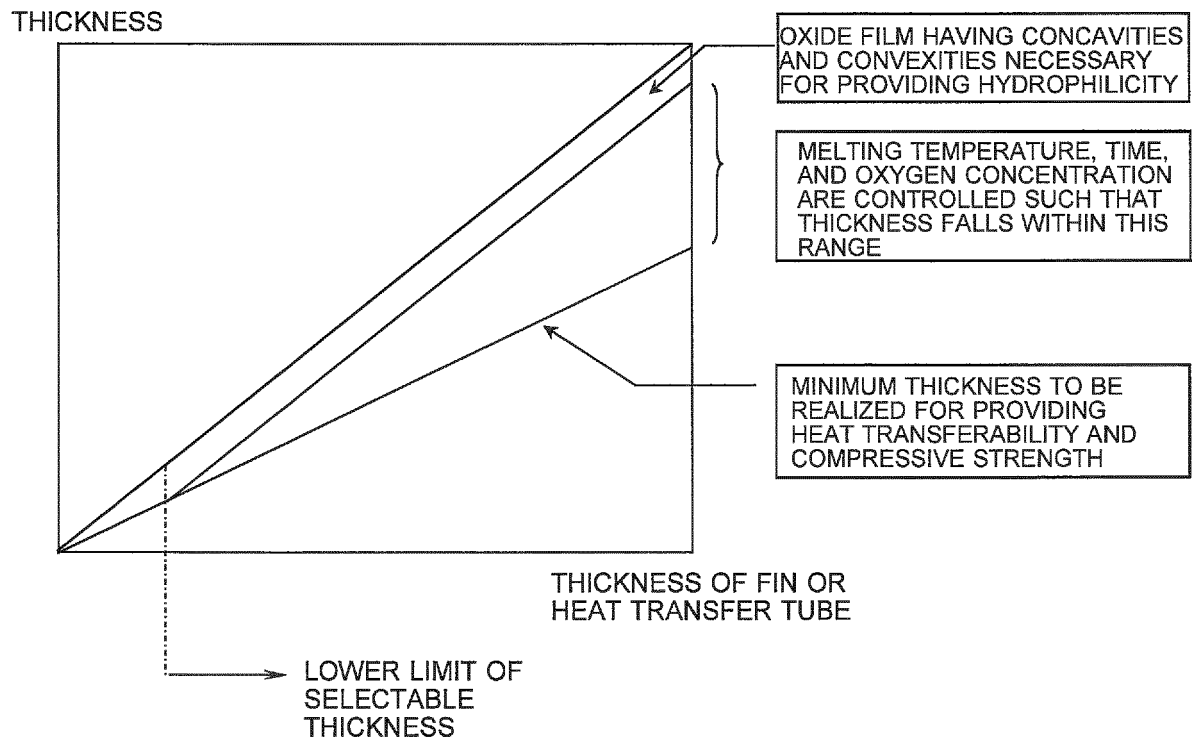
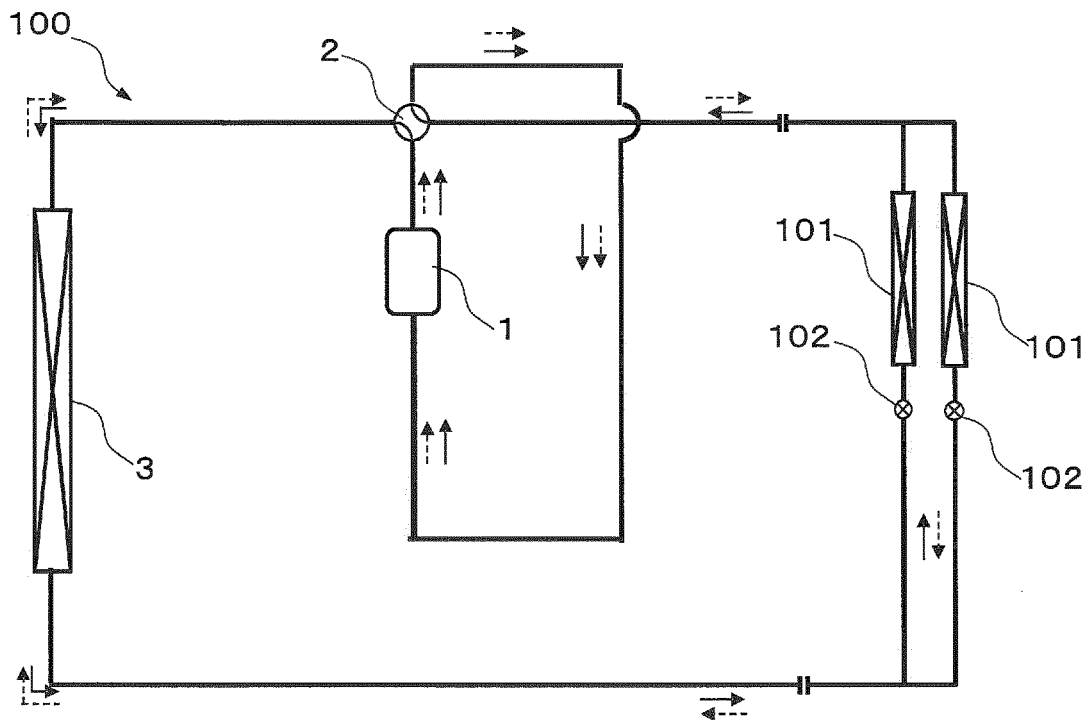


FIG. 12



REFERENCES CITED IN THE DESCRIPTION

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