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(72) Inventors:

- **KUDO, Tomoyuki**
Tokyo 100-0004 (JP)
- **TAKEZAWA, Kouki**
Tokyo 100-0004 (JP)
- **TAZOE, Kiyonari**
Tokyo 100-0004 (JP)
- **EZAKI, Tomotaro**
Tokyo 100-0004 (JP)

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(74) Representative: **Barker Brettell LLP**

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

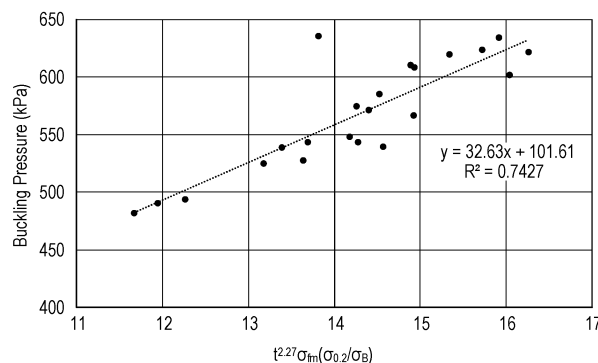
100 Hagley Road
Edgbaston
Birmingham B16 8QQ (GB)

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

(57) Provided is an aluminum alloy sheet for a can lid, the sheet achieving both high strength and high toughness while blending scrap materials derived from can materials. In one aspect of the present disclosure, the sheet comprises: a Si content of 0.10 mass % or more and 0.60 mass % or less; a Fe content of 0.20 mass % or more and 0.70 mass % or less; a Cu content of 0.10 mass % or more and 0.40 mass % or less; a Mn content of 0.5 mass % or more and 1.2 mass % or less, and a

Mg content of 1.1 mass % or more and 4.0 mass % or less, wherein a 0.2% yield strength $\sigma_{0.2}$, a tensile strength σ_B and an average value σ_{fm} , of the 0.2% yield strength and the tensile strength satisfy a following formula (1):

$$\sigma_{fm}/(\sigma_{0.2}/\sigma_B) \geq 350 \text{ MPa} \dots (1)$$



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Description

CROSS-REFERENCE TO RELATED APPLICATION

5 **[0001]** This international application claims the benefit of Japanese Patent Application No. 2022-036491 filed on March 9, 2022 with the Japan Patent Office, and the entire disclosure of Japanese Patent Application No. 2022-036491 is incorporated herein by reference.

TECHNICAL FIELD

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

BACKGROUND ART

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

[0004] The production of the primary aluminum requires a large amount of electricity in a refining process, and thus leads to large CO₂ emissions. Thus, reducing the blending amount of the primary aluminum and increasing a closed recycling rate will contribute to the reduction of CO₂ emissions in the production of the aluminum alloy sheet.

20 **[0005]** In general, it is said that CO₂ emissions can be reduced to about one-thirtieth when aluminum scrap is remelted for casting compared to a case where the primary aluminum is produced. In particular, an amount of the production of aluminum alloy sheets for beverage cans, which are widely used in the world, is very large. Thus, further improvement in the closed recycling rate has a significant effect on the reduction of an environmental load.

25 **[0006]** Especially, a can lid made of 5182 aluminum alloy (AA5182 alloy) has composition limits in terms of Si, Fe, Cu, Mn, and the like lower than those of a can body made of 3104 aluminum alloy (AA3104 alloy). Thus, it is difficult to blend scrap derived from can materials containing 3104 aluminum alloy.

[0007] For example, when can scrap (UBC: Used Beverage Can) from individuals or businesses is blended as it is, the resultant contains more components contained in 3104 aluminum alloy due to a weight ratio between a can body and a can lid. Thus, the composition limits of 5182 aluminum alloy are easily exceeded. As a result, it is necessary to dilute the resultant with primary metal.

30 **[0008]** Thus, an aluminum alloy sheet for a can lid is adjusted to comprise a composition of 5182 aluminum alloy by using a large amount of primary metal compared to an aluminum alloy sheet for a can body, and thus, its recycling rate is low. 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]** In Patent Documents 1-5, aluminum alloy sheets for can lids excellent in recyclability and each having a composition relatively closer to that of 3104 aluminum alloy are developed.

PRIOR ART DOCUMENTS

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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

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SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

55 **[0011]** Concern for making an alloy for a can lid similar in composition to 3104 aluminum alloy includes reductions in a buckling pressure (pressure resistance) of the can lid and the 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, and 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 applications, 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 is used for the 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 of the lid increases and the cost of the lid rises.

[0014] 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 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.

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

[0016] In one aspect of the present disclosure, it is preferable to provide an aluminum alloy sheet for a can lid, the sheet achieving both high strength and high toughness while blending scrap materials derived from can materials.

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 0.10 mass % or more and 0.60 mass % or less; an iron (Fe) content of 0.20 mass % or more and 0.70 mass % or less; a copper (Cu) content of 0.10 mass % or more and 0.40 mass % or less; a manganese (Mn) content of 0.5 mass % or more and 1.2 mass % or less, and a magnesium (Mg) of 1.1 mass % or more and 4.0 mass % or less, wherein a 0.2% yield strength $\sigma_{0.2}$, a tensile strength σ_B and an average value σ_{fm} of the 0.2% yield strength and the tensile strength satisfy a following formula (1):

$$\sigma_{fm}/(\sigma_{0.2}/\sigma_B) \geq 350 \text{ MPa} \dots (1)$$

[0018] With this configuration, it is possible to achieve the high strength and high toughness of the aluminum alloy sheet while blending scrap materials derived from can materials. That is, a certain amount of scrap 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 an aluminum alloy sheet for a can lid available for use in positive pressure can lid applications in which high buckling pressure is required.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

FIG. 1A is a schematic perspective view of an Erichsen cup, and FIG. 1B is a schematic plan view of the Erichsen cup. FIG. 2 is a graph showing an example of the measurement results of the side wall height of the Erichsen cup. FIG. 3 is a graph showing a relationship between values of " $t^{2.27} \times \sigma_{fm}/(\sigma_{0.2}/\sigma_B)$ " and buckling pressure in Examples.

EXPLANATION OF REFERENCE NUMERALS

[0020] 1 ... Erichsen cup

MODE FOR CARRYING OUT THE INVENTION

[0021] Hereinafter, an embodiment to which the present disclosure is applied is described with reference to the drawings.

[1. First Embodiment]

[1-1. Configuration]

5 <Composition>

[0022] 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).

10 **[0023]** The lower limit of Si content is 0.10 mass %, and preferably, 0.20 mass %. If the Si content is less than 0.10 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.

15 **[0024]** The average value of Si component specified for 3104 aluminum alloy according to JIS-H-4000:2014 is 0.30 mass %, and the average value of the Si component specified for 5182 aluminum alloy according to JIS-H-4000:2014 is 0.10 mass %. Thus, by setting the Si content to 0.20 mass % or more, a larger amount of scrap of 3104 aluminum alloy can be blended.

[0025] The upper limit of the Si content is 0.60 mass %, and preferably, 0.40 mass %. If the Si content is more than 0.60 mass %, more Mg_2Si particles are formed, and the toughness of the alloy sheet decreases.

20 **[0026]** The lower limit of Fe content is 0.20 mass %, and preferably, 0.30 mass %. The average value of Fe component specified for 3104 aluminum alloy is 0.40 mass %, and the average value of the Fe component specified for 5182 aluminum alloy is 0.18 mass %. Thus, by setting the Fe content to 0.30 mass % or more, a larger amount of scrap of 3104 aluminum alloy can be blended.

[0027] The upper limit of the Fe content is 0.70 mass %. If the Fe content is more than 0.70 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.

25 **[0028]** The lower limit of Cu content is 0.10 mass %, and preferably 0.11 mass %, and more preferably, 0.20 mass %. If the Cu content is less than 0.10 mass %, there is insufficient Cu to enhance the strength by solid solution or precipitation, and the average 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.

30 **[0029]** The average value of Cu component specified for 3104 aluminum alloy is 0.15 mass %, and the average value of the Cu component specified for 5182 aluminum alloy is 0.075 mass %. Thus, by setting the Cu content to 0.11 mass % or more, a larger amount of scrap of 3104 aluminum alloy can be blended.

[0030] The upper limit of the Cu content is 0.40 mass %. If the Cu content is more than 0.40 mass %, the toughness of the alloy sheet decreases.

35 **[0031]** The lower limit of Mn content is 0.5 mass %, and preferably 0.7 mass %, and more preferably, 0.8 mass %. If the Mn content is less than 0.5 mass %, there is insufficient Mn to enhance the strength by solid solution or precipitation, and the average strength of the alloy sheet decreases.

[0032] 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 0.7 mass % or more, a larger amount of scrap of 3104 aluminum alloy can be blended.

40 **[0033]** The upper limit of the Mn content is 1.2 mass %, and preferably, 1.0 mass %. If the Mn content is more than 1.2 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.

45 **[0034]** The lower limit of Mg content is 1.1 mass %. If the Mg content is less than 1.1 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 significantly increases by precipitating Mg in the process of the cold rolling after the hot rolling and the solution heat treatment.

50 **[0035]** The upper limit of the Mg content is 4.0 mass %, and preferably, 3.0 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 4.0 mass %, and more preferably, 3.0 mass % or less, it is possible to use a larger amount of scrap of 3104 aluminum alloy and to reduce the blending amount of additional Mg-containing raw material.

55 **[0036]** 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 %.

[0037] 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 and Mg in the above-mentioned respective ranges, and a balance comprises aluminum and the inevitable impurities. The upper limit of the total amount of the inevitable

impurities is preferably 0.15 mass %.

<Material Strength and Buckling Pressure>

- 5 **[0038]** A 0.2% yield strength $\sigma_{0.2}$, a tensile strength σ_B , and an average value σ_{fm} , of the 0.2% yield strength and the tensile strength of the aluminum alloy sheet of the present disclosure satisfy the following formula (1).

$$\sigma_{fm}/(\sigma_{0.2}/\sigma_B) \geq 350 \text{ MPa} \dots (1)$$

- 10 **[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 (3) that is empirically expressed by the material strength (i.e. the left side of the formula (1)) and sheet thickness t of the aluminum alloy sheet.

$$15 \quad V = t^{2.27} \times \sigma_{fm}/(\sigma_{0.2}/\sigma_B) \dots (3)$$

[0040] Thus, if the value of the material strength $\sigma_{fm}/(\sigma_{0.2}/\sigma_B)$ of the alloy sheet is 350 MPa or more, it is possible to form a lid having a sufficient buckling pressure value without greatly increasing the sheet thickness.

- 20 **[0041]** The lower limit on the left side of the formula (1) (i.e. a value on the right side of the formula (1)) is, more preferably, 370 MPa. By setting the material strength " $\sigma_{fm}/(\sigma_{0.2}/\sigma_B)$ " to 370 MPa or more, the buckling pressure value of the lid can be further increased.

[0042] The 0.2% yield strength $\sigma_{0.2}$ and the tensile strength σ_B in the formulas (1) and (3) are measured by a method specified in JIS-Z-2241:2011. The sheet thickness t is measured, for example, with a micro gauge.

- 25 **[0043]** The buckling pressure of an aluminum alloy sheet is measured, for example, by the following procedure. A shell formed of the aluminum alloy sheet is fixed to a jig, and internal pressure is applied. 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.

- 30 **[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 about 350 kPa to 400 kPa, the internal pressure is increased at a rate of 10 kPa/s.

35 <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.

40 (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. The aluminum alloy sheet of the present disclosure can achieve good number of cyclic bending.

- 45 **[0047]** The cyclic bending test is performed by the following procedure. For example, a strip-shaped test piece with 12.5 mm in width and 200 mm in length is processed so that a direction of a bending ridge line is parallel to a rolling direction 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. In this state, a jig having a bending radius R 2.0 mm is placed at the center in a length direction of the strip, and with the jig as a fulcrum, one chuck is rotated 90° to the left and the right, thereby the test piece is bent repeatedly.

50 The number of bending is measured until the test piece breaks.

[0048] The number of bending is counted as one when the test piece is bent 90° to the left or right and returned to its original 0° position (i.e. a 90° bend followed by a 90° bend back). If the test piece breaks during the test, the angle θ thereof is read (0° to 180°), and the number of cyclic bending N is calculated by the following formula (4). In the formula (4), " N_0 " is the number of times the test piece is bent 90° to the left or right and returned to the original 0° position (i.e., the number of times a series of operation from the 90° bend to the 90° bend back is performed).

$$N = N_0 + \theta/180 \dots (4)$$

[0049] Since an evaluation of the cyclic bending is unfavorable 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 (5) based on a sheet thickness of 0.245 mm. Here, " t " (mm) is a sheet thickness of the test piece.

$$N_s = N \times t/0.245 \dots (5)$$

(Second Phase Particle)

[0050] The toughness is affected by a strength and a distribution of second phase particles. That is, as the strength is greater 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, Mg_2Si particles are easily formed. As a result, the Mg_2Si particles may become a starting point or a propagation path of a crack, which affects the decrease in toughness.

[0051] In the aluminum alloy sheet of the present disclosure, it is preferable that a ratio of a total area of the Mg_2Si particles each having an area of $0.3 \mu m^2$ or more is 1.0% or less in a center region in a sheet thickness direction of an L-LT cross section parallel to both a sheet surface and the rolling direction.

[0052] The ratio of the area of the Mg_2Si particles can be measured by the following method. Among the surfaces of a measurement sample, a surface to be measured (i.e., the L-LT cross section) is mechanically polished to a mirror finish. The depth of the polishing is approximately 1% of the sheet thicknesses of the measurement sample.

[0053] The polished surface (i.e., the L-LT cross-section) is observed using a scanning electron microscope (SEM), and 10 fields of view are obtained. The magnification of the SEM is set to 500 times and a range of one field of view is set to $0.48 mm^2$, and imaging is performed. Then, a COMPO image (a backscattered electron composition image) is obtained.

[0054] The obtained COMPO image is analyzed by image analysis software Imaged. 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.

[0055] 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-LT cross-section is calculated.

(Earing Ratio)

[0056] The number of cyclic bending is also affected by textures and the result thereof is better as the degree of integration of Cube orientation is higher. The degree of integration of Cube orientation is observed in an earing profile of an Erichsen cup 1 made of an aluminum alloy sheet according to the Erichsen test as shown in FIGS. 1A and 1B.

[0057] Specifically, it is suggested that the degree of integration of Cube orientation is high when a relative side wall height H (i.e. ear height) in the $0^\circ/180^\circ$ direction to a rolling direction RD of the aluminum alloy sheet of the Erichsen cup 1 is large, with reference to a side wall height H in the 45° direction to the rolling direction RD. That is, the aluminum alloy sheet of the present disclosure includes the one having a relatively high degree of integration of Cube orientation and having a higher side wall height H in the $0^\circ/180^\circ$ direction.

[0058] The relative side wall height in the $0^\circ/180^\circ$ direction with reference to the side wall height in the 45° direction can be evaluated in the index called "earring ratio (earring balance)". Hereinafter, a procedure for measuring the earing ratio is described.

[0059] The earing ratio is expressed by the left side of the following formula (2).

$$(h_{0p} - h_{45p})/h_v \times 100 \geq -7.0 \dots (2)$$

[0060] In the formula (2), " h_{0p} " represents an average value obtained from a maximum wall height in each of a first region A1 at approximately 0° and a second region A2 at approximately 180° with respect to the rolling direction. The first region A1 is, for example, located within $0^\circ \pm 11^\circ$ to the rolling direction. The second region A2 is, for example, located within $180^\circ \pm 11^\circ$ to the rolling direction.

[0061] " h_{45p} " represents an average value obtained from a maximum side wall height in each of a third region A3 at approximately 45° , a fourth region A4 at approximately 135° , a fifth region A5 at approximately 225° , and a sixth region A6 at approximately 315° with respect to the rolling direction.

[0062] The third region A3 is, for example, located within $45^\circ \pm 22^\circ$ to the rolling direction. The fourth region A4 is, for example, located within $135^\circ \pm 22^\circ$ to the rolling direction. The fifth region A5 is, for example, located within $225^\circ \pm$

22° to the rolling direction. The sixth region A6 is, for example, located within $315^\circ \pm 22^\circ$ to the rolling direction.

[0063] " h_v " represents an average value obtained from a minimum side wall height in each of a seventh region A7 at 0° to 45° , an eighth region A8 at 45° to 135° , a ninth region A9 at 135° to 180° , a tenth region A10 at 180° to 225° , an eleventh region A11 at 225° to 315° , and a twelfth region A12 at 315° to 360° with respect to the rolling direction.

[0064] FIG. 2 is a graph showing an example of the measurement results of the side wall height of the Erichsen cup. The angles shown in FIG. 2 are angles to the rolling direction. The distance from the center of the graph shows the side wall height.

[0065] In the graph, the signs "a" to "d" show maximum values in the third region A3 to the sixth region A6, respectively. The signs "e" and "f" show maximum values in the first region A1 and the second region A2, respectively. The signs "g" to "i" show minimum values in the seventh region A7 to the twelfth region A12, respectively.

[0066] The Erichsen cup 1 is formed, for example, under the condition of a blank diameter of 57 mm and a punch diameter of 33 mm. The side wall height of the Erichsen cup is measured, for example, using Roncorder EC1550-H manufactured by Kosaka Laboratory Ltd.

[0067] Specifically, a measuring terminal is placed on the opening portion of the Erichsen cup with the rolling direction as a reference ($0^\circ/180^\circ$), and a table on which the Erichsen cup is placed is rotated one revolution, and the height of the opening portion in a 360° circumferential direction is measured.

[0068] With the formula (2) being satisfied, i.e. the earing ratio being -7.0% or more, the degree of integration of Cube orientation is high. As a result, the number of cyclic bending of the alloy sheet can be increased.

<Production Method of Aluminum Alloy Sheet>

[0069] The aluminum alloy sheet of the present disclosure can be produced, for example, by the following procedure. First, an aluminum alloy having a composition same 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.

[0070] Then, the surface of the ingot is 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.

[0071] If the temperature in the homogenizing treatment is 400°C or higher, the 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 490°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.

[0072] If the duration of the homogenizing treatment is one hour or longer, the temperature of the entire slab becomes uniform, and the 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 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.

[0073] 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.

[0074] If a total rolling reduction in the finish rolling is high, a recrystallization texture is formed after coiling, and the integration degree of Cube orientation can be increased. If a coiling temperature in the finish rolling is high, the recrystallization is formed after coiling, and the integration degree of Cube orientation can be increased.

[0075] By performing the solution heat treatment on the hot-rolled coil and by resolutionizing Mg and the like, a high-strength alloy sheet can be obtained. For example, a continuous annealing furnace 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.

[0076] 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.

[0077] 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.

[0078] 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 Cube orientation remains. The cold rolling reduction is preferably 92% or less.

[0079] The cold rolling reduction R (%) is obtained by the following formula (6), where "t₀" is a sheet thickness (mm) of a hot-rolled sheet and "t₁" is a product sheet thickness (mm) after the cold rolling.

$$R = (t_0 - t_1)/t_0 \times 100 \dots (6)$$

[0080] The product sheet thickness can be selected as appropriate so that a desired buckling pressure is obtained. As shown in the above-described formula (3), the buckling pressure increases as the sheet thicknesses increases. It is preferable that the product sheet thickness is selected from the range satisfying " $t^{2.27} \times \sigma_{fm}/(\sigma_{0.2}/\sigma_B) \geq 14$ ". As described above, with the aluminum alloy sheet of the present disclosure, it is possible to avoid increasing the sheet thickness to keep the buckling pressure high.

[0081] As long as the functions and effects of the aluminum alloy sheet of the present disclosure are achieved, for example, annealing may be performed before and/or after the cold rolling and/or between the passes in the production method of the aluminum alloy sheet described above.

[0082] The coil that has been cold-rolled to have a product sheet thickness is precoated on a coating line or the like. The surface(s) of the cold-rolled coil is subjected to degreasing, cleaning, and chemical conversion treatment, followed by paint coating and paint baking treatment.

[0083] 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 220C° or higher and 270C° or lower for approximately 30 seconds or shorter. At this time, the recovery of the material is inhibited at lower PMT, and thus, high strength of the alloy sheet can be maintained.

[1-2. Effects]

[0084] According to the embodiment detailed above, the following effects can be obtained.

[0085] (1a) Both the high strength and high toughness of the aluminum alloy sheet can be achieved while blending scrap materials derived from can materials. That is, a certain amount of scrap 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 an aluminum alloy sheet for a can lid available for use in positive pressure can lid applications in which high buckling pressure is required.

[2. Other Embodiments]

[0086] 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.

[0087] (2a) The present disclosure also includes various forms other than the aluminum alloy sheet of the above-described embodiment, such as a member comprising this aluminum alloy sheet and a production method of this aluminum alloy sheet.

[0088] (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 one 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]

[0089] Hereinafter, some tests conducted to confirm the effects of the present disclosure and the evaluation thereof are described.

<Production of Aluminum Alloy Sheet>

[0090] As examples and comparative examples, aluminum alloy sheets of S1 to S22 shown in Table 1 and Table 2 were produced. Hereinafter, specific production procedures are described.

[0091] First, ingots each comprising components (mass %) specified by alloy numbers 1 to 11 shown in Table 3 and

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a balance comprising 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.

[0092] Next, the four surfaces 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 removed from the furnace and hot rolling was immediately started to thereby obtain a rolled sheet.

[0093] Annealing was performed on the obtained rolled sheet. The temperature of annealing is shown in Table 1 and the duration thereof was 30 seconds. After annealing, the rolled sheet was cooled to the room temperature by air-cooling. After cooling, cold rolling was performed on the rolled sheet. The target total rolling reduction in the cold rolling is shown in Table 1. The product sheet thickness (i.e. " t_1 " in formula (6)) after the cold rolling is within a range of approximately 0.245 ± 0.01 mm. In the cold rolling and after the final cold rolling, the finish temperature shown in Table 1 was applied.

[0094] After the cold rolling, a paint was applied to a sheet surface, and paint baking treatment was performed for 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 S22 were obtained.

[Table 1]

Example	Alloy	Sheet Thickness mm	Homogenizing Treatment Temperature C°	Annealing Temperature after Hot Rolling C°	Cold Rolling		Paint Baking Temperature (PMT) C°	Tensile Properties		
					Target Rolling Reduction %	Finish Temperature C°		$\sigma_{0.2}$ MPa	σ_B MPa	σ_{fm} MPa
S1	1	0.236	600	550	88	150	270	330	354	342
S2	2	0.252	490	460	88	120	270	266	304	285
S3	3	0.253	490	460	88	120	270	268	307	287
S4	4	0.245	490	460	88	120	250	273	306	290
S5	4	0.245	490	460	88	120	270	259	298	278
S6	5	0.248	490	460	88	120	270	271	312	292
S7	6	0.247	490	460	88	120	230	300	336	318
S8	7	0.256	490	460	88	120	230	310	342	326
S9	7	0.256	490	460	88	120	250	295	333	314
S10	8	0.245	490	460	88	120	270	267	308	288
S11	9	0.249	490	460	88	120	270	259	299	279
S12	10	0.243	490	460	88	120	230	255	286	270
S13	10	0.243	490	460	88	120	250	244	277	260
S14	10	0.243	490	460	88	120	270	231	268	249
S15	11	0.242	490	520	88	100	230	323	362	343
S16	11	0.242	490	520	88	100	250	310	351	331
S17	11	0.242	490	520	88	100	270	296	339	317
S18	11	0.236	490	520	88	130	230	324	361	343
S19	11	0.236	490	520	88	130	250	318	356	337
S20	11	0.241	550	520	88	130	230	352	385	368
S21	11	0.241	550	520	88	130	250	340	377	359
S22	11	0.241	550	520	88	130	270	318	355	337

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[Table 2]

Example	Alloy	$t^{2.27} \times \sigma_{fm} / (\sigma_{0.2} / \sigma_B)$	$\sigma_{fm} / (\sigma_{0.2} / \sigma_B)$	Mg ₂ Si Area Ratio	Earing Ratio	Buckling Pressure	Number of Cyclic Bending	3104 Possible Blending Ratio
		-	MPa	%	%	kPa	Number of Times	wt%
S1	1	14	366.3	0.02	-2.0	635	-	≥50
S2	2	14	326.2	0.41	-	543	21.4	<50
S3	3	15	330.0	0.76	-	539	18.3	<50
S4	4	13	325.2	1.25	-5.9	539	15.3	<50
S5	4	13	320.0	1.25	-	525	20.1	<50
S6	5	14	335.2	0.57	-	548	20.4	<50
S7	6	15	356.0	0.33	-	566	17.1	<50
S8	7	16	359.9	0.27	-	622	15.7	<50
S9	7	16	355.2	0.27	-4.9	602	17.7	<50
S10	8	14	332.4	0.64	-	527	17.8	<50
S11	9	14	322.7	0.82	-	543	18.5	<50
S12	10	12	303.7	0.43	-	494	19.4	<50
S13	10	12	296.0	0.43	-5.5	490	19.4	<50
S14	10	12	289.1	0.43	-	482	22.0	<50
S15	11	15	384.2	1.09	-	619	11.2	≥50
S16	11	15	374.0	1.09	-7.0	608	12.3	≥50
S17	11	15	363.8	1.09	-	585	13.9	≥50
S18	11	14	381.9	1.06	-	571	11.9	≥50
S19	11	14	378.0	1.06	-7.2	574	12.4	≥50
S20	11	16	402.5	0.83	-	634	10.1	≥50
S21	11	16	397.5	0.83	-6.5	623	12.0	≥50
S22	11	15	376.4	0.83	-	610	13.2	≥50

[Table 3]

Alloy No.	Si	Fe	Cu	Mn	Mg
1	0.40	0.40	0.22	1.1	1.5
2	0.15	0.23	0.17	0.4	2.5
3	0.24	0.24	0.18	0.4	2.5
4	0.34	0.23	0.18	0.4	2.5
5	0.15	0.24	0.25	0.3	2.5
6	0.16	0.24	0.18	0.5	2.6
7	0.15	0.24	0.18	0.6	2.5
8	0.24	0.23	0.25	0.3	2.5
9	0.25	0.24	0.26	0.3	2.5

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(continued)

Alloy No.	Si	Fe	Cu	Mn	Mg
10	0.14	0.19	0.05	0.2	2.3
11	0.35	0.46	0.22	0.8	2.7

[0095] <Evaluation of Aluminum Alloy Sheet>

(Tensile Properties)

[0096] The aluminum alloy sheets of S1 to S22 were used to form test pieces No. 5 specified in JIS-Z-2241:2011. The test pieces extend in a direction at an angle of 0° to a rolling direction. The test pieces were subjected to a tensile test according to JIS-Z-2241:2011, and 0.2% yield strength and tensile strength were measured. Table 1 shows the measurement results of the 0.2% yield strength $\sigma_{0.2}$ and the tensile strength σ_B , and the average values σ_{fm} of the 0.2% yield strength and the tensile strength.

[0097] In each of the aluminum alloy sheets of S1 to S22, a sheet thickness was measured with a micro gauge, and a value $V (= t^{2.27} \times \sigma_{fm}/(\sigma_{0.2}/\sigma_B))$ of the above-described formula (3) was calculated. Table 2 shows the calculation results of the values V and the values " $\sigma_{fm}/(\sigma_{0.2}/\sigma_B)$ ".

(Toughness)

[0098] In each of the aluminum alloy sheets of S1 to S22, the ratio of the total area (area ratio) of the Mg_2Si particles each having an area of $0.31 \mu m^2$ or more in the L-LT cross section was calculated by the measurement method described in the embodiment. The measurement results are shown in Table 2.

[0099] In each of the aluminum alloy sheets of S1 to S22, the earing ratio was calculated by the measurement method and the left side of the formula (2) described in the embodiment. The results are shown in Table 2. Note that "-" in the table means "not measured".

[0100] In each of the aluminum alloy sheets of S1 to S22, the normalized number of cyclic bending was calculated by the measurement method and formulas (4) and (5) described in the embodiment. The results are shown in Table 2. Note that "-" in the table means "not measured".

(Scrap Blending Ratio)

[0101] With respect to the composition of each of the aluminum alloy sheets of S1 to S22, it was determined whether the possible blending ratio of the scrap of 3104 aluminum alloy was 50 mass % or more. The results are shown in Table 2.

[0102] 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 scrap of 3104 aluminum alloy is determined based on Table 4.

[0103] 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.

[0104] 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 %.

[0105] 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 content of Si, Fe, Cu and Mn increases, and the content of Mg decreases. In the aluminum alloy sheets of S1, S15 to S22, 50 mass % or more of the scrap 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

(continued)

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

(Buckling Pressure)

[0106] In each of the aluminum alloy sheets of S1 to S22, the buckling pressure was measured by the measurement method described in the embodiment. The results are shown in Table 2. The aluminum alloy sheets of S1, S7 to S9, and S15 to S22 showed high buckling pressure of 550 kPa or more.

[0107] FIG. 3 shows a graph depicting the relationship between the values $V (= t^{2.27} \times \sigma_{fm}/(\sigma_{0.2}/\sigma_B))$ of formula (3) and the buckling pressure of the alloy sheets. From FIG. 3, it is confirmed that there is a high correlation between the values V and the buckling pressure. Therefore, if the value of " $\sigma_{fm}/(\sigma_{0.2}/\sigma_B)$ " on the left side of the formula (1) is 350 MPa or more, the high buckling pressure of 550 kPa or more can be provided without greatly increasing the sheet thickness.

[0108] The aluminum alloy sheets of S20 to S22 that were subjected to a high homogenizing treatment temperature showed remarkably high buckling pressure. Also, the aluminum alloy sheet of S1 exhibited high strength and high buckling pressure even with low Mg content due to the high annealing temperature after the hot rolling.

[0109] In every aluminum alloy, when the paint baking temperature (PMT) was lower, the strength got higher. For example, when the aluminum alloy sheets of S15 to S17 and S20 to S22 are compared, those subjected to lower paint baking temperatures exhibited higher buckling pressure.

[0110] The aluminum alloys of S1 to S3, S6 to S14, and S20 to S22 had small area ratios of the Mg_2Si particles, equal to or less than 1.0%. Among the aluminum alloys of S15 to S22, the aluminum alloy sheets of S20 to S22, which were subjected to the high homogenizing treatment temperature, had particularly small area ratios of the Mg_2Si particles.

[0111] Thus, when the aluminum alloy sheet of S18 and the aluminum alloy sheet of S21 are compared, the numbers of cyclic bending were equal to or greater, regardless of the fact that the buckling pressure of the aluminum alloy of S21 was nearly 50 kPa higher than that of the aluminum alloy sheet of S18. The aluminum alloy sheet of S8 also had a greater number of cyclic bending than that of the aluminum alloy sheet of S17 regardless of the higher buckling pressure because the area ratio of the Mg_2Si particles is small.

Claims

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

a silicon (Si) content of 0.10 mass % or more and 0.60 mass % or less;
 an iron (Fe) content of 0.20 mass % or more and 0.70 mass % or less;
 a copper (Cu) content of 0.10 mass % or more and 0.40 mass % or less;
 a manganese (Mn) content of 0.5 mass % or more and 1.2 mass % or less; and
 a magnesium (Mg) content of 1.1 mass % or more and 4.0 mass % or less,
 wherein a 0.2% yield strength $\sigma_{0.2}$, a tensile strength σ_B and an average value σ_{fm} , of the 0.2% yield strength
 and the tensile strength satisfy a following formula (1).

$$\sigma_{fm}/(\sigma_{0.2}/\sigma_B) \geq 350 \text{ MPa} \dots (1)$$

2. The aluminum alloy sheet for a can lid according to claim 1,
 wherein in an L-LT cross section parallel to both a sheet surface and a rolling direction, a ratio of a total area of
 Mg_2Si particles each having an area of $0.3\mu\text{m}^2$ or more is 1.0% or less.

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

wherein in a circumferential direction of an Erichsen cup formed according to an Erichsen test,
 an average value " h_{0p} " obtained from a maximum side wall height in each of a region at approximately 0° and
 a region at approximately 180° with respect to a rolling direction,
 an average value " h_{45p} " obtained from a maximum side wall height in each of a region at approximately 45° , a
 region at approximately 135° , a region at approximately 225° , and a region at approximately 315° with respect
 to the rolling direction and
 an average value " h_v " obtained from a minimum side wall height in each of a region at 0° to 45° , a region at 45°
 to 135° , a region at 135° to 180° , a region at 180° to 225° , a region at 225° to 315° , and a region at 315° to
 360° with respect to the rolling direction
 satisfy a following formula (2).

$$(h_{0p} - h_{45p})/h_v \times 100 \geq -7.0 \dots (2)$$

4. The aluminum alloy sheet for a can lid according to any one of claims 1 to 3,

wherein the sheet comprises
 the Si content of 0.20 mass % or more and 0.60 mass % or less,
 the Fe content of 0.30 mass % or more and 0.70 mass % or less,
 the Cu content of 0.11 mass % or more and 0.40 mass % or less,
 the Mn content of 0.7 mass % or more and 1.2 mass % or less, and
 the Mg content of 1.1 mass % or more and 3.0 mass % or less.

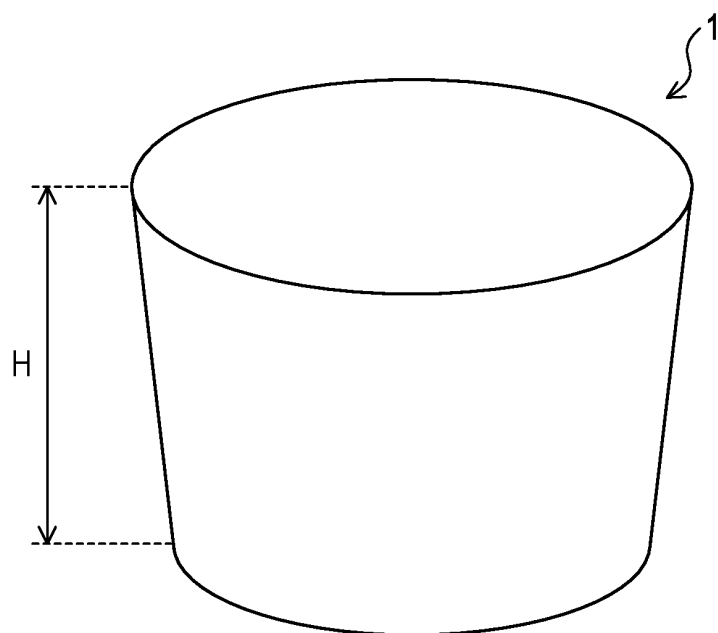


FIG. 1A

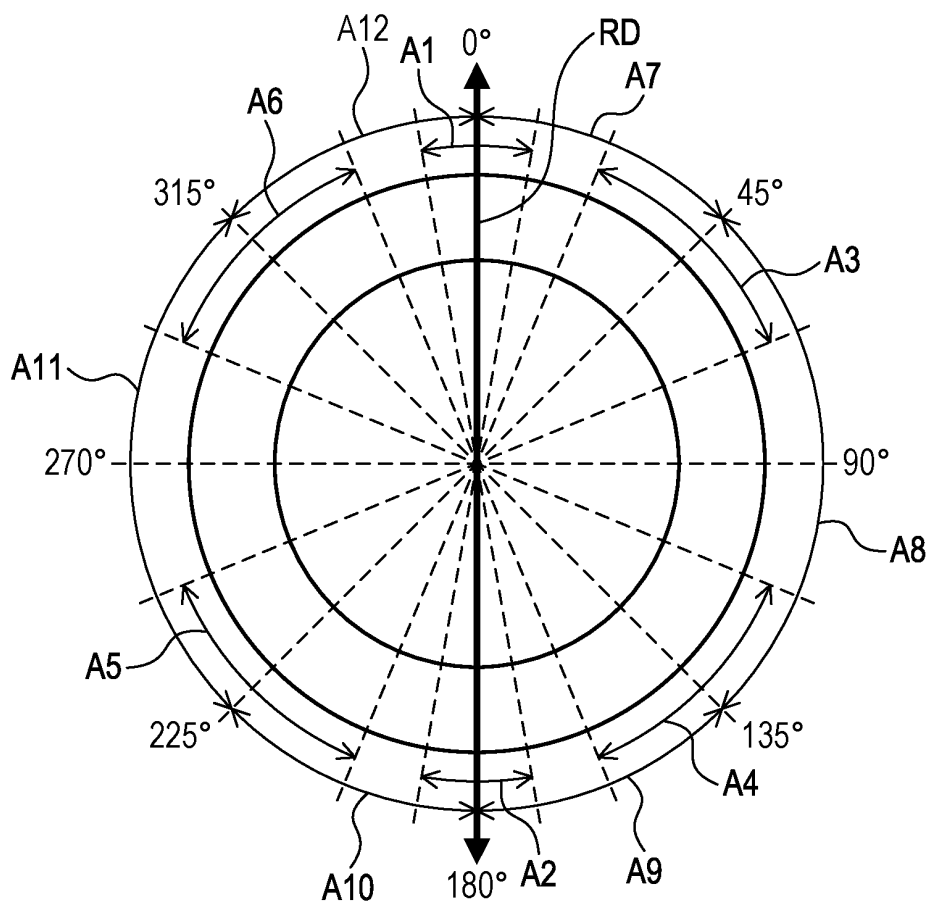


FIG. 1B

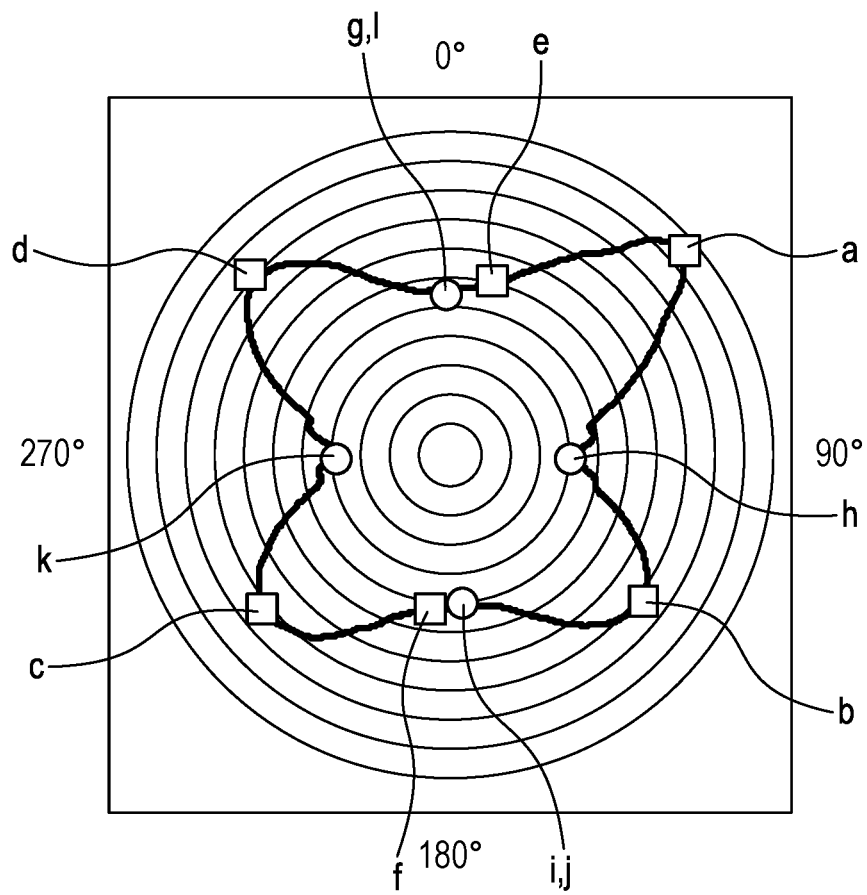


FIG. 2

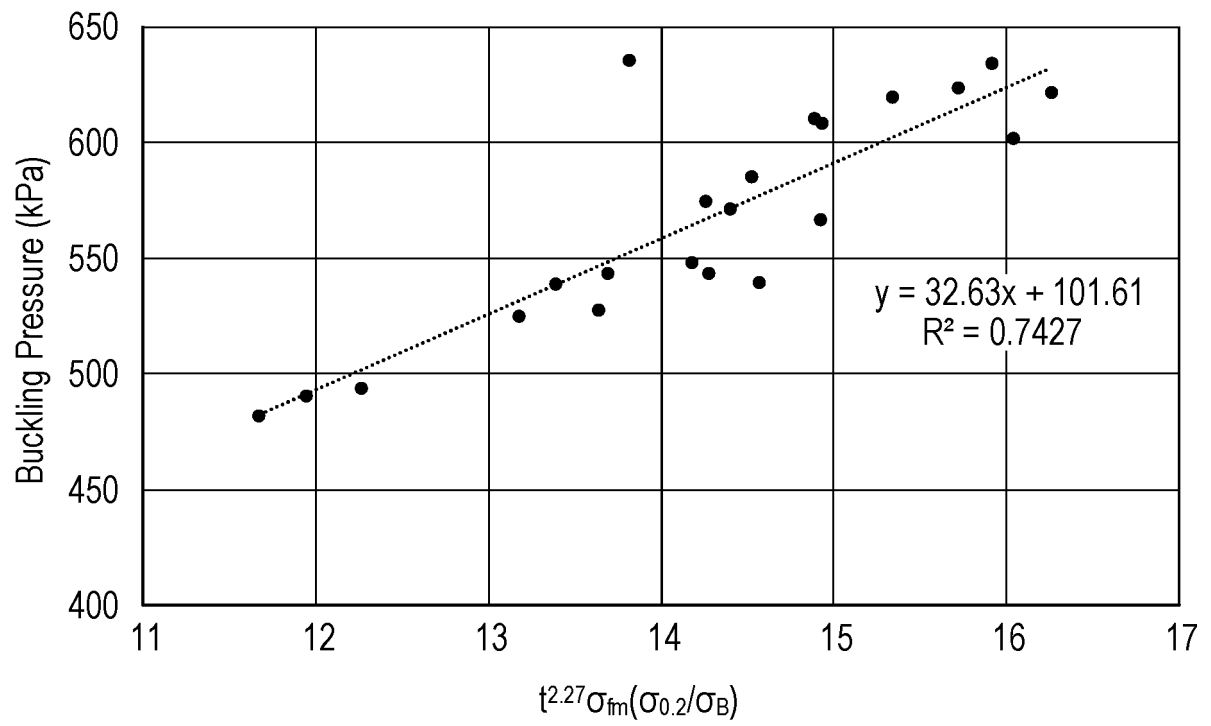


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/008126

A. CLASSIFICATION OF SUBJECT MATTER

C22C 21/06(2006.01)i; *C22F 1/00*(2006.01)i; *C22F 1/047*(2006.01)iFI: C22C21/06; C22F1/00 623; C22F1/00 630A; C22F1/00 630B; C22F1/00 630K; C22F1/00 673; C22F1/00 682;
C22F1/00 683; C22F1/00 685Z; C22F1/00 691B; C22F1/00 691C; C22F1/00 694A; C22F1/00 694B; C22F1/047

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)

C22C21/06; C22F1/00; C22F1/047

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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 55-134149 A (MITSUBISHI METAL CORP.) 18 October 1980 (1980-10-18) page 2, upper left column, lines 16-18, page 5, lower left column, line 17 to lower right column, line 14, table 1, this invention A1 alloy plate no. 2, 3	1-2, 4
X	JP 60-258454 A (FURUKAWA ARUMINIUMU KOGYO KK) 20 December 1985 (1985-12-20) page 1, lower right column, lines 1-4, page 4, upper left column, lines 1-5, tables 1-3, alloy no. 2	1-4
X	JP 2002-180173 A (MITSUBISHI ALUM. CO., LTD.) 26 June 2002 (2002-06-26) paragraphs [0001], [0027], tables 1, 2, examples 1, 2	1-2, 4
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A	JP 2011-21239 A (UNIVERSAL SEIKAN KK) 03 February 2011 (2011-02-03) entire text, all drawings	1-4

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
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Date of the actual completion of the international search

02 May 2023

Date of mailing of the international search report

23 May 2023

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/JP2023/008126

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	JP 2012-167333 A (SUMITOMO LIGHT METAL IND., LTD.) 06 September 2012 (2012-09-06) entire text, all drawings	1-4
A	JP 2008-57030 A (UNIVERSAL SEIKAN KK) 13 March 2008 (2008-03-13) entire text, all drawings	1-4
A	JP 7-197173 A (KOBELCO STEEL, LTD.) 01 August 1995 (1995-08-01) entire text	1-4
A	CN 111910111 A (CHALCO RUIJIN CO., LTD.) 10 November 2020 (2020-11-10) entire text, all drawings	1-4

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/008126

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CN 111910111 A	10 November 2020	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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