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(72) Inventors:
• **TAKAI, Daichi**
Tokyo 100-0004 (JP)
• **EZAKI, Tomotaro**
Tokyo 100-0004 (JP)
• **KUDO, Tomoyuki**
Tokyo 100-0004 (JP)
• **TAZOE, Kiyonari**
Tokyo 100-0004 (JP)

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(74) Representative: **RavensPAT Patentanwälte Partnerschaft mbB**
Großtobeler Straße 39
88276 Berg / Ravensburg (DE)

(71) Applicant: **UACJ Corporation**
Chiyoda-ku
Tokyo 100-0004 (JP)

(54) **ALUMINUM ALLOY PLATE FOR CAN LID**

(57) One aspect of the present disclosure provides an aluminum alloy sheet for a can lid, the sheet including: 0.27 mass % or more and 0.39 mass % or less of Si; 0.35 mass % or more and 0.55 mass % or less of Fe; 0.17 mass % or more and 0.25 mass % or less of Cu; 0.75 mass % or more and 0.95 mass % or less of Mn, and 2.2 mass % or more and 2.8 mass % or less of Mg, wherein, in each of 0°, 45°, and 90° directions to a rolling direction, a minimum evaluation value $S_{\min}$ among evaluation values S calculated by a following formula (1) using a 0.2% proof stress $\sigma_{0.2}$, a tensile strength σ_B , and an average value σ_{fm} of the 0.2% proof stress and the tensile strength is 370 MPa or more and 410 MPa or less.

$$S = \sigma_{fm} / (\sigma_{0.2} / \sigma_B) \dots (1)$$

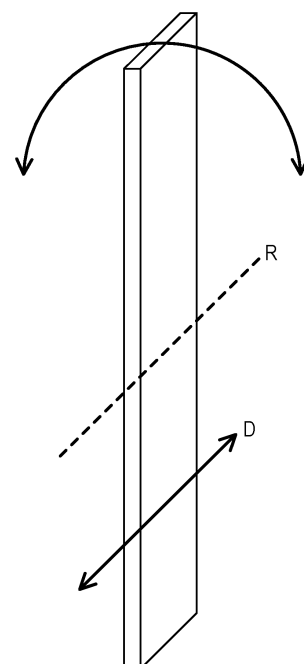


FIG. 1

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Description**CROSS-REFERENCE TO RELATED APPLICATION**

- 5 **[0001]** This international application claims the benefit of Japanese Patent Application No. 2023-067371 filed on April 17, 2023 with the Japan Patent Office, the entire disclosure of which is incorporated herein by reference.

TECHNICAL FIELD

- 10 **[0002]** The present disclosure relates to an aluminum alloy sheet for a can lid.

BACKGROUND ART

- 15 **[0003]** In recent years, there has been a demand for an aluminum alloy sheet that emits less CO₂ during its manufacturing process due to growing environmental awareness. A major and indirect cause of CO₂ emissions in the manufacturing process of aluminum is to blend primary aluminum in a casting process.

[0004] Production of the primary aluminum requires a large amount of electricity in its refining process, which leads to large CO₂ emissions. Thus, reducing an amount of blending the primary aluminum and increasing a closed recycling rate lead to reduction of CO₂ emissions in production of the aluminum alloy sheet.

- 20 **[0005]** In general, it is said that CO₂ emissions can be reduced to approximately one-thirtieth when aluminum scraps are re-melted for casting compared to a case where the primary aluminum is produced. In particular, an amount of aluminum alloy sheets produced for beverage cans, which are widely used around the world, is very large. Thus, further improvement in the closed recycling rate has great significance in reducing the burden on the environment.

- 25 **[0006]** Among those alloy sheets, a can lid made of 5182 aluminum alloy (AA5182 alloy) has lower upper compositional limits of Si, Fe, Cu, Mn, and the like than those of a can body made of 3104 aluminum alloy (AA3104 alloy). Thus, it is difficult to blend scraps derived from can stock containing the 3104 aluminum alloy.

- 30 **[0007]** For example, when can scraps (UBC: Used Beverage Can) collected from around the city are blended as they are, the resultant contains more components contained in the 3104 aluminum alloy due to a weight ratio between a can body and a can lid. Thus, the upper compositional limits for the 5182 aluminum alloy are easily exceeded. As a result, it is necessary to dilute the resultant composition with primary metal.

[0008] Thus, an aluminum alloy sheet for a can lid is adjusted to include a composition of the 5182 aluminum alloy by using a large amount of primary metal compared to an aluminum alloy sheet for a can body, resulting in a lower recycling rate. Thus, by changing the alloy for a can lid to an alloy having a composition in which more 3104 aluminum alloy can be blended, the usage rate of the primary metal for a can lid can be greatly reduced.

- 35 **[0009]** Patent Documents 1 to 5 disclose aluminum alloy sheets for can lids each having excellent recyclability and a composition relatively closer to that of the 3104 aluminum alloy.

PRIOR ART DOCUMENTS

- 40 **PATENT DOCUMENTS**

[0010]

- 45 Patent Document 1: Japanese Unexamined Patent Application Publication No. 2001-73106
 Patent Document 2: Japanese Unexamined Patent Application Publication No. H9-070925
 Patent Document 3: Japanese Unexamined Patent Application Publication No. H11-269594
 Patent Document 4: Japanese Unexamined Patent Application Publication No. 2000-160273
 Patent Document 5: Japanese Unexamined Patent Application Publication No. 2016-160511

- 50 **SUMMARY OF THE INVENTION**

PROBLEMS TO BE SOLVED BY THE INVENTION

- 55 **[0011]** Problems in making an alloy for a can lid similar in composition to the 3104 aluminum alloy include reduction in a buckling pressure (pressure resistance) of the can lid and toughness of a material. The buckling pressure of the can lid is an internal pressure value when the can lid bulges (buckles) under a pressure inside the can, which is a resistance value when the internal pressure of the can accidentally increases due to changes in the external environment.

[0012] Especially for positive pressure cans used for beer and carbonated beverage, high buckling pressure is required.

In general, the buckling pressure increases as the strength of the material increases and the sheet thickness increases. For this reason, high-strength 5182 aluminum alloy that is high in Mg, which is a component contributing to increased strength, is used for lids of the positive pressure cans.

[0013] In contrast, if the conventional 3104 aluminum alloy is used for a can lid, the buckling pressure thereof is greatly reduced, and it is highly possible that the lid bulges and the content leaks when the internal pressure of the can is unexpectedly increased. If the sheet thickness is greatly increased to improve the buckling pressure, the weight and cost of the lid are increased.

[0014] Moreover, the toughness of a material affects the formability and the opening property of a lid. If the toughness of the materials is low, a molding crack may occur especially in a rivet part and a countersink part of the lid. In addition, when the internal pressure of the can is unexpectedly increased, a crack may occur in a score part, and it is highly possible that the content of the can leaks. In particular, these cracks occur along a rolling direction. Thus, toughness is required against tensile stress and bending stress in a direction perpendicular to the rolling direction.

[0015] However, the conventional aluminum alloy sheets for can lids each having a composition relatively close to the composition of the 3104 aluminum alloy do not satisfy either or both of the above two problems: the strength of the material (that is, buckling pressure of the lid) and the toughness of the material (that is, formability and opening property).

[0016] In one aspect of the present disclosure, it is desirable to be able to provide an aluminum alloy sheet for a can lid that achieves both high strength and high toughness while blended with scrap materials derived from can stock.

MEANS FOR SOLVING THE PROBLEMS

[0017] One aspect of the present disclosure is an aluminum alloy sheet for a can lid, the sheet comprising: a silicon (Si) content of 0.27 mass % or more and 0.39 mass % or less; an iron (Fe) content of 0.35 mass % or more and 0.55 mass % or less; a copper (Cu) content of 0.17 mass % or more and 0.25 mass % or less; a manganese (Mn) content of 0.75 mass % or more and 0.95 mass % or less, and a magnesium (Mg) content of 2.2 mass % or more and 2.8 mass % or less, and a balance consisting of or including aluminum (Al) and inevitable impurities, wherein, in each of 0°, 45°, and 90° directions to a rolling direction of the alloy sheet, a minimum evaluation value $S_{\min}$, which is a minimum value among evaluation values S calculated by a following formula (1) using a 0.2% proof stress $\sigma_{0.2}$, a tensile strength σ_B , and an average value σ_{fm} of the 0.2% proof stress and the tensile strength, is 370 MPa or more and 410 MPa or less.

$$S = \sigma_{fm}/(\sigma_{0.2}/\sigma_B) \dots (1)$$

[0018] With this configuration, the aluminum alloy sheet can achieve both of the high strength and high toughness while blended with scrap materials derived from can stock. That is, a certain amount of scraps derived from 3104 aluminum alloy for a can body can be blended, thereby reducing the usage rate of the primary metal and the amount of CO₂ emissions. Furthermore, it is possible to obtain a highly formable aluminum alloy sheet for a can lid that can be used for a positive pressure can lid, which is required to have high buckling pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

FIG. 1 is a schematic diagram of a cyclic bending test.

FIG. 2 is an explanatory view of an L-ST cross-section.

FIG. 3 is a graph showing a relationship between values V and single shell buckling pressure in Examples.

MODE FOR CARRYING OUT THE INVENTION

[0020] Hereinafter, an embodiment to which the present disclosure is applied is described with reference to the drawings.

[1. First Embodiment]

[1-1. Configuration]

<Composition>

[0021] An aluminum alloy sheet for a can lid of the present disclosure (hereinafter, also simply referred to as "alloy

sheet") comprises aluminum (Al), silicon (Si), iron (Fe), copper (Cu), manganese (Mn), and magnesium (Mg).

[0022] The lower limit of Si content is 0.27 mass %, and preferably, 0.30 mass %. If the Si content is less than 0.27 mass %, an amount of Si precipitation by processing heat during cold rolling, which is conducted after hot rolling and solution heat treatment, may decrease and the strength of the alloy sheet may be insufficient.

[0023] The average value of Si component specified for 3104 aluminum alloy according to JIS-H-4000:2014 is 0.30 mass %. Thus, by setting the Si content to 0.27 mass % or more, preferably 0.30 mass % or more, a larger amount of scraps of 3104 aluminum alloy can be blended.

[0024] The upper limit of the Si content is 0.39 mass %, and preferably, 0.35 mass %. If the Si content is more than 0.39 mass %, more Mg_2Si particles are formed, and the toughness of the alloy sheet decreases.

[0025] The lower limit of Fe content is 0.35 mass %, and preferably, 0.40 mass %. The average value of Fe component specified for 3104 aluminum alloy is 0.40 mass %. Thus, by setting the Fe content to 0.35 mass % or more, preferably 0.40 mass % or more, a larger amount of scraps of 3104 aluminum alloy can be blended.

[0026] The upper limit of the Fe content is 0.55 mass %. If the Fe content is more than 0.55 mass %, more Al-Fe-Mn base or Al-Fe-Mn-Si base intermetallic compounds (that is, second phase particles) are formed. As a result, a crack propagation path is generated, and the toughness of the alloy sheet decreases.

[0027] The lower limit of Cu content is 0.17 mass %, and more preferably, 0.20 mass %. If the Cu content is less than 0.17 mass %, there is insufficient Cu to enhance the strength by solid solution or precipitation, and the strength of the alloy sheet decreases. The strength of the alloy sheet significantly increases by precipitating Cu in the process of the cold rolling after the hot rolling and the solution heat treatment.

[0028] The average value of Cu component specified for 3104 aluminum alloy is 0.15 mass %. Thus, by setting the Cu content to 0.17 mass % or more, a larger amount of scraps of 3104 aluminum alloy can be blended.

[0029] The upper limit of the Cu content is 0.25 mass %. If the Cu content is more than 0.25 mass %, the toughness of the alloy sheet decreases.

[0030] The lower limit of Mn content is 0.75 mass %, and preferably 0.80 mass %. If the Mn content is less than 0.75 mass %, there is insufficient Mn to enhance the strength by solid solution or precipitation, and the average strength of the alloy sheet decreases.

[0031] The average value of Mn component specified for 3104 aluminum alloy is 1.1 mass %, and the average value of the Mn component specified for 5182 aluminum alloy is 0.35 mass %. Thus, by setting the Mn content to 0.75 mass % or more, a larger amount of scraps of 3104 aluminum alloy can be blended compared to the conventional 5182 aluminum alloy.

[0032] The upper limit of the Mn content is 0.95 mass %, and preferably, 0.90 mass %. If the Mn content is more than 0.95 mass %, more Al-Fe-Mn base or Al-Fe-Mn-Si base intermetallic compounds (that is, second phase particles) are formed. As a result, a crack propagation path is generated, and the toughness of the alloy sheet is reduced.

[0033] The lower limit of Mg content is 2.2 mass %. If the Mg content is less than 2.2 mass %, there is insufficient Mg to enhance the strength by solid solution, and the average strength of the alloy sheet decreases. The strength of the alloy sheet is significantly increased by precipitating Mg in the process of the cold rolling after the hot rolling and the solution heat treatment.

[0034] The upper limit of the Mg content is 2.8 mass %. The average value of Mg component specified for 3104 aluminum alloy is 1.05 mass %, and the average value of the Mg component specified for 5182 aluminum alloy is 4.5 mass %. Thus, by setting the Mg content to 2.8 mass % or less, it is possible to use a larger amount of scraps of 3104 aluminum alloy and to reduce the amount of blending additional Mg-containing raw material.

[0035] The alloy sheet may comprise titanium (Ti). The upper limit of Ti content is preferably 0.10 mass %. If Ti is contained, an ingot structure of the alloy sheet is refined. The alloy sheet may also comprise zinc (Zn). The upper limit of Zn content is preferably 0.25 mass %. Furthermore, the alloy sheet may comprise chromium (Cr). The upper limit of Cr content is preferably 0.10 mass %.

[0036] The alloy sheet may comprise inevitable impurities to the extent that the performance of the alloy sheet is not significantly impaired. That is, the alloy sheet contains Si, Fe, Cu, Mn, Mg, Ti, Zn and Cr in the above-mentioned respective ranges, and a balance consists of or includes aluminum and inevitable impurities. The upper limit of the total amount of the inevitable impurities is preferably 0.15 mass %. The balance may contain substances other than aluminum and the inevitable impurities.

<Material Strength and Buckling Pressure>

[0037] A rolled aluminum alloy sheet has material anisotropy, and the strength shows different values in 0°, 45°, and 90° directions to a rolling direction of the alloy sheet. When an internal pressure of the can has increased, deformation begins in the direction with the least strength.

[0038] Thus, in the alloy sheet of the present disclosure, in each of the 0°, 45°, and 90° directions to the rolling direction, a minimum evaluation value $S_{\min}$ ($= \min(S_{0^\circ}, S_{45^\circ}, S_{90^\circ})$), which is a minimum value among evaluation values S ($S_{0^\circ}, S_{45^\circ}$,

and S_{90°) calculated by the following formula (1) using a 0.2% proof stress $\sigma_{0.2}$, a tensile strength σ_B , and an average value σ_{fm} of the 0.2% proof stress and the tensile strength, is 370 MPa or more and 410 MPa or less.

$$S = \sigma_{fm}/(\sigma_{0.2}/\sigma_B) \dots (1)$$

[0039] A buckling pressure value of a lid made of aluminum alloy has a strong positive correlation with a value V obtained from the following formula (2) that is empirically expressed by the minimum evaluation value S_{min} and sheet thickness t of the aluminum alloy sheet.

$$V = t^{2.27} \times S_{min} \dots (2)$$

[0040] Thus, by setting the minimum evaluation value S_{min} of the alloy sheet to 370 MPa or more, it is possible to form a lid having a sufficient buckling pressure without increasing the sheet thickness.

[0041] If the minimum evaluation value S_{min} exceeds 410 MPa, the material strength becomes excessively high and the toughness of the material decreases. That is, shear bands are more likely to occur on the materials due to tensile stress and bending stress during forming, and forming breakage is likely to occur. By setting the minimum evaluation value S_{min} to 410 MPa or less, it is possible to achieve both the strength of the material (that is, buckling pressure of the lid) and the toughness of the material (that is, formability and opening property).

[0042] The 0.2% proof stress $\sigma_{0.2}$ and the tensile strength σ_B in the formula (1) are measured by a method specified in JIS-Z-2241:2011. The sheet thickness t is measured, for example, with a micro gauge.

[0043] The buckling pressure of an aluminum alloy sheet is measured, for example, by the following procedure. First, a shell formed of the aluminum alloy sheet is fixed to a jig, and internal pressure is applied. Then, the internal pressure is gradually increased, and an internal pressure value when the shell bulges (i.e. buckles) is defined as the buckling pressure value.

[0044] Specifically, a $\phi 204$ Fullform (B64) shaped shell mold is used to form the shell. The internal pressure value is measured using a buckle & missile gauge DV036E manufactured by VERSATILE TECHNOLOGY. More specifically, after fixing the molded shell to the special jig, the internal pressure is increased by a program, and an internal pressure value when the shell bulged is read. For example, the internal pressure is increased at a rate of about 175 kPa/s, and when the internal pressure reaches approximately 350 kPa to 400 kPa, the internal pressure is increased at a rate of 10 kPa/s.

<Toughness>

[0045] It is known that the toughness of the aluminum alloy sheet affects the formability of a lid and a force (i.e. an opening force) required to open a score part.

(Number of Cyclic Bending)

[0046] A cyclic bending test is one of the evaluation indices of the toughness of an aluminum alloy sheet. For aluminum alloy sheets having the same sheet thickness, the higher the number of cyclic bending is, the more excellent in toughness the alloy sheet is.

[0047] The cyclic bending test is performed by the following procedure. For example, as shown in FIG. 1, a test piece cut into a strip with 12.5 mm in width and 200 mm in length is arranged so that a bending ridge line R is parallel to a rolling direction D of the alloy sheet. Both ends of this test piece are fixed with chucks, and the test piece is tensioned with a load of 200 N.

[0048] In this state, a jig having a bending radius R 2.0 mm is placed at a position 150 mm in a longitudinal direction of the test piece from the end of the test piece fixed with a stationary chuck, and with the jig as a fulcrum, the other chuck is rotated 90° to the left and the right, thereby the test piece is bent repeatedly. The number of bending is measured until the test piece breaks.

[0049] As for the number of bending, each of an operation of bending the test piece 90° to the left or the right and an operation of returning to its original position is counted as one. If the test piece breaks halfway, the angle θ thereof is read (0° to 90°), and the number of cyclic bending N is calculated by the following formula (3). In the formula (3), " N_0 " is a total of the number of operations of bending the test piece 90° to the left or the right and the number of operations of returning from the 90° bent position to its original 0° position until the test piece breaks.

$$N = N_0 + \theta/90 \dots (3)$$

[0050] Since an evaluation of the cyclic bending becomes less favorable as the sheet thickness increases, it is

necessary to correct the number of cyclic bending N using a reference sheet thickness to carry out the evaluation. Thus, a normalized number of cyclic bending N_s is obtained by the following formula (4) based on a sheet thickness of 0.235 mm. Here, "t" (mm) is a sheet thickness of the test piece.

$$N_s = N \times t/0.235 \dots (4)$$

[0051] It is preferable that the aluminum alloy sheet of the present disclosure has the normalized number of cyclic bending N_s of 14.0 or more.

(Second Phase Particle)

[0052] The toughness is affected by strength and distribution of second phase particles. That is, as the strength is higher and the density of the second phase particles is higher, the toughness decreases. In particular, if the Mg content and the Si content are increased, it is more likely that Mg_2Si particles are formed. As a result, the Mg_2Si particles may become a starting point or a propagation path of a crack, and affects the decrease in toughness.

[0053] In the aluminum alloy sheet of the present disclosure, it is preferable that, in an L-ST cross section of a central part in a width direction of the alloy sheet shown by diagonal lines in FIG. 2, a ratio of a total area in the L-ST cross section of the Mg_2Si particles each having an area of $0.3 \mu m^2$ or more is 0.2% or less. In FIG. 2, "L" indicates a longitudinal direction, "ST" indicates a sheet thickness direction, and "LT" indicates the width direction.

[0054] The ratio of the area of the Mg_2Si particles can be measured by the following method, for example. First, a measurement sample is cut, and a surface to be measured (i.e., the L-ST cross section) is mechanically polished to a mirror finish. Then, the polished surface (i.e., the L-ST cross-section) is observed using a scanning electron microscope (SEM), and 10 fields of view are obtained. The accelerating voltage of the SEM is set to 15 kV, the magnification of the SEM is set to 500 times and an area of one field of view is set to $0.049 mm^2$, and imaging is performed. Then, a COMPO image (a backscattered electron composition image) is obtained.

[0055] The obtained COMPO image is analyzed by image analysis software "ImageJ". Specifically, the most frequent brightness value of the image in 256 shades is used as a background brightness, and particles with brightness of less than a value obtained by subtracting 30 from the most frequent brightness value is determined to be the Mg_2Si particles.

[0056] In the determined Mg_2Si particles, a total area of particles each having an area of $0.3 \mu m^2$ or more is calculated. Then, the obtained value is divided by an imaged area of the 10 fields of view (i.e., an imaged total area). Thereby, the ratio of the total area of the Mg_2Si particles each having the area of $0.3 \mu m^2$ or more in the L-ST cross-section is calculated.

<Strength Anisotropy>

[0057] It is known that materials with low reduction during cold rolling (hereinafter, abbreviated as cold rolling reduction) have high toughness, and materials with high cold rolling reduction have high strength. In addition, the higher the cold rolling reduction is, the greater the 0.2% proof stress $\sigma_{0.2_90^\circ}$ in the 90° direction to the rolling direction becomes compared to the 0.2% proof stress $\sigma_{0.2_0^\circ}$ in the 0° direction to the rolling direction. Thus, a difference in the 0.2% proof stress between the 0° direction to the rolling direction and the 90° direction to the rolling direction, that is, the strength anisotropy, can be associated with the cold rolling reduction of the material.

[0058] In the alloy sheet of the present disclosure, to achieve the toughness that ensures formability of a lid, it is preferable that a value D obtained by subtracting the 0.2% proof stress $\sigma_{0.2_90^\circ}$ in the 90° direction to the rolling direction from the 0.2% proof stress $\sigma_{0.2_0^\circ}$ in the 0° direction to the rolling direction, using the formula (5), is -20 MPa or more. However, if the value D is set to -10 MPa or more, the cold rolling reduction may decrease, which may result in insufficient strength. Thus, it is preferable that the value D of the strength anisotropy is - 10 MPa or less.

$$D = \sigma_{0.2_0^\circ} - \sigma_{0.2_90^\circ} \dots (5)$$

[0059] The metallographic meaning of the strength anisotropy obtained by subtracting the 0.2% proof stress $\sigma_{0.2_90^\circ}$ in the 90° direction to the rolling direction from the 0.2% proof stress $\sigma_{0.2_0^\circ}$ in the 0° direction to the rolling direction can be explained as follows.

[0060] The material after hot rolling or annealing is in a recrystallized state, and has high degree of integration of isotropic Cube orientation. From here, by plastic deformation due to cold rolling, the material is transformed into a rolling texture in which the Cube orientation has anisotropy in the rolling direction. Moreover, the higher the cold rolling reduction is, the more the crystal grains are elongated in the rolling direction. Thus, while diameters of the crystal grains along the 0° direction to the rolling direction increase, the change in diameters of the crystal grains along the 90° direction to the rolling direction decreases compared to that in the 0° direction to the rolling direction.

[0061] Referring to the Hall-Petch equation, a relationship between the texture changes caused by the rolling and the 0.2% proof stress $\sigma_{0.2}$ shows a relationship in the formula (6). In the formula (6), "x" is a resistance to crystal grain boundary sliding, and "d" is a crystal grain diameter.

$$\sigma_{0.2} \propto \kappa \times d^{-\frac{1}{2}} \dots (6)$$

[0062] For the tension in the 0° direction to the rolling direction or the 90° direction to the rolling direction, the resistance κ has different values. This is because the degree of integration of the rolling texture having anisotropy in the rolling direction increases as the cold rolling reduction increases, causing changes in resistance to the crystal grain boundary sliding depending on the tensile direction.

[0063] Furthermore, while the crystal grains are elongated and the diameters increase as the cold rolling reduction increases in the 0° direction to the rolling direction, the change in the crystal grain diameter with respect to the cold rolling reduction is relatively small in the 90° direction to the rolling direction. Accumulation of these effects results in strength anisotropy with respect to the increase in the cold rolling reduction.

<Production Method of Aluminum Alloy Sheet>

[0064] The aluminum alloy sheet of the present disclosure can be produced, for example, by the following procedure. First, an aluminum alloy having the same composition as that of the aluminum alloy sheet of the present disclosure is subjected to a semi-continuous casting (i.e. Direct Chill (DC) casting) in a normal manner to produce an ingot.

[0065] Then, four surfaces, except for a front end surface and a back end surface, of the ingot are scalped. After that, the ingot is placed in a soaking furnace, and a homogenizing treatment is performed. The temperature in the homogenizing treatment is preferably, for example, 470°C or higher and 620°C or lower. The duration of the homogenizing treatment is preferably, for example, one hour or longer and 20 hours or shorter.

[0066] If the temperature in the homogenizing treatment is 400°C or higher, segregation in the ingot structure can be easily resolved. Furthermore, if the temperature in the homogenizing treatment is 450°C or higher, the Mg_2Si particles are re-solutionized, and the strength and toughness of the alloy sheet can be improved. Moreover, if the temperature in the homogenizing treatment is 470°C or higher, and more preferably 550°C or higher, re-solutionization of the Mg_2Si particles is promoted and the strength and toughness of the alloy sheet can be further improved. On the other hand, if the temperature in the homogenizing treatment is 620°C or lower, local melting of the aluminum alloy is less likely to occur.

[0067] If the duration of the homogenizing treatment is one hour or longer, the temperature of the entire slab becomes uniform, segregation of the ingot structure is easily resolved, and the Mg_2Si particles can be easily re-solutionized. The longer the duration of the homogenizing treatment is, the more the Mg_2Si particles can be re-solutionized. However, if the duration of the homogenizing treatment is longer than 20 hours, the effect of the homogenizing treatment is saturated.

[0068] After the homogenizing treatment, the ingot is subjected to hot rolling. The hot rolling process comprises a rough rolling process and a finish rolling process. In the rough rolling process, the ingot is processed into a plate material having a thickness of approximately several tens of millimeters by reverse rolling. In the finish rolling process, the thickness of the plate material is reduced to approximately several millimeters by, for example, tandem rolling or the like, and the plate material is coiled to form a hot-rolled coil.

[0069] If a total rolling reduction in the finish rolling is high, a recrystallization texture is formed after coiling, and an integration degree of Cube orientation can be increased. If a coiling temperature in the finish rolling is high, the recrystallization texture is formed after coiling, and the integration degree of Cube orientation can be increased.

[0070] By performing the solution heat treatment on the hot-rolled coil and by re-solutionizing Mg and the like, a high-strength alloy sheet can be obtained. For example, a continuous annealing line (CAL) is used to perform a heat treatment (i.e. annealing) at a target peak metal temperature of 440°C or higher for 30 seconds or longer followed by forced cooling such as air-cooling, whereby the strength of the alloy sheet can be effectively increased.

[0071] After the hot rolling, the sheet material is subjected to cold rolling. In the cold rolling, the hot-rolled coil is rolled until a product sheet thickness is achieved. The cold rolling may be either single cold rolling or tandem cold rolling. In the single cold rolling, the rolling is preferably divided into several times and performed in two or more rolling passes.

[0072] By setting a finish temperature at 120°C or higher in intermediate passes other than the final pass of the cold rolling, Si, Cu and Mg are finely precipitated and age-hardening occurs, making it possible to increase the strength of the alloy sheet. When the finish temperature is set at 130°C or higher, the strength of the alloy sheet can be further increased.

[0073] A cold rolling reduction (i.e. a target total rolling reduction) is preferably 80% or more. When the cold rolling reduction is 80% or more, the strength of the alloy sheet can be increased. The lower the cold rolling reduction is, the more the Cube orientation remains. Thus, the cold rolling reduction is preferably 92% or less.

[0074] The cold rolling reduction R (%) is obtained by the following formula (7), where " t_0 " is a sheet thickness (mm) of a sheet after the hot rolling or solution heat treatment, and " t_1 " is a product sheet thickness (mm) after the cold rolling.

$$R = (t_0 - t_1)/t_0 \times 100 \dots (7)$$

[0075] The product sheet thickness can be selected as appropriate so that a desired buckling pressure is obtained. As shown in the above-described formula (2), the buckling pressure increases as the sheet thicknesses increases. The product sheet thickness can be selected in accordance with the value V of the formula (2). A condition providing the value V of 13.0 or more, and more preferably 14.0 or more, is preferable. As described above, with the aluminum alloy sheet of the present disclosure, it is possible to avoid increasing the sheet thickness to maintain the buckling pressure high.

[0076] The coil that has been cold-rolled to have a product sheet thickness is precoated in a coating line or the like. The surface of the cold-rolled coil is subjected to degreasing, cleaning, and chemical conversion treatment, followed by paint coating and paint baking treatment.

[0077] In the chemical conversion treatment, a chemical solution such as a chromate-based solution and a zirconium-based solution is used. Examples of the paint to be used may include an epoxy-based paint and a polyester-based paint. These can be selected according to applications. In the paint baking treatment, the coil is heated at a peak metal temperature (PMT) of 220°C or higher and 270°C or lower for approximately 30 seconds or shorter. At this time, as the PMT is lower, the recovery of the material can be inhibited more, and the strength of the alloy sheet can be maintained to be higher.

[1-2. Effects]

[0078] According to the embodiment detailed above, the following effects can be obtained.

[0079] (1a) The aluminum alloy sheet can achieve both the high strength and high toughness while blended with scrap materials derived from can stock. That is, a certain amount of scraps derived from 3104 aluminum alloy for a can body can be blended, thereby reducing the usage rate of the primary metal and the amount of CO₂ emissions. Furthermore, it is possible to obtain a highly formable aluminum alloy sheet for a can lid that can be used for a positive pressure can lid, which is required to have high buckling pressure.

[2. Other Embodiments]

[0080] The embodiment of the present disclosure has been described; however, it is needless to say that the present disclosure is not limited to the above-described embodiment, and that the present disclosure can take various forms.

(2a) In addition to the aluminum alloy sheet of the above-described embodiment, the present disclosure also includes various forms such as a member comprising this aluminum alloy sheet and a production method of this aluminum alloy sheet.

(2b) A function of a single component in the aforementioned embodiments may be distributed to a plurality of components, and functions of a plurality of components may be achieved by a single component. A part of the configuration of each of the aforementioned embodiments may be omitted. At least a part of the configuration of the aforementioned embodiments may be added to or replaced with the configuration of another embodiment or other embodiments of the aforementioned embodiments. All the modes that are encompassed in the technical idea defined by the language in the claims are embodiments of the present disclosure.

[3. Examples]

[0081] Hereinafter, some tests conducted to confirm the effects of the present disclosure and the evaluation results thereof are described.

<Production of Aluminum Alloy Sheet>

[0082] As examples and comparative examples, aluminum alloy sheets of S1 to S8 shown in Table 1 and Table 2 were produced. Hereinafter, specific production procedures are described.

[0083] First, ingots each comprising components (mass %) specified by each of alloy numbers 1 to 4 shown in Table 3 and a balance consisting of aluminum and inevitable impurities were produced by a semi-continuous casting method. Each ingot includes 0.10 mass % or less of Ti, 0.25 mass % or less of Zn, 0.10 mass % or less of Cr, and 0.15 mass % or less of inevitable impurities.

[0084] Next, four surfaces, except for a front end surface and a back end surface, of each ingot were scalped. Then, the ingot was placed in the furnace, and subjected to homogenizing treatment. The temperature of the homogenizing treatment is shown in Table 1. After the homogenizing treatment, the ingot was taken out of the furnace and hot rolling was

immediately started to thereby obtain a rolled sheet.

[0085] Moreover, for the aluminum alloy sheets of S1 to S6 and S8, cold rolling was performed on the hot-rolled sheet until a CAL sheet thickness shown in Table 1 is achieved. Then, annealing was performed on the rolled sheet having the CAL sheet thickness in a continuous annealing line (CAL). The CAL temperature during annealing is shown in Table 1.

After the annealing, the rolled sheet was cooled to the room temperature by air-cooling. After the cooling, cold rolling was again performed on the rolled sheet. The target cold rolling reduction in the cold rolling after the annealing is shown in Table 1.

[0086] For the aluminum alloy sheet of S7, cold rolling was performed on the rolled sheet after the hot rolling without performing the annealing. The target cold rolling reduction in the cold rolling is shown in Table 1.

The product sheet thickness of the aluminum alloy sheets of S1 to S8 (i.e. " t_1 " in formula (7)) after the cold rolling is within a range of approximately 0.235 ± 0.03 mm.

[0088] In the aluminum alloy sheets of S1 to S8, after the cold rolling, a paint was applied to a sheet surface, and paint baking treatment was performed for approximately 30 seconds. The peak metal temperature (PMT) at the time of the paint baking is shown in Table 1. After the paint baking, the aluminum alloy sheets of S1 to S8 were obtained. Also, for the aluminum alloy sheets of S1 to S8, the sheet thickness (i.e., product sheet thickness) measured with a micro gauge is shown in Table 1.

[Table 1]

Example	Alloy No.	Homogenizing Treatment Temperature °C	CAL Sheet Thickness mm	CAL Temperature °C	Cold Rolling Reduction %	PMT °C	Sheet Thickness mm	0° Direction to Rolling Direction			45° Direction to Rolling Direction		
								$\sigma_{0.2}$ MPa	σ_B MPa	σ_{fm} MPa	$\sigma_{0.2}$ MPa	σ_B MPa	σ_{fm} MPa
S1	1	520	2.0	520	88	250	0.237	342	370	356	344	376	360
S2	1	520	2.0	520	88	260	0.237	331	359	345	332	365	349
S3	1	520	2.0	520	88	270	0.238	319	349	334	323	355	339
S4	2	550	2.0	520	88	250	0.237	352	380	366	350	384	367
S5	2	550	2.0	520	88	260	0.237	346	374	360	346	379	363
S6	2	550	2.0	520	88	270	0.237	335	365	350	336	370	353
S7	3	600	-	-	87	260	0.236	250	279	264	262	285	274
S8	4	490	0.7	440	67	270	0.234	306	374	340	289	364	326

[Table 2]

Example	Alloy No.	90° Direction to Rolling Direction			S _{min} $\sigma_{fm}/(\sigma_{0.2}/\sigma_B)$	Mg ₂ Si Area Ratio	Number of Cyclic Bending	Normalized Number of Cyclic Bending	Strength Anisotropy	Single Shell Buckling Pressure	$V = t^{2.27} \times \sigma_{fm}/(\sigma_{0.2}/\sigma_B)$	3104 Possible Blending Ratio
		$\sigma_{0.2}$	σ_B	σ_{fm}								
		MPa	MPa	MPa		%	Number of Times	Number of Times	MPa	kPa	-	mass %
S1	1	357	391	374	384.6	0.672	12.3	12.3	-14.7	641.6	14.6	≥50
S2	1	348	382	365	374.0	0.672	12.2	12.3	-17.0	625.5	14.2	≥50
S3	1	341	371	356	364.7	0.672	13.1	13.3	-21.3	612.1	14.1	≥50
S4	2	363	398	381	394.8	0.014	14.3	14.4	-11.7	655.9	15.1	≥50
S5	2	359	394	377	388.6	0.014	14.6	14.7	-13.3	644.6	14.8	≥50
S6	2	350	385	368	380.8	0.014	14.7	14.9	-15.0	634.9	14.5	≥50
S7	3	270	296	283	295.4	0.000	21.2	21.4	-20.7	487.1	11.2	≥50
S8	4	296	373	335	411.5	0.400	28.2	28.1	9.7	621.1	15.2	<50

[Table 3]

Alloy No.	Si	Fe	Cu	Mn	Mg
	mass %				
1	0.32	0.43	0.22	0.80	2.60
2	0.32	0.43	0.22	0.80	2.60
3	0.33	0.45	0.22	1.00	1.20
4	0.10	0.23	0.09	0.33	4.50

<Evaluation of Aluminum Alloy Sheet>

(Tensile Properties)

[0089] The aluminum alloy sheets of S1 to S8 were each milled to form three test pieces No. 5 specified in JIS-Z-2241:2011. Longitudinal directions of the three test pieces extend in respective directions forming angles of 0°, 45° and 90° to the rolling direction.

[0090] These test pieces were subjected to a tensile test according to JIS-Z-2241:2011, and 0.2% proof stress and tensile strength were measured. Tables 1 and 2 show the measurement results of the 0.2% proof stress $\sigma_{0.2}$ and the tensile strength σ_B , and the average values σ_{fm} of the 0.2% proof stress and the tensile strength.

[0091] In addition, three evaluation values S were calculated from the measurement results of the respective tensile tests in the 0° direction, 45° direction, and 90° direction to the rolling direction and the formula (1). Table 2 shows a minimum evaluation value S_{min} , which is the minimum value of these evaluation values S.

(Toughness)

[0092] In each of the aluminum alloy sheets of S1 to S8, the ratio of the total area (area ratio) of the Mg_2Si particles each having an area of $0.3\mu m^2$ or more in the L-ST cross section was calculated by the measurement method described in the embodiment. The measurement results are shown in Table 2.

[0093] In each of the aluminum alloy sheets of S1 to S8, the number of cyclic bending and the normalized number of cyclic bending were calculated by the measurement method and formulas (3) and (4) described in the embodiment. The results are shown in Table 2.

(Strength Anisotropy)

[0094] In each of the aluminum alloy sheets of S1 to S8, the strength anisotropy (i.e., value D) was calculated by the formula (5) described in the embodiment. The results are shown in Table 2.

(Single Shell Buckling Pressure)

[0095] In each of the aluminum alloy sheets of S1 to S8, the buckling pressure was calculated by the measurement method described in the embodiment. The results are shown in Table 2. The aluminum alloy sheets of S1 to S6 and S8 showed high buckling pressure of 550 kPa or more.

(Scrap Blending Ratio)

[0096] With respect to the composition of each of the aluminum alloy sheets of S1 to S8, it was determined whether the possible blending ratio of the scraps of 3104 aluminum alloy was 50 mass % or more. The results are shown in Table 2.

[0097] In Table 2, the aluminum alloy sheet marked "≥ 50" means that 50 mass % or more of 3104 aluminum alloy can be blended in the sheet. The possible blending ratio of the scraps of 3104 aluminum alloy is determined based on Table 4.

[0098] Table 4 shows the correspondence between the blending ratio of 3104 aluminum alloy and 5182 aluminum alloy and the average values of the components. The first line of Table 4 shows the average values of the components of 3104 aluminum alloy, and the second line shows the average values of the components of 5182 aluminum alloy.

[0099] For example, if the blending ratio of 3104 aluminum alloy is 50 mass %, the average value of Si is 0.20 mass %, the average value of Fe is 0.29 mass %, the average value of Cu is 0.11 mass %, the average value of Mn is 0.7 mass %, and the average value of Mg is 2.8 mass %.

[0100] Therefore, when the ratios of the respective components in the aluminum alloy sheets are equal to or more than

the above-described values of Si, Fe, Cu, Mn, and Mg, these sheets have 50 mass % or more of the possible blending ratio of 3104 aluminum alloy sheet. As the blending ratio of 3104 aluminum alloy increases, the contents of Si, Fe, Cu and Mn increase, and the content of Mg decreases. In the aluminum alloy sheets of S1 to S10, 50 mass % or more of the scraps of 3104 aluminum alloy can be blended.

[Table 4]

Alloy	Si	Fe	Cu	Mn	Mg
3104	0.30	0.40	0.15	1.10	1.05
5182	0.10	0.18	0.08	0.35	4.50
3104 Blending Ratio	Si	Fe	Cu	Mn	Mg
5%	0.11	0.19	0.08	0.4	4.3
10%	0.12	0.20	0.08	0.4	4.2
15%	0.13	0.21	0.09	0.5	4.0
20%	0.14	0.22	0.09	0.5	3.8
25%	0.15	0.23	0.09	0.5	3.6
30%	0.16	0.24	0.10	0.6	3.5
35%	0.17	0.25	0.10	0.6	3.3
40%	0.18	0.27	0.11	0.7	3.1
45%	0.19	0.28	0.11	0.7	2.9
50%	0.20	0.29	0.11	0.7	2.8
55%	0.21	0.30	0.12	0.8	2.6
60%	0.22	0.31	0.12	0.8	2.4
65%	0.23	0.32	0.12	0.8	2.3
70%	0.24	0.33	0.13	0.9	2.1
75%	0.25	0.34	0.13	0.9	1.9
80%	0.26	0.36	0.14	1.0	1.7
85%	0.27	0.37	0.14	1.0	1.6
90%	0.28	0.38	0.14	1.0	1.4
95%	0.29	0.39	0.15	1.1	1.2
100%	0.30	0.40	0.15	1.1	1.1

(Evaluation)

[0101] FIG. 3 shows the relationship between the values V and the shell buckling pressure of the respective aluminum alloy sheets of S1 to S8. From a graph of FIG. 3, it is confirmed that there is a high correlation between the value V and the buckling pressure. Therefore, an alloy sheet having the minimum evaluation value $S_{\min}$ of 370 MPa or more can have a high buckling pressure equivalent to that of an alloy sheet formed of the conventional A5182 aluminum alloy without greatly increasing the sheet thickness.

[0102] The aluminum alloy sheets of S1 to S6 showed high strength although its Mg content is lower than that of the aluminum alloy sheet of S8. In addition, the aluminum alloy sheets of S4 to S6 have higher homogenizing treatment temperatures than the aluminum alloy sheets of S1 to S3, and thus have higher strength and higher number of cyclic bending even though the process and paint baking temperature are the same.

[0103] Moreover, the lower the paint baking temperature (PMT), the higher the strength of the alloy sheet. For example, when the aluminum alloy sheets of S1 to S3 and S4 to S6 are compared, Examples with lower paint baking temperatures showed higher minimum evaluation values $S_{\min}$.

[0104] The aluminum alloy sheets of S4 to S6 had small area ratios of the Mg_2Si particles, equal to or less than 0.2%. From the comparison between the alloy sheets of S1 to S3 and the alloy sheets of S4 to S6, it can be seen that by increasing the homogenizing treatment temperature, the area ratio of the Mg_2Si particles can be significantly reduced.

[0105] The number of cyclic bending varies also depending on the strength. When the alloy sheets of S4 to S6 that have relatively small area ratios of the Mg_2Si particles and the same cold rolling reduction are compared, it can be seen that the number of cyclic bending increases as the strength decreases due to the increase of PMT.

Claims

1. An aluminum alloy sheet for a can lid, the sheet comprising:

a silicon (Si) content of 0.27 mass % or more and 0.39 mass % or less;
 an iron (Fe) content of 0.35 mass % or more and 0.55 mass % or less;
 a copper (Cu) content of 0.17 mass % or more and 0.25 mass % or less;
 a manganese (Mn) content of 0.75 mass % or more and 0.95 mass % or less;
 a magnesium (Mg) content of 2.2 mass % or more and 2.8 mass % or less; and
 a balance consisting of or including aluminum (Al) and inevitable impurities,
 wherein, in each of 0°, 45°, and 90° directions to a rolling direction of the alloy sheet, a minimum evaluation value S_{min} , which is a minimum value among evaluation values S calculated by a following formula (1) using a 0.2% proof stress $\sigma_{0.2}$, a tensile strength σ_B , and an average value σ_{fm} of the 0.2% proof stress and the tensile strength, is 370 MPa or more and 410 MPa or less.

$$S = \sigma_{fm} / (\sigma_{0.2} / \sigma_B) \dots (1)$$

2. The aluminum alloy sheet for a can lid according to claim 1,

wherein a value obtained by subtracting a 0.2% proof stress $\sigma_{0.2_90^\circ}$ in the 90° direction to the rolling direction from a 0.2% proof stress $\sigma_{0.2_0^\circ}$ in the 0° direction to the rolling direction is -20 MPa or more and -10 MPa or less.

3. The aluminum alloy sheet for a can lid according to claim 2,

wherein, in an L-ST cross section of a central part in a width direction, a ratio of a total area in the L-ST cross section of Mg_2Si particles each having an area of $0.3 \mu m^2$ or more is 0.2% or less.

4. The aluminum alloy sheet for a can lid according to claim 2 or 3,

wherein a bending operation is an operation of bending 90° a test piece cut into a strip with 12.5 mm in width and 200 mm in length and then returning the test piece to a 0° position, a number of cyclic bending N is a number of times of the bending operation until the test piece breaks when the bending operation is repeatedly performed such that a direction of a bending ridge line is parallel to the rolling direction, and a normalized number of cyclic bending N_s obtained by normalizing the number of cyclic bending N by a sheet thickness t and a following formula (2) is 14.0 or more.

$$N_s = N \times t / 0.235 \dots (2)$$

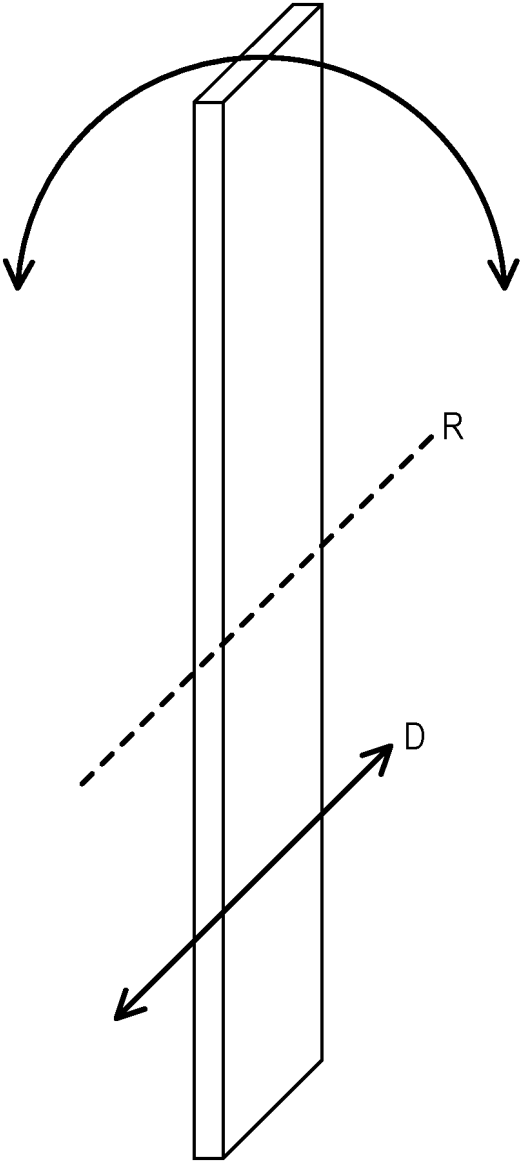


FIG. 1

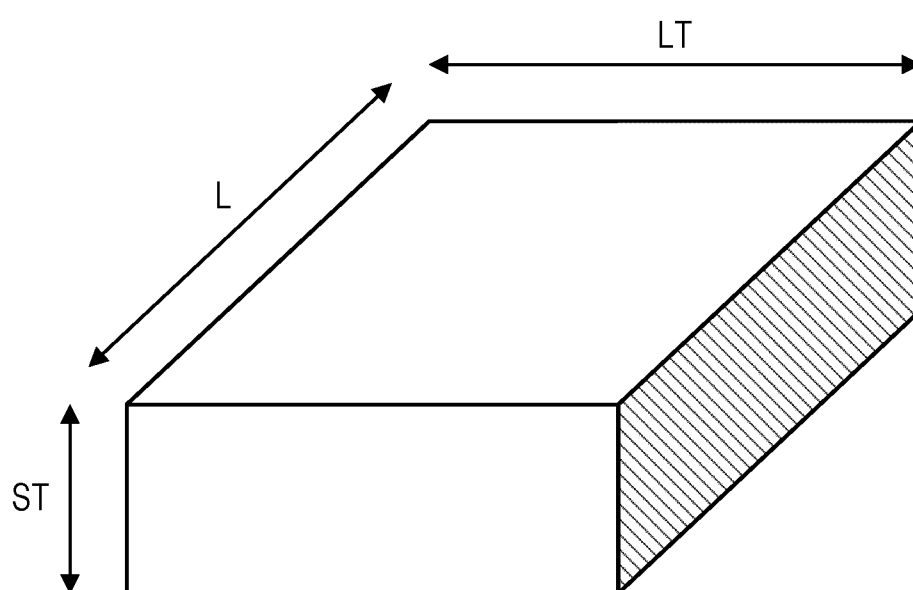


FIG. 2

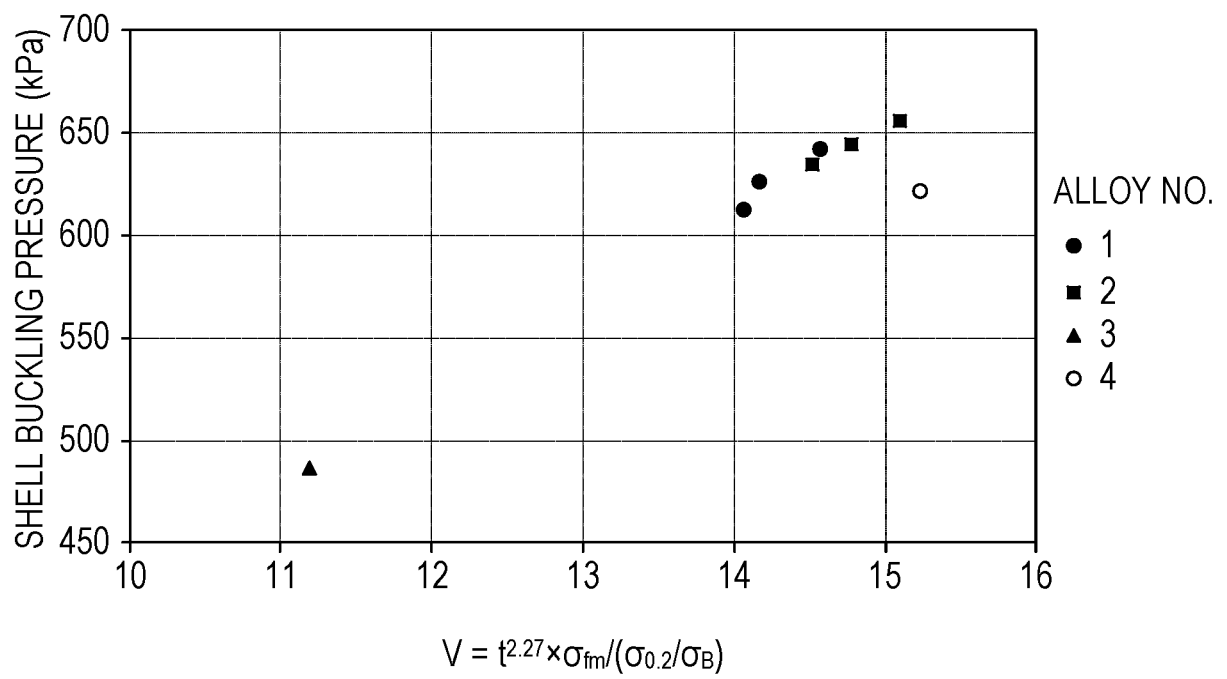


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2024/015125

A. CLASSIFICATION OF SUBJECT MATTER

C22C 21/06(2006.01)i; *C22F 1/00*(2006.01)n; *C22F 1/047*(2006.01)n

FI: C22C21/06; C22F1/047; C22F1/00 623; C22F1/00 630A; C22F1/00 630B; C22F1/00 673; C22F1/00 682; C22F1/00 683; C22F1/00 684B; C22F1/00 685Z; C22F1/00 686A; C22F1/00 691B; C22F1/00 691C; C22F1/00 694A

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)

C22C21/00-21/06; C22F1/04-1/057

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

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2024
 Registered utility model specifications of Japan 1996-2024
 Published registered utility model applications of Japan 1994-2024

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.
A	JP 8-60284 A (SUMITOMO LIGHT METAL INDUSTRIES LTD.) 05 March 1996 (1996-03-05) claims, tables 1-3	1-4
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A	JP 2020-514556 A (NOVELIS INC.) 21 May 2020 (2020-05-21) claims, tables 1-4	1-4



Further documents are listed in the continuation of Box C.



See patent family annex.

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“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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“&” document member of the same patent family

Date of the actual completion of the international search

03 July 2024

Date of mailing of the international search report

16 July 2024

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915
 Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2024/015125

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	伊藤清文ら, アルミニウム缶エンド(シェル)の耐圧強度に及ぼす材料強度及び厚さの影響, 住友軽金属技報, 1992, vol. 33, no. 1, pp. 18-21, (ITO, Kiyofumi et al., Influence of Material Strength and Thickness on Buckle Strength of Aluminium Can End Shells, Sumitomo Light Metal Technical Reports)	1-4
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P, A		3

INTERNATIONAL SEARCH REPORT
Information on patent family members

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PCT/JP2024/015125

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