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(71) Applicant: **KABUSHIKI KAISHA KOBE SEIKO SHO**
Kobe-shi,
Hyogo 651-8585 (JP)

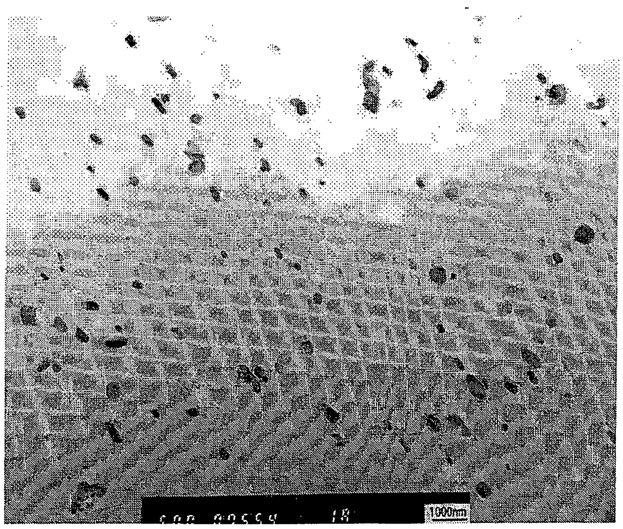
(72) Inventors:
- **KAJIHARA, Katsura**
  Kobe-shi, Hyogo 651-2271 (JP)
- **TSURUDA, Kiyohito**
  Moka-shi, Tochigi 321-4367 (JP)

(74) Representative: **Müller-Boré & Partner**
Patentanwälte
Grafinger Strasse 2
81671 München (DE)

(54) **COLD-ROLLED ALUMINUM ALLOY SHEET FOR BOTTLE CAN WITH EXCELLENT NECK PART FORMABILITY AND PROCESS FOR PRODUCING THE COLD-ROLLED ALUMINUM ALLOY SHEET**

(57) A cold-rolled aluminum alloy sheet has a composition containing 0.7 to 1.5% by mass Mn, 0.8 to 1.7% by mass Mg, 0.1 to 0.7% by mass Fe, 0.05 to 0.5% by mass Si, 0.1 to 0. 6% by mass Cu, and Al and inevitable impurities as other elements. In the structure of the cold-rolled aluminum alloy sheet, 50 to 400 particles of particle sizes in the range of 0.05 to 1 μm are dispersed in an area of 300 μm^2 when observed under a TEM at a magnification in the range of 5, 000× to 15,000× magnification, and the ratio of the number of the dispersed particles of sizes of 0.3 μm or above to the number of all the dispersed particles is in the range of 15 to 70%.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a cold-rolled aluminum alloy sheet (bottle-forming sheet), for forming a body of a bottle (beverage can), excellent in formability in forming a neck of a bottle. A cold-rolled aluminum alloy sheet mentioned herein is a rolled sheet (cold-rolled sheet) manufactured by hot rolling and subsequent cold rolling. Hereinafter, an aluminum alloy will be referred to as an Al alloy.

BACKGROUND ART

[0002] Most aluminum beverage cans are two-piece aluminum cans each formed by fastening a lid (end wall) to a can body by a seaming process. Most two-piece aluminum cans are made by forming a can body by processing a prescribed aluminum sheet by a cupping process and a DI process (drawing-with-ironing process), and subjecting the can body to a neck forming process to form an end part of a diameter smaller than that of the can body. Hereinafter, such two-piece cans will be referred to as two-piece aluminum cans.

[0003] A neck can be comparatively easily formed in such a two-piece aluminum can because the neck can be formed by drawing the can body at a comparatively low drawing ratio, namely, the ratio of the diameter of an end part to that of the body.

[0004] Hard Al-Mg-Mn alloy sheets, such as 3004 and 3104 series, are widely used as cold-rolled sheets for forming can bodies. The 3004 and 3104 alloys are excellent in ironing formability and can exhibit comparatively satisfactory formability even when those materials are cold rolled at a high draft to enhance the strength, and hence those alloys are suitable for forming DI can bodies.

[0005] Demands for bottle-shaped aluminum cans (hereinafter, referred to as "metal bottles") having a body, an opening part, and a screw cap has increased in recent years. A drawing ratio at which the body is drawn to form the opening part, namely, the ratio of the diameter of the opening part to that of the body, to form the metal bottle is high as compared with the drawing ratio used for forming the neck of the two-piece aluminum can. Therefore, creases and cracks are liable to form in the neck by a neck forming process.

[0006] Such metal bottles include three-piece metal bottles having, as principal parts, a body, a bottom, namely, a member separate from the body, and a screw cap, and two-piece metal bottles having a bottomed body, and a screw cap.

[0007] Generally, some steps of a conventional two-piece metal bottle manufacturing method are used for manufacturing the three-piece metal bottle. As mentioned in Patent documents 1 and 2, a prescribed aluminum sheet is processed by a cupping and DI processes, a baking process, a trimming process, a printing process, a baking process, a necking process (top forming process: neck forming process) in that order. The necking process forms a neck in a bottomed end part of the body, and then the end wall of the neck is opened to form a mouth. A screw thread for a screw cap is formed in the neck by a threading process. A flange is formed in an open end part opposite the mouth, and a bottom member is fastened to the flange by a seaming process to form a bottom.

[0008] The neck of the three-piece metal bottle is formed in the bottomed end part of the bottomed body formed by DI process. Therefore, neck can be comparatively easily formed even if the ratio of the diameter of the neck to that of the body is high.

[0009] Demand for two-piece metal bottles has been progressively increased instead of demand for three-piece metal bottles from the viewpoint of cost reduction and recycling facility. Generally, most two-piece metal bottles are manufactured by a conventional two-piece aluminum can manufacturing method. A conventional die neck forming process and a conventional spin neck forming process are employed just as they are.

[0010] As disclosed in Patent documents 1 and 2, the two-piece metal bottle manufacturing method processes a prescribed aluminum sheet A by cupping and DI processes to form a body and a bottom. Then an open end part of the body is processed by a die neck-forming process or a spin neck-forming process to form a neck. The open end of the neck is a mouth. A thread with which a cap is engaged is formed in a part of the neck around the mouth to complete a two-piece metal bottle.

[0011] Since the neck of the two-piece metal bottle is formed by processing the open end part of the body by the die neck-forming process or the spin neck-forming process, it is difficult to reduce the diameter of the opening part at a high drawing ratio.

[0012] When the neck of a two-piece metal bottle of a hard sheet of the 3000 series aluminum alloy mentioned above is formed by drawing at a high drawing ratio, creases and cracks are liable to form in the neck. Therefore, it has been difficult to apply a drawing ratio used for forming the three-piece metal bottles to forming the conventional two-piece metal bottles.

[0013] To solve problems in the two-piece metal bottle, Patent document 1 proposes a technique that specifies proper ranges respectively for the Fe, the Si, the Mn and the Mg content and the offset yield strength (0.2% offset yield strength) after baking of the aluminum alloy sheet of a 3000 series aluminum alloy so that formability, such as DI formability or neck formability, of the aluminum sheet may be improved and the neck can be formed by drawing the body at a high drawing ratio.

[0014] Similarly, Patent document 2 proposes a technique that specifies proper ranges respectively for the Fe, the Si, the Mn, the Mg and the Cu content and the offset yield strength (0.2% offset yield strength) after baking of the aluminum alloy sheet of a 3000 series aluminum alloy so that formability, such as DI formability or neck formability, of the aluminum sheet may be improved and the neck can be formed by drawing the body at a high drawing ratio, namely, a ratio of the diameter of the mouth to that of the body.

[0015] Various techniques that control grain structure have been proposed to improve formability. Patent document 3 controls the content of Mn in solid solution and grain size in the hot-rolled sheet so as to be in predetermined ranges, respectively, stably maintains earing ratio in the range of 3 to 6%, and subject the hot-rolled sheet directly to a cold-rolling process without processing the same by an annealing process to keep the earing ratio of cold-rolled sheet formed by the cold-rolling process stably in the range of 0 to 2%.

Patent document 1: JP 2002-256366 A
Patent document 2: JP 2004-250790 A
Patent document 3: JP 2003-342657 A

DISCLOSURE OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0016] The size and diameter of two-piece metal bottles trend to decrease with the recent growing demand for small metal bottles. Requirement for improvement of the sealing performance of a cap screwed onto a threaded part of a small two-piece metal bottle, for retort pouch, has been increased. To meet such a requirement, screwing force for screwing the cap on the threaded part is increased and hence the body of the two-piece bottle trends to have strength enough to withstand the increased screwing force.

[0017] However, if the strength of the material of the bottle is increased by controlling the compositions of the aluminum alloy sheet of the 3000 series aluminum alloy and the yield strength after baking, there is a tendency that creases and cracks are liable to form in a neck formed by a neck forming process or a spin neck forming process, and in a threaded part for a screw cap formed in a part of a neck around a mouth.

[0018] Cost reduction through the reduction of the amount of metal needed to form a can and the weight of a can required of all types of cans is required also of small two-piece metal bottles. To meet such a requirement, improvement of the strength of a material of cans is inevitable.

[0019] The present invention has been made in view of such problems and it is therefore an object of the present invention to provide a cold-rolled aluminum alloy sheet, for forming a small two-piece metal bottle, excellent in formability when shaped by a neck forming process and a threaded part forming process, and a method of manufacturing the cold-rolled aluminum alloy sheet.

MEANS FOR SOLVING THE PROBLEM

[0020] To achieve the object, the present invention provides a cold-rolled aluminum alloy sheet, for forming a metal bottle, excellent in neck formability and having a composition containing 0. 7 to 1.5% by mass (hereinafter, referred to as "%") Mn, 0.8 to 1.7% Mg, 0.1 to 0.7% Fe, 0.05 to 0.5% Si, 0.1 to 0.6% Cu, and A1 and inevitable impurities as other elements, wherein 50 to 400 particles of sizes of 0.05 to 1 μm are dispersed in an area of 300 μm^2 when observed under a TEM at a magnification in the range of 5, 000× to 15,000× magnification, and the ratio of the number of the dispersed particles of sizes of 0.3 μm or above to the number of all the dispersed particles is in the range of 15 to 70%.

[0021] A method of manufacturing a cold-rolled aluminum alloy sheet, for forming a metal bottle, excellent in neck formability or a preferable cold-rolled aluminum alloy sheet includes the steps of: annealing a ingot at 550˚C or above; slowly cooling the ingot at a cooling rate of 25˚C/hr or below to a temperature in the range of 450˚C to 550˚C; and hot rolling and cold rolling the ingot such that 50 to 400 particles of particle sizes in the range of 0.05 to 1 μm are dispersed in an area of 300 μm^2 when observed under a TEM at a magnification in the range of 5,000 to 15, 000 magnification, and the ratio of the number of the dispersed particles of sizes of 0.3 μm or above to the number of all the dispersed particles is in the range of 15 to 70%.

EFFECT OF THE INVENTION

[0022] As mentioned above, it is required to reduce the thickness of the DI body of a metal bottle mainly with a view to reduce the manufacturing cost and the weight of the metal bottle. The strength of a cold-rolled aluminum alloy sheet, namely, the material of the metal bottle, needs to be increased so that the buckling strength of the DI body may not be reduced. To reduce the thickness of the DI body it is strongly required that a DI process can be achieved at a low earing ratio. When the earing ratio is low in the DI process, the yield of the DI process can be increased, and the break of the body due to edge crack can be prevented.

[0023] As mentioned above, it is well known conventionally to control the microstructure of the cold-rolled aluminum alloy sheet for aluminum DI can bodies for bottles with lower anisotropy (earing). There are typical methods of controlling the grain size, the number density and the size of intermetallic compounds such as Mg_2Si, micro segregation, the content of alloy elements such as Mn and crystal orientation such as Cube orientation.

[0024] Control of the number and size of particles dispersed in a cold-rolled aluminum alloy sheet, such as Mg_2Si, and precipitates is the same as a conventional metallurgical control of structure.

[0025] Whereas the conventional idea reduces sizes of dispersed particles to the least possible extent, the present invention allows dispersed particles to grow to some extent in uniform size so that a fixed amount (fixed number) of such particles may be formed.

[0026] The present inventors found that coarse dispersed particles reduce the effect on the pinning force of fine particles which makes recrystallization retard, thereby, the hot-rolled sheet has the isotropic grain microstructure (lower anisotropy), that is, lower "earing".

[0027] When sizes of dispersed particles are reduced to disperse fine particles, the dispersed particles have strong pinning effect, original soft PFZ recrystallizes easily during hot rolling, and precipitation bands are liable to recrystallize to form large crystal grains. Therefore, when fine particles are dispersed according to the conventional idea, some large crystal grains formed by recrystallization are contained in the dispersed fine particles. Consequently,' the structure includes large and small crystal grains, and the uniformity and isotropy of crystal grains are liable to be lost.

[0028] Consequently, earing ratio is reduced, and creases and cracks are liable to form in a neck formed in an open end part of the body of a small two-[piece metal bottle by a die neck forming process or a spin neck forming process, and in a part near the mouth when a screw thread onto which a screw cap is screwed is formed therein.
The present invention grows a certain amount of dispersed particles to some extent in uniform particle size and grows isotropic crystal grains not having anisotropy in a hot-rolled sheet.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029]

Fig. 1 is a photograph of an aluminum alloy in a first embodiment according to the present invention containing distributed particles;
Fig. 2 is a photograph of an aluminum alloy in a second embodiment according to the present invention containing distributed particles; and
Fig. 3 is a development of a cup formed by processing a sheet by a DI process.

BEST MODE FOR CARRYING OUT THE INVENTION

Composition of Cold-rolled Aluminum Alloy Sheet

[0030] Description will be made of a preferable chemical composition (unit: percent by mass) of a cold-rolled aluminum alloy sheet of the present invention meeting properties including strength and formability required of a material for forming two-piece metal bottles, and restrictive reasons for elements.

[0031] A cold-rolled aluminum alloy sheet excellent in high-temperature characteristics for forming metal bottles has a composition containing 0.7 to 1.5% (percent by mass) Mn, 0.8 to 1.7% Mg, 0.1 to 0.7% Fe, 0.05 to 0.5% Si, 0.1 to 0.6% Cu, and Al and inevitable impurities as other elements.

[0032] Mn Content: 0.7 to 1.5%
Mn is effective in improving strength and formability. A material (cold-rolled sheet) according to the present invention for forming two-piece metal bottles is subjected to an ironing process in a DI process, a neck forming process, and a screw thread forming process. Therefore, Mn is a very important element.

[0033] Manganese (Mn) is used for making various Mn-containing intermetallic compounds including an Al-Fe-Mn-Si intermetallic compound (α phase). Formability and workability can be improved by properly distributing the α phase. Usually, an emulsion-type lubricant is used for ironing an aluminum sheet. The lubricating effect of the emulsion-type lubricant is insufficient if the amount of the α phase is small, and hence it is possible that defects that spoil appearance, such as galling including local welding and scratches, are formed. Thus Mn is indispensable to avoid forming surface defects during an ironing process by producing the α phase.

[0034] If the Mn content is excessively low, Mn cannot exercise an effect of improving formability and workability. Therefore, the Mn content be 0.7% or above, preferably, 0.8% or above, desirably, 0.85% or above, more desirably, 0.9% or above.

[0035] If the Mn content is excessively high, gigantic Mn-Al primary crystal grains crystallize to deteriorate formability. Therefore, an upper limit Mn content is 1.5%, preferably, 1.3%, desirably, 1.1%, more desirably, 1.0%.

[0036] Mg Content: 0.8 to 1.7%

Magnesium (Mg) is effective in improving strength. When Mg is contained in the cold-rolled sheet in combination with Cu, softening of the cold-rolled sheet can be suppressed when the cold-rolled sheet is subjected to a final annealing process (finish annealing process) that heats the cold-rolled sheets at temperatures in the range of about 100˚C to about 150˚C for a time in the range of about 1 to about 2 hr, and a can made of the cold-rolled sheet is subjected to a print-baking process. When the cold-rolled sheet contains both Mg and Cu, Al-Cu-Mg grains precipitate to suppress softening when the can is subjected to a print-baking process.

[0037] If the Mg content is excessively low, the foregoing effect cannot be exhibited. Therefore, the Mg content be 0.8% or above, preferably, 0.9% or above, desirably, 1.0% or above.

[0038] If the Mg content is excessively high, work hardening is liable to occur and hence formability deteriorates. Therefore, an upper limit Mg content is 1.7%, preferably, 1.6%, desirably, 1.35%.

[0039] Mg affects the amount of precipitated Mn and the Mn content in solid solution. The larger amount of Mg suppress the precipitation of Al-Fe-Mn-Si (α phase) more effectively, and hence the Mn content in solid solution tends to increase. Thus it is preferable to determine the Mg content in connection with the amount of Mn in the solid solution.

[0040] Fe Content: 0.1 to 0.7%

Iron (Fe) has an effect of decreasing the grain size and improves formability by forming the Al-Fe-Mn-Si intermetallic compound (α phase). Iron (Fe) is useful for promoting the crystallization and precipitation of Mn and in controlling the Mn content of the aluminum and the dispersion of a Mn intermetallic compound in the aluminum base. If the aluminum alloy containing Mn has an excessively high Fe content, gigantic intermetallic compound primary crystal grains are liable to form, which is possible to deteriorate formability.

[0041] Therefore, the Fe content can be determined according to the Mn content. A preferable ratio in mass of Fe to Mn (Fe/Mn ratio) is, for example, in the range of 0.1 to 0.7, desirably, 0.2 to 0.6, more desirably, .0.3 to 0.5.

[0042] When the Mn content is in the foregoing Mn content range, a lower limit Fe content is 0.1% or above, preferably, 0.2% or above, desirably, 0.3% or above. Preferably, an upper limit Fe content is 0.7% or below, desirably, 0.6% or below, more desirably, 0.5% or below.

[0043] Si Content: 0.05 to 0.5%

Silicon (Si) is useful for producing dispersed particles of Mg_2Si intermetallic compound and the Al-Fe-Mn-Si intermetallic compound (α phase). Formability improves when those dispersed particles are distributed in an appropriate distribution specified by the present invention.

[0044] The Si content is 0.05% or above, preferably, 0.1% or above, desirably, 0.2% or above. A excessively high Si content obstructs recrystallization during finish hot rolling, increases 45˚ ears, and deteriorates formability. Therefore, an upper limit Si content is 0.5%, preferably, 0.45%, desirably, 0.4%.

[0045] Cu Content: 0.1 to 0.6%

Copper (Cu) produces an Al-Cu-Mg intermetallic compound when a can formed by processing a cold-rolled sheet is subjected to a baked-finishing process. When Cu contained in combination with Mg in the aluminum alloy sheet suppresses softening. A lower limit Cu content is 0.1% or above, preferably, 0.15% or above, desirably, 0.2% or above. Whereas age hardening can be readily achieved, the aluminum alloy sheet becomes excessively hard, formability deteriorates and corrosion resistance deteriorates if the Cu content is excessively high. An upper limit Cu content is 0.6%, preferably, 0.5%, desirably, 0.35%.

[0046] Elements having the same strength improving effect as Cu are Cr and Zn. The aluminum alloy sheet may contain, in addition to Cu, Cr and Zn or may selectively contain Cr or Zn.

[0047] Cr Content: 0.001 to 0.3%

To improve strength, the Cr content is 0.001% or above, preferably, 0.002% or above. If the Cr content is excessively high, gigantic crystal grains forms and formability deteriorates. An upper limit Cr content is 0.3%, preferably, 0.25%.

[0048] Zn Content: 0.05 to 1.0%

Precipitation of Al-Mg-Zn particles occurs and strength improves when the aluminum alloy sheet contains Zn. To make Zn exhibit this effect, the Zn content is 0.05% or above, preferably, 0.06% or above. An excessively high Zn content deteriorates corrosion resistance. Therefore, an upper limit Zn content is 0.5%, preferably, 0.45%.

[0049] Ti Content: 0.005 to 0.2%

Titanium (Ti) has a crystal grain micronizing effect. The aluminum alloy sheet contains Ti selectively when such an effect is necessary. To make Ti exhibit such an effect, the Ti content is 0.005% or above, preferably, 0.01% or above, desirably, 0.015% or above. If the Ti content is excessively high, gigantic Al-Ti intermetallic compound grains crystallize and deteriorate formability. An upper limit Ti content is 0.2%, preferably, 0.1%, desirably, 0.05%.

[0050] The aluminum alloy sheet may contain Ti singly or in combination with a small amount of B. When the aluminum alloy sheet contains Ti and B in combination, the crystal grain micronizing effect of Ti improves still further. When B is used, the B content is 0.0001% or above, preferably, 0.0005% or above, desirably, 0.0008% or above. If the B content is excessively high, large Ti-B particles are produced to deteriorate formability. An upper limit B content is 0.05%, preferably, 0.01%, desirably, 0.005%.

[0051] The aluminum alloy sheet contains inevitable impurities in additions to the foregoing elements. Basically, lower impurity contents are desirable to avoid deteriorating the properties of the aluminum alloy sheet. However, the aluminum alloy sheet may contain impurities in impurity contents that will not deteriorate the desired properties of the aluminum alloy sheet and not exceeding upper limit element contents specified for 3000 series aluminum alloys in JIS.

Dispersed Particles

[0052] The structure of the cold-rolled aluminum alloy sheet of the present invention will be described.
As mentioned above, the present invention allows dispersed particles of intermetallic compounds, such as Mg_2Si and Al-Fe-Mn-Si intermetallic compound (α phase), and precipitates, to grow to some extent in uniform size so that a fixed amount (fixed number) of such particles may be formed. Thus the pinning effect of the dispersed particles is moderated to form uniform, isotropic crystal grains not having directionality and anisotropy in the hot-rolled sheet and to improve earing ratio.

[0053] More concretely, dispersed particles of sizes (barycentric diameters) in the range of 0.05 to 1 μm are contained in the structure of a cold-rolled aluminum alloy sheet as observed under a TEM at a magnification in the range of, 5000x to 15, 000$\times$ in a density in the range of 50 to 400 particles per 3000 μm^2. The ratio of the number of the dispersed particles of sizes not smaller than 0.3 μm to the number of all the dispersed particles is in the range of 15 to 70%. Preferably, a lower limit to the ratio of the number of the dispersed particles of sizes not smaller than 0.3 μm to the number of all the dispersed particles is 20% or above, desirably, 25% or above. Preferably, the ratio is in the range of 20 to 70%, desirably, 25 to 70%.

[0054] Figs. 1 and 2 are TEM photographs of the structure of cold-rolled aluminum alloy sheets of the present invention taken at 10,000$\times$ magnification. In Figs. 1 and 2, white parts are those of the matrix, and black parts are dispersed particles of compounds, such as Mg_2Si, and precipitates. Figs. 1 and 2 show the structure of a cold-rolled aluminum alloy sheets in Examples 1 and 2 shown in Table 3, respectively.

[0055] It is known from the comparative observation of Figs. 1 and 2 that the structure shown in Figs. 1 and 2 contains dispersed particles of sizes in the range of 0.05 to 1 μm in a density in the range of 50 to 400 particles per 300 μm^2. The dispersed particles in Fig. 1 are comparatively large and are uniformly distributed as compared with those shown in Fig. 2.

[0056] In the structure according to the present invention shown in Fig. 1, the ratio of the number of the comparatively large dispersed particles of sizes in the range of 0.3 to 1 μm to the number of all the dispersed particles is high; that is, the ratio of the number of the comparatively large dispersed particles to the number of all the dispersed particles is 48%. The comparatively large dispersed particles uniform in size are uniformly distributed.

[0057] In the structure in Example 2 shown in Fig. 2, the ratio of the number of the comparatively large dispersed particles of sizes in the range of 0.3 to 1 μm to the number of all the dispersed particles is 20%; that is, the ratio of the number of the comparatively small dispersed particles to the number of all the dispersed particles is high and dispersed particles in a wide range of size are distributed.

[0058] If the ratio of the number of comparatively small dispersed particles to the number of all the dispersed particles is higher than that in the structure according to the present invention shown in Fig. 2 or particles of different sizes are dispersed and the ratio of the number of the dispersed particles of sizes not smaller than 0.3 μm to the number of all the dispersed particles is below 15%, the mode of dispersion of the dispersed particles is the same as that in the structure of the conventional sheet. In such a case, original soft PEZ recrystallizes easily during hot rolling. Consequently, precipitation bands are liable to recrystallize to form large crystal grains, and cube orientation is liable to develop. Therefore, although the mean grain size of the crystal grains is small similarly to that of crystal grains in the structure of the conventional sheet, some large crystal grains formed by recrystallization are contained in the dispersed fine particles. Consequently, the structure includes large and small crystal grains, and the uniformity and isotropy of crystal grains are liable to be lost.

[0059] Thus the earing ratio decreases and there is a tendency that creases and cracks are liable to form in a neck formed by a neck forming process or a spin neck forming process, and in a threaded part for a screw cap formed in a part of a neck around a mouth in forming a small two-piece bottle.

[0060] As mentioned above, the present invention allows dispersed particles to grow to some extent in uniform size so that a fixed amount (fixed number) of such particles may be formed, and grows uniform, isotropic crystal grains not having directionality and anisotropy in the hot-rolled sheet, and improves the earing ratio of the cold-rolled sheet.

[0061] Dispersed particles to be analyzed and measured are those that can be observed under a TEM at 5,000x to

15,000× magnification and have sizes (barycentric diameters) of 0.05 μm or above. The dispersed particles having sizes of 0.05 μm or above have significant influence on formability and dispersed particles having sizes below 0.05 μm have insignificant influence on formability. It is difficult to observe and measure small dispersed particles having sizes below 0.05 μm under a TEM and measured sizes are distributed in a wide range. Therefore, the present invention does not deal with those small particles and omits the same from subjects of measurement.

Measurement of Particle Size and Number of Particles

[0062] Particle sizes of the dispersed particles are measured through the observation of the structure of the sheet under a TEM (transmission electron microscope). Specimens are sampled from a middle part, with respect to thickness of the sheet, and a rolled upper surface of the sheet. The specimens are mirror finished by polishing. The structure of ten fields of about 10 μm x 15 μm in the polished surface of each specimen was observed under a TEM, such as field-emission transmission electron microscope (HF-2000, Hitachi) at 5,000× to 15,000x magnification.

[0063] Reflected electron images are observed for the clear observation of the dispersed particle phase (intermetallic compound phase). Parts of Al are represented by white images. The image of the dispersed particle phase is clearly contrasted with the white image. Outlines of the images of the dispersed particles are traced. Image-ProPlus (MEDIA-CYBERNETICS), namely, image analyzing software, was used to determine the mean barycentric diameter through image analysis.

[0064] The number of the dispersed particles of sizes in the range of 0.05 to 1 μm was counted, and the number of the dispersed particles of sizes in the range of 0.05 to 1 μm in 300 μm^2 was calculated. The mean of the numbers of the dispersed particles in the ten fields was calculated.

[0065] The number of the dispersed particles of sizes of 0.3 μm or above among those of sizes in the range of 0.05 to 1 μm was counted. The number of the disperse particles of sizes in the range of 0.05 to 1 μm was counted. The ratio (%) of the number of the dispersed particles of sizes of 0.3 μm or above to the number of the dispersed particles of sizes in the range of 0.05 to 1 μm was calculated.

Mean Aspect Ratio of Crystal Grains

[0066] Preferably, a mean aspect ratio of grains in the cold-rolled sheet is 2 or above, which means the grains stretched in the rolling direction, not equiaxial grains. This brings an effect on the maintenance of the material strength after heat treatment at higher temperature for a shorter time, which enables to speed up the heat treatment, because of being suppressed the thermal deformation of the cold-rolled aluminum sheet during a print-baking process. In other words, the stretched grains in the rolling direction in the cold-rolled aluminum alloy sheet contributes to maintain the high formability during DI processing, and the appropriate composition, the distribution of precipitation and solute content, as mentioned later, contributes to maintain the strength of a bottle can after the heat treatment. In addition, these factors suppressed the thermal deformation during the baking processing.

[0067] If the mean aspect ratio of the crystal grains is below 2, the crystal grains do not differ a great deal from equiaxial crystal grains and are deficient in the foregoing effects. A cold-rolled aluminum alloy sheet having such crystal grains cannot suppress thermal deformation during the baking process and cannot ensure the strength of cans after the baking process. Thus greater stretching of the crystal grains greatly in the rolling direction is desirable. Preferably, the crystal grains are stretched so that the mean aspect ratio is 2.1 or above.

[0068] The aspect ratios of the crystal grains are dependent on the crystalline structure of the hot-rolled sheet and the rolling reduction in the cold rolling process. An upper limit mean aspect ratio is determined on the basis of the limit of the stretching ability of the manufacturing process, such as the hot-rolling process or the cold-rolling process. The upper limit mean aspect ratio is on the order of 4.

Method of Measuring Mean aspect Ratio

[0069] The mean aspect ratio of crystal grains is determined through the observation (observation under polarized light) of the upper surface of a middle part of the sheet with respect to the thickness. The rolled surface of a middle part, with respect to the thickness, of the sheet processed by a tempering process and not yet processed by a bottle forming process is observed under polarized light after finishing the surface by mechanical polishing or electrolytic polishing, and anodizing using a Barker solution.

[0070] When the crystalline structure of the upper surface of the middle part is observed under polarized light, crystals respectively having different crystal orientations appear in black and white. The maximum length in the rolling direction and the maximum length in the direction of the width of the sheet of each of crystal grains having a clearly recognizable outline in the observation field are measured. Then, the aspect ratio of each crystal grain is calculated by using: (Aspect ratio) = (Maximum length in the rolling direction)/ (Maximum length in the direction of width). Suppose that 100 crystal grains are observed under an optical microscope at 100x magnification. Then, the mean aspect ratio of the respective aspect ratios of the 100 crystal grains is calculated. The mean crystal grain size may be the mean of the maximum lengths in the rolling direction of the 100 crystal grains.

Manufacturing Method

[0071] The cold-rolled aluminum alloy sheet of the present invention can be manufactured by the conventional manufacturing method including soaking, hot-rolling, and cold-rolling processes without introducing many changes into the conventional manufacturing method, except that the ingot needs to be heated at a temperature not lower than 550˚C by a soaking process, and then cooled slowly at a cooling rate of 25˚C/hr or below to a temperature in the range of 450˚C to 550˚C to form the dispersed particle structure specified by the present invention by hot-rolling and cold-rolling the ingot , and to provide a cold-rolled aluminum alloy sheet with basic requisite properties, such as earing ratio, strength, formability and ironing formability necessary for forming metal bottles.

Conditions for Homogenizing Heat Treatment

[0072] A homogenizing temperature for the homogenizing heat treatment (soaking treatment) is in the range of 550˚C to 650˚C. The homogenizing heat treatment takes long time and reduces productivity if the homogenizing temperature is excessively low. Bulges form in the surface of the ingot if the homogenizing temperature is excessively high. A homogenizing temperature in the foregoing temperature range is used. Preferably, the homogenizing temperature is in the range of 580˚C to 615˚C, more desirably, in the range of 590˚C to 610˚C.

[0073] A shorter soaking time (homogenizing time) is desirable, provided that the ingot can be homogenized in the soaking time. For example, it is desirable that the soaking time is 6 hr or below. According to the present invention, the ingot processed by the soaking process needs to be slowly cooled, which takes a long cooling time. Therefore, the shortest possible soaking time is preferable from the view point of productivity and the efficiency of the soaking process.

Conditions for Cooling after Soaking Process

[0074] As mentioned above, the ingot needs to be cooled slowly at a cooling rate of 25˚C/hr or below to a temperature in the range of 450˚C to 550˚C after being processed by the soaking process under the foregoing conditions to form the dispersed particle structure specified by the present invention in the cold-rolled aluminum alloy sheet processed by hot-rolling and cold-rolling the sheet, and to provide the cold-rolled aluminum alloy sheet with basic properties necessary for forming a metal bottle. Preferably, the ingot processed by the soaking process is cooled by furnace cooling for such slow cooling.

[0075] Cooling rate necessarily exceeds the upper limit cooling rate of 25˚C/hr if the ingot processed by the soaking process is cooled by natural cooling outside the soaking furnace or by forced cooling by using a fan. Then, the dispersed particle structure specified by the present invention cannot form, the ratio of the number of comparatively small dispersed particles to the number of all the dispersed particles increases beyond that of the number of the small dispersed particles in the structure shown in Fig. 2 or particles of different sizes are dispersed, and the ratio of the number of the dispersed particles of sizes not smaller than 0.3 μm to that of all the dispersed particles decreases below 15%. Consequently, the mode of dispersion of the dispersed particles becomes the same as the conventional one.

[0076] The soaking process may be divided into a plurality of soaking stages. At least a cooling process subsequent to the final soaking stage is a slow cooling process that cools the ingot at the abovementioned cooling rate.

Hot Rolling Starting Conditions

[0077] The ingot processed by the soaking process may be cooled, and subjected to rough hot rolling after reheating or may be subjected to rough hot rolling without being excessively cooled. The ingot is cooled by slow cooling at the abovementioned cooling rate to a rough hot rolling starting temperature after the soaking process in such a case as well.

Conditions for Rough Hot Rolling

[0078] When hot rolling includes rough hot rolling and finish hot rolling continuous with rough hot rolling, cracks are liable to form in the edges of a sheet during finish hot rolling due to low rolling temperature if the temperature of the sheet after the rough hot rolling state is excessively low. If the temperature of the sheet at the end of the rough hot rolling is excessively low, an unrecrystallized phase remains in the sheet due to insufficient heat in the sheet or the quality of the surface of the sheet is deteriorated by increased rolling force. Therefore, it is preferable that the temperature of the sheet at the end of rough hot rolling is 420˚C or above, desirably, 430˚C or above, more desirably 440˚C or above, and

470˚C or below, desirably, 460˚C or below.

[0079] Preferably, the temperature of the sheet at the start of rough hot rolling is, for example, in the range of about 490 to about 550˚C, desirably, in the range of about 495˚C to about 540˚C, more desirably, in the range of about 500˚C to about 530˚C to obtain the sheet of a temperature in the range of about 420˚C to 480˚C at the end of rough hot rolling. Oxidation of the surface of the hot-rolled sheet can be prevented, and formation of large recrystallized grains can be prevented to improve the formability still further when the temperature of the sheet at the start of rough hot rolling is 550˚C or below.

[0080] It is desirable to process an aluminum alloy sheet processed by rough hot rolling immediately by finish hot rolling. Recovery of a strain caused in the aluminum alloy sheet during rough hot rolling can be prevented and the strength of the aluminum alloy sheet formed by cold rolling subsequent to the hot rolling can be enhanced when the aluminum alloy sheet processed by rough hot rolling is processed immediately to finish hot rolling after rough hot rolling. Preferably, the aluminum alloy sheet rolled by rough hot rolling is subjected to finish hot rolling in, for example 5 min, desirably, in 3 min.

Conditions for Finish Hot Rolling

[0081] Preferably, the temperature of the sheet at the end of finish hot rolling is in the range of 310˚C to 350˚C. Finish hot rolling forms a sheet in a predetermined size. Heat generated in the finish hot rolled sheet forms recrystallized structure. Therefore, the heat of the sheet at the end of finish hot rolling affects the recrystallized structure. When the temperature of the sheet at the end of the finish hot rolling is 310˚C or above, the final structure having crystal grains stretched in the rolling direction in an aspect ratio of 3 or above can be easily formed by cold rolling subsequent to the final hot rolling. If the temperature of the sheet at the end of the finish hot rolling is below 310˚C, it is difficult to form crystal grains having high mean aspect ratio even if the sheet is processed by cold rolling at a high rolling reduction.

[0082] If the temperature of the sheet at the end of the finish hot rolling is above 350˚C, final structure includes crystal grains stretched in the rolling direction in a mean aspect ratio of 3 or above, large Mg_2Si grains precipitate and it is difficult to form distributed particle structure specified by the present invention. The temperature of the sheet at the end of finish hot rolling is in the range of 310˚C to 350˚C, preferably, in the range of 320˚C to 340˚C.

Type of Finish Hot-rolling Mills

[0083] A tandem hot-rolling mill having three or more roll stands is used for finish hot rolling. In the tandem hot-rolling mill having three or more roll stands, the rolling reduction in each of the roll stands may be low, the surface quality of the hot-rolled sheet can be maintained, and strain can be accumulated. Consequently, the respective strengths of a cold-rolled sheet and an object formed by subjecting the cold-rolled sheet to a DI process can be enhanced still further.

Total Rolling Reduction in Finish Hot Rolling

[0084] Desirably, the total rolling reduction of the finish hot rolling is 80% or above. When a sheet hot-rolled at a total reduction of 80% or above, structure including crystal grains stretched in the rolling direction in a mean aspect ratio of 3 or above can be formed and a sheet of dispersed particle structure specified by the present invention can be easily produced by cold rolling, and the respective strengths of the cold-rolled sheet and an object formed by subjecting the cold-rolled sheet to a DI process can be enhanced.

Thickness of Hot-rolled Sheet

[0085] Desirably, the thickness of an alloy sheet produced by finish hot rolling is in the range of about 1.8 to about 3 mm. When a sheet is hot-rolled in a thickness of 1.8 mm or above, the deterioration of surface quality thereof, such as formation of galling and surface roughening, and thickness profile can be prevented. When a sheet is hot-rolled in a thickness of 3 mm or below, it is possible to avoid cold-rolling the sheet at an excessively high rolling reduction in manufacturing a cold-rolled sheet having a thickness in the range of about 0.28 to 0.35mm, and earing ratio after a DI process can be suppressed.

Cold Rolling

[0086] It is desirable that a cold-rolling process rolls a hot-rolled sheet at a total rolling reduction in the range of 77% to 90% by the so-called direct rolling process using a plurality of passes and omitting intermediate annealing. When a sheet is cold-rolled at a total rolling reduction of 77% or above without using intermediate annealing, structure including crystal grains stretched in the rolling direction in a mean aspect ratio of 3 or above can be formed, dispersed particle structure specified by the present invention can be formed, and cans having an increased compressive strength can be formed. If the sheet is subjected to intermediate annealing during the cold-rolling process or when the total rolling reduction is low, equiaxial crystal grains are liable to crystallize and it is difficult for stretched crystal grains to crystallize.

[0087] Although the mean aspect ratio of crystal grains is high when the rolling reduction is above 90%, 45˚ ears grow excessively during a DI process, the strength is excessively high and, consequently, it is highly likely that cupping cracks and bottom cracks form during a DI process.

[0088] The thickness of the cold-rolled sheet for forming metal bottles is in the range of about 0.28 to about 0.35 mm.

[0089] Desirably, the cold-rolling process uses a tandem rolling mill formed by arranging two or more rolling stands in a line. The tandem rolling mill, as compared with a single rolling mill including a single rolling stand and reducing the thickness of a sheet to a predetermined thickness by passing the sheet repeatedly through the single rolling stand, can roll a sheet at the same total rolling reduction as the single rolling mill by a number of passes smaller than that of the single rolling mill. The tandem rolling mill can roll a sheet at a high rolling reduction by a single pass.

[0090] A sheet can be easily formed in final structure containing crystal grains stretched in the rolling direction in a mean aspect ratio of 3 or above.

[0091] The cold-rolling process, as compared with the conventional cold-rolling process that uses a single rolling mill and processes a cold-rolled sheet by finish annealing, can cause continuous recovery at low temperatures and can produce subgrains. A rolling mill other than the tandem rolling mill may be used, provided that the rolling mill can cause recovery by cold rolling and can produce sufficient subgrains.

[0092] When a sheet is cold-rolled by the tandem rolling mill, the amount of heat generated by one pass is large because the rolling reduction of each pass is high. If an excessively large amount of heat is generated, it is possible that the grain sizes of dispersed particles increase.

[0093] Preferably, an aluminum sheet processed by a cold-rolling process using the tandem rolling mill is cooled forcibly upon the rise of the temperature of the aluminum sheet to a maximum temperature so that the temperature of the aluminum sheet at the end of cold rolling may not rise to a temperature above 200˚C.

[0094] To cool the aluminum sheet forcibly during the cold-rolling process, an emulsion of a water-soluble oil or a water-soluble lubricant may be used instead of a rolling oil not containing water. It is preferable to cool the aluminum sheet efficiently without reducing lubricating performance by using the emulsion.

[0095] When necessary, the cold-rolled sheet may be processed by a finish annealing process (final annealing process) at a temperature below a recrystallization temperature to improve DI formability and bottom formability by recovering a deformation texture. The temperature of finish annealing is in the range of, for example, about 100˚C to about 150˚C, desirably, in the range of about 115˚C to about 150˚C. Annealing at 100˚C or above can satisfactorily recover the deformation texture. Annealing at 150˚C or below can prevent the excessive precipitation of the elements of the solid solution and can improve DI formability and flange formability still further.

[0096] Desirably, the duration of finish annealing is 4 hr or below (particularly, in the range of 1 to 3 hr). The excessive precipitation of the elements of the solid solution can be prevented and DI formability can be improved still more by avoiding excessively long annealing.

[0097] Since cold rolling using the tandem rolling mill can produce subgrains by causing continuous recovery at lower temperatures, basically, a sheet produced by the tandem rolling mill does not need to be subj ected to a finish annealing process.

[0098] The present invention will be more concretely described in terms of examples thereof. It goes without saying that the following examples are not restrictive and changes and variations may be made therein in light of the forgoing and the following teachings without departing from the technical cope of the present invention.

Examples

[0099] Aluminum bullion and scrap cans were used as source materials. The source materials were melted to obtain molten aluminum alloys A to N respectively having compositions shown in Table 1. The molten aluminum alloys were cast by a DC casting method (Direct chill cast) to make ingots of 600 mm in thickness and 2100 mm in width. Aluminum alloys A to D are examples of the present invention, and aluminum alloys E to N are comparative examples. In Table 1, "-" indicates an element content below a detection limit.

[0100] As shown in Table 1, each of those ingots of aluminum alloys A to N contains Zr, Bi, Sn, Ga, V, Co, Ni, Ca, Mo, Be, Pb and W as inevitable impurities in a total impurity content of 0.03% or above.

[0101] The ingots respectively having those compositions were subjected to a soaking process under conditions shown in Tables 2 and 4. The soaking process heated the ingots from 300˚C to soaking temperatures at heating rates shown in Tables 2 and 4. The ingots processed by the soaking process were cooled from the soaking temperatures to temperatures to hot-rolling starting temperatures above 450˚C in the range of 450˚C to 550˚C at cooling rates shown in Tables 2 and 4, respectively.

[0102] The ingots cooled respectively at cooling rates of 25˚C/hr or below among those in examples of the present invention and the comparative examples were furnace cooled in a soaking furnace. The ingots in comparative examples cooled respectively at cooling rates above of 25˚C/hr were cooled by natural cooling outside the soaking furnace.

[0103] Each of the ingots processed by the soaking process was hot-rolled by using a single-stand reversing rolling mill for rough hot-rolling, and by using a tandem hot rolling mill having four roll stands for finis hot-rolling. The ingot was subjected to finish hot rolling within 3 min after the ingot had been processed by rough hot rolling. All the ingots were processed by finish hot rolling to produce hot-rolled aluminum alloy sheets having a thickness of 2.5 mm.

[0104] The hot-rolled sheets were cold-rolled by a tandem or single rolling mill to produce cold-rolled sheets having a thickness of 0.3 mm intended for forming metal bottles. The cold-rolled sheets were not processed by finish annealing (final annealing).

[0105] All the sheets shown in Table 2 were not processed by intermediate annealing and were produced by single-pass cold rolling by a tandem rolling mill having two roll stands. All the sheets shown in Table 4 were produced by four-pass cold rolling by a single rolling mill having a single roll stand and were processed by final annealing at 150˚C for 1 hr.

[0106] Cold rolling by the tandem rolling mill for producing the sheets shown in Table 2 cooled the aluminum sheets by forced cooling using an aqueous emulsion so that the temperature of the aluminum sheets might not rise beyond 250˚C.

[0107] Specimens were sampled from rolls of the cold-rolled sheets for forming metal bottles. The specimens were examined by the abovementioned measuring method under a TEM at 10,000× magnification. The number of dispersed particles of particle sizes in the range of 0.05 to 1 μm in an area of 300 μm^2 of each specimen was counted. The ratio (%) of the number of dispersed particles having particle sizes not smaller than 0.3 μm among those dispersed particles to the number of those dispersed particles was calculated, and the metal aspect ratio of the disperse particles was calculated. The measurements and those calculated values are shown in Table 3 continued from Table 2, and Table 5 continued from Table 4.

Mechanical Properties

[0108] The respective 0.2% offset yield strengths of the specimens were measured by a tensile test method specified in Z 2201, JIS. Test specimens were formed in the shape of a test specimen No. 5 specified in JIS such at the length thereof extends in the rolling direction. The cross head was moved at a fixed speed of 5 mm/min until the test specimen broke.

[0109] The respective 0.2% offset yield strengths of specimens were measured after heating the specimens at 200˚C for 20 min by a heating process simulating a baking process for baking printed cans. The 0.2% offset yield strengths of the specimens kept at a room temperature and those of the specimens processed by the heating process were compared to determine 0.2% offset yield strength reductions. Those data are shown in Table 3 continued from Table 2, and Table 5 continued from Table 4.

[0110] Earing ratio indicating formability to be basically satisfied by a sheet for forming metal bottles, and formability required by each of forming processes for forming two-piece metal bottles were measured and evaluated. Measured results are shown in Table 3.

Earing ratio

[0111] A blank cut out from the sheet for forming metal bottles was coated with a lubricant (Naruko 6461, D. A. Stuart) and was drawn in a cup by an Erichsen tester for a 40% deep-drawing test. These conditions were the diameter of the blank: 66.7 mm, the diameter of the punch: 40 mm, the radius R of the rounded side shoulder of the die: 2.0 mm, the radius R of the rounded edge of the punch: 3.0 mm, and blank holder pressure: 400 kgf.

[0112] Shapes of ridges and valleys in the edge of the open end of the cup at eight angular positions with respect to the rolling direction, namely, directions at 0˚, 45˚, 90˚, 135˚, 180˚, 225˚, 270˚ and 315˚ to the rolling direction, were measured, and earing ratio was calculated.

[0113] A method of calculating earing ratio will be explained with reference to Fig. 3. Fig. 3 is a development of a cup obtained by processing the sheet for forming a metal bottle by a DI process. The respective heights T1, T2, T3 and T4 from the bottom of the cup of negative ears extending in directions at 0˚, 90˚, 180˚ and 270˚ to the rolling direction, and the respective heights Y1, Y2, Y3 and Y4 from the bottom of the cup of positive ears extending in directions at 45˚, 135˚, 225˚ and 315˚ to the rolling direction were measured. An earing ratio was calculated by using the measured values and the following expression.

$$\text{Earing ratio} = [\{(Y1 + Y2 + Y3 + Y4) - (T1 + T2 + T3 + T4)\}/\{1/2 \times (Y1 + Y2 + Y3 + Y4 + T1 + T2 + T3 + T4)\}] \times 100\ (\%)$$

[0114] When the earing ratio is nearly equal to 0, the cold-rolled sheet of the present invention suppresses the growth of the four positive ears Y1 to Y4 and the two negative ears T2 and T4 in the directions at 90˚ and 270˚, but has difficulty in suppressing the growth of the two negative ears T1 and T3 in the directions at 0˚ and 180˚ shown in Fig. 3. If the absolute value of the earing ratio is simply reduced, for example, if the earing ratio is between -2 and 2%; that is, if the absolute value of the earing ratio is 2% or below, the suppression of the negative ears T1 and T3 shown in Fig. 3 is insufficient even if the earing ratio is between -2 and 0%. Consequently, the blank holder pressure is concentrated on the two negative ears T1 and T3 shown in Fig. 3 causing edge rise and edge crack to cause problems in production. If the earing ratio is between 0 and 2%, the two negative ears T1 and T3 shown in Fig. 3 can be satisfactorily suppressed and hence the fracture of the body due to edge crack can be prevented. According to the present invention, an allowable earing ratio is in the range of 0 to +3.5%.

Ironing Formability

[0115] The ironing formability of the sheet for forming metal bottles was evaluated. Blanks of 160 mm in diameter were punched our from the sheet for forming metal bottles, and the blanks were formed in cups of 92 mm in diameter. DI bottle bodies for metal bottles were manufactured at a manufacturing rate of 300 bottle bodies/min by processing the cups by a redrawing process, an ironing process and a trimming process. The DI bottle bodies were 66 mm in inside diameter, 170 mm in height, 115 μm in side wall thickness, and 190 mm in end-of-side-wall thickness. The ironing ratio of the final ironing process, namely, a third ironing process, was 40%. The number of broken cans (broken bottle bodies) among 50,000 cans was counted to evaluate the formability.

[0116] The formability of the sheet was rated excellent and was marked with a double circle when none of the cans formed by processing the sheet was broken, the formability of the sheet was rated good and was marked with a circle when four or less cans among the cans formed by processing the sheet were broken, and the formability of the sheet was rated unacceptable and was marked with a cross when five or more cans among the cans formed by processing the sheet were broken.

Neck Formability

[0117] Neck formability of the sheet for forming metal bottles was evaluated. The nondefective ones, namely, not broken ones, of the DI can bodies formed for the formability evaluation were used. A neck was formed by processing a part of each of the DI can bodies near the open end by a die neck forming process to shape the open end in a mouth. The outside diameter of the can body was 66.2 mm. The neck was formed in four steps. The outside diameter of the end of the neck was 60.3 mm. The necks of 10,000 cans were inspected for wrinkles to evaluate neck formability.

[0118] The necks of 100 cans were inspected for wrinkles to evaluate the neck formability of the sheet. The sheet was rated acceptable and marked with a circle when the number of cans having a wrinkled neck among the 100 cans was one or zero, and the sheet was rated unacceptable and marked with a cross when the number of cans having a wrinkled neck among the 100 cans was two or greater.

Threaded Neck Formability

[0119] Threaded neck formability of the sheet for forming metal bottles was evaluated. A screw thread, with which a screw cap is to be engaged, was formed in a part near the mouth of the unwrinkled neck of a two-piece metal bottle to evaluate the threaded neck formability of the sheet.

[0120] The threaded necks of 9, 000 metal bottles were examined. The sheet was rated excellent and marked with a double circle when all the 9,000 threaded necks were satisfactory in dimensional accuracy and did not have any partial deformation at all. The sheet was rated good and marked with a circle when one threaded neck among the 9, 000 threaded necks was defective in shape. The sheet was rated unacceptable and marked with a cross when three or more threaded necks among the 9, 000 threaded necks were defective in shape.

Buckling Strength of Threaded Neck

[0121] Axial compressive load was placed on each of ten two-piece metal bottles each having the threaded neck. The mean buckling load of ten measured buckling loads at which the threaded necks buckled was calculated. Threaded necks having a buckling strength not lower than 1,500 N are practically acceptable.

[0122] As obvious from Tables 3 and 5, cold-rolled aluminum alloy sheets in Examples 1 to 5 shown in Table 3 and those in Examples 20 to 24 shown in Table 5 have compositions specified by the present invention, and the ratio of the number of the dispersed particles of sizes of 0.3 μm or above to the number of all the dispersed particles of sizes in the range of 0.05 to 1 μm in those cold-rolled aluminum alloy sheets are within the range specified by the present invention.

[0123] The cold-rolled aluminum alloy sheets in Examples 1 to 5 and 20 to 24 are excellent in earing ratio, neck formability and threaded neck formability required by the two-piece metal bottle forming processes, and excellent in the buckling strength of the threaded neck.

[0124] The cold-rolled aluminum alloy sheets in Examples 1 to 5 shown in Table 3 have crystal grains having aspect ratios of 3 or above, have the offset yield strength that is reduced only a little by baking and have excellent high-temperature characteristics.

[0125] Although the cold-rolled aluminum alloy sheets in Comparative examples 6 to 9 shown in Table 3 and in Comparative examples 25 to 28 shown in Table 5 have compositions corresponding to those specified by the present invention, the cooling rate after the soaking process is higher than 25°C/hr. Therefore, those cold-rolled aluminum alloy sheets do not have the dispersed particle structure specified by the present invention, the ratio of the number of small dispersed particles to the number of all the dispersed particles is high, dispersed particles having different particle sizes are dispersed, and the ratio of the number of the dispersed particles of sizes of 0.3 μm or above to the number of all the dispersed particles in those cold-rolled aluminum alloy sheets is below 15%.

[0126] The cold-rolled aluminum alloy sheet in Comparative example 10 shown in Table 3 has an excessively high Mn content, contains gigantic crystal grains and does not have a dispersed particle composition required by the present invention. Therefore many cracks formed when the cold-rolled aluminum alloy sheet was processed to form metal bottles.
The cold-rolled aluminum alloy sheet in Comparative example 11 has an excessively low Mn content. Therefore the buckling strength of the neck of the bottle formed by processing the same is insufficient.
The cold-rolled aluminum alloy sheet in Comparative example 12 has an excessively high Mg content. Therefore the formability, particularly, ironing formability, is deteriorated by high work hardening.
The cold-rolled aluminum alloy sheet in Comparative example 13 has an excessively low Mg content. Therefore, the buckling strength is insufficient.
The cold-rolled aluminum alloy sheet in Comparative example 14 has an excessively high Cu content and hence unsatisfactory in formability.
The cold-rolled aluminum alloy sheet in Comparative example 15 has an excessively low Cu content and hence the buckling strength is insufficient.
The cold-rolled aluminum alloy sheet in Comparative example 16 has an excessively low Si content and hence large positive ears form. Since the α phase is insufficient, the ironing formability is inferior.
The cold-rolled aluminum alloy sheet in Comparative example 17 has an excessively high Si content and large positive ears forms owing to unrecrystallized grains remaining therein.
The cold-rolled aluminum alloy sheet in Comparative example 18 has an excessively low Fe content, contains unrecrystallized grains, does not have many crystallized grains, and has inferior ironing formability.
The cold-rolled aluminum alloy sheet in Comparative example 19 has an excessively high Fe content, forms large positive ears, has excessive crystallized grains, and propagation of cracks therein is promoted to deteriorate ironing formability.

[0127] Those cold-rolled aluminum alloy sheets in comparative examples are unsatisfactory in earing ratio, ironing formability, neck formability and threaded neck formability, which are essential properties needed to form two-piece metal bottles, and form threaded necks having insufficient buckling strength.

[0128] The cold-rolled aluminum alloy sheets in Comparative examples 10 to 19 shown in Table 3 are cooled after the soaking process at a desirable cooling rate. However, the respective alloy compositions of those cold-rolled aluminum alloy sheet do not correspond to the dispersed particle structure specified by the present invention and, even if those cold-rolled aluminum alloy sheets have the disperse particle structure specified by the present invention, the ironing formability, neck formability and threaded neck formability necessary for forming two-piece metal bottles thereof are inferior.

[0129] The critical significance of the present invention can be known from the abovementioned results.

[0130]

Table 1

Classification	Quality symbol	Chemical composition (percent by mass, B content: ppm, Other element: Al)									
		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	B	Other elements
Example	A	0.25	0.44	0.21	0.88	0.88	-	-	-	-	0.03
	B	0.26	0.43	0.20	0.91	1.05	0.03	0.19	0.03	0	0.03
	C	0.25	0.42	0.2	0.9	0.9	0.03	0.2	0.02	10	0.04
	D	0.3	0.45	0.1	1.3	1	-	-	0.02	10	0.05

(continued)

Classification	Quality symbol	Chemical composition (percent by mass, B content: ppm, Other element: Al)									
		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	B	Other elements
Comparative example	E	0.4	0.5	0.4	1.6	1	-	-	0.01	40	0.04
	F	0.2	0.4	0.2	0.6	1	-	-	0.01	40	0.04
	G	0.1	0.2	0.3	1	1.8	-	-	0.03	30	0.03
	H	0.1	0.2	0.2	1	0.7	-	-	0.03	30	0.03
	I	0.3	0.4	0.7	1.1	0.9	-	-	0.02	30	0.03
	J	0.12	0.45	0.03	1.05	0.97	-	-	0.02	30	0.03
	K	0.03	0.5	0.4	0.9	1	-	-	0.03	30	0.03
	L	0.6	0.4	0.4	0.95	1.05	-	-	0.03	30	0.03
	M	0.3	0.05	0.35	1.2	1.0	-	-	0.02	30	0.03
	N	0.2	0.8	0.33	0.99	1.2	-	-	0.02	30	0.03
Other elements: Zr, Bi, Sn, Ga, V, Co, Ni, Ca, Mo, Be, Pb and W											

[0131]

Table 2

Classification	No.	Quality symbol (Table 1)	Soaking process				Rough hot-rolling process		Finish hot-rolling process			Cold-rolling process		
			Heating rate (˚C/hr)	Soaking temperature (˚C)	Soaking time (hr)	Cooling rate (˚C/hr)	Initial temperature (˚C)	Final temperature (˚C)	Total rolling reduction (%)	Final temperature (˚C)	Thickness (nun)	Type of rolling mill	Rolling reduction (%)	Final thickness (mm)
Example	1	A	23	610	2	14	504	461	92	341	2.5	Tandem	86	0.36
	2	A	26	610	6	22	511	442	92	335	2.5	Tandem	86	0.36
	3	B	24	610	4	15	501	451	92	321	2.5	Tandem	86	0.36
	4	C	22	610	4	12	512	469	92	332	2.5	Tandem	86	0.36
	5	D	23	610	4	14	549	483	92	340	2.5	Tandem	86	0.36
Comparative example	6	A	27	610	4	40	502	459	92	342	2.5	Tandem	86	0.36
	7	B	24	610	6	39	505	453	92	321	2.5	Tandem	86	0.36
	8	C	25	610	6	35	514	471	92	333	2.5	Tandem	86	0.36
	9	D	23	610	6	28	548	480	92	339	2.5	Tandem	86	0.36
	10	E	41	610	6	15	503	462	92	342	2.5	Tandem	86	0.36
	11	F	39	610	6	14	489	443	92	335	2.5	Tandem	86	0.36
	12	G	42	610	6	14	477	441	92	334	2.5	Tandem	86	0.36
	13	H	40	610	6	15	496	488	92	320	2.5	Tandem	86	0.36
	14	I	41	610	6	13	497	465	92	315	2.5	Tandem	86	0.36
	15	J	41	610	6	13	474	459	92	326	2.5	Tandem	86	0.36
	16	K	40	610	6	14	505	468	92	304	2.5	Tandem	86	0.36
	17	L	42	610	6	14	483	442	92	321	2.5	Tandem	86	0.36
	18	M	40	610	6	14	492	466	92	327	2.5	Tandem	86	0.36
	19	N	39	610	6	14	496	471	92	324	2.5	Tandem	86	0.36

[0132]

Table 3

Classification	No.	Quality symbol (Table 1)	Dispersed particle structure			Mechanical properties		Formability					High-temperature characteristic	
			Number of particle of sizes between 0.05 and 1 μm in 300 μm²	Ratio of the number of particles of sizes not smaller than 0.3 μm to the number of all the particles (%)	Mean aspect ratio of crystal grains	Tensile strength (MPa)	0.2% offset yield strength (MPa)	Earing ratio (%)	Ironing formability	Neck formability	Threaded neck formability	Buckling strength of threaded neck (N)	AB 0.2% offset yield strength (MPa)	2% offset yield strength reduction (MPa)
Example	1	A	129	48	4.8	280	257	+1.1	◎	◎	◎	1552	240	17
	2	A	300	20	5.3	284	260	+2.1	○	○	○	1597	242	18
	3	B	290	35	6.1	295	270	+2.0	○	○	○	1625	252	18
	4	C	254	62	5.4	283	258	+1.2	○	○	○	1560	241	17
	5	D	362	41	4.6	307	282	+2.3	○	○	○	1862	260	22
Comparative example	6	A	437	10	4.3	277	252	+3.1	○	×	×	1511	233	19
	7	B	462	11	4.5	284	262	+1.1	○	×	×	1583	244	18
	8	C	430	13	4.7	286	250	+3.2	○	×	×	1522	236	19
	9	D	487	13	5.2	300	277	+2.0	○	×	×	1631	253	24
	10	E	493	75	5.8	326	301	+4.1	×	×	×	1843	285	16
	11	F	45	19	4.2	272	246	+0.2	×	×	×	1470	228	18
	12	G	234	48	5.1	327	305	-1.9	×	×	×	1866	289	16
	13	H	186	52	4.3	269	245	-0.8	×	×	×	1445	229	16
	14	I	232	55	4.9	322	297	+3.5	×	×	×	1815	284	13
	15	J	273	57	4.7	285	259	+1.5	×	×	×	1488	234	25
	16	K	232	38	3.9	308	285	+4.8	×	×	×	1746	270	15
	17	L	225	46	3.5	289	263	+2.4	×	×	×	1605	249	14
	18	M	200	41	3.6	319	294	-0.8	×	×	×	1778	278	16
	19	N	373	78	4.0	314	287	+4.5	×	×	×	1752	271	16

[0133]

Table 4

Classification	No.	Quality symbol (Table 1)	Soaking process				Rough hot-rolling process		Finish hot-rolling process			Cold-rolling process		
			Heating rate (˚C/hr)	Soaking temperature (˚C)	Soaking time (hr)	Cooling rate (˚C/hr)	Initial temperature (˚C)	Final temperature (˚C)	Total rolling reduction (%)	Final temperature (˚C)	Thickness (mm)	Type of rolling mill	Rolling reduction (%)	Final thickness (mm)
Example	20	A	23	610	2	14	501	456	92	339	2.5	Single	86	0.36
	21	A	26	610	6	22	508	443	92	334	2.5	Single	86	0.36
	22	B	24	610	4	15	505	446	92	325	2.5	Single	86	0.36
	23	C	22	610	4	12	516	472	92	330	2.5	Single	86	0.36
	24	D	23	610	4	14	540	479	92	339	2.5	Single	86	0.36
Comparative example	25	A	27	610	4	40	508	454	92	342	2.5	Single	86	0.36
	26	B	24	610	6	39	519	458	92	325	2.5	Single	86	0.36
	27	C	25	610	6	35	506	454	92	335	2.5	Single	86	0.36
	28	D	23	610	6	28	548	467	92	338	2.5	Single	86	0.36

[0134]

Table 5

Classification	No.	Quality symbol (Table 1)	Dispersed particle structure			Mechanical properties		Formability						High-temperature characteristic	
			Number of particle of sizes between 0.05 and 1 μm in 300 μm²	Ratio of the number of particles of sizes not smaller than 0.3 μm to the number of all the particles (%)	Mean aspect ratio of crystal grains	Tensile strength (MPa)	0.2% offset yield strength (MPa)	Earing ratio (%)	Ironing formability	Neck formability	Threaded neck formability	Buckling strength of threaded neck (N)	AB 0.2% offset yield strength (MPa)	2% offset yield strength reduction (MPa)
Example	20	A	133	50	5.2	283	265	+1.5	○	○	○	1545	243	23
	21	A	298	19	5.8	284	267	+2.3	○	○	○	1578	245	22
	22	B	295	23	6.6	297	278	+2.1	○	○	○	1622	254	24
	23	C	263	65	5.7	284	265	+1.3	○	○	○	1538	243	22
	24	D	355	43	5.1	303	285	+2.5	○	○	○	1678	259	26
Comparative example	25	A	443	11	5.5	290	262	+4.0	○	×	×	1513	234	28
	26	B	456	12	5.9	299	280	+0.9	○	×	×	1619	253	27
	27	C	422	14	6.8	282	264	+3.5	○	×	x	1527	236	28
	28	D	474	14	5.9	310	292	+2.5	○	×	×	1701	263	29

[0135] As apparent from the foregoing description, the present invention provides a cold-rolled aluminum alloy sheet excellent in neck formability and threaded neck formability for forming metal bottles. Thus.the cold-rolled aluminum alloy sheet is suitable for uses that requires severe requisite properties, such as excellent formability necessary for forming small two-piece metal bottles having a small wall thickness and capable of maintaining strength when processed by a heat treatment.

Claims

1. A cold-rolled aluminum alloy sheet, for forming metal bottles, excellent in neck formability, and having a composition containing 0.7 to 1.5% by mass Mn, 0.8 to 1.7% by mass Mg, 0.1 to 0.7% by mass Fe, 0.05 to 0.5% by mass Si, 0.1 to 0.6% by mass Cu, and Al and inevitable impurities as other elements;
   wherein 50 to 400 particles of particle sizes in the range of 0.05 to 1 μm are dispersed in an area of 300 μm^2 when observed under a TEM at a magnification in the range of 5, 000× to 15, 000× magnification, and the ratio of the number of the dispersed particles of sizes of 0.3 μm or above to the number of all the dispersed particles is in the range of 15 to 70%.

2. The cold-rolled aluminum alloy sheet according to claim 1, wherein the mean aspect ratio of crystal grains in the structure of the cold-rolled aluminum alloy sheet as viewed from above with respect to the thickness of the cold-rolled aluminum alloy sheet in a middle part of the cold-rolled aluminum alloy sheet is 3 or above.

3. The cold-rolled aluminum alloy sheet according to claim 1 or 2, wherein the composition further contains either of or both Cr in a Cr content in the range of 0.001 to 0.3% by mass and Zn in a Zn content in the range of 0.05 to 1.0% by mass.

4. The cold-rolled aluminum alloy sheet according to any one of claims 1 to 3, wherein the composition contains 0.005 to 0.2% by mass Ti or both 0.005 to 0.2% by mass Ti and 0.0001 to 0.05% by mass B.

5. A method of manufacturing a cold-rolled aluminum alloy sheet, for forming a metal bottle, excellent in neck formability according to any one of claims 1. to 4, comprising the steps of:

   soaking a ingot at 550˚C or above;
   slowly cooling the ingot at a cooling rate of 25˚C/hr or below to a temperature in the range of 450˚C to 550˚C; and
   hot rolling and cold rolling the ingot such that 50 to 400 particles of particle sizes in the range of 0.05 to 1 μm are dispersed in an area of 300 μm^2 when observed under a TEM at a magnification in the range of 5,000× to 15,000× magnification, and the ratio of the number of the dispersed particles of sizes of 0.3 μm or above to the number of all the dispersed particles is in the range of 15 to 70%.

6. The method according to claim 5, wherein cold rolling cold-rolls a hot-rolled sheet in a cold-rolled sheet of a final thickness without annealing the hot-rolled sheet during cold rolling.

FIG.1

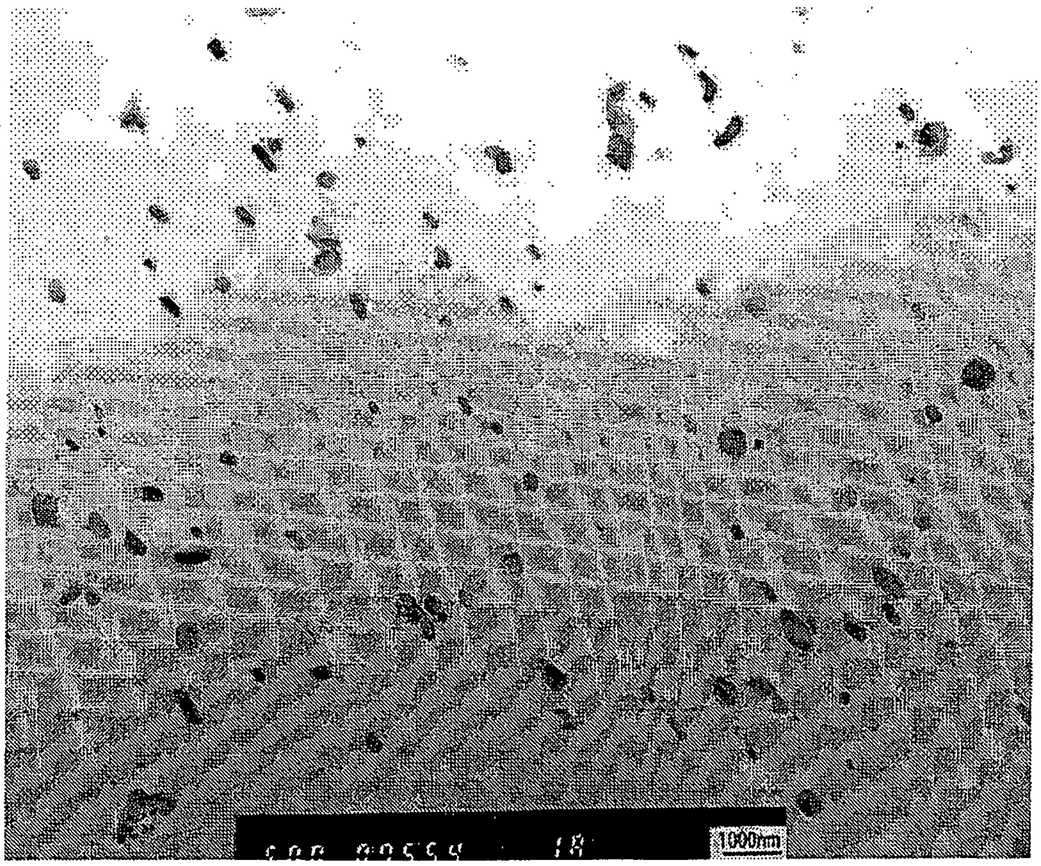


FIG. 2

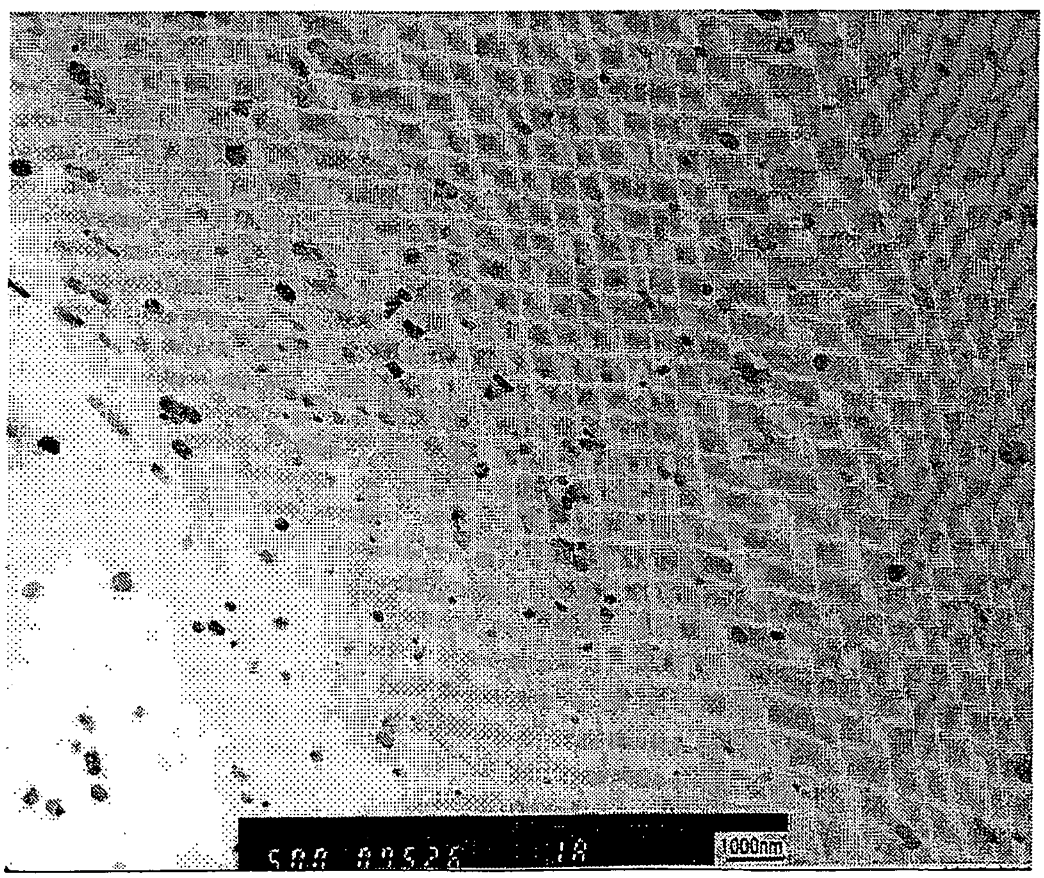
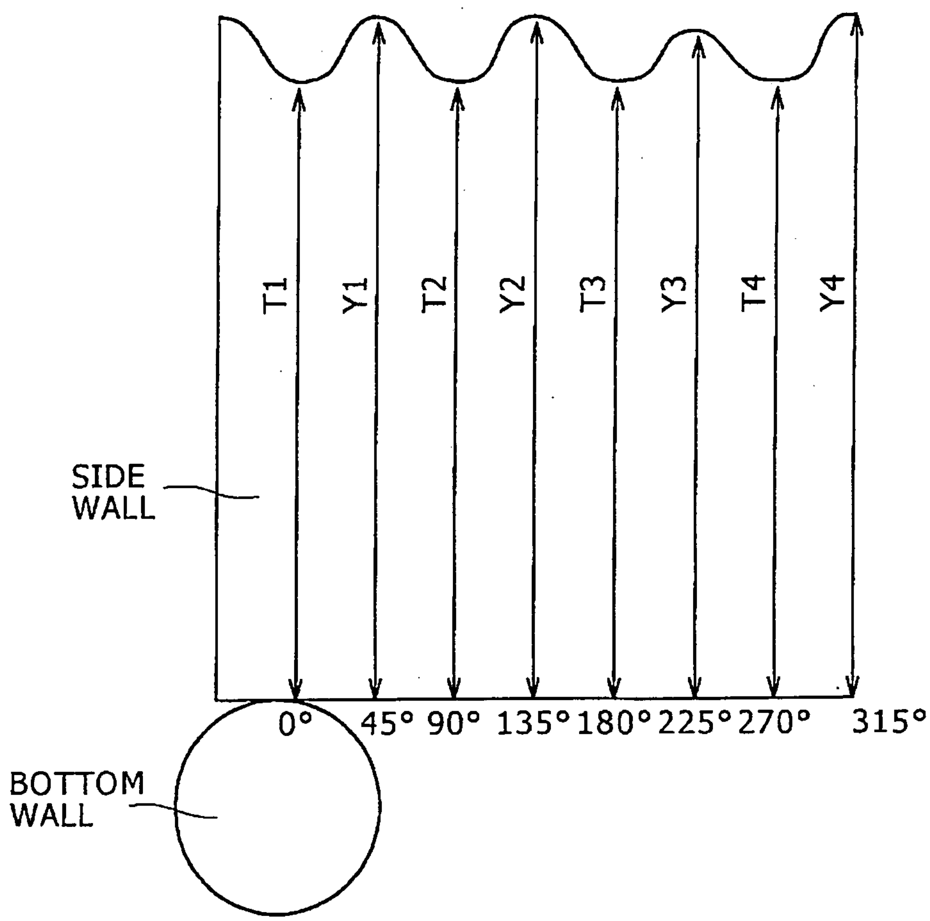


FIG. 3


T1
Y1
T2
Y2
T3
Y3
T4
Y4
SIDE WALL
0°
45°
90°
135°
180°
225°
270°
315°
BOTTOM WALL

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2006/318241

A. CLASSIFICATION OF SUBJECT MATTER
C22C21/06(2006.01)i, *C22C21/00*(2006.01)i, *C22F1/04*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22C21/00-21/18, C22F1/04-1/057

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2006
Kokai Jitsuyo Shinan Koho	1971-2006	Toroku Jitsuyo Shinan Koho	1994-2006

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2003-342657 A (Kobe Steel, Ltd.), 03 December, 2003 (03.12.03), Claims; Par. Nos. [0002], [0017], [0056], [0082] (Family: none)	1-6
A	JP 2004-183035 A (Sumitomo Light Metal Industries, Ltd.), 02 July, 2004 (02.07.04), Claims; Par. Nos. [0004], [0005], [0009], [0017] (Family: none)	1-6

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search 17 October, 2006 (17.10.06)	Date of mailing of the international search report 07 November, 2006 (07.11.06)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2006/318241

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2005-48288 A (Mitsubishi Aluminum Co., Ltd.), 24 February, 2005 (24.02.05), Claims; Par. Nos. [0004] to [0019] (Family: none)	1-6
A	JP 63-4049 A (Furukawa Aluminum Co., Ltd.), 09 January, 1988 (09.01.88), Claims; page 2, lower left column, lines 13 to 20 (Family: none)	1-6

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REFERENCES CITED IN THE DESCRIPTION

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