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(71) Applicants:
- **Furukawa-Sky Aluminum Corp.
Chiyoda-ku
Tokyo (JP)**
- **DENSO CORPORATION
Kariya-shi,
Aichi-ken (JP)**

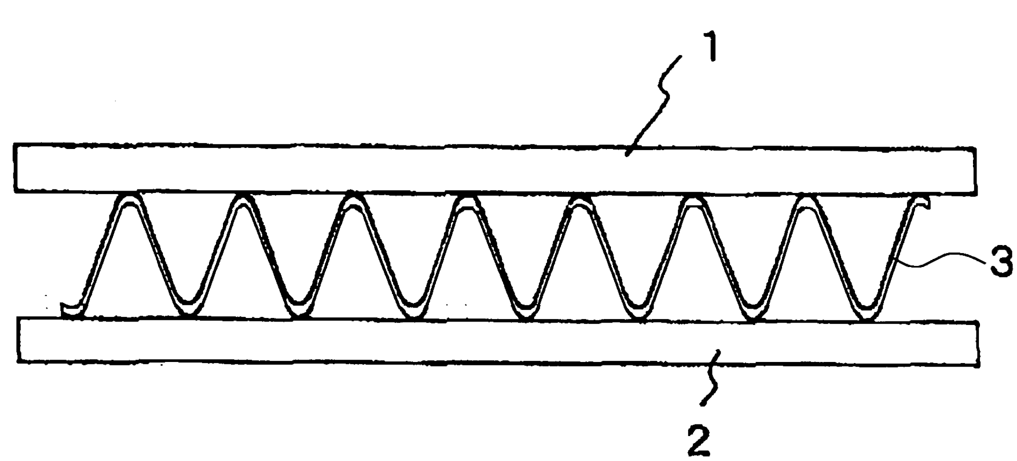
(72) Inventors:
- **Ninomiya, Junji, c/o Furukawa-Sky Aluminium Corp.
Tokyo (JP)**
- **Tanaka, Satoshi, c/o Furukawa-Sky Aluminium Corp.
Tokyo (JP)**
- **Kashiwazaki, Kazuhisa, c/o Furukawa-Sky Aluminium
Tokyo (JP)**
- **Katou, Kazumi, c/o Furukawa-Sky Aluminium
Tokyo (JP)**
- **Oya, Yoshiyuki, c/o Furukawa-Sky Aluminium
Tokyo (JP)**
- **Nakamura, Tomohiko, c/o Denso Corp.
Kariya-shi, Aichi (JP)**

(74) Representative: **Forstmeyer, Dietmar et al
BOETERS & LIECK
Oberanger 32
80331 München (DE)**

(54) Aluminium alloy extruded tube material for heat exchanger using natural refrigerant

(57) An aluminum alloy extruded tube material for a heat exchanger using a natural refrigerant, which is composed of an aluminum alloy containing 0.1 to 0.5% by mass of Si, 0.3 to 0.8% by mass of Fe, 0.5 to 1.5% by mass of Mn, 0.05 to 0.25% by mass of Cu, 0.05 to 0.25% by mass of Ti, and 0.05 to 0.30% by mass of V, the balance being aluminum and an unavoidable impurity(s).

Fig. 1



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Description

FIELD OF THE INVENTION

[0001] The present invention relates to an aluminum alloy extruded tube material, which can be used as a structural member to be applied to a heat exchanger in which a refrigerating cycle using a natural refrigerant as typified by carbon dioxide (CO_2) as a refrigerant is incorporated, such as a gas conditioner (condenser) for cooling a high temperatures and pressures gas refrigerant which has been heated and compressed in a car air-conditioner. In particular, the present invention relates to an aluminum alloy extruded tube material having a plurality of refrigerant-flowing holes.

BACKGROUND OF THE INVENTION

[0002] In recent years, for non-using of flons in refrigerators, refrigerators each using a natural refrigerant as typified by carbon dioxide as a refrigerant have been under development. Air conditioners employing such refrigerators using carbon dioxide as their refrigerants will have to respond to new requests different from those in using a flon as a conventionally usual refrigerant.

[0003] In other words, an air conditioner using carbon dioxide as a refrigerant has higher working pressures as well as higher refrigerant temperatures when compressed, as compared with those when a flon is employed. For example, in a gas conditioner for cooling a carbon dioxide refrigerant which has been compressed on the downstream of a compressor, the refrigerant may be heated up to a temperature as high as 130 to 200°C at the inlet of the conditioner. Therefore, when carbon dioxide is used as a refrigerant, the conditioner requires better durability at high temperatures and pressures than that in the case where a flon is used as a refrigerant.

[0004] The conventional, usual heat exchangers employ tube materials having refrigerant-flowing holes for allowing refrigerants to flow through it, particularly aluminum alloy extruded tube materials. Among them, in many cases, pure aluminum-based alloys as typified by an inexpensive JIS 1050 alloy excellent in extrudability are used. Such a pure aluminum-based alloy has a significantly lowering in mechanical strength under high temperature conditions of 150°C or higher. For compensating for a decrease in strength when carbon dioxide is used as a refrigerant, a tube may be provided with enhanced pressure resistance (pressure-resisting strength) at high temperature by making the wall of the tube much thicker than the case of using a flon.

[0005] However, the thick aluminum alloys as described above have not coped with the demands on reductions in weight and thickness of a car air conditioner in recent years. For improving mechanical strength while coping with the demands on reductions in weight and thickness, attempts have been conducted to obtain an extruded tube material high in pressure resistance at high temperature while having a thinner wall, by adding an element contributing to improvement in material strength, that is a reinforcing element, to an aluminum alloy to be used in an extruded tube material, thereby to enhance mechanical strength of the aluminum alloy itself for the tube material particularly, the high-temperature strength. Herein, examples of the reinforcing element for the aluminum alloy include Cu, Mn, Si, Fe, Ti, and V. Among them, an element for easily reinforcing the material may be Cu that contributes to improvement in strength by forming a solid solution. Hitherto, therefore, attempts have been conducted to use an aluminum alloy for an extruded tube material with the addition of a larger amount of Cu than the conventional one.

[0006] For making an aluminum alloy extruded tube material for a heat exchanger reduced in weight and thickness, which uses carbon dioxide as a refrigerant as described in the above, the content of Cu as an alloy element in an aluminum alloy for the tube material may be increased, thereby to easily improve the mechanical strength of such a tube material. In other words, pressure resistance at high temperature required for the tube material can be easily enhanced.

[0007] However, the following problem can be found when the content of Cu is simply raised. That is, when an aluminum alloy having a large amount of Cu is subjected to a high refrigerant temperature of 130 to 200°C as described above, the amount of solid-solution Cu around a grain boundary decreases as a Cu-Al-series intermetallic compound precipitates in the grain boundary, thereby causing a Cu-shortage layer. When such a material is placed in a corrosive environment, an electric potential difference may be caused between a portion having a high Cu content (Cu-rich portion) in the grain boundary and a Cu-shortage layer of the grain boundary, so occurrence of corrosion at the grain boundary is apt to occur. Thus, the aluminum alloy added with a large amount of Cu has difficulty in retaining its corrosion resistance satisfactorily, as well as difficulty in obtaining good extrudability.

[0008] On the other hand, measures for obtaining the strength properties while avoiding the problem of corrosion at the grain boundary due to a large amount of Cu added as described above, include the addition of Si without adding Cu (see, for example, JP-A-7-41894 ("JP-A" means unexamined published Japanese patent application)).

[0009] However, when Si is added as described, another problem may be caused in that crystallized Si conspicuously shortens the operable life of an extrusion die even though the strength can be enhanced. Further, when the aluminum alloy added with Si in such a manner is subjected to high refrigerant temperatures of 130 to 200°C as described above, the strength may conspicuously reduce in comparison with the strength at room temperature before the alloy is subjected to such temperatures. In addition, there is another problem in that the high-temperature strength in the high temperature region of higher than 130°C also conspicuously reduces.

SUMMARY OF THE INVENTION

[0010] The present invention resides in an aluminum alloy extruded tube material for a heat exchanger using a natural refrigerant, which is composed of an aluminum alloy comprising 0.1 to 0.5% by mass of Si, 0.3 to 0.8% by mass of Fe, 0.5 to 1.5% by mass of Mn, 0.05 to 0.25% by mass of Cu, 0.05 to 0.25% by mass of Ti, and 0.05 to 0.30% by mass of V, the balance being aluminum and an unavoidable impurity(s).

[0011] Other and further features and advantages of the invention will appear more fully from the following description, taken in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

[0012]

Fig. 1 is a schematic side view that illustrates a test piece provided as an assembly of a tube material and a fin material in Example 1.

DETAILED DESCRIPTION OF THE INVENTION

[0013] According to the present invention, there is provided the following means:

(1) An aluminum alloy extruded tube material for a heat exchanger using a natural refrigerant, which is composed of an aluminum alloy comprising 0.1 to 0.5% by mass of Si, 0.3 to 0.8% by mass of Fe, 0.5 to 1.5% by mass of Mn, 0.05 to 0.25% by mass of Cu, 0.05 to 0.25% by mass of Ti, and 0.05 to 0.30% by mass of V, the balance being aluminum and an unavoidable impurity(s);

(2) The aluminum alloy extruded tube material for a heat exchanger using a natural refrigerant according to the above item (1), wherein a sacrificial material is provided on an outer surface of the aluminum alloy extruded tube material; and

(3) The aluminum alloy extruded tube material for a heat exchanger using a natural refrigerant according to the above item (1) or (2), wherein a plurality of refrigerant-flowing holes are formed in the aluminum alloy extruded tube material, to provide a multi-hole extruded tube material.

[0014] For solving the conventional problems as described above, the inventors of the present invention have conducted experiments and studies in detail with respect to the correlation of corrosion resistance, mechanical strength, and strength after thermal history, with the composition of the alloy elements of the aluminum alloy extruded tube material. Consequently, the inventors of the present invention found that high pressure resistance at high temperature as well as high strength after thermal history can be obtained while sufficient corrosion resistance is retained, when the amounts of Si, Fe, Mn, Cu, Ti, and V as alloy elements to be added are appropriately adjusted, particularly the appropriate amounts of Cu, Ti, and V are simultaneously added. The present invention has been attained based on the above finding.

[0015] Preferred embodiments for carrying out the invention will be described in detail hereinafter.

[0016] At first, the reasons for restricting the elements of the aluminum alloy extruded tube material of the present invention for a heat exchanger using a natural refrigerant will be described.

[0017] In the present invention, the content of manganese (Mn) is 0.5 to 1.5% by mass.

[0018] Mn may be crystallized or precipitated as an Al-Mn-series intermetallic compound and contribute to enhancement in mechanical strength after brazing. Further, Mn is an element which is coexistent with Si to generate an Al-Mn-Si-series intermetallic compound, to thereby enhance the mechanical strength. Further, the addition of Mn makes an electric potential of the aluminum alloy noble, and the electric potential difference with a fin can be increased by previously adding Mn in a tube material when the fin is provided on the outer surface of the tube material, thereby enhancing external-corrosion resistance. For surely attaining those effects, Mn should be added in an amount of 0.5% by mass or more, preferably 0.7% by mass or more. Further, if a large amount of Mn is added, extrudability may be lowered. However, in the case of the tube material of the present invention as described below, the addition of Si prevents lowering of extrudability, so that Mn in an amount of 0.5% by mass or more, or 0.7% by mass or more, may cause no particular trouble. In contrast, when the content of Mn exceeds 1.5% by mass, lowering of extrudability may be inevitable even though the material contains Si. For this reason, the upper limit of the Mn content is defined as 1.5% by mass.

[0019] In the present invention, the content of silicon (Si) is 0.1 to 0.5% by mass.

[0020] As described above, a crystallized or precipitated product of an Al-Mn-series intermetallic compound (an Al compound containing only Mn, e.g. Al_6Mn), which can be generated by the addition of Mn, may contribute to improvement in mechanical strength after brazing. On the other hand, the crystallized or precipitated product of the Al-Mn-series intermetallic compound can conspicuously lower extrudability by raising an extrusion contact pressure. However, the addition of Si allows the generation of an Al-Mn-Si-series intermetallic compound, as a consequence the generation of an Al-Mn-series intermetallic compound too much as compared to a necessary amount can be prevented, and the extrusion contact pressure can be lowered. Therefore, the addition of Si in conjunction with the addition of Mn can prevent lowering of extrudability. Further, Si can be provided in a solid-solution state in a matrix or generate an Al-Mn-Si-series intermetallic compound, thereby exhibiting an enhancing effect on the mechanical strength after brazing. For attaining those effects of Si addition, the tube material should contain Si in an amount of 0.1 % by mass or more. In addition, particularly in view of improving extrudability, the content of Si is preferably 0.2% by mass or more, more preferably 0.3% by mass or more. On the other hand, when Si is contained excessively, Si, which is solely crystallized, may conspicuously shorten the operable life of an extrusion die and may lower the melting point of the alloy, thereby melting the material at the time of brazing. Besides, the formation of a crystallized product may lower the extrudability. Further, when the alloy is subjected to a high refrigerant temperature of about 130 to 200˚C, the strength at room temperature may significantly reduce in comparison with one before the alloy is subjected to that high temperature. In addition, the high-temperature strength in a high-temperature region of higher than 130˚C can be significantly reduced. For avoiding an adverse effect caused by the addition of Si in an excess amount, the upper limit of Si content should be 0.5% by mass.

[0021] In the present invention, the content of iron (Fe) is 0.3 to 0.8% by mass.

[0022] Fe can be crystallized or precipitated as an intermetallic compound, to improve the mechanical strength after brazing. In addition, Fe can improve the extrudability by forming an Al-Mn-Fe-series or Al-Mn-Fe-Si-series intermetallic compound. For attaining the effects of Fe addition, the content of Fe should be 0.1 % by mass or more, preferably 0.3% by mass or more. In contrast, if an excess amount of Fe is contained, a Fe-containing intermetallic compound may be crystallized from the surface of the tube material and accelerate the rate of corrosion, thereby lowering the extrudability. For preventing an adverse effect due to the addition of such an excess amount of Fe, the content of Fe should be 0.8% by mass or less.

[0023] In the present invention, the tube material contains 0.05 to 0.25% by mass of cupper (Cu), 0.05 to 0.25% by mass of titanium (Ti), and 0.05 to 0.30% by mass of vanadium (V), respectively.

[0024] Various effects can be exerted even by adding Cu or Ti alone. In the present invention, particularly, excellent corrosion resistance can be retained while enhance of mechanical strength is achieved, by simultaneously adding Cu, Ti, and V. At first, the effects of singly adding Cu or Ti will be described.

[0025] The addition of Cu alone may enhance the strength after brazing by allowing Cu to be in a solid-solution state in a matrix; and further, it may make an electric potential of the tube material noble, to enlarge the electric potential difference between the tube material and a fin when the fin material is provided on the outer surface of the tube material, to remarkably enhance the external corrosion resistance. For attaining such effects, the amount of Cu to be added should be 0.05% by mass or more. For attaining particularly sufficient effects, the amount of Cu to be added is preferably 0.1 % by mass or more.

[0026] On the other hand, the addition of Ti alone may contribute to enhance corrosion resistance, particularly pitting corrosion resistance. That is, Ti added to an aluminum alloy can be distributed into high-concentration regions and low-concentration regions on its concentration, which are distributed in a layered structure in which the regions are laminated in alternation in the direction along the sheet thickness. Then, a low-Ti concentration region can be preferentially corroded, compared with a high-Ti concentration region, thereby allowing the formation of corrosion into a layered structure to prevent the progress of corrosion in the direction along the sheet thickness. As a result, pitting corrosion resistance is improved. For sufficiently attaining such improving effect on pitting corrosion resistance, the content of Ti should be 0.05% by mass or more.

[0027] As described above, the addition of Cu in an amount of 0.05% by mass or more may lead to a conspicuous lowering of corrosion resistance, because of an increase in sensitivity to grain boundary corrosion when the alloy is subjected to a high temperature of 130 to 200˚C after heating for brazing. In contrast, in the present invention, Ti and V are added together with the addition of Cu in an amount of 0.05% by mass or more, and it is possible not only to improve pitting corrosion resistance but also to suppress the sensitivity to grain boundary corrosion due to the addition of Cu. The reason that an inhibitory effect on the sensitivity to grain boundary corrosion can be obtained by simultaneously adding Ti and V when Cu is added, will be considered as follows.

[0028] That is, as previously described, when Ti is added, the alloy is in a state of a layered structure in which high-Ti concentration layers (Ti-rich layers) and low-Ti concentration layers are laminated one after another. The simultaneous addition of V allows V to be incorporated into the Ti-rich layer, thereby causing a TiN rich layer. The Ti/N rich layer comes across the grain boundary, and the grain boundary within the range being traversed by the Ti/N rich layer can be of a noble electric potential due to the Ti/V rich layers. In contrast, as described above, when Cu is added alone, the grain boundary can be of a Cu shortage phase to cause an ignoble potential, thereby causing increase in the sensitivity to grain boundary corrosion. However, as described above, the Ti/V rich layer alters the grain boundary so that the boundary has a noble electric potential. Thus, the grain boundary corrosion becomes difficult to progress, and the sensitivity to grain boundary corrosion may be thus prevented.

[0029] For attaining the preventing effects on the sensitivity to grain boundary corrosion as described above, Ti should be added in an amount of 0.05% by mass or more, particularly preferably 0.1 % by mass or more. In addition, V should be added in an amount of 0.05% by mass or more. On the other hand, if the amount of Ti to be added exceeds 0.25% by mass, the extrudability of the material is prohibited by the formation of a giant compound upon casting, thereby resulting in difficulty in obtaining a healthy material for extrusion. Further, when the amount of V to be added exceeds 0.30% by mass, the extrudability of the material is prohibited by the formation of a giant compound upon casting, thereby resulting in difficulty in obtaining a healthy material for extrusion and also prohibiting the corrosion resistance of the resultant extruded tube material. Further, when the content of Cu exceeds 0.25% by mass, the preventing effects on the sensitivity to grain boundary corrosion by Ti and V cannot be obtained. Moreover, the room temperature strength after the material is subjected to refrigerant temperatures (130 to 200˚C) for a long period of time is conspicuously reduced, as compared with the room temperature strength before the material is subjected to the refrigerant temperatures.

[0030] From the viewpoints of above, the tube material contains 0.05 to 0.25% by mass of Ti, 0.05 to 0.30% by mass of V, and 0.05 to 0.25% by mass of Cu.

[0031] Further, the balance other than the respective elements described above may be Al and an unavoidable impurity (s).

[0032] In the production of the aluminum alloy extruded tube material of the present invention, an aluminum alloy molten liquid is provided in a usual manner to attain the element composition described above, and then the resultant molten liquid is subjected to casting in a usual manner, and the method is not particularly limited. For producing an extruded tube material using the thus-obtained ingot (billet), the ingot is preferably subjected to a homogenization treatment in advance. Afterwards, at least before extruding, a soaking treatment may be carried out, and followed by extruding. Further, heating methods or heating conditions, structures of heating furnaces, and the like for the above homogenization treatment and soaking treatment are not particularly limited. Further, in the above extruding, the form after extruded is not particularly limited, and any of appropriate extruded forms can be selected depending on, for example, the shape of a heat exchanger to which the resultant tube is applied. For the extrusion, since the extrudability of the material is good, a multiple hollow die in the form of a hollow may be used for the extrusion in a favorable manner. In addition, an extrusion method (system) for extruding is not particularly limited, and any of usual methods can be suitably applied in combination with the shape after extruded and the like.

[0033] The extruded material that can be obtained, for example, in the manner as described above, can be used as a material for a heat exchanger, and it can be generally used as a material for a tube for flowing a refrigerant (heat medium) through it. Such an extruded tube material may be generally assembled with other members (e.g., a fin material and a header) and then brazed by brazing when used as a part of a heat exchanger. Herein, the conditions of atmosphere, heat temperature, time period, and the like upon brazing are not particularly limited, and also the brazing method is not particularly limited. The heat exchanger thus obtained can be efficiently manufactured because its tube material has good extrudability, and the exchanger has high pressure resisting property and good corrosion resistance. Therefore, the heat exchanger can exhibit good durability even in a car or the like, for example, when used under a severe corrosive environment.

[0034] Further, the extruded tube material of the present invention may be directly used in a heat exchanger as it is. In some cases, a sacrificial material made of a material having an ignoble electric potential compared with that of the tube material may be provided on the outer surface of the extruded tube material, to further improve corrosion resistance, thereby forming a tube having a sacrificial material, which can also be used in heat exchangers. In that case, examples of the sacrificial materials that can be used include metal Zn, and an Al-Zn alloy. Further, a concrete method of forming the sacrificial material on the surface of an extruded tube material, and the thickness or the like of the sacrificial material, are not particularly limited, and they may be determined similarly to those of the usual aluminum alloy tube material having a sacrificial material for heat exchangers.

[0035] Further, the extruded tube material of the present invention for a heat exchanger is not limited to one having a single hole as a refrigerant-flowing hole, but it may be in the form to give a multi-hole tube having a plurality of refrigerant-flowing holes. As described above, the tube material of the present invention is excellent in extrudability, and a multi-hole extruded tube material can be prepared in an easy manner.

[0036] The aluminum alloy extruded tube material of the present invention for a heat exchanger using a natural refrigerant can exhibit remarkably excellent corrosion resistance even in a corrosive environment, as well as high pressure resistance at high temperature, while showing high room-temperature strength after thermal history applied. Therefore, the tube material of the present invention can provide a tube for flowing a refrigerant in a heat exchanger, which uses a natural refrigerant as typified by carbon dioxide, and which has a thinner wall and sufficient durability. Therefore, the tube material of the present invention is preferable as a tube material for a heat exchanger subjected to severe corrosive environments such as a car air-conditioner.

[0037] The present invention will be described in more detail based on the following examples, but the invention is not intended to be limited thereto.

EXAMPLES

(Example 1)

[0038] Each of Al alloys having the respective element composition as shown by Nos. 1 to 19 in Table 1 below, was molten and then subjected to casting in a usual manner, to cast into a billet of diameter 200 mm. The resultant billet was subjected to a homogenization treatment under the conditions of retaining at 610˚C for 4 hours, followed by cutting into a length of 1,000 mm, to give a billet for extrusion. The thus-obtained billet was again heated to 500˚C and then extruded through a mandrel die, thereby preparing a multi-hole tube material having 20 holes.

[0039] The surface of the thus-obtained multi-hole tube was subjected to a sandblasting method, to make it rough with approximately 10 μm in a center line average roughness (height) (Ra). Then, metal Zn as a sacrificial material was sprayed onto the resultant surface. The method of spraying was an electric arc spraying method, under the spraying conditions of thermal source temperature 4,000˚C and particle velocity 75 m/s. The amount of metal Zn covered was adjusted to about 9 g/m^2. In this way, the extruded multi-hole tube covered with the metal Zn was obtained, followed by cutting into a piece of length 100 mm.

[0040] Separately, a clad fin (thickness 0.1 mm) that was prepared by cladding a JIS 4343 alloy in a cladding amount of 10% by mass on a JIS 3003 alloy added with 2% by mass of Zn, was corrugated, and followed by assembling with the multi-hole tube, to give an assemble having a shape as shown in Fig. 1. In Fig. 1, reference numerals 1 and 2 each represent a multi-hole tube, and 3 represents a fin corrugated. The thus-assembled test piece was subjected to brazing by heating at 600˚C for 3 minutes, under a nitrogen atmosphere. After that, an additional thermal history of 180˚C x 48 hours was applied thereto, to prepare a test piece for corrosion.

[0041] For the test piece for corrosion, the CASS test was carried out for 1,500 hours according to JIS H8601. After the CASS test, a fin was cut off from the test piece, and then the corrosion product on the tube was removed, followed by measuring the depth of pitting corrosion of the tube material with an optical microscope. Further, for the pitting corrosion cite, the cross section of the tube was observed with an optical microscope. Table 1 shows grain boundary corrosion, if observed, and the results of the CASS test. Further, the tube material obtained as described above was examined for mechanical strength, and evaluated for extrudability. The results are shown in Table 1.

Table 1

Classification	No.	Element composition of tube material (mass%)							Extrudability	Mechanical strength (MPa)	CASS test results (µm)	Grain boundary corrosion
		Si	Fe	Cu	Mn	Ti	V	Al				
This invention	1	0.1	0.3	0.06	0.5	0.05	0.05	Balance	○	134	70	None
	2	0.2	0.6	0.15	1.1	0.1	0.1	Balance	○	137	75	None
	3	0.2	0.6	0.15	1.1	0.19	0.27	Balance	○	145	50	None
	4	0.1	0.3	0.06	0.5	0.25	0.15	Balance	○	135	70	None
	5	0.5	0.8	0.25	1.5	0.05	0.1	Balance	○	142	90	None
	6	0.3	0.6	0.15	0.8	0.1	0.25	Balance	○	138	75	None
	7	0.3	0.6	0.2	0.8	0.15	0.2	Balance	○	141	80	None
	8	0.5	0.8	0.25	1.5	0.25	0.15	Balance	○	143	90	None
	9	0.1	0.3	0.05	0.5	0.15	0.23	Balance	○	142	70	None
	10	0.3	0.5	0.15	1.1	0.15	0.12	Balance	○	139	80	None
	11	0.2	0.6	0.15	1.1	0.15	0.3	Balance	○	146	60	None
Comparative example	12	0.2	0.6	0.15	1.1	0	0.32	Balance	×	-	-	-
	13	0.2	0.6	0.15	1.1	0.03	0.03	Balance	○	132	Penetration due to grain boundary corrosion	Observed
	14	0.2	0.9	0.15	1.1	0.27	0.03	Balance	○	135	190	None
	15	0.2	0.9	0.15	1.1	0.3	0.35	Balance	×	-	-	-
	16	0.05	0.02	0	0.04	0.03	0.03	Balance	○	80	80	None
	17	0.6	0.9	0.3	1.8	0.03	0.35	Balance	×	-	-	-
	18	0.6	0.9	0.3	1.8	0.3	0.03	Balance	×	-	-	-
Conventional example	19	0.2	0.4	0.4	0.6	0	0	Balance	○	95	Penetration due to grain boundary corrosion	Observed

Note) Evaluation for extrudability: "○" good; "×" poor

[0042] It was confirmed that each of the multi-hole tube materials of Nos. 1 to 11 of Examples according to the present invention exhibited good corrosion resistance even after 1,500 hours from the CASS test, and inhibited grain boundary corrosion. Contrary to the above, in Comparative Example No. 13, grain boundary corrosion occurred, to cause penetration through the tube walls. Further, in Comparative Example No. 14, since the contents of Fe and Ti each were too high over the ranges defined in the present invention, pitting corrosion resistance was poor. Further, in Comparative Examples Nos. 12 and 15, since the content of V was too high over the range defined in the present invention, the extrusion could not be conducted. Further, in Comparative Examples Nos. 16 to 18, since the contents of Si, Fe, Cu, Mn, Ti, and V were outside of the range defined in the present invention, the mechanical strength was insufficient or the extrusion could not be carried out. Further, in Conventional Example No. 19, the grain boundary corrosion occurred, to cause penetration through the tube walls.

(Example 2)

[0043] Each of Al alloys having the respective element composition as shown by Nos. 21 to 36 in Table 2 below, was molten and then subjected to casting in a usual manner, to cast into a billet of diameter 200 mm. The resultant billet was subjected to a homogenization treatment under the conditions of retaining at 610˚C for 4 hours, followed by cutting into a length of 1,000 mm, to give a billet for extrusion. The thus-obtained billet was again heated to 500˚C and then extruded through a mandrel die, thereby preparing a multi-hole tube material having 20 holes.

[0044] The thus-obtained tube materials were subjected to brazing by heating at 600˚C for 3 min under a nitrogen atmosphere, followed by applying thermal history 180˚C, for any time period of 24 hours, 150 hours, 500 hours, 700 hours, 1,000 hours, or 2,000 hours, thereby to prepare test pieces for evaluation of mechanical strength properties. After each thermal history, the room-temperature strength was measured in a state after each material was left standing to cool to the room temperature. The results are shown in Table 3.

Table 2

Classification	No.	Element composition of tube material (mass%)							Extrudability
		Si	Fe	Cu	Mn	Ti	V	Al	
This invention	21	0.1	0.3	0.06	0.5	0.05	0.05	Balance	○
	22	0.2	0.6	0.15	1.1	0.1	0.1	Balance	○
	23	0.2	0.6	0.2	1.1	0.15	0.27	Balance	○
	24	0.1	0.3	0.06	0.5	0.25	0.15	Balance	○
	25	0.5	0.8	0.25	1.5	0.05	0.1	Balance	○
	26	0.3	0.6	0.15	0.8	0.1	0.25	Balance	○
	27	0.3	0.6	0.2	0.8	0.15	0.2	Balance	○
	28	0.5	0.8	0.25	1.5	0.25	0.15	Balance	○
	29	0.1	0.3	0.05	0.5	0.15	0.23	Balance	○
	30	0.3	0.5	0.15	1.1	0.15	0.12	Balance	○
	31	0.2	0.6	0.15	1.1	0.15	0.3	Balance	○
Comparative example	32	1.2	0.7	0.3	0.8	0.1	0.1	Balance	○ (Large scratches on the die)
	33	1.4	0.7	0.3	0.8	0.1	0.1	Balance	○(Large scratches on the die)
	34	0.2	0.7	0.4	1.5	0.1	0.1	Balance	○
	35	0.2	0.7	0.6	1.6	0.1	0.1	Balance	○
Conventional example	36	0.2	0.4	0.4	0.3	0	0	Balance	○
Note) Evaluation for extrudability: "○" good; "×" poor									

Table 3

Classification	No.	Mechanical strength (MPa) *1	Room-temp. strength after thermal history at 180˚C (MPa)						Decrease in room-temp. strength (MPa) *2
			24hr	150hr	500hr	700hr	1,000hr	2,000hr	
This invention	21	134	134	135	133	136	135	132	2
	22	137	137	137	136	137	135	136	1
	23	145	143	144	142	141	144	144	1
	24	135	135	135	133	134	134	135	0
	25	142	142	144	143	145	145	142	0
	26	138	138	137	136	137	138	139	1
	27	141	142	141	143	143	142	140	1
	28	143	143	142	142	142	142	141	2
	29	142	141	142	143	144	140	140	2
	30	139	139	140	138	137	138	140	1
	31	146	145	144	145	145	146	147	1
Comparative example	32	142	140	138	137	133	129	122	20
	33	144	143	137	135	132	129	125	19
	34	143	141	135	135	133	130	126	17
	35	146	144	136	135	134	131	126	20
Conventional example	36	95	90	86	85	75	70	70	25

*1: This represents the room-temperature strength in a state of no heated temperature history applied.
*2: This represents the difference between the room-temperature strength in a state of no heated temperature history applied and the room-temperature strength after applying thermal history at 180˚C for 2,000 hrs.

[0045] As shown in Table 3, the multi-hole tube materials of Nos. 21 to 31 of Examples according to the present invention did not show any decrease in the room-temperature strength even after a thermal history for 24 to 2,000 hours at 180˚C. In contrast, in each of Nos. 32 and 33 of Comparative Examples, since the contents of Si and Cu were too high over the ranges defined in the present invention, a conspicuous decrease in the room-temperature strength was observed when the heating time was long. Further, in each of Nos. 34 and 35 of Comparative Examples, since the contents of Cu and Mn were too high over the ranges defined in the present invention, a conspicuous decrease in the room-temperature strength was observed when the heating time was long, similarly. Further, in Conventional Example No. 36, the mechanical strength was conspicuously insufficient, regardless of before or after applying the thermal history.

(Example 3)

[0046] Each of Al alloys having the respective element composition as shown by Nos. 41 to 56 in Table 4 below, was molten and then subjected to casting in a usual manner, to cast into a billet of diameter 200 mm. The resultant billet was subjected to a homogenization treatment under the conditions of at 610˚C for 4 hours, followed by cutting into a length of 1,000 mm, to give a billet for extrusion. The thus-obtained billet was again heated to 500˚C and then extruded through a mandrel die, thereby preparing a multi-hole tube material having 20 holes.
[0047] The thus-obtained tube materials were subjected to brazing by heating at 600˚C for 3 min under a nitrogen atmosphere, to prepare test pieces for evaluation of high-temperature strength. Then, each of the test pieces was heated to any temperature at 80˚C, 100˚C, 130˚C, 150˚C, or 180˚C, followed by retaining for 15 minutes, and the mechanical strength was measured for each sample at said temperature. The results are shown in Table 5.

Table 4

Classification	No.	Element composition of tube material (mass%)							Extrudability
		Si	Fe	Cu	Mn	Ti	V	Al	Extrudability
This invention	41	0.1	0.3	0.06	0.5	0.05	0.05	Balance	○
	42	0.2	0.6	0.15	1.1	0.1	0.1	Balance	○
	43	0.2	0.6	0.2	1.1	0.15	0.27	Balance	○
	44	0.1	0.3	0.06	0.5	0.25	0.15	Balance	○
	45	0.5	0.8	0.25	1.5	0.05	0.1	Balance	○
	46	0.3	0.6	0.15	0.8	0.1	0.25	Balance	○
	47	0.3	0.6	0.2	0.8	0.15	0.2	Balance	○
	48	0.5	0.8	0.25	1.5	0.25	0.15	Balance	○
	49	0.1	0.3	0.05	0.5	0.15	0.23	Balance	○
	50	0.3	0.5	0.15	1.1	0.15	0.12	Balance	○
	51	0.2	0.6	0.15	1.1	0.15	0.3	Balance	○
Comparative example	52	1.2	0.7	0.3	0.8	0.1	0.1	Balance	○ (Large scratches on the die)
	53	1.4	0.7	0.3	0.8	0.1	0.1	Balance	○ (Large scratches on the die)
	54	0.2	0.7	0.4	1.5	0.1	0.1	Balance	○
	55	0.2	0.7	0.6	1.6	0.1	0.1	Balance	○
Conventional example	56	0.2	0.4	0.4	0.3	0	0	Balance	○
Note) Evaluation for extrudability: "○" good; "×" poor									

Table 5

Classification	No.	Mechanical strength (MPa) *3	High-temperature strength at each retention temperature (MPa)					Decrease in strength after high-temperature retention (MPa) *4
			80°C	100°C	130°C	150°C	180°C	
This invention	41	134	130	128	125	124	114	20
	42	137	135	132	130	126	116	21
	43	145	140	138	136	135	123	22
	44	135	132	130	129	128	116	19
	45	142	138	136	134	132	119	23
	46	138	134	133	131	129	116	22
	47	141	137	135	131	128	114	27
	48	143	139	137	133	124	115	28
	49	142	139	136	130	126	122	20
	50	139	136	131	130	130	117	22
	51	146	139	136	133	131	119	27

(continued)

Classification	No.	Mechanical strength (MPa) *3	High-temperature strength at each retention temperature (MPa)					Decrease in strength after high-temperature retention (MPa) *4
			80°C	100°C	130°C	150°C	180°C	
Comparative example	52	142	138	122	115	97	87	55
	53	144	140	134	120	101	90	54
	54	143	138	128	118	99	86	57
	55	146	140	127	119	98	86	60
Conventional example	56	95	79	78	62	45	38	57

*3: This represents the room-temperature strength in a state of no retention under heating.
*4: This represents the difference between the room-temperature strength in a state of no retention under heating, and the high-temperature strength in a state of retention at 180°C for 15 min.

[0048] As shown in Table 5, each of the multi-hole tube materials of Nos. 41 to 51 of Examples according to the present invention showed a slight decrease in the high-temperature strength at each retention temperature of 130, 150, and 180°C. Contrary to the above, in Comparative Example Nos. 52 and 53, since the contents of Si and Cu were too high over the ranges defined in the present invention, a conspicuous reduction in the high-temperature strength at each of the above temperatures was observed. Further, in Comparative Example Nos. 54 and 55, since the contents of Cu and Mn were too high over the ranges defined in the present invention, a conspicuous reduction in the high-temperature strength at each of the above temperatures was observed, similarly. Further, in Conventional Example No. 56, in addition to the insufficient room-temperature strength from the beginning, the reduction in the high-temperature strength at each temperature was conspicuous.

[0049] Having described our invention as related to the present embodiments, it is our intention that the invention not be limited by any of the details of the description, unless otherwise specified, but rather be construed broadly within its spirit and scope as set out in the accompanying claims.

Claims

1. An aluminum alloy extruded tube material for a heat exchanger using a natural refrigerant, which is composed of an aluminum alloy comprising 0.1 to 0.5% by mass of Si, 0.3 to 0.8% by mass of Fe, 0.5 to 1.5% by mass of Mn, 0.05 to 0.25% by mass of Cu, 0.05 to 0.25% by mass of Ti, and 0.05 to 0.30% by mass of V, the balance being aluminum and an unavoidable impurity(s).

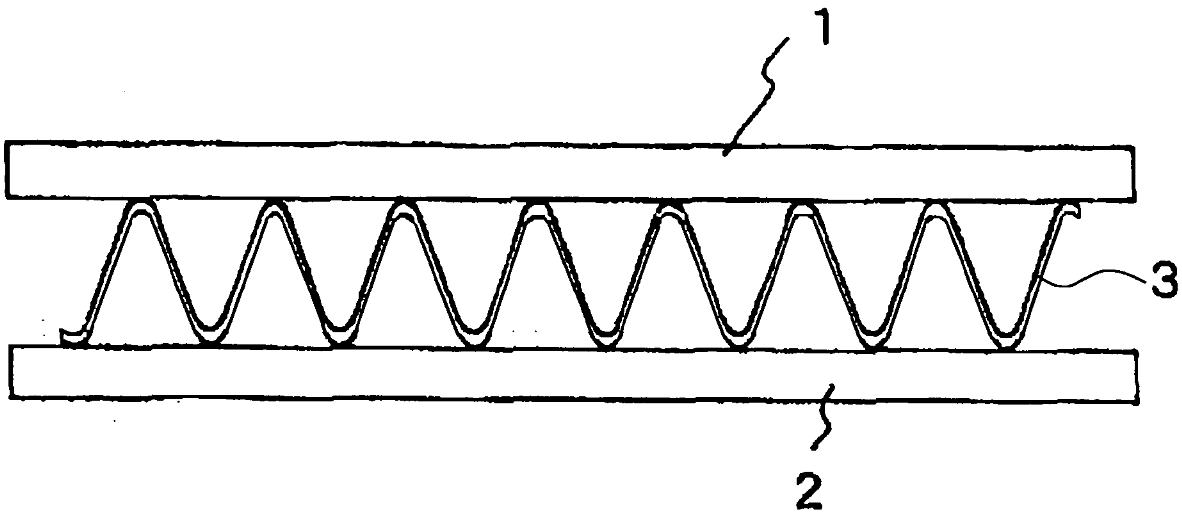
2. The aluminum alloy extruded tube material according to Claim 1, wherein a plurality of refrigerant-flowing holes are formed in the aluminum alloy extruded tube material, to provide a multi-hole extruded tube material.

3. The aluminum alloy extruded tube material according to Claim 1, wherein a sacrificial material is provided on an outer surface of the aluminum alloy extruded tube material.

4. The aluminum alloy extruded tube material according to Claim 3, wherein the sacrificial material is metal Zn or an Al-Zn alloy.

5. The aluminum alloy extruded tube material according to Claim 3, wherein a plurality of refrigerant-flowing holes are formed in the aluminum alloy extruded tube material, to provide a multi-hole extruded tube material.

Fig. 1



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EUROPEAN SEARCH REPORT

Application Number
EP 06 00 9528

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	10 August 2006	Patton, G

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2

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