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(54) **ALUMINUM ALLOY MATERIAL**

(57) An aluminum alloy material contains Mg: 7.0% to 10.0% (% by mass, the same applies hereinafter) and Ca: not more than 0.1%, and the aluminum alloy material contains a remainder constituted by aluminum and an

inevitable impurity. The aluminum alloy material has a tensile strength of not less than 500 MPa and an elongation of not less than 3% and less than 10%.

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DescriptionTechnical Field

5 **[0001]** The present invention relates to a high-strength aluminum alloy material having reduced strength anisotropy.

Background Art

10 **[0002]** Recently, there has been a demand for using an aluminum alloy material to make stronger and lighter various products including, for example, a housing of an electrical device. Using an aluminum alloy material having higher strength makes it possible to reduce the amount of usage of the aluminum alloy material while maintaining the strength of the products at the same degree as before, and thus enables reduction in the weights of the products.

15 **[0003]** Typical high-strength aluminum alloys include, for example, a 6000 series alloy and a 7000 series alloy. However, the above-described alloys are heat-treatable alloys, which require solution treatment and aging heat treatment, and thus have a problem of low production efficiency. In addition, the 7000 series alloy contains Zn and Cu in a large amount, and thus have a problem of causing corrosion to easily occur depending on usage environments.

20 **[0004]** In view of the above, non-heat-treatable aluminum alloys are used in some cases. Typical non-heat-treatable aluminum alloys include a 5000 series alloy, which has the highest strength. The 5000 series alloy, which typically has excellent corrosion resistance, does not require the solution treatment and the aging heat treatment, so that the 5000 series alloy is produced with high efficiency. Further, increase in the amount of an element added to the 5000 series alloy makes it possible to achieve the 5000 series alloy having strength not less than that of a 6000 series alloy. For the above reasons, proposed is a 5000 series aluminum alloy material containing not less than 5% by weight of Mg, which is a major additive element (see Patent Literatures 1 to 3).

25 Citation List**[0005]**

30 [Patent Literature 1]
Japanese Patent Application Publication, Tokukai, No. 2007-186747
[Patent Literature 2]
Japanese Patent Application Publication, Tokukai, No. 2001-98338
[Patent Literature 3]
Japanese Patent Application Publication, Tokukaihei, No. 7-197170

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Summary of InventionTechnical Problem

40 **[0006]** The contents of Mg in the aluminum alloy materials described in the above Patent Literatures 1 to 3 are increased to an amount of not less than 5% by weight to make the aluminum alloy material stronger. However, Patent Literatures 1 to 3 do not give any consideration to strength anisotropy of the aluminum alloy materials.

45 **[0007]** In a case where an aluminum alloy material has high strength anisotropy, an end product has low rigidity in a particular direction, so that the reliability of the end product could decrease. In addition, failure in dimension accuracy or other accuracy could occur in a production process such as press forming. In particular, an aluminum alloy material (H tempered material) having an increased strength through working and curing has a problem of being prone to have remarkable strength anisotropy compared to an aluminum alloy material (O tempered material) which has been annealed.

50 **[0008]** It is an object of an aspect of the present invention, which has been made to solve the above problem, to provide an aluminum alloy material which has both high strength and reduced strength anisotropy, by controlling the metal structure.

Solution to Problem

55 **[0009]** To solve the above problems, an aluminum alloy material in accordance with an aspect of the present invention contains Mg: 7.0% to 10.0% (% by mass, the same applies hereinafter) and Ca: not more than 0.1%, the aluminum alloy material containing a remainder constituted by aluminum and an inevitable impurity, and the aluminum alloy material having a tensile strength of not less than 500 MPa and an elongation of not less than 3% and less than 10%.

Advantageous Effects of Invention

[0010] An aspect of the present invention makes it possible to produce an aluminum alloy material which has both high strength and reduced strength anisotropy.

Brief Description of Drawings

[0011] Fig. 1 is a view illustrating measurement directions of tensile strengths of an aluminum alloy material in the present embodiment.

Description of Embodiments

[0012] The inventors of the present invention diligently investigated and studied alloy composition and metal structure which enable reduction in the strength anisotropy of a high-strength aluminum alloy material containing Mg (magnesium) in a large amount. The inventors eventually found that it is possible to reduce the strength anisotropy by controlling an appropriate metal structure through adjustments to the alloy composition and to a production process.

[0013] The following description will discuss an aluminum alloy material in accordance with an embodiment of the present invention in detail. Note that it is assumed that the aluminum alloy material of the present embodiment is used for members of household electrical appliances, buildings, structures, transport equipment, and the like that are required to have strength and isotropy of strength. In the following description, the unit "% by mass" is abbreviated and written simply as "%".

(Elements Which Must Be Contained in Aluminum Alloy)

[Mg]

[0014] Mg (magnesium) is present mainly in the form of a solid solution element, and has an effect of improving strength. The content of Mg in the aluminum alloy being not less than 7.0% makes it possible to sufficiently obtain the effect of improving strength.

[0015] However, the content of Mg in the aluminum alloy exceeding 10.0% causes occurrence of cracking during hot rolling, and thus could lead to difficulty in production. Accordingly, the content of Mg in the aluminum alloy is preferably in a range of not less than 7.5% and not more than 9.0%, and more preferably in a range of not less than 7.5% and not more than 8.5%.

[Ca]

[0016] Ca (Calcium) is present in the aluminum alloy mainly in the form of a compound. Even trace amounts of Ca cause cracking during hot working, and thus could lower workability. The content of Ca in the aluminum alloy being not more than 0.1% makes it possible to prevent cracking during hot working. The content of Ca in the aluminum alloy is more preferably not more than 0.05%.

(Elements Selectively Contained in Aluminum Alloy)

[Si]

[0017] Si (silicon) forms mainly second phase particles (for example, single Si, Al-Si-Fe-Mn-based compound), and has an effect of making crystal grains finer by acting as a nucleation site for recrystallization. The content of Si in the aluminum alloy being not less than 0.02% makes it possible to successfully obtain the effect of making crystal grains finer.

[0018] However, the content of Si in the aluminum alloy exceeding 0.3% cause generation of a large amount of coarse second phase particles, and thus could lower the elongation of a produced aluminum alloy material. Accordingly, the content of Si in the aluminum alloy is preferably in a range of not less than 0.02% and not more than 0.2%, and more preferably in a range of not less than 0.02% and not more than 0.15%.

[Fe]

[0019] Fe (iron) is present mainly in the form of second phase particles (such as an Al-Fe-based compound), has an effect of making crystal grains finer by acting as a nucleation site for recrystallization. The content of Fe in the aluminum alloy being not less than 0.02% makes it possible to obtain the effect of making crystal grains finer.

[0020] However, the content of Fe in the aluminum alloy exceeding 0.5% causes generation of a large amount of coarse second phase particles, and thus could lower the elongation of a produced aluminum alloy material. Accordingly, the content of Fe in the aluminum alloy is preferably in a range of not less than 0.02% and not more than 0.25%, and more preferably in a range of not less than 0.02% and not more than 0.2%.

[Cu]

[0021] Cu (copper) is present mainly in the form of a solid solution element, and has an effect of improving strength. The content of Cu in the aluminum alloy being not less than 0.05% makes it possible to sufficiently obtain the effect of improving strength.

[0022] However, the content of Cu in the aluminum alloy exceeding 1.0% causes occurrence of cracking during hot rolling, and thus could lead to difficulty in production. Accordingly, the content of Cu in the aluminum alloy is preferably in a range of not less than 0.05% and not more than 0.5%, and more preferably in a range of not less than 0.10% and not more than 0.3%.

[Mn]

[0023] Mn (manganese) is present mainly in the form of second phase particles (an Al-Mn-based compound), and has an effect of making crystal grains finer by acting as a nucleation site for recrystallization. Specifically, the content of Mn in the aluminum alloy being not less than 0.05% makes it possible to sufficiently obtain the effect of making crystal grains finer.

[0024] However, the content of Mn in the aluminum alloy exceeding 1.0% causes generation of a large amount of coarse second phase particles, and thus lower the elongation of a produced aluminum alloy material. Accordingly, the content of Mn in the aluminum alloy is preferably in a range of not less than 0.1% and not more than 0.5%, and more preferably in a range of not less than 0.15% and not more than 0.3%.

[Cr, V, Zr]

[0025] Cr (chromium), V (vanadium), and Zr (zirconium) are present mainly in the form of second phase particles (such as an Al-Fe-Mn-based compound, an Al-Cr-based compound, an Al-V-based compound, and an Al-Zr-based compound), and have an effect of making crystal grains finer by acting as a nucleation site for recrystallization. Specifically, the content of Cr or V in the aluminum alloy being not less than 0.05% or the content of Zr in the aluminum alloy being not less than 0.02% makes it possible to sufficiently obtain the effect of making crystal grains finer.

[0026] However, the content of Cr or V in the aluminum alloy exceeding 0.3%, or the content of Zr exceeding 0.2% causes generation of a large amount of coarse second phase particles, and thus could lower the elongation of a produced aluminum alloy material.

[0027] Accordingly, the content of Cr or V in the aluminum alloy is preferably not more than 0.2%. In addition, the content of Zr in the aluminum alloy is preferably 0.1%.

[0028] The contents of Cr, V, and Zr in the aluminum alloy are not limited to the above respective contents, provided that at least one of Cr, V, and Zr is contained in the aluminum alloy.

[Ti]

[0029] Ti (titanium) inhibits the growth of a solidified phase of aluminum formed during casting and makes a cast structure finer, thus having an effect of preventing a defect such as cracking during casting. However, an excessively high content of Ti in the aluminum alloy makes second phase particles coarse, and thus could decrease the elongation of a produced aluminum alloy material.

[0030] In light of the above, the content of Ti in the aluminum alloy being not more than 0.2% makes it possible to prevent a decrease in the elongation of the produced aluminum alloy material. The content of Ti in the aluminum alloy is more preferably not more than 0.1%. Note that substances other than the elements described above are basically Al and an inevitable impurity.

(Tensile Strength and Elongation)

[0031] The present embodiment enables production of an aluminum alloy material (H tempered material) having a tensile strength of not less than 500 MPa and an elongation of not less than 3% and less than 10%, by performing production treatments (which will be discussed later) on the aluminum alloy of the above composition. This makes it possible to prevent an end product from having poor strength due to the aluminum alloy having a tensile strength falling

below 500 MPa. It is also possible to prevent the occurrence of a defect such as cracking during working on the end product due to the aluminum alloy having an elongation falling below 3%.

[0032] The tensile strength of the aluminum alloy material is more preferably not less than 550 MPa. Further, the elongation of the aluminum alloy material is more preferably not less than 5% and less than 10%.

(Strength Anisotropy)

[0033] As illustrated in Fig. 1, an aluminum alloy material 1 of the present embodiment is set such that, in a plane defined by a rolling direction (a final working direction) during a final rolling using a set of rolls 2 and a transverse direction, a standard deviation of tensile strengths is not more than 20 [MPa], wherein the tensile strengths are: a tensile strength in a 0° direction forming an angle of 0° with the rolling direction toward the transverse direction, a tensile strength in a 45° direction forming an angle of 45° with the rolling direction toward the transverse direction, and a tensile strength in a 90° direction forming an angle of 90° with the rolling direction towards the transverse direction. This setting is made in consideration of the fact that the standard deviation of the tensile strengths exceeding 20 [MPa], which means an excessively high strength anisotropy, decreases the strength in a particular direction of an end product and could decrease the reliability of the end product. The standard deviation of the tensile strengths is calculated by using Formula (1) (which will be described later).

[0034] The standard deviation of the tensile strengths of the aluminum alloy material 1 is preferably not more than 15 [MPa], and more preferably not more than 12 [MPa].

(Crystallographic Texture)

[0035] The aluminum alloy material of the present embodiment is set to have a {013}<100> orientation density and a {011}<100> orientation density which are calculated using a Crystallite Orientation Distribution Function (ODF) and which are each not more than 5 (for example, approximately 1). This setting is made in consideration of the fact that the {013}<100> orientation density and the {011}<100> orientation density both exceeding 5 makes the strength anisotropy remarkable and thus could decrease the strength of an end product in a particular direction.

[0036] In addition, the aluminum alloy material of the present embodiment is set to have a {011}<211> orientation density calculated using the crystallite orientation distribution function (ODF) such that a ratio obtained by dividing the {011}<211> orientation density by a {112}<111> orientation density is not less than 0.4. Such a setting is made in consideration of the fact that the {011}<211> orientation density being less than 0.4 times the {112}<111> orientation density makes the strength anisotropy remarkable and thus could decrease the strength of an end product in a particular direction.

[0037] Now, a method for calculating an orientation density using the crystallite orientation distribution function (ODF) will be described in detail. In the present embodiment, a three-dimensional orientation analyzing method (see, Journal of Japan Institute of Light Metals, 1992, volume 42, No. 6, pp. 358 to 367) using the crystallite orientation distribution function (ODF) is applied to a produced aluminum alloy material to calculate an orientation density. First, a cross section of the aluminum alloy material perpendicular to the working direction (rolling direction) is measured by an X-ray diffractometry. In this measurement, incomplete pole figures of (111), (220), and (200) planes are measured in an inclination angle range of 15 degrees to 90 degrees, using the Schlz reflection method (see, Journal of Japan Institute of Light Metals, 1983, volume 33, No. 4, pp. 230 to 239). Next, the crystallite orientation distribution function (ODF) is determined through a series expansion. From this, an orientation density of each orientation is calculated as a ratio with respect to the orientation density of a standard sample having random crystallographic texture.

(Method for Producing Aluminum Alloy Material)

[0038] The following description will discuss a method for producing the aluminum alloy material in accordance with the present embodiment. The method for producing the aluminum alloy material of the present embodiment is carried out in the order of a casting step, a homogenization step, a hot rolling step, a cold rolling step, and an anneal step. Steps of the production method are not limited to these steps, which are illustrated by way of example.

[0039] First, a slab is casted in the casting step by a semi-continuous casting process such as a Direct Chill (DC) casting process and a hot top process. The casting speed in the casting step is preferably 20 mm/min to 100 mm/min to prevent formation of coarse second phase particles.

[0040] Upon completion of the casting step, the homogenization step is carried out. The treatment temperature is set to not less than 400°C and not more than 490°C. This is because (i) the treatment temperature being not more than 400°C could cause insufficient homogenization, and (ii) the treatment temperature exceeding 490°C could cause melting of an Al-Mg-based compound remaining without dissolving as a solid solution, and thus cause a defect such as cracking during the hot rolling. Further, coarsening of second phase particles excessively progresses, and crystal grains in a

particular orientation tend to preferentially grow in the subsequent recrystallization process, so that the strength anisotropy could decrease.

[0041] In the homogenization step of the present embodiment, a two-stage homogenization treatment may be carried out. In that case, the treatment temperature for the first stage is set to not less than 400°C and not more than 450°C. This is because (i) the treatment temperature for the first stage being not more than 400°C could cause insufficient homogenization, and (ii) the treatment temperature for the first stage exceeding 450°C could cause melting of an Al-Mg-based compound remaining without dissolving as a solid solution, and thus cause a defect such as cracking during the hot rolling.

[0042] Further, the treatment time for the first stage is set to be in a range of not less than five hours and not more than 20 hours. This is because (i) the treatment time for the first stage being less than five hours causes insufficient homogenization, and (ii) the treatment time for the first stage exceeding 20 hours causes decrease in productivity. Carrying out the homogenization treatment in the first stage with the treatment temperature and the treatment time being appropriately set as described above makes it possible to cause the Al-Mg-based compound to dissolve as a solid solution, and thus enables homogenization at a higher temperature.

[0043] Subsequently, the treatment temperature for the second stage is set to not less than 450°C and not more than 490°C. This is because (i) the treatment temperature for the second stage being less than 450°C causes insufficient homogenization, and (ii) the treatment temperature for the second stage exceeding 490°C causes oxidization of Mg on the surface to progress and thus could decrease concentration of Mg on the surface.

[0044] Further, the treatment time for the second stage is set to be in a range of not less than five hours and not more than 20 hours. This is because (i) the treatment time for the second stage being less than five hours causes insufficient homogenization, and (ii) the treatment time for the second stage exceeding 20 hours causes coarsening of second phase particles to excessively progress, causes crystal grains in a particular orientation to tend to preferentially grow in the subsequent recrystallization process, and thus could decrease the strength anisotropy.

[0045] Next, the hot rolling step is carried out. In the hot rolling step, the starting temperature for the hot rolling is set to be in a range of not less than 350°C and not more than 480°C. This is because (i) the treatment temperature for the hot rolling being less than 350°C could make the rolling difficult due to excessively high deformation resistance, and (ii) the treatment temperature for the hot rolling exceeding 480°C causes the material to partially melt, and thus could lead to the occurrence of cracking. Note that the hot rolling step may be carried out with the homogenization step omitted.

[0046] Subsequently, upon completion of the hot rolling step, the cold rolling step is carried out. In the cold rolling step, the cold rolling is carried out such that a rolling reduction from the plate thickness at the time of completion of the hot rolling step to the plate thickness at the time of completion of the cold rolling step (a ratio of a plate thickness after working to a plate thickness before the working) is not less than 50%. The rolling reduction only needs to be not less than 50%, and may be changed as appropriate.

[0047] Note that an intermediate annealing may be carried out before or in the middle of the cold rolling step. In this case, the cold rolling is also carried out such that the rolling reduction from the plate thickness at the time of completion of the intermediate annealing to the plate thickness at the time of completion of the cold rolling is not less than 50%. A treatment temperature for the intermediate annealing is preferably in a range of not less than 300°C and not more than 400°C. Further, a retention time for the intermediate annealing is preferably in a range of not less than one hour and not more than 10 hours. This is because carrying out the intermediate annealing at a high temperature for a long time could cause deterioration in appearance quality due to progression of oxidization on the surface.

[0048] According to the aluminum alloy material of the present embodiment described above, it is possible to produce an aluminum alloy material having both high strength and reduced strength anisotropy by appropriately controlling the metal structure through adjustments to the composition of the aluminum alloy and the production process for the aluminum alloy. This enables improvement in productivity of the aluminum alloy material and improvement in reliability of an end product.

Examples

[0049] The following description will discuss Example 1 of the present embodiment with reference to Table 1 and Table 2.

(Composition of Aluminum Alloy)

[0050] Table 1 shows the composition of the aluminum alloy used in Example 1.

[Table 1]

[0051]

(Table 1)

Present Invention	Composition of Aluminum Alloy [% by Mass]										
	Fe	Si	Cu	Mn	Mg	Cr	Ti	V	Zr	Ca	Al
Example 1	0.22	0.10	<0.01	0.40	7.6	0.02	0.03	0.01	<0.01	<0.01	Remaining Percentage

[0052] As shown in Table 1, the composition of the aluminum alloy of Example 1 is within a predetermined range. The predetermined range means that the content of Mg is in a range of 7.0% to 10.0%, and the content of Ca is in a range of not more than 0.1%.

(Production Method)

[0053] After the aluminum alloy having the composition shown in Table 1 is molten and is subjected to the DC casting, the homogenization step, the hot rolling step, and the cold rolling step are carried out. The plate thickness of the aluminum alloy material after completion of the cold rolling step is assumed to be 1.0 mm.

[0054] In Example 1, heating at 465°C for 12 hours is carried out in the homogenization step prior to the hot rolling step. In the cold rolling step, the rolling reduction from the plate thickness at the time of completion of the hot rolling to the plate thickness at the time of completion of the cold rolling is assumed to be 80%.

(Property of Aluminum Alloy Material)

[0055] Table 2 shows the strength property, the strength anisotropy, and the productivity of an aluminum alloy material produced by performing the above treatment on the aluminum alloy of Example 1 having the composition shown in Table 1.

[Table 2]

[0056]

(Table 2)

Present Invention	Strength Property		Anisotropy				Productivity
	Tensile Strength [MPa]	Elongation [%]	Strength Anisotropy [MPa]	{013}<100> Orientation Density	{011}<100> Orientation Density	Orientation Density Ratio of {011}<211> / {011}<100>	
Example 1	572	8	10	G	G	G	G

(Tensile Strength and Elongation)

[0057] As shown in Table 2, the aluminum alloy material produced in Example 1 has a tensile strength and an elongation within the respective predetermined ranges. In other words, the aluminum alloy material produced in Example 1 has a tensile strength in a range of not less than 500 MPa and an elongation in a range of not less than 3% and less than 10%.

[0058] Note that the tensile strength and the elongation of the produced aluminum alloy material are measured in conformity with JIS Z-2241-2011. As illustrated in Fig. 1, in a plane defined by a rolling direction along which the set of rolls 2 moves (final working direction) and a transverse direction, tensile strengths and elongations of the produced aluminum alloy material 1 are measured in a 0° direction, which is the rolling direction, in a 45° direction forming an angle of 45° with the 0° direction from the rolling direction toward the transverse direction, and in a 90° direction forming an angle of 90° with the 0° direction from the rolling direction toward the transverse direction. The tensile strength and the elongation of the produced aluminum alloy material 1 are defined respectively as the average value for the measured tensile strengths and the average value for the measured elongations.

(Strength Anisotropy)

[0059] Tensile strengths are measured, in the plane defined by the rolling direction (final working direction) and the

transverse direction, in the 0° direction, which is the rolling direction, in the 45° direction forming an angle of 45° with the 0° direction from the rolling direction toward the transverse direction, and in the 90° direction forming an angle of 90° with the 0° direction from the rolling direction toward the transverse direction. The strength anisotropy is defined as a standard deviation [MPa] calculated by using the following Formula (1).

$$\sqrt{\frac{\sum_{i=1}^n (TS_i - TS)^2}{(n-1)}} \quad (n \geq 2) \quad \dots \text{Formula (1)}$$

[0060] In the formula, TS_i [MPa] represents a tensile strength of each direction, TS [MPa] represents the average value for the tensile strengths in the respective directions, and n represents the total number of pieces of the tensile strength data.

(Crystallographic Texture)

[0061] The three-dimensional orientation analyzing method using the crystallite orientation distribution function (ODF) described above is applied to the aluminum alloy material of Example 1 to calculate an orientation density. Specifically, a cross section of a portion of the produced aluminum alloy material in a plane perpendicular to the working direction (rolling direction) of the aluminum alloy material is measured with an X-ray diffractometry. In this measurement, after incomplete pole figures of the (111), (220), and (200) planes are measured using the above Schiz reflection method in an inclination angle range of 15 degrees to 90 degrees, a series expansion is performed to determine the crystallite orientation distribution function (ODF).

[0062] The orientation density of each orientation thus obtained is calculated as a ratio with respect to the orientation density of a standard sample having a random crystallographic texture. Table 2 shows results of evaluations performed such that an aluminum alloy material having a $\{013\}<100>$ orientation density of not more than 5 and a $\{011\}<100>$ orientation density of not more than 5 is rated as "G (good)", and an aluminum alloy material having a $\{013\}<100>$ orientation density exceeding 5 and a $\{011\}<100>$ orientation density exceeding 5 is rated as "P (poor)". Further, an aluminum alloy material having a ratio obtained by dividing a $\{011\}<211>$ orientation density by a $\{112\}<111>$ orientation density of not less than 0.4 is rated as "G", and an aluminum alloy material having a ratio obtained by dividing a $\{011\}<211>$ orientation density by a $\{112\}<111>$ orientation density falling below 0.4 is rated as "P".

[0063] As shown in Table 2, it is understood that Example 1 successfully reduced strength anisotropy. In addition, Example 1 shows the results that indicate no problem with productivity.

(Comparative Examples)

[0064] As comparative examples to Example 1 described above, Table 4 shows properties of aluminum alloy materials produced by performing a treatment similar to that for Example 1 on aluminum alloys of Comparative Example 1 to Comparative Example 5 having their respective compositions shown in Table 3. Note that, for Comparative Examples 1 to 3, a treatment at 500°C and for eight hours was performed as the homogenization treatment.

[Table 3]

[0065]

(Table 3)

Comparative Example	Composition of Aluminum Alloy [% by Mass]										
	Fe	Si	Cu	Mn	Mg	Cr	Ti	V	Zr	Ca	Al
Comparative Example 1	0.16	0.07	0.08	<0.01	6.8	<0.01	0.01	<0.01	<0.01	<0.01	Remaining Percentage
Comparative Example 2	0.16	0.07	0.08	0.24	6.7	<0.01	0.01	<0.01	<0.01	<0.01	Remaining Percentage
Comparative Example 3	0.16	0.07	0.08	<0.01	5.7	0.20	0.01	<0.01	<0.01	<0.01	Remaining Percentage
Comparative Example 4	0.16	0.07	0.08	<0.01	11.0	<0.01	0.01	<0.01	<0.01	<0.01	Remaining Percentage
Comparative Example 5	0.16	0.07	0.08	<0.01	9.0	<0.01	0.01	<0.01	<0.01	0.50	Remaining Percentage

[Table 4]

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[0066]

(Table 4)

Comparative Example	Strength Property		Anisotropy				Productivity
	Tensile Strength [MPa]	Elongation [%]	Strength Anisotropy [MPa]	{013}<100> Orientation Density	{011}<100> Orientation Density	Orientation Density Ratio of {011}<211>/{011}<100>	
Comparative Example 1	470	9	12	G	G	G	G
Comparative Example 2	487	9	21	G	G	P	G
Comparative Example 3	478	8	15	G	G	G	G
Comparative Example 4	-	-	-	-	-	-	P
Comparative Example 5	-	-	-	-	-	-	P

[0067] Comparative Example 1, in which the content of Mg is too low, results in a produced aluminum alloy material having a tensile strength falling below the predetermined range, and thus fails to yield good mechanical properties.

[0068] Comparative Example 2, in which the content of Mg is too low, results in a produced aluminum alloy material having a tensile strength falling below the predetermined range, and thus fails to yield good mechanical properties.

Further, since the homogenization treatment temperature is too high, the strength anisotropy exceeds the predetermined range, so that Comparative Example 2 fails to yield good mechanical properties.

[0069] Comparative Example 3, in which the content of Mg is too low, results in a produced aluminum alloy material having a tensile strength falling below the predetermined range, and thus fails to yield good mechanical properties.

[0070] Comparative Example 4, in which the content of Mg is too high, causes occurrence of cracking during the hot rolling. This makes rolling difficult, so that the production is impossible.

[0071] Comparative Example 5, in which the content of Ca is too high, causes occurrence of cracking during the hot rolling. This makes rolling difficult, so that the production is impossible.

[0072] The present invention is not limited to the embodiments, but can be altered by a skilled person in the art within the scope of the claims. An embodiment based on a proper combination of technical means disclosed in different embodiments is encompassed in the technical scope of the present invention.

[0073] An aluminum alloy material in accordance with an aspect of the present invention contains Mg: 7.0% to 10.0% (% by mass, the same applies hereinafter) and Ca: not more than 0.1%, the aluminum alloy material containing a remainder being constituted by aluminum and an inevitable impurity, the aluminum alloy material having a tensile strength of not less than 500 MPa and an elongation of not less than 3% and less than 10%.

[0074] The aluminum alloy material preferably contains Mn: 0.05% to 1.0%.

[0075] Further, the aluminum alloy material has a standard deviation of tensile strengths of not more than 20, in a plane defined by a final working direction and a transverse direction of the aluminum alloy material, wherein the tensile strengths are a tensile strength in a 0° direction, which is the final working direction, a tensile strength in a 45° direction forming an angle of 45° with the 0° direction from the final working direction toward the transverse direction, and a tensile strength in a 90° direction forming an angle of 90° with the 0° direction from the final working direction toward the transverse direction.

[0076] The aluminum alloy material preferably has a {013}<100> orientation density of not more than 5 and a {011}<100> orientation density of not more than 5, wherein the {013}<100> orientation density and the {011}<100> orientation density are calculated using a crystallite orientation distribution function (ODF).

[0077] The aluminum alloy material preferably has a {011}<211> orientation density which is not less than 0.4 times a {112}<111> orientation density, wherein the {011}<211> orientation density is calculated using a crystallite orientation distribution function (ODF).

Reference Signs List

[0078]

- 1 aluminum alloy material
- 2 roll

Claims

1. An aluminum alloy material containing Mg: 7.0% to 10.0% (% by mass, the same applies hereinafter) and Ca: not more than 0.1%,

- the aluminum alloy material containing a remainder being constituted by aluminum and an inevitable impurity,
- the aluminum alloy material having a tensile strength of not less than 500 MPa and an elongation of not less than 3% and less than 10%.

2. The aluminum alloy material according to Claim 1, wherein the aluminum alloy material contains Mn: 0.05% to 1.0%.

3. The aluminum alloy material according to Claim 1 or 2, wherein the aluminum alloy material has a standard deviation of tensile strengths of not more than 20, in a plane defined by a final working direction and a transverse direction of the aluminum alloy material, wherein the tensile strengths are a tensile strength in a 0° direction, which is the final working direction, a tensile strength in a 45° direction forming an angle of 45° with the 0° direction from the final working direction toward the transverse direction, and a tensile strength in a 90° direction forming an angle of 90° with the 0° direction from the final working direction toward the transverse direction.

4. The aluminum alloy material according to Claim 3, wherein the aluminum alloy material has a $\{013\}\langle 100 \rangle$ orientation density of not more than 5 and a $\{011\}\langle 100 \rangle$ orientation density of not more than 5, wherein the $\{013\}\langle 100 \rangle$ orientation density and the $\{011\}\langle 100 \rangle$ orientation density are calculated using a crystallite orientation distribution function (ODF).
5. The aluminum alloy material according to Claim 3 or 4, wherein the aluminum alloy material has a $\{011\}\langle 211 \rangle$ orientation density which is not less than 0.4 times a $\{112\}\langle 111 \rangle$ orientation density, wherein the $\{011\}\langle 211 \rangle$ orientation density is calculated using a crystallite orientation distribution function (ODF).

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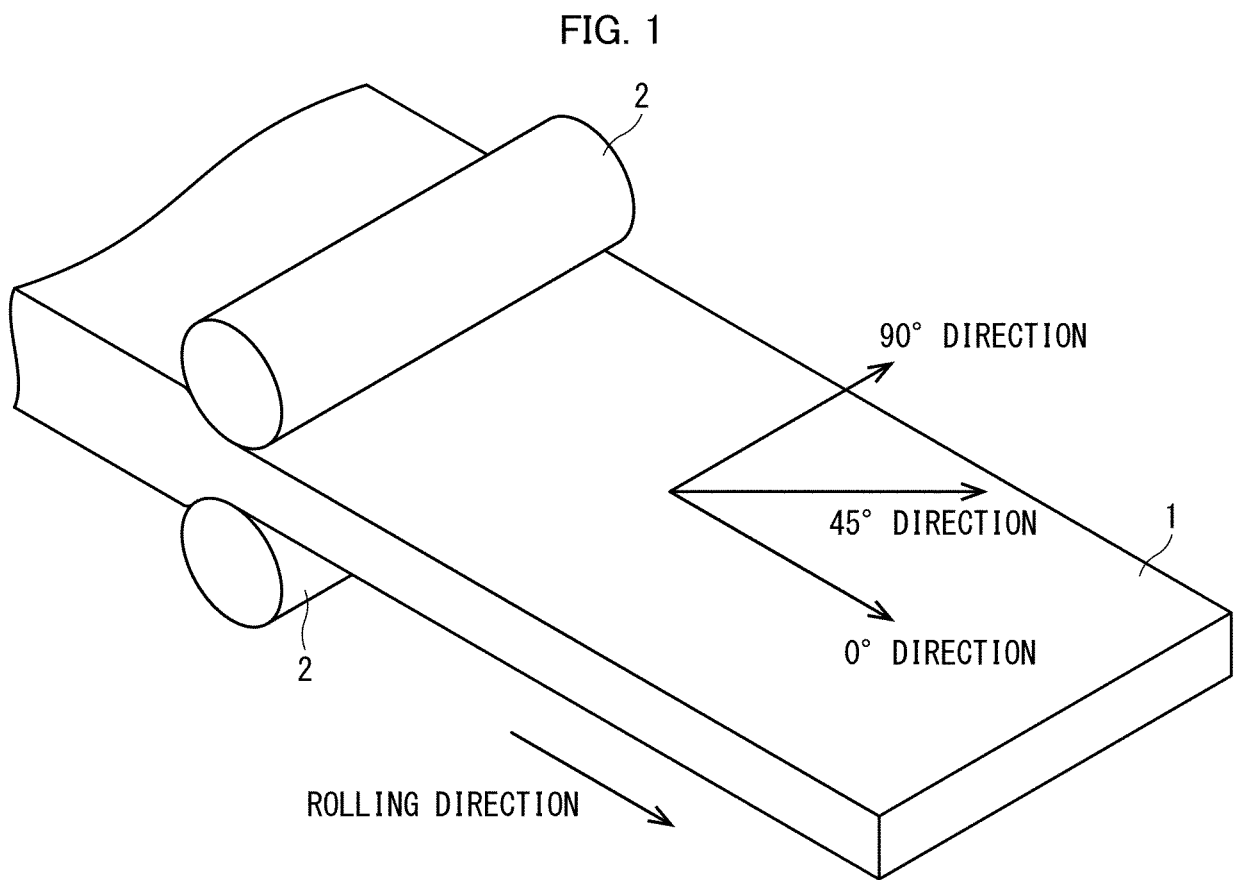
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/038086

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; C22F1/00 623; C22F1/00 630A; C22F1/00 630K; C22F1/00 681; 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	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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 6-145868 A (FURUKAWA ALUMINUM CO., LTD.) 27 May 1994 (1994-05-27)	1-5
A	JP 2006-200018 A (KOBE STEEL, LTD.) 03 August 2006 (2006-08-03)	1-5
A	JP 2014-125665 A (SUMITOMO ELECTRIC INDUSTRIES, LTD.) 07 July 2014 (2014-07-07)	1-5
A	JP 53-86610 A (KUBOTA TEKKO KABUSHIKI KAISHA) 31 July 1978 (1978-07-31)	1-5
A	JP 2001-98338 A (KOBE STEEL, LTD.) 10 April 2001 (2001-04-10)	1-5
A	JP 2009-24219 A (KOBE STEEL, LTD.) 05 February 2009 (2009-02-05)	1-5



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search
02 December 2020 (02.12.2020)Date of mailing of the international search report
15 December 2020 (15.12.2020)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application no.

PCT/JP2020/038086

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 6-145868 A	27 May 1994	US 5605586 A EP 598358 A1	
JP 2006-200018 A	03 Aug. 2006	(Family: none)	
JP 2014-125665 A	07 Jul. 2014	(Family: none)	
JP 53-86610 A	31 Jul. 1978	(Family: none)	
JP 2001-98338 A	10 Apr. 2001	(Family: none)	
JP 2009-24219 A	05 Feb. 2009	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2007186747 A [0005]
- JP 2001098338 A [0005]
- JP 7197170 A [0005]

Non-patent literature cited in the description

- *Journal of Japan Institute of Light Metals*, 1992, vol. 42 (6), 358-367 [0037]
- *Journal of Japan Institute of Light Metals*, 1983, vol. 33 (4) [0037]