(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 612 938 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
06.11.2019 Bulletin 2019/45

(21) Application number: **11821611.8**

(22) Date of filing: **23.08.2011**

(51) Int Cl.:
C22C 21/00 $^{(2006.01)}$
F28F 21/08 $^{(2006.01)}$
C22C 21/12 $^{(2006.01)}$
F28F 1/24 $^{(2006.01)}$
C22F 1/04 $^{(2006.01)}$
C22F 1/00 $^{(2006.01)}$
F28F 19/02 $^{(2006.01)}$

(86) International application number:
PCT/JP2011/068973

(87) International publication number:
WO 2012/029594 (08.03.2012 Gazette 2012/10)

(54) HEAT EXCHANGER ALUMINUM ALLOY FIN MATERIAL AND METHOD FOR PRODUCING SAME

LAMELLENMATERIAL AUS EINER ALUMINIUMLEGIERUNG FÜR WÄRMETAUSCHER UND VERFAHREN ZU SEINER HERSTELLUNG

MATÉRIAU D'AILETTE EN ALLIAGE D'ALUMINIUM POUR ÉCHANGEUR DE CHALEUR ET SON PROCÉDÉ DE PRODUCTION

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **31.03.2011 JP 2011080856**
03.09.2010 JP 2010198326

(43) Date of publication of application:
10.07.2013 Bulletin 2013/28

(73) Proprietor: **Kobe Steel, Ltd.**
Kobe, Hyogo 651-8585 (JP)

(72) Inventors:
- **KANEDA, Daisuke**
  Tochigi, 321-4367 (JP)
- **UMEDA, Hidetoshi**
  Tochigi, 321-4367 (JP)
- **OTA, Yosuke**
  Tochigi, 321-4367 (JP)
- **HOSHINO, Kozo**
  Tokyo, 141-8688 (JP)

(74) Representative: **Elkington and Fife LLP**
Prospect House
8 Pembroke Road
Sevenoaks, Kent TN13 1XR (GB)

(56) References cited:
JP-A- H 032 343
JP-A- 3 002 343
JP-A- 5 230 579
JP-A- 9 137 242
JP-A- 11 080 869
JP-A- 58 224 156
JP-A- 2005 264 289
JP-A- 2006 104 488
JP-A- S 648 240
JP-A- 4 371 541
JP-A- 8 313 191
JP-A- 9 176 805
JP-A- 57 155 340
JP-A- 59 190 346
JP-A- 2006 104 488
JP-A- 2009 250 510

Printed by Jouve, 75001 PARIS (FR)

Description

Technical Field

[0001] The present invention relates to an aluminum alloy fin material for use in heat exchangers, and a manufacturing method of the aluminum alloy fin material.

Background Art

[0002] Air conditioners should recently employ non-CFC refrigerants instead of CFCs to meet controlling of the production and consumption of CFCs and, in addition, should have smaller sizes and smaller weights, or should exhibit higher functions. To meet these requirements, aluminum alloy fin materials for use in heat exchangers typically of air conditioners (hereinafter also conveniently referred to as "fin material(s)") require smaller and smaller thicknesses. For example, some aluminum alloy fin materials have small sheet thicknesses of about 0.15 mm or less, and some recent ones have further smaller thicknesses of down to about 0.09 mm.

[0003] Forming processes of fins may be categorized as a drawing process, a drawless process, and a drawing-drawless composite process (combination process). The draw process includes the steps of bulging, drawing, piercing-burring, and reflaring. The drawless process includes the steps of piercing-burring, ironing, and reflaring. The combination process mainly includes the steps of bulging, drawing, piercing-burring, ironing, and reflaring.

[0004] In any of the forming processes, the piercing-burring step and the reflaring step for the formation of collars around holes for copper tubes are essential forming steps for fins. These forming processes, however, act severely upon fin materials designed to have small thicknesses of 0.15 mm or less. Fin materials having improved workability have been developed so as to meet such reduction requirements in thickness.

[0005] Typically, Patent Literature (PTL) 1 discloses an aluminum alloy fin material which has a thickness of 0.12 mm or less, contains Si and Fe in a predetermined ratio and in predetermined amounts, and has a maximum grain size of 30 μm or less. This aluminum alloy fin material has excellent workability in drawing to form a fin. PTL 2 discloses a heat-exchanging aluminum alloy fin material which has a thickness of less than 0.11 mm, contains Fe and Ti in predetermined amounts, has Si and Cu contents controlled to predetermined levels or less, and has a predetermined elongation percentage. This aluminum alloy fin material excels in resistance to "avec" phenomenon (fin-pitch disorder) and stacking properties.

[0006] PTL 3 discloses an Al alloy for a heat-exchanger fin containing, by weight, 0.8-2.0% Fe, 0.05-0.5% Cu, and 0.01-0.15% Ti, wherein the Si content is limited to $\leq$0.10% and the remainder being Al and inevitable impurities.

Citation List

Patent Literature

[0007]

PTL 1: Japanese Unexamined Patent Application Publication (JP-A) No. H11-80869
PTL 2: Japanese Patent No. 4275560
PTL 3: Japanese Unexamined Patent Application Publication (JP-A) No. H03-2343

Summary of Invention

Technical Problem

[0008] The customary fin materials, however, have disadvantages as mentioned below.

[0009] While the customary techniques are intended to improve workability, demands are still made to further improve workability, because recent heat exchangers are demanded to have further reduced sizes and weights or to have further higher functions, and, in addition, fin materials enabling easier processing or working is expected to be supplied.

[0010] Fin materials may often suffer from cracks called "collar cracks" during forming. Specifically, fine cracks are generated at worked edges during the piercing and burring step and become collar cracks in the final reflare forming. Collar cracks, if generated, may facilitate the occurrence of a so-called "avec phenomenon" in which pitches of stacked fins are extremely narrowed when a copper tube is passed through a collared hole and is expanded in a formed article after fin forming. The avec phenomenon disadvantageously increases draft resistance of the heat exchanger. Specifically, collar cracks disadvantageously not only impair appearance of fins but also cause troubles such as insufficient performance of the heat exchanger to thereby impair the product value. To avoid these, demands have been made to develop a fin material that less suffers from the generation of collar cracks.

[0011] The present invention has been made under these circumstances, and an object thereof is to provide an aluminum alloy fin material for heat exchangers, which is satisfactorily resistant to collar cracking and less suffers from the generation of collar cracks upon forming process.

Solution to Problem

[0012] Specifically, the present invention provides an aluminum alloy fin material for heat exchangers, which includes Fe in a content of 0.20 to 1.0 % by mass, Cu in a content of 0.02 to 0.1 % by mass, Si in a content of 0% by mass or more and 0.15 % by mass or less, Mn in a content of 0% by mass or more and 0.015 % by mass or less, Cr in a content of 0% by mass or more and 0.015 % by mass or less, further including Al and inevitable impurities, and optionally further including Ti in a content of 0.01 to 0.08 % by mass, in which the aluminum alloy fin material has a thickness of 0.1 mm or less; and the aluminum alloy fin material has an average subgrain size of 2.5 μm or less and a volume fraction of β-fiber of 80% or more.

[0013] The fin material having this configuration may exhibit advantages as below. Specifically, the fin material, as containing Fe and Cu in predetermined amounts, has higher strengths due to solid-solution strengthening. The fin material also includes fine subgrains, thereby exhibits a better elongation and undergoes sufficient formation of the β-fiber. The fin material, as having Si, Mn, and Cr contents controlled within predetermined levels or less, is protected from coarsening of precipitates (i.e., intermetallic compounds). In addition, the fin material, as having an average subgrain size of 2.5 μm or less and a volume fraction of the β-fiber of 80% or more, has better resistance to collar cracking.

[0014] The aluminum alloy fin material according to the present invention may further contain Ti in a content of 0.01 to 0.08 % by mass.

[0015] The fin material, as having this configuration and containing Ti in a predetermined amount, may have a fine ingot structure.

[0016] The aluminum alloy fin material according to the present invention may have a surface-treatment coating film on a surface thereof. The surface-treatment coating film is typified by a corrosion resistant coating film, a hydrophilic coating film, and a lubricative coating film.

[0017] The fin material having this configuration can be improved in properties such as corrosion resistance, hydrophilicity, or formability, according to the use environment and intended use.

[0018] In addition and advantageously, the present invention provides a method for manufacturing the aluminum alloy fin material according to the present invention. This method is a method for manufacturing the aforementioned aluminum alloy fin material (one not having a surface-treatment coating film) and includes the steps of heat-treating an aluminum alloy ingot having the chemical composition at a temperature of 450°C to 510°C for a holding time of one hour or longer (heat treatment step); hot-rolling the aluminum alloy ingot after the heat treatment under such conditions that a finish temperature of hot finish rolling be 250°C or higher and lower than 300°C (hot rolling step); cold-working the aluminum alloy material after the hot rolling with a cold working ratio of 96% or more (cold working step); and temper-annealing the aluminum alloy material after the cold working by holding the material at a temperature of 160°C to 250°C for a holding time of 1 to 6 hours (temper annealing step).

[0019] According to the manufacturing method, the heat treatment step homogenizes the ingot structure, and the hot rolling step rolls the ingot into a hot-rolled sheet without becoming a recrystallization structure. The cold working step allows the sheet to have a thickness of 0.1 mm or less without causing coarsening of subgrains or insufficient formation of the β-fiber after the temper annealing; and the temper annealing step allows the structure to sufficiently recover. These steps give an aluminum alloy fin material having an average subgrain size of 2.5 μm or less and a volume fraction of β-fiber of 80% or more.

Advantageous Effects of Invention

[0020] The aluminum alloy fin material according to the present invention less suffers from collar cracks upon forming process and is thereby protected from disadvantages such as poor appearance of the fin and insufficient performance of the heat exchanger.

[0021] The method for manufacturing an aluminum alloy fin material according to the present invention enables manufacturing of an aluminum alloy fin material having excellent resistance to collar cracking.

Description of Embodiments

[0022] Some embodiments of the aluminum alloy fin material according to the present invention (hereinafter also conveniently referred to as "fin material") and the manufacturing method of the fin material will be illustrated below.

<Fin Material>

[0023] A fin material according to an embodiment of the present invention contains Fe and Cu in predetermined amounts, has Si, Mn, and Cr contents controlled to predetermined levels or less, and further contains Al and inevitable impurities. The fin material has a thickness of 0.1 mm or less and has a specific average subgrain size of 2.5 μm or less and a specific volume fraction of β-fiber of 80% or more. The fin material may further contain Ti in a predetermined amount according to necessity.

[0024] Hereinafter the chemical composition will be described first, followed by description of other configurations.

Fe: 0.20 to 1.0 % by mass

[0025] Iron (Fe) element is added to contribute to higher strengths due to solid-solution strengthening, better corrosion resistance, and higher elongation due to finer subgrains. Fe, if contained in a content of less than 0.20 % by mass, may fail to exhibit these effects sufficiently. In contrast, Fe, if contained in a content of more than 1.0 % by mass, may impair the corrosion resistance and may cause precipitates (intermetallic compounds) to be coarse, and such coarse precipitates may act as stress concentration points upon forming process to cause cracks. To avoid these, the Fe content may be 0.20 to 1.0 % by mass.

Cu: 0.02 to 0.1 % by mass

[0026] Copper (Cu) element is added in a trace amount to contribute to higher strengths due to solid-solution strengthening, better elongation due to finer subgrains, and sufficient formation of the β-fiber. Cu, if contained in a content of less than 0.02 % by mass, may not exhibit these effects sufficiently. In contrast, Cu, if contained in a content of more than 0.1 % by mass, may cause work hardening, thereby impair resistance to "avec" phenomenon (fin-pitch disorder), and invite insufficient resistance to collar cracking and insufficient corrosion resistance. To avoid these, the Cu content may be 0.02 to 0.1 % by mass. The Cu content is more preferably 0.031 to 0.06 % by mass, and furthermore preferably 0.04 to 0.06 % by mass.

Si: 0 % by mass or more and 0.15 % by mass or less

[0027] Silicon (Si) element is contained as an inevitable impurity. Si, if contained in a content of more than 0.15 % by mass, may cause precipitates (intermetallic compounds) to be coarse, and such coarse precipitates may act as stress concentration points upon forming process to cause cracks. To avoid these, the Si content is controlled to 0.15 % by mass or less. The Si content may be controlled down to 0 % by mass.

Mn: 0 % by mass or more and 0.015 % by mass or less

[0028] Manganese (Mn) element is included as an inevitable impurity. Mn, if contained in a content of more than 0.015 % by mass, may cause precipitates (intermetallic compounds) to be coarse, and such coarse precipitates may act as stress concentration points upon forming process to cause cracks. To avoid these, the Mn content is controlled to 0.015 % by mass or less. The Mn content may be controlled down to 0 % by mass.

Cr: 0 % by mass or more and 0.015 % by mass or less

[0029] Chromium (Cr) element is included as an inevitable impurity. Cr, if contained in a content of more than 0.015 % by mass, may cause precipitates (intermetallic compounds) to be coarse, and such coarse precipitates may act as stress concentration points upon forming process to cause cracks. To avoid these, the Cr content is controlled to 0.015 % by mass or less. The Cr content may be controlled down to 0 % by mass.

Ti: 0.01 to 0.08 % by mass

[0030] Titanium (Ti) may be added as an Al-Ti-B intermediate alloy so as to allow the ingot to have a finer structure. Specifically, an Al-Ti-B ingot refiner containing Ti and B in a ratio of titanium to boron (T:B) of 5:1 or 5:0.2 may be added in the form of a waffle or rod to a molten metal. The resulting aluminum alloy may contain Ti in a content of up to 0.08 % by mass. The molten metal herein is one before solidification into a slab and fed into any of a melting furnace, inclusion filter, degassing apparatus, or molten metal flow rate controller. Ti, if contained in a content of less than 0.01 % by mass, may not effectively allow the ingot to have a finer structure. In contrast, Ti, if contained in a content of more than 0.08 % by mass, may cause precipitates (intermetallic compounds) to be coarse, and such coarse precipitates may act as stress concentration points upon forming process to cause cracks. To avoid these, the content of Ti, when added, is preferably 0.01 to 0.08 % by mass.

Remainder: Al and inevitable impurities

[0031] The fin material contains the above chemical compositions (elements) and further contains Al and inevitable impurities. The inevitable impurities are typified by the aforementioned elements, i.e., Si, Mn, and Cr, as well as other elements such as Mg, Zn, Ga, V, and Ni. These elements may be contained in the ingot and/or in the intermediate alloy within generally known ranges and may be contained in the fin material each in a content of at most 0.015 % by mass.

Thickness: 0.1 mm or less

[0032] The present invention is applied to fin materials having a thickness of 0.1 mm or less, so as to allow the fin materials to have smaller thicknesses to meet the recent requirements of heat exchangers such as reduction in size and weight, and higher functions. Accordingly, the fin material according to the present invention has a thickness of 0.1 mm or less.

Average Size of Subgrains: 2.5 μm or less

[0033] To exhibit a higher elongation, the fin material having a small thickness of 0.1 mm or less should have an average subgrain size in the alloy of 2.5 μm or less. A fin material having an average subgrain size of more than 2.5 μm may not have a sufficient elongation. To avoid this, the fin material has an average subgrain size of 2.5 μm or less. The average subgrain size is not specified in its lower limit, but may be 0 μm (namely, the fin material does not have to contain subgrains). The fin material, as having an average subgrain size within this range, less suffers from the generation of collar cracks, even when undergoing work hardening by the action typically of solute Mn or solute Cu.

Volume Fraction of β-Fiber: 80% or more

[0034] As used herein the term "β-fiber" refers to a rolling texture of a face-centered cubic metal and refers to a total sum of Copper orientation, S orientation, and Brass orientation.

[0035] To have a higher elongation, the fin material having a small thickness of 0.1 mm or less should have a volume fraction of β-fiber in the alloy of 80% or more. A fin material having a volume fraction of β-fiber of less than 80% may suffer from the generation of collar cracks with a decreasing Lankford value. The volume fraction of β-fiber is not specified in its upper limit, but may be 100%.

[0036] Next, ways to measure the average subgrain size and the volume fraction of β-fiber will be illustrated.

[0037] Initially, a structure imaged in the observation under a scanning electron microscope (SEM) is subjected to orientation analysis by an electron backscattered diffraction pattern (EBSP) technique. In the EBSP technique, a specimen is irradiated with electron beams, and crystal orientations are identified using an electron backscattered diffraction pattern formed upon irradiation. The crystal orientations can be analyzed by employing OIM (Orientation Imaging Microscopy: registered trademark) supplied by TexSEM Laboratories, Inc. The volume fraction of β-fiber is calculated based on the crystal orientation analysis.

[0038] The average subgrain size is determined by calculating the number of grains based on SEM/EBSP measurement data, dividing the total area of the fin material by the number of grains, approximating the area of each grain to a circle, determining the diameter of the circle, and defining the diameter as the average subgrain size.

[0039] The average subgrain size and the volume fraction of β-fiber can be controlled by the chemical composition and manufacturing conditions mentioned later. Specifically, the average subgrain size may be controlled by contents of respective elements, soaking conditions (temperature and time), finish temperature of hot finish rolling, cold working ratio, and temper annealing conditions (temperature and time). The volume fraction of β-fiber may be controlled by contents of respective elements, soaking conditions (temperature and time), finish temperature of hot finish rolling, cold working ratio, and temper annealing conditions (temperature and time).

[0040] The fin material according to the present invention may further have a surface-treatment coating film on a surface thereof. The term "surface" of the fin material refers to one side or both sides of the fin material.

Surface-treatment Coating Film

[0041] The surface-treatment coating film may be typified by chemical conversion coating films, resin coating films, and inorganic coating films as chosen according to the use environment and intended use. Each of these coating films may be employed in combination. Specifically, a resin coating film and/or an inorganic coating film may be provided on a chemical conversion coating film. The resin coating films and the inorganic coating films are typified by corrosion resistant resin coating films, hydrophilic resin coating films, hydrophilic inorganic coating films, and lubricative resin coating films, and each of them may be employed in combination according to necessity.

[0042] The chemical conversion coating films are exemplified by phosphate-chromate coating films. The corrosion resistant resin coating films are exemplified by coating films of resins such as epoxy, urethane, acrylic, and polyester resins. These coating films preferably have a thickness of 0.5 to 5 μm. The hydrophilic coating films are typified by coating films of water-glass inorganic substances; resins containing a poly(acrylic acid) or a poly(acrylic acid salt); and resins containing a sulfonic group or a sulfonic group derivative. These coating films preferably have a thickness of 0.05 to 10 μm. The lubricative resin coating films are typified by coating films of resins containing a polyetherpolyol and preferably have a thickness of 0.1 to 10 μm.

[0043] When two or more of such a corrosion resistant resin coating film, a hydrophilic resin coating film, a hydrophilic inorganic coating film, and a lubricative resin coating film are employed in combination, it is preferred that a hydrophilic resin coating film is provided on a corrosion resistant resin coating film; and that a lubricative resin coating film is provided on a hydrophilic resin coating film or hydrophilic inorganic coating film.

<Manufacturing Method for Fin Material>

[0044] A method for manufacturing the fin material according to the present invention is a method for manufacturing the fin material and includes a heat treatment step, a hot rolling step, a cold working step, and a temper annealing step. Where necessary, the method may further include an ingot-making step and/or a surface treatment step.

[0045] The respective steps will be illustrated below.

Ingot-making Step

[0046] The ingot-making step is the step of melting and casting an aluminum alloy to make an aluminum alloy ingot.

[0047] In the ingot-making step, an aluminum alloy having the aforementioned chemical composition is melted to give a molten metal, and the molten metal is cast into an ingot having a predetermined shape. The aluminum alloy may be melted and cast according to a known procedure not limited. Typically, the aluminum alloy may be melted in a vacuum induction furnace and cast through continuous casting or semi-continuous casting.

Heat Treatment Step

[0048] The heat treatment step is the step of subjecting an aluminum alloy ingot having the chemical composition to a heat treatment (soaking) at a temperature of 450°C to 510°C for a holding time of one hour or longer.

[0049] A heat treatment at a temperature of lower than 450°C may not sufficiently homogenize (soak) the ingot structure, invite insufficient hot workability, and further cause a larger average subgrain size and a smaller volume fraction of β-fiber. In contrast, a heat treatment at a temperature of higher than 510°C may cause fine intermetallic compounds, which will have smaller grain sizes during heating, to be coarse and thereby cause coarse subgrains, resulting in insufficient elongation, and cause a larger amount of solid solution. To avoid these, the heat treatment may be performed at a temperature of 450°C to 510°C. There is no need for specifying the upper limit of the holding time in the heat treatment because the heat treatment can exhibit the effects as long as performed for a holding time of one hour or longer. However, a heat treatment for a holding time longer than 10 hours may exhibit saturated effects, and from the economical viewpoint, the heat treatment is preferably performed for a holding time of 1 to 10 hours.

Hot Rolling Step

[0050] The hot rolling step is the step of subjecting the material after the heat treatment to hot rolling under such conditions that a finish temperature of hot finish rolling be 250°C or higher and lower than 300°C.

[0051] A hot finish rolling performed with a finish temperature of lower than 250°C may cause insufficient rolling properties of the material, and this may impede rolling itself or impede the thickness control, resulting in poor productivity. In contrast, a hot finish rolling performed with a finish temperature of 300°C or higher may cause the resulting hot-rolled sheet to have a recrystallized structure, and the recrystallized structure may form a group of fibrous crystals having an identical crystal orientation to cause necking in the piercing and burring step. This hot finish rolling may also cause the fin material to have a small volume fraction of β-fiber. To avoid these, the hot finish rolling may be performed with a finish temperature of 250°C or higher and lower than 300°C and is more preferably performed with a finish temperature of 260°C to 290°C.

Cold Working Step

[0052] The cold working step is the step of subjecting the material after the hot rolling to a cold working (cold rolling) to a cold working ratio of 96% or more.

[0053] After the completion of the hot rolling, the cold working is performed once or multiple times to allow the fin material to have a desired final thickness. However, a cold working performed to a cold working ratio of less than 96% may cause the fin material to have coarse subgrains after the temper annealing and to suffer from insufficient formation of β-fiber. To avoid these, the cold working is performed to a cold working ratio of 96% or more. If a process annealing is performed in the middle of cold working, the term "cold working ratio" refers to a reduction of area after the process annealing down to the final thickness. Accordingly, a process annealing is not employed herein because, if a process annealing is performed, a cold working ratio of 96% or more may not be achieved. The upper limit of the cold working ratio is not critical, because the higher cold working ratio is, the better.

Temper Annealing Step

[0054] The temper annealing (refining heat treatment) step is the step of subjecting the fin material after the cold working to a temper annealing (final annealing) at a temperature of 160°C to 250°C for a holding time of 1 to 6 hours.

[0055] A temper annealing at a temperature of lower than 160°C may not achieve sufficiently effective recovery of the structure. In contrast, a temper annealing at a temperature of higher than 250°C may cause the generation of recrystallized grains after the heat treatment, and these recrystallized grains may cause cracks. In addition, the fin material may fail to have sufficiently fine subgrains and suffer from insufficient formation of β-fiber. To avoid these, the temper annealing may be performed at a temperature of 160°C to 250°C.

[0056] When the fin material is to be subjected to drawless forming, the temper annealing is preferably performed at a temperature of up to 210°C in terms of upper limit. When a fin material having undergone a temper annealing at a temperature of higher than 210°C is subjected to drawless forming, the fin material may be liable to exhibit somewhat lower formability than one having undergone combination forming. However, a fin material having undergone a temper annealing at a temperature of 210°C or lower may exhibit further better formability than one having undergone a temper annealing at a temperature of higher than 210°C. For these reasons, the temper annealing on a fin material to be subjected to drawless forming is preferably performed at a temperature of 160°C to 210°C.

[0057] The temper annealing is generally performed for a holding time of one hour or longer, and a temper annealing performed for a holding time of longer than 6 hours may exhibit saturated effects. For these reasons, the temper annealing is economically preferably performed for a holding time of 1 to 6 hours.

Surface Treatment Step

[0058] The surface treatment step is the step of applying a surface treatment to the fin material after the temper annealing.

[0059] A chemical conversion coating film, when to be formed in the surface treatment step, may be formed by a chemical conversion treatment using a common coat-type or reactive agent. A resin coating film, when to be formed, may be formed by applying a resin composition using a roll coater and drying the applied film. The resin coating film is typified by a corrosion resistant resin coating film, a hydrophilic resin coating film, and a lubricative resin coating film.

[0060] The method according to the present invention may further include one or more other steps between, before, or after the respective steps within ranges not adversely affecting the respective steps. Typically, the method may further include one or more of steps such as foreign substance removing step for removing foreign substances such as dust; facing step of applying facing to the ingot; and machining step of suitably performing machining so as to provide a fin material after the temper annealing step or the surface treatment step.

[0061] The resulting fin material according to the present invention may be subjected to a forming process according to the type of forming procedure and is particularly advantageously subjected to drawless forming or combination forming.

[0062] The drawless forming performs piercing and burring (piercing and burring forming) in the first step; ironing in the second and third steps; and reflaring in the fourth step. The combination forming performs bulging in the first step; draw forming in the second step; piercing and burring (piercing and burring forming) in the third step; ironing in the fourth step; and reflaring in the fifth step. The fin material according to the present invention excels in resistance to collar cracking and thereby less suffers from collar cracks upon these forming processes.

EXAMPLES

[0063] While having been described with reference to embodiments thereof, the present invention will be illustrated in further detail with reference to several working examples exhibiting advantageous effects of the present invention in comparison to comparative examples not satisfying the conditions specified in the present invention.

[Preparation of Specimens]

Examples Nos. 1 to 11 and Comparative Examples Nos. 12 to 20

[0064] Aluminum alloys having compositions given in Table 1 were melted and cast into ingots, the ingots were subjected to facing and subsequently to soaking at 480°C for 4 hours. The soaked (homogenized) ingots were subjected to hot rolling controlled so as to perform hot finish rolling with a finish temperature of 270°C, and yielded hot-rolled sheets having a thickness of 3.0 mm. The hot-rolled sheets were respectively subjected to cold rolling to a cold working ratio of about 97.0% or about 97.3% so as to have a thickness of 90 μm or 80 μm, subjected to temper annealing at temperatures for holding times each given in Table 1, and thereby yielded fin materials.

Examples Nos. 21 to 26 and Comparative Examples Nos. 27 to 33

[0065] Aluminum alloys given in Table 2 (corresponding to Alloys A, B, and D in Table 1) were melted and cast into ingots, the ingots were subjected sequentially to facing, soaking, and hot rolling, and thereby yielded hot-rolled sheets having a thickness of 3.0 mm. The specimens other than No. 33 were respectively subjected to cold rolling to a cold working ratio of about 97.0% or about 97.3% so as to have a thickness of 90 μm or 80 μm, subjected to temper annealing, and thereby yielded fin materials. In Specimen No. 33, the hot-rolled sheets having a thickness of 3.0 mm were subjected to cold rolling to a cold working ratio of 50%, and then subjected to a process annealing in a batch furnace at 360°C for 3 hours. The sheets were then respectively subjected to cold rolling to a cold working ratio of about 94.0% or about 94.7% so as to have a thickness of 90 μm or 80 μm, subjected to temper annealing, and thereby yielded fin materials. Soaking conditions, finish temperatures of hot finish rolling, and temper annealing conditions are as indicated in Table 2. Specimen No. 29 was impossible to manufacture a fin material.

Examples Nos. 34 to 37 and Comparative Examples Nos. 38 to 41

[0066] Following surface treatments (Nos. 1 to 4) were performed on fin materials of Nos. 34 and 35 (corresponding to No. 21 in Table 2); fin materials of Nos. 36 and 37 (corresponding to No. 22 in Table 2); fin materials of Nos. 38 and 39 (corresponding to No. 27 in Table 2); and fin materials of Nos. 40 and 41 (corresponding to No. 32 in Table 2).

[0067] Surface Treatment No. 1: a surface treatment under the same conditions as Comparative Example 1 in JP-A No. 2010-223520 (to provide a chemical conversion coating film, a hydrophilic coating film, and a lubricative coating film in this order)

[0068] Surface Treatment No. 2: a surface treatment under the same conditions as Example 1 in Japanese Patent No. 3383914 (to provide a chemical conversion coating film, a hydrophilic coating film, and a lubricative resin coating film in this order)

[0069] Surface Treatment No. 3: a surface treatment under the same conditions as Example 1 in JP-A No. 2008-224204 (to provide a chemical conversion coating film, a corrosion resistant resin coating film, and a hydrophilic coating film in this order)

[0070] Surface Treatment No. 4: a surface treatment under the same conditions as Comparative Example 21 in JP-A No. 2010-223514 (to provide a chemical conversion coating film and a corrosion resistant resin coating film in this order)

[0071] The chemical compositions are given in Table 1, and manufacturing conditions are given in Tables 2 and 3. In these tables, data not falling within a range specified in the present invention are underlined, and a composition (element) not contained is indicated by "-". Specimen No. 29 was impossible to manufacture a fin material and is indicated by "-" in the temper annealing. Specimen No. 19 (Alloy C) corresponds to an aluminum alloy fin material described in PTL 2; Specimen No. 20 (Alloy D) corresponds to an aluminum alloy fin described in PTL 1 but manufactured under different conditions; and Specimen No. 32 corresponds to an aluminum alloy sheet described in PTL 1.

[0072] Next, the average subgrain sizes and volume fractions of β-fiber of the fin materials in terms of their structure morphologies were measured by the following methods. In addition, strengths and elongations thereof were measured by the following methods.

[Average Subgrain Size]

[0073] An average subgrain size was measured in the following manner. The structure of a specimen surface was imaged in the observation under a scanning electron microscopic (SEM) at a 1000-fold magnification, orientations of which were analyzed by EBSP at measurement intervals of 0.10 μm to give data, and the data were automatically calculated on OIM (Orientation Imaging Microscopy: registered trademark) software supplied by TexSEM Laboratories, Inc. to give an average subgrain size. Specifically, the number of grains was counted based on the SEM/EBSP measured data, the total area of the specimen fin material was divided by the number of grains, the area of each grain was approximated to a circle, and a diameter of the circle was defined as the average subgrain size. The number of grains was counted so that a grain surrounded by grain boundaries with a difference in orientation between adjacent grains of 2° or less is defined as one grain.

[Volume Fraction of β-Fiber]

[0074] A volume fraction of β-fiber was measured in the following manner. The structure of a specimen surface was imaged in the observation under a scanning electron microscope (SEM) at a 1000-fold magnification, orientations of which were analyzed by EBSP at measurement intervals of 0.10 μm to give data, and the data were automatically calculated on OIM (Orientation Imaging Microscopy: registered trademark) software supplied by TexSEM Laboratories, Inc. to give a volume fraction of β-fiber. Specifically, a total of volume fractions of Brass orientation, S orientation, and Copper orientation in the area of a total field of view of 2 mm by 2 mm or more of the image of the specimen surface was defined as the volume fraction of β-fiber. For each orientation, orientations within 15° from the ideal orientation were analyzed as an identical orientation component.

[Strength and Elongation]

[0075] From the fin materials, Japanese Industrial Standard (JIS) No. 5 tensile specimens were cut so that the tensile direction be parallel to the rolling direction. The specimens were subjected to tensile tests according to JIS Z 2241 to measure a tensile strength and an elongation. The tensile tests for the evaluation of the examples and comparative examples were performed at a tensile speed of 5 mm/min.

[Evaluations]

[0076] The prepared fin materials were stamped (press-formed) through drawless forming and combination forming, respectively, and examined on resistance to collar cracking.

[0077] The resistance to collar cracking was evaluated by visually counting cracks generated in collars around 400 holes formed by stamping.

[0078] A frequency was calculated according to the expression: "(Number of cracks)/400×100 (%)". A sample having a frequency of less than 5% was evaluated as excellent, a sample having a frequency of 5% or more and less than 10% was evaluated as good, a sample having a frequency of 10% or more and less than 20% was evaluated as fair, and a sample having a frequency of 20% or more was evaluated as failure. A sample evaluated as any of excellent, good, and fair in all the specimens having thicknesses of 90 μm and 80 μm formed through drawless forming and the specimens thicknesses of 90 μm and 80 μm formed through combination forming was evaluated as accepted.

[0079] The results of measurements and evaluations are indicated in Tables 1 to 3. In Tables 1 to 3, data out of a range specified in the present invention are underlined, and data on a sample which was impossible to give a fin material and was impossible to measure and evaluate is indicated by "-".

TABLE 1

Category	No.	Alloy type	Chemical composition (in mass %)*							Temper annealing (°C × hr)	Structural form		Mechanical properties		Resistance to collar cracking			
			Si	Fe	Cu	Ti	Mn	Cr	Al		Average sub-grain size (μm)	Volume fraction of β-fiber (%)	Tensile strength (MPa)	Elongation (%)	Drawless		Combination	
															90 μm	80 μm	90 μm	80 μm
Example	1	A	0.05	0.3	0.05	-	-	-	99.53	170 × 4	1.1	94	158	3.2	excellent	good	good	fair
	2		0.05	0.3	0.05	-	-	-	99.52	230 × 4	2.2	83	112	28.2	good	fair	excellent	good
	3		-	0.6	0.08	-	-	-	99.24	170 × 4	1.3	90	156	3.4	excellent	good	good	fair
	4		0.03	0.6	0.08	-	-	-	99.25	230 × 4	2.3	84	108	27.9	good	fair	excellent	good
	5		0.07	0.7	0.031	0.01	0.005	0.003	99.10	170 × 4	1.2	86	160	2.5	excellent	good	good	fair
	6		0.08	0.4	0.031	0.01	0.002	-	99.45	170 × 4	1.1	92	157	2.8	excellent	good	good	fair
	7		0.08	0.4	0.02	-	-	-	99.45	230 × 4	1.9	85	110	27.4	good	fair	excellent	good
	8		0.04	0.7	0.031	-	0.002	0.002	99.2	170 × 4	1.4	86	156	3.0	excellent	good	good	fair
	9		0.12	0.8	0.031	0.02	-	-	99.01	200 × 4	1.6	88	132	12.5	good	good	good	good
	10		0.08	0.8	0.04	-	0.003	-	99.05	200 × 4	1.7	90	127	13.8	good	good	good	good
	11	B	0.07	0.6	0.031	-	-	0.002	99.26	230 × 4	2.1	82	112	27.5	good	fair	excellent	good
Comparative Example	12		0.20	0.7	0.04	-	-	-	99.03	230 × 4	2.5	83	108	27.2	failure	failure	fair	failure
	13		0.04	0.1	0.05	-	-	-	99.79	230 × 4	3.8	82	111	28.2	failure	failure	failure	failure
	14		0.07	1.5	0.02	-	-	-	98.38	200 × 4	2.4	85	134	13.2	fair	failure	fair	failure
	15		0.05	0.3	0.01	-	-	-	99.62	230 × 4	3.1	75	104	27.5	failure	failure	fair	failure
	16		0.04	0.7	0.30	-	-	-	98.95	200 × 4	2.4	81	123	16.1	fair	failure	failure	failure
	17		0.08	0.8	0.03	-	0.018	-	99.06	170 × 4	2.4	82	158	2.6	fair	failure	failure	failure
	18		0.07	0.6	0.03	-	-	0.017	99.26	200 × 4	2.3	83	136	13.2	fair	failure	fair	failure
	19	C	0.06	0.74	0.03	0.09	-	-	99.07	230 × 6	2.3	82	107	27.3	failure	failure	fair	fair
	20	D	0.06	0.92	-	-	-	-	99.01	260 × 4	4.0	76	98	30.2	failure	failure	fair	fair

* The remainder including inevitable impurities

TABLE 2

Category	No.	Alloy type	Soaking (°C×hr)	Finish temperature of hot finish rolling (°C)	Process annealing	Temper annealing (°C × hr)	Structural form		Mechanical properties		Resistance to collar cracking			
							Average sub-grain size (μm)	Volume fraction of β-fiber (%)	Tensile strength	Elongation	Drawless		Combination	
									(MPa)	(%)	90 μ m	80 μ m	90 μ m	80 μ m
Example	21	A	450 × 4	275	None	160 × 4	1.0	91	161	1.5	excellent	good	good	fair
	22	B	480 × 4	278	None	185 × 4	1.3	86	143	4.3	excellent	good	good	fair
	23	A	470 × 4	265	None	210 × 4	1.6	88	118	19.2	good	good	good	good
	24	B	500 × 4	260	None	230 × 4	2.2	85	103	22.5	good	fair	excellent	good
	25	B	460 × 24	270	None	170 × 4	1.1	90	152	2.1	excellent	good	good	fair
	26	B	480 × 4	270	None	245 × 4	2.5	86	97	20.1	good	fair	excellent	good
Comparative Example	27	B	400 × 4	277	None	240 × 4	2.8	75	95	18.5	failure	failure	fair	failure
	28	A	540 × 4	272	None	240 × 4	3.1	82	107	26.5	failure	failure	fair	failure
	29	A	500 × 4	245	None	–	–	–	–	–	–	–	–	–
	30	A	480 × 4	320	None	190 × 4	1.6	76	135	8.2	failure	failure	failure	failure
	31	B	480 × 4	276	None	260 × 4	2.9	76	98	19.2	failure	failure	fair	failure
	32	D	540 × 4	246	None	260 × 4	3.2	72	103	25.8	failure	failure	failure	failure
	33	A	480 × 4	276	Performed*	190 × 4	4.5	68	125	15.6	failure	failure	failure	failure

*Annealing at 360°C for 3 hr was performed in a batch furnace after cold working to a reduction of area of 50% (to a thickness of 1.5 mm)

TABLE 3

Category	No.	Alloy type	Soaking (°C × hr)	Finish temperature of hot finish rolling (°C)	Process annealing	Temper annealing (°C × hr)	Surface treatment No.	Structural form		Mechanical properties		Resistance to collar cracking			
								Average sub-grain size (μm)	Volume fraction of β-fiber (%)	Tensile strength	Elongation	Drawless		Combination	
										(MPa)	(%)	90 μ m	80 μ m	90 μ m	80 μ m
Example	34	A	450 × 4	275	None	160 × 4	1	1.0	91	161	1.5	excellent	good	good	fair
	35						2	1.0	91	161	1.5	excellent	good	good	fair
	36	B	480 × 4	278	None	185 × 4	3	1.3	86	143	4.3	excellent	good	good	fair
	37						4	1.3	86	143	4.3	excellent	good	good	fair
Comparative Example	38	B	400 × 4	277	None	240 × 4	1	2.8	75	95	18.5	failure	failure	fair	failure
	39						2	2.8	75	95	18.5	failure	failure	fair	failure
	40	D	540 × 4	246	None	260 × 4	3	3.2	72	103	25.8	failure	failure	failure	failure
	41						4	3.2	72	103	25.8	failure	failure	failure	failure

Surface treatment
No. 1: Surface treatment under the conditions of Comparative Example 1 in JP-A No. 2010-223520
No. 2: Surface treatment under the conditions of Example 1 in Japanese Patent No. 3383914
No. 3: Surface treatment under the conditions of Example 1 in JP-A No. 2008-224204
No. 4: Surface treatment under the conditions of Comparative Example 21 in JP-A No. 2010-223514

Evaluation Based on Chemical Composition

[0080] As is demonstrated by Table 1, Specimens Nos. 1 to 11 as the examples had chemical compositions within the range specified in the present invention and exhibited satisfactory resistance to collar cracking.

[0081] By contrast, Specimens Nos. 12 to 20 as the comparative examples had chemical compositions out of the range specified in the present invention and had the following results.

[0082] Specimen No. 12 had a Si content higher than the upper limit, thereby suffered from larger amounts of coarse intermetallic compounds, and exhibited poor resistance to collar cracking.

[0083] Specimen No. 13 had an Fe content of less than the lower limit, thereby had an average subgrain size of more than the upper limit, and exhibited poor resistance to collar cracking. Specimen No. 14 had an Fe content of more than the upper limit, thereby suffered from larger amounts of coarse intermetallic compounds, and exhibited poor resistance to collar cracking.

[0084] Specimen No. 15 had a Cu content of less than the lower limit, thereby had an average subgrain size of more than the upper limit, had a volume fraction of β-fiber of less than the lower limit, and exhibited poor resistance to collar cracking. Specimen No. 16 had a Cu content of more than the upper limit, thereby underwent work hardening, and exhibited poor resistance to collar cracking.

[0085] Specimen No. 17 had a Mn content of more than the upper limit, suffered from larger amounts of coarse intermetallic compounds, and exhibited poor resistance to collar cracking. Specimen No. 18 had a Cr content of more than the upper limit, thereby suffered from larger amounts of coarse intermetallic compounds, and exhibited poor resistance to collar cracking.

[0086] Specimen No. 19 had a Ti content of more than the upper limit, thereby suffered from coarse intermetallic compounds, and exhibited poor resistance to collar cracking. Specimen No. 20 did not contain Cu and underwent temper annealing at an excessively high temperature, thereby had an average subgrain size of more than the upper limit, had a volume fraction of β-fiber of less than the lower limit, and exhibited poor resistance to collar cracking.

Evaluation Based on Manufacturing Method

[0087] As is demonstrated by Table 2, Specimens Nos. 21 to 26 as the examples were manufactured by methods under conditions within the range specified in the present invention and thereby exhibited satisfactory resistance to collar cracking.

[0088] By contrast, Specimens Nos. 27 to 33 as the comparative examples were manufactured by methods under conditions out of the range specified in the present invention and had the following results.

[0089] Specimen No. 27 underwent soaking at a temperature of lower than the lower limit, thereby had an average subgrain size of more than the upper limit and a volume fraction of β-fiber of less than the lower limit, and exhibited poor resistance to collar cracking. Specimen No. 28 underwent soaking at a temperature of higher than the upper limit, thereby had an average subgrain size of more than the upper limit, and exhibited poor resistance to collar cracking.

[0090] Specimen No. 29 underwent hot finish rolling with a finish temperature of lower than the lower limit, was hardly rolled, and was impossible to manufacture a fin material. Specimen No. 30 underwent hot finish rolling with a finish temperature of higher than the upper limit, thereby had a volume fraction of β-fiber of less than the lower limit, and exhibited poor resistance to collar cracking. Specimen No. 31 underwent temper annealing at a temperature of higher than the upper limit, thereby had an average subgrain size of more than the upper limit, had a volume fraction of β-fiber of less than the lower limit, and exhibited poor resistance to collar cracking.

[0091] Specimen No. 32 underwent soaking at a temperature of higher than the upper limit, underwent hot finish rolling with a finish temperature of lower than the lower limit, and underwent temper annealing at a temperature of higher than the upper limit, thereby had an average subgrain size of more than the upper limit, had a volume fraction of β-fiber of less than the lower limit, and exhibited poor resistance to collar cracking. This specimen was rolled with difficulty. Specimen No. 33 underwent process annealing, thereby underwent cold rolling to a cold working ratio of less than the lower limit, had an average subgrain size of more than the upper limit, had a volume fraction of β-fiber of less than the lower limit, and exhibited poor resistance to collar cracking.

Evaluation of Specimens Subjected to Surface Treatment

[0092] Specimens Nos. 34 to 41 as fin materials subjected to a surface treatment exhibited resistance to collar cracking similar to that of corresponding fin materials not subjected to the surface treatment.

[0093] The fin materials of Specimens Nos. 19, 20, and 32 correspond to customary aluminum alloy fin materials described in PTL 2, PTL 1, and PTL 1, respectively. As is demonstrated by this experimental example, the customary aluminum alloy fin materials did not meet the predetermined levels in the evaluations. This experimental example therefore objectively demonstrates that the aluminum alloy fin materials according to the present invention are superior to the customary aluminum alloy fin materials.

Industrial Applicability

[0094] The aluminum alloy fin materials according to the present invention do not suffer from collar cracks upon forming process and give fins with good appearances to constitute high-performance heat exchangers.

Claims

1. An aluminum alloy fin material for heat exchangers, comprising Fe in a content of 0.20 to 1.0 % by mass, Cu in a content of 0.02 to 0.1 % by mass, Si in a content of 0% by mass or more and 0.15 % by mass or less, Mn in a content of 0% by mass or more and 0.015 % by mass or less, Cr in a content of 0% by mass or more and 0.015 % by mass or less, further comprising Al and inevitable impurities, and optionally further comprising Ti in a content of 0.01 to 0.08 % by mass,
   wherein the aluminum alloy fin material has a thickness of 0.1 mm or less; and
   the aluminum alloy fin material has an average subgrain size of 2.5 μm or less and a volume fraction of β-fiber of 80% or more.

2. The aluminum alloy fin material of claim 1, wherein the aluminum alloy fin material comprises a surface-treatment coating film on a surface thereof.

3. A method for manufacturing the aluminum alloy fin material of claim 1, the method comprising the steps of
   heat-treating an aluminum alloy ingot having the chemical composition at a temperature of 450°C to 510°C for a holding time of one hour or longer;
   hot-rolling the aluminum alloy ingot after the heat treatment under such conditions that a finish temperature of hot finish rolling be 250°C or higher and lower than 300°C;
   cold-working the aluminum alloy material after the hot rolling with a cold working ratio of 96% or more so as to have a thickness of 0.1 mm or less; and
   temper-annealing the aluminum alloy material after the cold working by holding the material at a temperature of 160°C to 250°C for a holding time of 1 to 6 hours.

Patentansprüche

1. Lamellenmaterial aus einer Aluminiumlegierung für Wärmetauscher, das Fe in einem Anteil von 0,20 bis 1,0 Masse-%, Cu in einem Anteil von 0,02 bis 0,1 Masse-%, Si in einem Anteil von 0 Masse-% oder mehr und 0,15 Masse-% oder weniger, Mn in einem Anteil von 0 Masse-% oder mehr und 0,015 Masse-% oder weniger, Cr in einem Anteil von 0 Masse-% oder mehr und 0,015 Masse-% oder weniger umfasst und ferner umfassend Al und unvermeidliche Verunreinigungen, und gegebenenfalls ferner umfassend Ti in einem Anteil von 0,01 bis 0,08 Masse-%,
   wobei das Lamellenmaterial aus einer Aluminiumlegierung eine Dicke von 0,1 mm oder weniger aufweist; und
   wobei das Lamellenmaterial aus einer Aluminiumlegierung eine durchschnittliche Subkorngröße von 2,5 μm oder weniger und eine Volumenfraktion von β-Fasern von 80 % oder mehr aufweist.

2. Lamellenmaterial aus einer Aluminiumlegierung nach Anspruch 1, wobei das Lamellenmaterial aus einer Aluminiumlegierung einen Beschichtungsfilm einer Oberflächenbehandlung auf einer Oberfläche davon umfasst.

3. Verfahren zur Herstellung des Lamellenmaterials aus einer Aluminiumlegierung nach Anspruch 1, wobei das Verfahren die folgenden Schritte umfasst:

   Wärmebehandeln eines Blocks der Aluminiumlegierung, der die chemische Zusammensetzung aufweist, bei einer Temperatur von 450 °C bis 510 °C für eine Haltezeit von einer Stunde oder länger;
   Warmwalzen des Blocks der Aluminiumlegierung nach der Wärmebehandlung unter derartigen Bedingungen, dass eine Endtemperatur eines Wärmefertigwalzens 250 °C oder höher und geringer als 300 °C ist;
   Kaltbearbeiten des Aluminiumlegierungsmaterials nach dem Warmwalzen mit einem Kaltbearbeitungsverhältnis von 96 % oder mehr dazu, eine Dicke von 0,1 mm oder weniger aufzuweisen; und
   Anlassglühbehandeln des Aluminiumlegierungsmaterials nach dem Kaltbearbeiten durch ein Halten des Materials bei einer Temperatur von 160 °C bis 250 °C für eine Haltezeit von 1 bis 6 Stunden.

Revendications

1. Matériau pour ailettes en alliage d'aluminium pour échangeurs thermiques, comprenant Fe à raison de 0,20 à 1,0 % en masse, Cu à raison de 0,02 à 0,1 % en masse, Si à raison de 0 % en masse ou davantage et 0,15 % en masse ou moins, Mn à raison de 0 % en masse ou davantage et 0,015 % en masse ou moins, Cr à raison de 0 % en masse ou davantage et 0,015 % en masse ou moins, comprenant en outre Al et les impuretés inévitables, et comprenant en outre optionnellement Ti à raison de 0,01 à 0,08 % en masse,
le matériau pour ailettes en alliage d'aluminium ayant une épaisseur de 0,1 mm ou moins ; et
le matériau pour ailettes en alliage d'aluminium ayant une taille de sous-grain moyenne de 2,5 μm ou moins et une fraction volumique de fibre β de 80 % ou plus.

2. Matériau pour ailettes en alliage d'aluminium selon la revendication 1, le matériau pour ailettes en alliage d'aluminium comprenant un film de revêtement de traitement de surface sur une surface dudit matériau.

3. Procédé de fabrication du matériau pour ailettes en alliage d'aluminium selon la revendication 1, le procédé comprenant les étapes de :

   traitement thermique d'un lingot d'alliage d'aluminium ayant la composition chimique à une température de 450°C à 510°C pendant un temps de maintien d'une heure ou davantage
   laminage à chaud du lingot d'alliage d'aluminium après le traitement thermique dans des conditions telles qu'une température terminale de laminage à chaud terminal soit de 250°C ou plus et plus basse que 300°C ;
   écrouissage de l'alliage d'aluminium après le laminage à chaud avec un rapport d'écrouissage de 96 % ou plus de manière à obtenir une épaisseur de 0,1 mm ou moins ; et
   revenu-recuit de l'alliage d'aluminium après l'écrouissage en maintenant le matériau à une température de 160°C à 250°C pendant un temps de maintien de 1 à 6 heures.

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP H1180869 A **[0007]**
- JP 4275560 B **[0007]**
- JP H032343 A **[0007]**
- JP 2010223520 A **[0067]**
- JP 3383914 B **[0068]**
- JP 2008224204 A **[0069]**
- JP 2010223514 A **[0070]**