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(54) ALUMINUM ALLOY ROLLED MATERIAL FOR MOLDING, WITH IMPROVED PRESS FORMABILITY, BENDING WORKABILITY, AND RIDGING RESISTANCE

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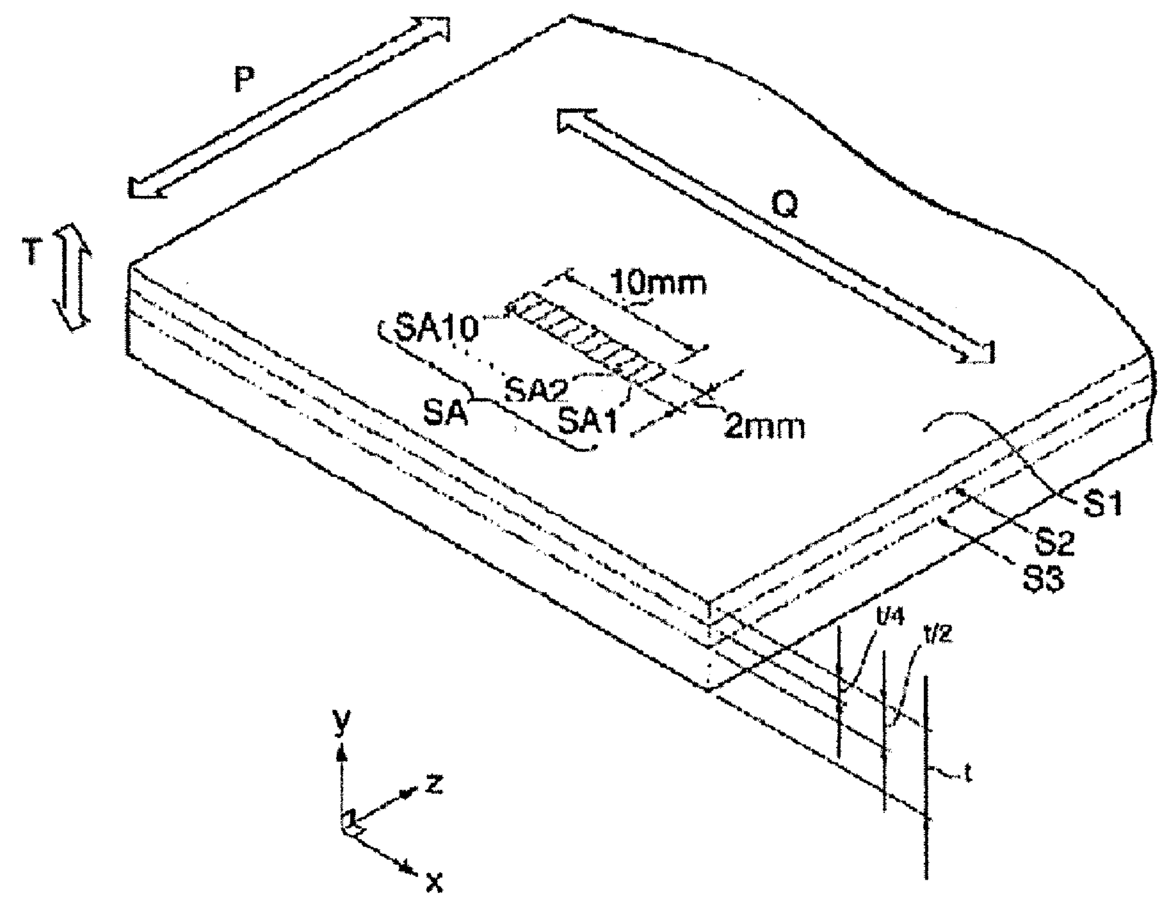
(57) **ABSTRACT**

The present disclosure provides an aluminum alloy rolled material for molding, including an Al—Mg—Si—Cu-based alloy containing 0.30 mass % or more Cu. A ratio of a cube orientation density to a random orientation is 10 or more in a plane that is perpendicular to a sheet thickness direction and is at a depth of ¼ of a total sheet thickness from a surface. An absolute value of a difference between a maximum value and a minimum value of an average Taylor factor in a case in which molding is assumed to cause plane strain deformation having a main strain direction that is a rolling width direction is 1.0 or less. The average Taylor factor is obtained for each of subareas that are obtained by equal division of an area, having a 10 mm width in the rolling width direction and a 2 mm length in a rolling direction, into 10 subareas in the rolling width direction. The subareas are in a plane that is perpendicular to the sheet thickness direction and is at a depth of ½ of the total sheet thickness from the surface.



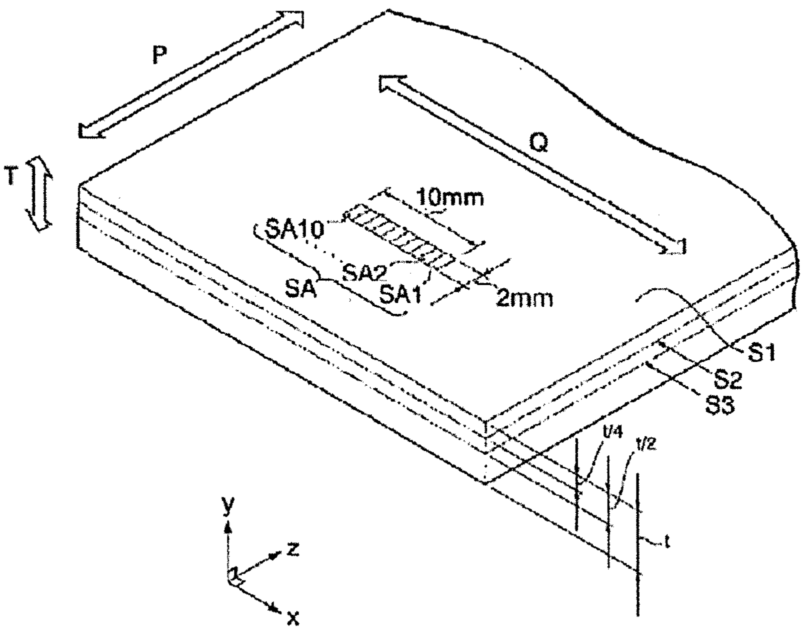


FIG.1

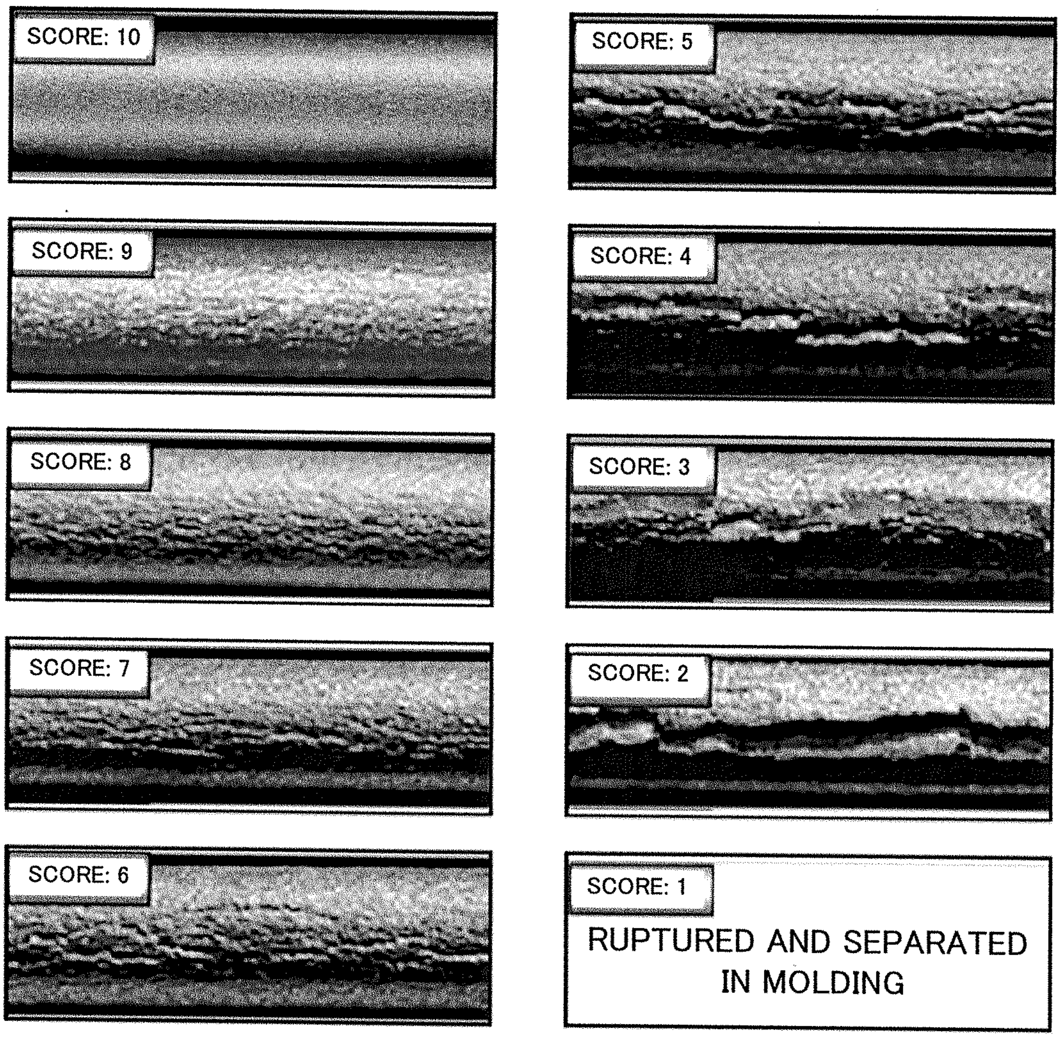

SCORE: 10
SCORE: 5
SCORE: 9
SCORE: 4
SCORE: 8
SCORE: 3
SCORE: 7
SCORE: 2
SCORE: 6
SCORE: 1
RUPTURED AND SEPARATED IN MOLDING

FIG.2

ALUMINUM ALLOY ROLLED MATERIAL FOR MOLDING, WITH IMPROVED PRESS FORMABILITY, BENDING WORKABILITY, AND RIDGING RESISTANCE

TECHNICAL FIELD

[0001] The present disclosure relates to an Al—Mg—Si—Cu-based aluminum alloy rolled material which is subjected to molding and coating baking and is used as the members and components of various automobiles, ships, aircraft, and the like, such as automobile body sheets and body panels, construction materials, structural materials, and other materials for various machinery and appliances, household electrical appliances, the components thereof, and the like. In particular, the present disclosure relates to an aluminum alloy rolled material for molding, with improved press formability, bending workability, and ridging resistance, which is preferred for the applications.

BACKGROUND ART

[0002] Demands for improvement in fuel efficiency through a reduction in the weights of automobiles have been increased against recent requirements such as suppression of global warming and a reduction in energy costs as backgrounds. In response to the demands, aluminum alloy sheets have also increasingly tended to be used as automotive body sheets applied to automobile body panels, in place of conventional cold rolled steel sheets. An aluminum alloy sheet has a specific gravity about one-third the specific gravity of a conventional cold rolled steel sheet while having a strength approximately equivalent to the strength of the conventional cold rolled steel sheet, and can contribute to a reduction in the weight of an automobile. Aluminum alloy sheets have also been recently often used in molded components such as the panels and chassis of electronic and electrical instruments and the like, in addition to automotive applications. Like automotive body sheets, such aluminum alloy sheets have been often pressed and used.

[0003] The press formability of the sheet materials for molding has been more strictly required because the design properties of the shapes of automobiles and the like have been highly required in recent years. The automotive body panels have been often used after hemming of the edges of sheets in order to join and integrate outer and inner panels. The hemming can be considered to be very severe working for a material because 180-degree bending is performed at an extremely small bend radius. Thus, improved hemming workability and improved bending workability in consideration of such applications are required. In addition, automobile body sheets have been usually used after subjected to coating baking. In a balance between formability and strength, therefore, it is necessary to obtain high strength after the coating baking in the case of attaching great importance to the strength, whereas it is necessary to obtain high press formability at the expense of the strength to some extent after the coating baking in the case of attaching great importance to the formability.

[0004] As described above, more severe molding of aluminum alloy sheets for molding has been particularly recently often performed. In addition to severe molding conditions, importance has been placed on surface appearance quality. With regard to the surface appearance quality, it is strongly demanded that not only no Lueders mark is generated but also no ridging mark is generated even when the severe molding described above is performed.

[0005] The ridging mark is a fine recessed and projected pattern that appears in a stripe shape in a direction parallel to the direction of rolling in a step of producing a sheet when the sheet is molded. Surface appearance quality may be deteriorated because a site at which such a ridging mark is generated appears as, for example, a site with less luster or the like even after a sheet surface is coated. Therefore, a material for an automobile body sheet or the like particularly requiring high surface appearance quality strongly requires that a ridging mark is prevented from being generated in molding. Hereinafter, in this specification, resistance to generation of a ridging mark in molding is referred to as "ridging resistance."

[0006] Examples of known aluminum alloys commonly used for automotive body sheets include an Al—Mg-based alloy, as well as an Al—Mg—Si-based alloy or Al—Mg—Si—Cu-based alloy with an aging property. In particular, an Al—Mg—Si-based alloy with an aging property and an Al—Mg—Si—Cu-based alloy with an aging property have relatively low strength and improved formability in molding prior to coating baking, has an advantage of being aged by heating during the coating baking, thereby enhancing strength after the coating baking, and has an advantage in that, for example, generation of a Lueders mark is inhibited.

[0007] As described above, aluminum alloy sheet materials for molding have required more severe working conditions for press formability and bending workability. Not only securing of press formability and bending workability but also ridging resistance for improving surface appearance quality has been demanded. Various commitments have also been made to the aluminum alloy sheet materials described above.

[0008] Drawability and stretchability are required for press formability. A number of findings for improving the press formability have been conventionally obtained. In particular, it has been proposed that press formability is improved by controlling the amounts of elements added to an aluminum alloy to adjust strength and increasing a difference between a tensile strength and a proof stress as well as an elongation in a tensile test (Patent Literatures 1 and 2).

[0009] It has been pointed out that the bending workability of an aluminum alloy sheet material is profoundly associated with the particle sizes of Al—Fe—Si-based particles, Mg—Si-based particles, or the like which are precipitates in an alloy, and the texture of the alloy. For example, in Patent Literatures 3 to 6, proposals are made from the viewpoints of the control of the sizes of particles and the dispersion state of the particles, and the control of a texture and an r-value caused by the texture.

[0010] In parallel with such proposals for improvement of workability as described above, some commitments to improvement of ridging resistance associated with appearance quality after working have been reported. According to the commitments, generation of a ridging mark has been confirmed to be profoundly associated with a recrystallization behavior in a material. In addition, it has been proposed as a manner for inhibiting the generation of a ridging mark that recrystallization is controlled in a process for producing a sheet by hot rolling and/or the like performed after homogenization treatment of an alloy ingot.

[0011] As such a specific manner for improving ridging resistance, for example, a temperature at which hot rolling is started is principally set at a relatively low temperature of 450° C. or less, thereby inhibiting crystal grains from coarsening during hot rolling and then controlling a material structure after cold working and solution treatment, in Patent Literatures 7 and 8. Patent Literature 9 mentions differential speed rolling in a warm region and differential speed rolling in a cold region after hot rolling. In Patent Literatures 8, 9, and 10, it is proposed that intermediate annealing is performed after hot rolling, or that cold rolling is temporarily performed, followed by performing intermediate annealing.

[0012] In Patent Literatures 10 and 11, it is proposed that self-annealing is performed by heat in winding of a rolled sheet that has been hot-rolled, thereby temporarily decomposing a stripe-shaped structure caused by ingot crystal grains. It is considered that a sheet material with favorable ridging resistance can be produced because the stripe-shaped structure is sufficiently decomposed when recrystallization is re-performed in solution treatment.

[0013] Patent Literature 12 describes that an alloy ingot is subjected to homogenization treatment and then to hot rolling into a rolled material having a thickness of 4 to 20 mm, and the rolled material is cold-rolled to have a sheet thickness of 2 mm or more at a sheet thickness reduction rate of 20% or more, thereby allowing the cube orientation of a sheet material to be appropriate.

CITATION LIST

Patent Literature

[0014] Patent Literature 1: Unexamined Japanese Patent Application Kokai Publication No. 2001-342577

[0015] Patent Literature 2: Unexamined Japanese Patent Application Kokai Publication No. 2002-146462

[0016] Patent Literature 3: Unexamined Japanese Patent Application Kokai Publication No. 2012-77319

[0017] Patent Literature 4: Unexamined Japanese Patent Application Kokai Publication No. 2006-241548

[0018] Patent Literature 5: Unexamined Japanese Patent Application Kokai Publication No. 2004-10982

[0019] Patent Literature 6: Unexamined Japanese Patent Application Kokai Publication No. 2003-226926

[0020] Patent Literature 7: Japanese Patent No. 2823797

[0021] Patent Literature 8: Japanese Patent No. 3590685

[0022] Patent Literature 9: Unexamined Japanese Patent Application Kokai Publication No. 2012-77318

[0023] Patent Literature 10: Unexamined Japanese Patent Application Kokai Publication No. 2010-242215

[0024] Patent Literature 11: Unexamined Japanese Patent Application Kokai Publication No. 2009-263781

[0025] Patent Literature 12: Unexamined Japanese Patent Application Kokai Publication No. 2015-67857

SUMMARY OF INVENTION

Technical Problem

[0026] Individual characteristics of press workability, bending workability, and ridging resistance have been confirmed to be improved in the techniques for improving the conventional production processes described above and aluminum alloy sheet materials for molding produced by the techniques. However, mutual compatibility among the press workability, the bending workability, and the ridging resistance is needed for addressing more severe requirements of improvement in molding characteristics and surface quality in recent years but is not easily achieved. This is because the criteria for improving press formability, bending workability, and ridging resistance described in Patent Literatures 1 to 6 are not intrinsically designed for satisfying all the three characteristics.

[0027] With regard to production processes, it is also considered that, for example, in a case in which additional elements are controlled for strength adjustment useful for improving press formability, it may be impossible to apply, to alloy composition considered to be preferred in the case, criteria as indices for a production process for improving bending workability and ridging resistance as well as for a produced sheet material. Even a production process conventionally considered to be effective is incapable of having such an effect when a material structure, particularly the constitution or property of a precipitate, is changed by adjustment of alloy composition. It is also possible that the effect of the setting of a temperature at which hot rolling is started at a relatively low temperature in Patent Literatures 7 and 8 is not always sufficient when molding conditions become more severe. The intermediate annealing after hot rolling performed in Patent Literatures 2, 8, 9, and 10 and the differential speed rolling in Patent Literature 9 may exhibit no effect of improving ridging resistance under the alloy composition made in consideration of the press formability. With regard to the performance of self-annealing by heat in winding in hot rolling proposed in Patent Literatures 10 and 11, a precipitate which is not taken into consideration in these literatures may prevent recrystallization, thereby precluding the self-annealing. According to the present inventors, it is impossible to obtain an aluminum alloy sheet material improved in both bending workability and ridging resistance even in the case of making such definitions of a sheet thickness and the like after hot rolling as described in Patent Literature 12.

[0028] Thus, the present disclosure provides an aluminum alloy sheet material for molding that can have surface quality after working while addressing severe molding conditions and that achieves mutual compatibility among press workability, bending workability, and ridging resistance.

Solution to Problem

[0029] The present inventors performed intensive examination in order to solve the problems described above and first found, from targeted Al—Mg—Si—Cu-based alloys, an aluminum alloy having a great difference between a tensile strength and a 0.2% proof stress as an indicator for improvement in press formability. As a result, there was adopted an aluminum alloy having a Cu concentration of 0.30 mass % (hereinafter simply referred to as "%") or more. Addition of 0.30% or more Cu to an Al—Mg—Si—Cu-based alloy, which is an aluminum alloy with an aging property as described above, enables the alloy to have a higher strength after solution treatment, regardless of the number of aging days. According to the present inventors, the Al—Mg—Si—Cu-based alloy can have a great difference between a tensile strength and a 0.2% proof stress as well as a high strength, and can have press formability.

[0030] Thus, the present inventors examined means of allowing compatibility between the bending workability and anti-ridging property of an alloy sheet material on the basis of securing of press formability by application of the Al—

Mg—Si—Cu-based alloy to which 0.30% or more Cu is added. The present inventors considered that items associated closely with the means include behaviors and features in a process of producing an Al—Mg—Si—Cu-based alloy sheet.

[0031] According to the examination by the present inventors, Mg—Si-based particles as precipitates are very finely precipitated as particles containing Cu (Mg—Si—Cu-based particles) in a production step prior to hot rolling, in an Al—Mg—Si-based alloy sheet material containing Cu. The precipitation of the Mg—Si—Cu-based particles occurs in a cooling process after homogenization treatment, a heating process until reaching a hot-rolling temperature, and a heating and retention process until the start of the hot rolling. When the state of fine dispersion of Mg—Si—Cu-based particles is not addressed, even hot rolling does not enable the fine precipitates to function as the origin of a recrystallized structure, but rather causes recrystallization to be suppressed. Therefore, a state occurs in which hot rolling does not cause an expected recrystallized structure or in which even if recrystallization occurs, a very coarse recrystallized structure is generated and ridging resistance is not improved.

[0032] The structure of such a hot-rolled material with recrystallization insufficient due to the influence of fine precipitates as described above is not sufficiently improved even by setting a temperature at which a rolled sheet that has been hot-rolled is wound at 300° C. or more and by performing self-annealing of the hot-rolled material, as in the conventional technologies (Patent Literatures 10 and 11) described above. Any effect caused by intermediate annealing after the hot rolling is incapable of being expected.

[0033] Thus, the present inventors tried to control the state of the distribution of Mg—Si—Cu-based particles in an Al—Mg—Si—Cu-based alloy sheet material. In this examination, the features of the Mg—Si—Cu-based particles were summarized as follows.

[0034] (a) The state of the precipitation of Mg—Si—Cu-based particles is influenced by a cooling rate after homogenization treatment. When the cooling rate after the homogenization treatment is high, the precipitation of the Mg—Si—Cu-based particles occurs at a lower temperature, and particle sizes become smaller. In addition, the amounts of Mg, Si, and Cu taken in solid solution states are increased, and therefore, fine precipitation further occurs in subsequent heating.

[0035] (b) When an ingot of an aluminum alloy is heated to a hot-rolling temperature and retained, the Mg—Si—Cu-based particles precipitated after the homogenization treatment are coarsened in the processes of the heating and the retention.

[0036] (c) The state of the precipitation of the Mg—Si—Cu-based particles in (a) and the rate of the coarsening by the heating in (b) as described above are influenced by the content of Cu in the aluminum alloy. Specifically, an increase in the content of Cu tends to cause the Mg—Si—Cu-based particles to be finer. In addition, the rate of the coarsening of the Mg—Si—Cu-based particles by the heating is decreased with increasing the content of Cu. These actions due to Cu tend to become noticeable when the content of Cu is 0.30 mass % or more. For example, the coarsening rate of Mg—Si—Cu-based particles in an Al—Mg—Si—Cu-based alloy with 0.30% or more Cu is much lower than the coarsening rate of Mg—Si—Cu-based particles precipitated in an Al—Mg—Si-based alloy with less than 0.30% Cu.

[0037] On the basis of the findings of (a), (b), and (c) described above, examples of manners for controlling the state of the distribution of Mg—Si—Cu-based particles include, first, decreasing a cooling rate after homogenization treatment on the basis of the findings of (a). This manner is a manner for inhibiting the precipitation itself of fine Mg—Si—Cu-based particles. Decreasing a cooling rate after homogenization treatment can be mentioned on the basis of the findings of (a).

[0038] Coarsening of fine Mg—Si—Cu-based particles into appropriate sizes by intentional heating and retention at a temperature close to a hot-rolling temperature after homogenization treatment is also considered to be effective on the basis of the findings of (b). The precipitation of fine Mg—Si—Cu-based particles is not always able to be completely inhibited even if the cooling rate after the homogenization treatment is lowered. A case in which it is impossible to lower the cooling rate after the homogenization treatment can also be considered from the viewpoint of a production facility, production control, or the like. Thus, treatment of retaining an ingot of an aluminum alloy at a temperature close to the hot-rolling temperature enables the Mg—Si—Cu-based particles to be coarsened, and this manner can be considered to be a particularly effective manner.

[0039] On the basis of the findings of (c), it is necessary to strictly consider both of the state and rate of the precipitation of Mg—Si—Cu-based particles in the case of an aluminum alloy containing 0.30% or more Cu according to the present disclosure. In particular, it is required to appropriately examine the setting of the time of the heating and retention described above according to the content of Cu in consideration of the diffusion of Cu.

[0040] In the present disclosure, a precipitate is controlled as described above in an Al—Mg—Si—Cu-based alloy sheet material to which 0.30% or more Cu is added, the material is then hot-rolled, and self-annealing is thereafter performed by winding the material at an appropriate temperature. The thereby produced Al—Mg—Si—Cu-based alloy sheet material has improved press formability, includes an appropriately controlled texture, and also has improved bending workability. Further, the material also has improved ridging resistance. The present inventors revealed, as the constitutions of the Al—Mg—Si—Cu-based alloy sheet material with the improved various characteristics, the mechanical properties of the sheet material, as well as a relationship between a cube orientation density and a random orientation, and the deviation of an average Taylor factor in a predetermined plane of the sheet material, and arrived at the present disclosure.

[0041] In other words, the present disclosure provides an aluminum alloy rolled material for molding, with improved press formability, bending workability, and ridging resistance, the aluminum alloy rolled material including: an aluminum alloy including 0.30 to 1.50% Cu, 0.30 to 1.50% Si, 0.30 to 1.50% Mg, at least one of 0.50% or less Mn, 0.40% or less Cr, or 0.40% or less Fe, and a balance of Al and inevitable impurities, wherein a difference between a tensile strength and a 0.2% proof stress is 120 MPa or more, wherein a ratio of a cube orientation density to a random orientation is 10 or more in a plane that is perpendicular to a sheet thickness direction and is at a depth of ¼ of a total sheet thickness from a surface, and wherein an absolute value of a difference between a maximum value and a minimum value of an average Taylor factor in a case in which molding is assumed to cause plane strain deformation having a main strain direction that is a rolling width direction is 1.0 or less, the average Taylor factor being obtained for each of subareas that are obtained by equal division of an area, having a 10 mm width in the rolling width direction and a 2 mm length in a rolling direction, into 10 subareas in the rolling width direction, the subareas being in a plane that is perpendicular to the sheet thickness direction and is at a depth of ½ of the total sheet thickness from the surface.

[0042] The aluminum alloy rolled material according to the present disclosure may contain at least one of 0.03 to 0.50% Mn, 0.01 to 0.40% Cr, or 0.03 to 0.40% Fe, and may further contain at least one of 0.03 to 0.15% Mn, 0.01 to 0.04% Cr, or 0.03 to 0.40% Fe.

[0043] In the aluminum alloy rolled material of the present disclosure, the difference between the tensile strength and the 0.2% proof stress is preferably 121 to 133 MPa.

[0044] In the aluminum alloy rolled material of the present disclosure, the ratio of the cube orientation density to the random orientation is preferably 12 or more, and still more preferably 12 to 18.

[0045] In the aluminum alloy rolled material of the present disclosure, the absolute value of the difference between the maximum value and the minimum value of the average Taylor factor is preferably 0.9 or less, and preferably 0.5 to 0.9.

[0046] In the aluminum alloy rolled material of the present disclosure, a score given by comparison with workability evaluation samples is 6 or more, preferably 7 or more, and still more preferably 8 or more, in 180-degree bending working.

[0047] In the aluminum alloy rolled material of the present disclosure, the aluminum alloy rolled material is obtained by rolling working including hot rolling working, and an average particle size of precipitated particles having particle diameters of 0.4 to 4.0 μm is preferably 0.6 μm or more, and preferably 0.7 to 1.9 μm, in pre-rolling heating and retention prior to the hot rolling working.

[0048] In the aluminum alloy rolled material of the present disclosure, a density of the precipitated particles having particle diameters of 0.4 to 4.0 μm, is preferably equal to or less than 1500 particles/100 μm^2, and preferably 402 particles/100 μm^2 to 1411 particles/100 μm^2.

[0049] In the aluminum alloy rolled material of the present disclosure, a recrystallization rate after the hot rolling working is preferably 95% or more, and more preferably 100%.

Advantageous Effects of Invention

[0050] The aluminum alloy rolled material according to the present disclosure is an aluminum alloy rolled material that is produced by controlling Mg—Si—Cu-based particles precipitated in a sheet production process while setting the amount of added Cu to 0.30% or more in an Al—Mg—Si-based alloy containing Cu and that has compatibility among high press formability, ridging resistance, and bending workability.

BRIEF DESCRIPTION OF DRAWINGS

[0051] FIG. **1** is an explanatory diagram of planes (plane S**2** and plane S**3**) that define the texture of an aluminum alloy rolled material according to the present disclosure; and

[0052] FIG. **2** is an external view of samples for evaluation of bending test results in an embodiment of the present application.

DESCRIPTION OF EMBODIMENTS

[0053] An embodiment of an aluminum alloy rolled material according to the present disclosure will be specifically described below. In the following discussion, the alloy composition and mechanical characteristics of an aluminum alloy included in the aluminum alloy rolled material according to the present disclosure will first be described, and then the features of a texture will be described. A method preferred for producing the aluminum alloy rolled material according to the present disclosure will also be described in detail.

[0054] (1) Alloy Composition of Aluminum Alloy Rolled Material According to the Present Disclosure

[0055] As described above, the aluminum alloy rolled material according to the present disclosure is based on an aluminum alloy comprising Cu, Si, and Mg as essential additional elements, further at least one of Cr, Mn, or Fe, and a balance of Al and inevitable impurities. The action and addition amount of each additional element will be described below.

[0056] Cu: 0.30 to 1.50%

[0057] Cu is a fundamental alloy element in the alloy system of the present disclosure and contributes to improvement in strength in cooperation with Si and Mg described later. As described above, it is important to define the amount of added Cu in the aluminum alloy rolled material according to the present disclosure from the viewpoint of improvement in press formability. In other words, in the present disclosure, an alloy sheet is allowed to have a high strength after solution treatment by setting the amount of added Cu to 0.30% or more, and press formability is secured by setting a great difference between a tensile strength and a 0.2% proof stress. A Cu amount of less than 0.30% causes such effects to be insufficient. With regard to an upper limit, an amount of more than 1.50% results in degradation in corrosion resistance (intergranular corrosion resistance and filiform corrosion resistance). From the above viewpoints, the content of Cu is set within a range of 0.30 to 1.50%. The lower limit value, a Cu amount of 0.30%, has significances as a criterion for securing of press formability and as a criterion for showing the possibility or impossibility of compatibility between a relationship between a cube orientation density and a random orientation described later and the deviation of an average Taylor factor.

[0058] Si: 0.30 to 1.50%

[0059] Si is a fundamental alloy element in the alloy system of the present disclosure and contributes to improvement in strength in cooperation with Mg and Cu. The above-described effects are not sufficiently obtained when the amount of Si is less than 0.30%, while coarse Si particles and coarse Mg—Si—Cu-based particles are generated, resulting in the deterioration of press formability, particularly bending workability, when the amount of Si is more than 1.50%. Accordingly, the amount of Si is set within a range of 0.30 to 1.50%. A Si amount within a range of 0.60 to 1.30% is preferred for allowing a balance between press formability and bending workability to be more favorable.

[0060] Mg: 0.30 to 1.50%

[0061] Mg is also a fundamental alloy element in the alloy system as a subject of the present disclosure and contributes to improvement in strength in cooperation with Si and Cu. The amount of a generated G.P. zone which contributes to improvement in strength due to precipitation hardening in coating baking becomes small, and therefore a sufficient improvement in strength is not obtained when the amount of Mg is less than 0.30%, while coarse Mg—Si—Cu-based particles are generated, resulting in the deterioration of press formability, particularly bending workability, when the amount of Mg is more than 1.50%. Thus, the amount of Mg is set within a range of 0.30 to 1.50%. A Mg amount within a range of 0.30 to 0.80% is preferred for allowing the press formability, particularly bending workability, of a final sheet to be more favorable.

[0062] Mn: 0.50% or less, Cr: 0.40% or less

[0063] Mn and Cr are elements effective at allowing crystal grains to be finer and at stabilizing a structure. However, a Mn content of more than 0.50% or a Cr content of more than 0.40% may cause not only saturation of the above-described effects but also generation of a large number of intermetallic compounds, resulting in an adverse impact on formability, particularly hem-bendability. Accordingly, Mn is set at 0.50% or less, and Cr is set at 0.40% or less. With regard to the lower limit values of the contents of Mn and Cr, when the content of Mn is less than 0.03% or the content of Cr is less than 0.01%, the above-described effects are not sufficiently obtained, crystal grains are coarsened in solution treatment, and a surface may be roughened in hemming-bending. Thus, the contents of Mn and Cr are preferably set at Mn: 0.03 to 0.50% and Cr: 0.01 to 0.40%.

[0064] With regard to Mn and Cr, more than 0.15% Mn or more than 0.05% Cr may result in an excessive increase in the above-described effects and in inhibition of recrystallization in self-annealing after hot-rolling winding. Thus, further restrictions on Mn and Cr may be preferred in consideration of a balance with other additional elements. In such a case, Mn is more preferably 0.03% or more and 0.15% or less. Cr is more preferably 0.01% or more and 0.05% or less.

[0065] Fe: 0.40% or less

[0066] Fe is also an element effective at improving strength and allowing crystal grains to be finer, but more than 0.40% Fe may cause a large number of intermetallic compounds to be generated and bending workability to be deteriorated. Thus, the amount of Fe is set at 0.40% or less. With regard to the lower limit of the amount of Fe, an Fe amount of less than 0.03% may result in an insufficient effect. Thus, it is preferable to set the amount of Fe within a range of 0.03 to 0.40%. It is more preferable to set the amount of Fe at 0.03% to 0.20% when further bending workability is demanded.

[0067] The aluminum alloy in the present disclosure may fundamentally comprise Al and inevitable impurities as well as Si, Mg, Cu, Cr, Mn, and Fe described above. Examples of the inevitable impurities include Zn, Ti, and V. The effects of the present disclosure are prevented from deteriorating when Zn is 0.30% or less, the elements other than Zn are 0.10% or less, all the impurity elements other than Zn are 0.20% or less.

[0068] (2) Mechanical Characteristics of Aluminum Alloy Rolled Material According to the Present Disclosure

[0069] A greater difference between a tensile strength and a 0.2% proof stress is effective at improving the press formability of an aluminum alloy rolled material, as described above. The difference between these values relating to mechanical characteristics corresponds to an allowance against rupture after the start of plastic deformation and the proceeding of local deformation. Therefore, formability can be improved by increasing the difference between the tensile strength and the 0.2% proof stress. Specifically, the aluminum alloy rolled material according to the present disclosure has a difference between a tensile strength and a 0.2% proof stress of 120 MPa or more. An aluminum alloy rolled material of which the value of the difference is less than 120 MPa results in insufficient formability under severer press molding conditions in recent years. The difference between the tensile strength and the 0.2% proof stress is preferably 121 to 133 MPa. The tensile strength is preferably 225 MPa or more.

[0070] As already mentioned, in the aluminum alloy rolled material according to the present disclosure, an Al—Mg—Si—Cu-based alloy is adopted, and the difference between the tensile strength and the 0.2% proof stress of an alloy sheet is allowed to be 120 MPa or more by adding 0.30% or more Cu. The positive addition of Cu results in the effect of changing the state of a fine cluster formed after solution treatment and greatly improving work hardening characteristics. A common Al—Mg—Si-based alloy for an automobile panel, to which Cu is not positively added, has a difference between a tensile strength and a 0.2% proof stress of 115 MPa or less.

[0071] (3) Texture of Aluminum Alloy Rolled Material According to the Present Disclosure

[0072] The aluminum alloy rolled material produced by the method according to the present disclosure includes favorable characteristics in ridging resistance and bending workability as well as press formability. The aluminum alloy rolled material includes a texture exhibiting distinguishing characteristics. Specifically, the aluminum alloy rolled material includes features relating to each of a relationship between a cube orientation density and a random orientation, and the deviation of an average Taylor factor in a predetermined plane of the aluminum alloy sheet material, and also has both the indices thereof in preferred ranges. Each characteristic will be described below.

[0073] (3.1) Texture Based on Cube Orientation Density as Index, and Bending Workability

[0074] In the aluminum alloy rolled material according to the present disclosure, the constituent composition of an alloy is adjusted as described above, and the texture of the aluminum alloy rolled sheet as a final sheet is appropriately controlled based on a cube orientation density as an index. This is because, in particular, bending workability is improved stably. The cube orientation density is the orientation density of a crystal grain with a cube orientation ({100}<001> orientation). In the present disclosure, specifically, it is necessary that the ratio of the cube orientation density to a random orientation is 10 or more in a plane that is perpendicular to a sheet thickness direction and is at a depth of ¼ of a total sheet thickness from a surface. Crystal grains with a cube orientation inhibit a shear zone from being generated in hemming-bending and inhibit a bending crack from occurring and propagating along a shear zone. The bending workability can be improved by increasing the rate of cube orientation crystal grains inhibiting the formation and propagation of a shear zone by controlling the ratio of the cube orientation density to 10 or more. The ratio of the cube orientation density is preferably set at 12 or more, and more preferably at 12 to 18, in order to achieve further strict appearance quality after bending working.

[0075] The reason that the texture in the plane that is perpendicular to a sheet thickness direction and is at a depth of ¼ of a total sheet thickness from a surface is defined as a reference of improvement in bending workability is because the vicinity of a surface layer of a sheet particularly influences surface quality under a very severe working condition, hemming-bending, according to the present inventors.

[0076] The measurement of a cube orientation density will be specifically described with reference to FIG. **1**. First, a plane S**2** that is perpendicular to a sheet thickness direction T and is at a depth of ¼ of a total sheet thickness t from a sheet surface S**1** is exposed by mechanical polishing. Then, the orientation information of a texture is acquired by measuring the incomplete pole figures of a (111) plane, a (220) plane, and a (200) plane by reflection method of Schulz which is one of X-ray diffraction measurement methods at an inclination angle ranging from 15 to 90°. The cube orientation density can be determined based on the obtained orientation information of the texture by using pole figure analysis software.

[0077] For example, analysis software "Standard ODF" publicly distributed by Hirofumi Inoue [Associate Professor] in Osaka Prefecture University or "OIM Analysis" manufactured by 1TSL may be used as the analysis software. Specifically, first, the orientation information of the texture obtained by the above-described method is subjected to rotation operation as needed and to series expansion on the conditions that the expansion degrees of "even number term" and "odd number term" are "22" and "19", respectively, thereby determining a crystal orientation distribution function (ODF). The orientation density of each orientation obtained by the ODF can be calculated as a ratio with respect to the orientation density of a standard sample including a random texture obtained by sintering an aluminum powder (random ratio).

[0078] (3.2) Texture Based on Taylor Factor as Index, and Ridging Resistance

[0079] In the present disclosure, ridging resistance as well as press formability and bending workability is improved, and such preferably balanced characteristics are achieved. It is very important to appropriately control the texture of the aluminum alloy rolled material which is a final sheet on the basis of a Taylor factor as an index with regard to the ridging resistance. In other words, high-level ridging resistance can be achieved by controlling the texture so that the dispersion of average Taylor factors in a rolling width direction is within an appropriate range.

[0080] A ridging mark is a fine recessed and projected pattern that is generated in a stripe shape in a direction parallel to a rolling direction when a rolled sheet is molding-worked. The generation of the ridging mark is considered to be caused by a difference between the plastic deformation amounts of crystal orientations adjacent to each other in molding.

[0081] The actual strain state of a press molded component in the case of press molding of a rolled sheet is known to be distributed primarily in a region between a plane strain state and an equibiaxial strain state. It is considered that a ridging mark is most prominently generated due to the plane strain, of which the rolling width direction (direction perpendicular to a rolling direction and parallel to a sheet surface) is a main strain direction, of the strains in the region. The plane strain deformation in the rolling width direction can be considered to be a strain state in which only an extension in the rolling width direction and a decrease in sheet thickness occur.

[0082] The dispersion (fluctuation range) of Taylor factor values in a rolling width direction in a case in which molding is assumed to cause plane strain deformation having a main strain direction that is a rolling width direction is an effective index for ridging resistance. The Taylor factors are calculated from all crystal orientations existing in the texture, and the reduction of the dispersion of Taylor factors in a rolling width direction in a case in which molding is assumed to cause plane strain deformation having a main strain direction that is the rolling width direction in a sheet surface of the rolled sheet or a plane in a sheet parallel to the sheet surface is effective for improving ridging resistance.

[0083] In the present disclosure, in the control of a texture based on a Taylor factor as an index, the absolute value of the difference between the maximum value and the minimum value of the average Taylor factor in a case in which molding is assumed to cause plane strain deformation having a main strain direction that is a rolling width direction is 1.0 or less. The average Taylor factor is obtained for each of subareas that are obtained by equal division of an area, having a 10 mm width in the rolling width direction and a 2 mm length in a rolling direction, into 10 subareas in the rolling width direction. The subareas are in a plane that is perpendicular to the sheet thickness direction and is at a depth of ½ of the total sheet thickness from the surface. The absolute value of the difference between the maximum value and the minimum values of the average Taylor factors is preferably 0.9 or less.

[0084] The index will be specifically described with reference to FIG. **1**. FIG. **1** clearly illustrates three planes S**1**, S**2**, and S**3** which are a sheet surface S**1** that is perpendicular to a sheet thickness direction T, a plane S**2** that is perpendicular to the sheet thickness direction T and is at a depth of ¼ of a total sheet thickness t from the sheet surface S**1**, and a plane S**3** that is perpendicular to the sheet thickness direction T and is at a depth of ½ of the total sheet thickness t from the sheet surface S**1**. In the present disclosure, in the plane S**3** among the planes, an area SA having a 10 mm width in a rolling width direction Q and a 2 mm length in a rolling direction P is made in an arbitrary site in the plane, subareas SA**1**, SA**2**, . . . , SA**10** in the same plane are obtained by equal division of the area SA into 10 subareas in the rolling width direction Q, and the value of the average Taylor factor of each of the subareas SA**1**, SA**2**, . . . , SA**10** is measured. The average value of Taylor factors in a case in which molding is assumed to cause plane strain deformation having a main strain direction that is the rolling width direction Q is measured as described above. A ridging mark can be stably inhibited from being generated in the molding by controlling the absolute value of the difference between the maximum value and the minimum value of the measurement values of the corresponding subareas SA**1**, SA**2**, . . . , SA**10** to be 1.0 or less, that is, by reducing the maximum value of the dispersion of the values of the average Taylor factors of the micro-areas (the corresponding subareas SA**1**, SA**2**, . . . , SA**10**) in the plane S**3** in the rolling width direction to 1.0 or less.

[0085] In contrast, when the absolute value of the difference between the maximum value and the minimum value of the values of the average Taylor factors of the corresponding subareas SA**1**, SA**2**, . . . , SA**10** defined as described above is more than 1.0, the local dispersion of plastic deformation amounts in the rolling width direction becomes noticeable, ridging resistance is deteriorated, and a ridging mark may be generated.

[0086] In the present disclosure, the area SA having a 10 mm width in the rolling width direction and a 2 mm length in the rolling direction is set, and the subareas obtained by equal division of the area into 10 subareas in the rolling width direction are targets for the measurement of the average Taylor factors. The difference between the maximum value and the minimum value of the average Taylor factors measured in the corresponding subareas is regarded as an index for evaluating ridging resistance. The validity of the settings of the shapes, dimensions, and division number of the areas of the measurement of the average Taylor factors was confirmed by the present inventors. The present inventors confirmed by experiment that ridging resistance can be reliably and effectively evaluated based on the settings.

[0087] In the present disclosure, the maximum value of the dispersion of the average Taylor factors in the rolling width direction is defined only in the plane S**3**, that is, the plane located in the center of the sheet thickness. The reason that only the presence or absence of the dispersion of the average Taylor factors in the plane S**3** is regarded as the index for evaluating ridging resistance is because it is preferable to determine the presence or absence of the generation of a ridging mark on the basis of the state of crystals in the area. Like the plane S**3**, the states of crystals in the sheet surface (plane S**1**) and the plane (plane S**2**) at a depth of ¼ of the total sheet thickness can also influence the generation of a ridging mark, and a band-shaped structure which influences the generation of a ridging mark remains most easily in the vicinity of the center of the sheet thickness. Accordingly, an aluminum alloy rolled material can be considered to be improved in ridging resistance intended by the present disclosure by allowing the state of the crystals of the plane S**3** to be a favorable state and confirming the state. The reason that the maximum value of the dispersion of the average Taylor factors is regarded as the index is because the present disclosure is intended to decompose a band-shaped structure, and the index is preferred for evaluating the state of a formed texture on the basis of the success or failure thereof.

[0088] Accordingly, the present disclosure does not deny that subareas are set in the plane S**1** and the plane S**2** like plane S**3** and the dispersion of Taylor factors is measured. Further, it is not intended to exclude that the results of the dispersion of the Taylor factors in the plane S**1** and the plane S**2** are equivalent to or better than the results of the dispersion of the plane S**3** required by the present disclosure.

[0089] A specific method for measuring an average Taylor factor value in each of the predetermined subareas in the plane S**3** that is perpendicular to the sheet thickness direction and is at a depth of ½ of the total sheet thickness from the sheet surface S**1** will now be described. First, the surface S**3** at a depth of ½ of the total sheet thickness which becomes a measurement plane is exposed. This exposure can be performed by mechanical polishing, buffing-polishing, or electrolytic polishing. The orientation information of the texture is acquired by measuring each of the predetermined subarea ranges continuous in the rolling width direction in the exposed plane S**3** per visual field with a backscattered electron diffraction measurement apparatus attached to a scanning electron microscope (SEM-EBSD). A STEP size for the measurement may be set at around 1/10 of a crystal particle diameter.

[0090] An average Taylor factor is determined from the obtained orientation information using EBSD analysis software. For example, "OIM Analysis" manufactured by TSL may be used as the analysis software. Specifically, first, the orientation information of the texture obtained by the above-described method is subjected to rotation operation as needed so that measurement data shows the orientation information in the case of being viewed from the sheet thickness direction. Then, average Taylor factors in the corresponding subareas can be calculated by calculating an average Taylor factor under a plane strain state in which the sheet thickness decreases and the rolling width direction extends on a measurement data basis in each visual field. The calculation can be performed on the assumption that an active primary slip system is {111}<110>. The average Taylor factors in the corresponding subareas are calculated in such a manner, and the difference between the maximum and minimum values of the average Taylor factors is calculated, thereby evaluating ridging resistance.

[0091] (4) Production Method Preferred for Aluminum Alloy Rolled Material According to the Present Disclosure

[0092] A preferred method for producing an aluminum alloy rolled material according to the present disclosure will now be described. The aluminum alloy rolled material according to the present disclosure is a sheet material that comprises an Al—Mg—Si—Cu-based alloy and includes an optimized texture. The state of the distribution of Mg—Si—Cu-based particles is preferably controlled in a sheet production process to adjust a recrystallized structure after hot rolling in order to obtain such a preferred texture, as described above. According to the present inventors, examples of a method for controlling the state of the distribution of the Mg—Si—Cu-based particles include appropriately setting a cooling rate after homogenization treatment and intentionally retaining, at a hot-rolling temperature, an ingot after the homogenization treatment. The retention at the hot-rolling temperature enables the Mg—Si—Cu-based particles to be coarsened and an origin for causing a preferred recrystallized structure to be formed. Fine recrystallization can be achieved by self-annealing using heat generated in the case of winding of a rolled material in a subsequent hot-rolling step.

[0093] In other words, examples of the preferable method for producing the aluminum alloy rolled material according to present disclosure include a method for producing an aluminum alloy rolled material for molding, the method including: a step of performing homogenization treatment of an ingot including an aluminum alloy including the composition described above; a cooling step of cooling the aluminum alloy after the homogenization treatment so that an average cooling rate in a thickness of ¼ part from a surface of the ingot between 500° C. and a cooling temperature is 20° C./h to 2000° C./h, the cooling temperature being set at a temperature of more than 320° C. or at a temperature of 320° C. to room temperature; and a step of starting hot rolling at 370° C. to 440° C. and winding the hot-rolled aluminum alloy at 310 to 380° C., wherein the aluminum alloy after the cooling step is retained at a pre-rolling heating temperature set within a range of 370° C. to 440° C. before the hot rolling, thereby controlling the sizes of the precipitated particles of the aluminum alloy. The method for producing the aluminum alloy rolled material will be described below.

[0094] First, the aluminum alloy with the constituent composition described above is melted according to a usual method, and cast by selecting a usual casting method such as a continuous casting method or a semi-continuous casting method (DC casting method) as appropriate. The obtained ingot is subjected to homogenization treatment. Treatment conditions in the case of performing the homogenization treatment are not particularly limited, but heating may be performed typically at a temperature of 500° C. or more and 590° C. or less for 0.5 hour or more and 24 hours or less.

[0095] The ingot subjected to the homogenization treatment is cooled and hot-rolled. In the method for producing an aluminum alloy rolled material according to the present disclosure, it is needed to define the range of a cooling rate after the stage of ending the homogenization treatment and to intentionally retain the ingot at a set pre-rolling heating temperature for not less than a predetermined time before starting the hot rolling after cooling the ingot. With regard to the cooling rate after the stage of ending the homogenization treatment, the cooling is performed so that an average cooling rate at a temperature of from 500° C. to a cooling temperature in a thickness of ¼ part from a surface of the ingot is between 20° C./h and 2000° C./h. In such a case, the cooling temperature is a temperature of more than 320° C. or a temperature of 320° C. to room temperature. The reason that the cooling rate after the homogenization treatment is defined as described above is because an excessively high cooling rate tends to result in precipitation of fine Mg—Si—Cu-based particles. In addition, this is because an excessively low cooling rate results in the precipitation of Mg—Si—Cu-based particles having coarse sizes equal to or larger than sizes necessary for promoting recrystallization and in the need for wasting time for making the particles into a solid solution in final heat treatment (in solution treatment). It is preferable to set the cooling rate at 50° C./h to 1000° C./h.

[0096] In the present disclosure, a position at which the temperature of the ingot is measured is set at a thickness of ¼ part from the surface in the measurement of the cooling rate (the same applies hereafter). In addition, a position at which the temperature of the ingot is measured is also set at a thickness of ¼ part in the case of temperature management in retention at a pre-rolling heating temperature described later. This is because the temperature of a surface layer of the ingot widely changes, and therefore, it is difficult to appropriately measure the cooling rate. Although stable temperature measurement is also possible in the center of the ingot, a delay in temperature change may occur to some degree, and an ingot thickness of ¼ part is preferred in consideration of strict management of the cooling rate or the retention time. The temperature in an ingot thickness of ¼ part may be measured using an ingot in which a thermocouple is embedded or may be calculated using a heat transfer model. The temperature of an ingot in the following description means the temperature in an ingot thickness of ¼ part.

[0097] On the basis of the temperature of the ingot after the cooling step, plural patterns can be adopted for the heat history of the ingot after the cooling after the homogenization treatment. First, the ingot is cooled from the homogenization treatment temperature so as to be prevented from being cooled to 320° C. or less, and the ingot is then retained at a pre-rolling heating temperature set within a range of 370° C. to 440° C. before the hot rolling. In such a case, the ingot may be retained at the pre-rolling heating temperature when the temperature of the ingot reaches the pre-rolling heating temperature from the homogenization treatment temperature. It is preferable to slightly heat the ingot to the pre-rolling heating temperature and retain the ingot when the ingot is cooled to a temperature of more than 320° C. and less than the pre-rolling heating temperature. The reason that the temperature of the ingot after the cooling step is based on 320° C. as described above is because fine Mg—Si—Cu-based particles are inhibited from precipitating. Accordingly, in view of heat and energy, it is effective to cool the ingot from the homogenization treatment temperature to more than 320° C., particularly to a hot-rolling temperature in a straight manner, in the cooling step after the homogenization treatment.

[0098] However, the ingot may be temporarily cooled to a temperature in a range of 320° C. to room temperature in the cooling step. Even when the ingot is temporarily cooled to the temperature in a range of 320° C. to the room temperature, fine Mg—Si—Cu-based particles can be coarsened by re-heating the ingot to the pre-rolling heating temperature and retaining the ingot at the pre-rolling heating temperature. Thus, the ingot with such a heat history is not problematic at all for producing a fmal sheet of an aluminum alloy with improved ridging resistance and bendability. The temporal cooling of the ingot to the temperature in a range of 320° C. to the room temperature and the re-heating of the ingot are useful for obtaining stable product characteristics. When such re-heating is performed, time is needed for coarsening Mg—Si—Cu-based particles as represented by a heat history coefficient in Equation A described later; however, due to the time, excessive coarsening is inhibited even in the case of retention for long time at the pre-rolling heating temperature. As a result, the deterioration of strength characteristics and bending workability caused by incompletely melting coarse particles in solution treatment is inhibited.

[0099] In the present disclosure, the ingot is preferably retained at the pre-rolling heating temperature set within a range of 370° C. to 440° C. before starting the hot rolling. Mg—Si—Cu-based particles can be grown and coarsened by the retention at the pre-rolling heating temperature.

[0100] The reason that the pre-rolling heating temperature is set at 370° C. to 440° C. is because the temperature is needed for coarsening finely precipitated Mg—Si—Cu-based particles. When the temperature is less than 370° C., an element diffusion length becomes insufficient, and it is impossible to obtain a preferred particle size. When the temperature is more than 440° C., coarse recrystallized grains are formed in hot rolling, and ridging resistance is deteriorated. The range of the pre-rolling heating temperature is the same as the range of the hot-rolling temperature. Accordingly, the pre-rolling heating temperature and the hot-rolling temperature may be set at the same temperature. In such a case, the ingot after the cooling step is retained at the hot-rolling temperature, and the hot rolling of the ingot can be started on an as-is basis. The pre-rolling heating temperature and the hot-rolling temperature may also be set at different temperatures. In such a case, the ingot heated and retained at the pre-rolling heating temperature is cooled or re-heated, and the hot rolling of the ingot is then started. However, even a case in which the pre-rolling heating temperature and the hot-rolling temperature are set at different temperatures is not problematic if both of the temperatures are set in a range of 370° C. to 440° C. As described above, the temperature of the ingot is a temperature in a thickness of ¼ part from a surface of the ingot.

[0101] The optimal range of the retention time at the pre-rolling heating temperature is considered to exist depending on various conditions such as the composition of the aluminum alloy and the heat history after the homogenization treatment. Examples of the conditions include, first, the content of Cu in the aluminum alloy. This is because the dispersion state and coarsening rate of Mg—Si—Cu-based particles vary depending on the content of Cu as described above.

[0102] Examples of the conditions that can determine the retention time also include the heat history of the aluminum alloy after the homogenization treatment. The heat history is either the history of retaining the aluminum alloy at the pre-rolling heating temperature so that the aluminum alloy is prevented from being cooled to 320° C. or less after the homogenization treatment or the history of cooling the aluminum alloy to a temperature in a range of 320° C. to room temperature after the homogenization treatment, then re-heating the aluminum alloy to the pre-rolling heating temperature, and retaining the aluminum alloy at the pre-rolling heating temperature.

[0103] Further, the retention time at the pre-rolling heating temperature can also be determined by a cooling rate after the homogenization treatment (the average cooling rate of the ingot between 500° C. and the cooling temperature).

[0104] The present inventors found preferred retention time in consideration of the various conditions. The retention time at the pre-rolling heating temperature is preferably set at not less than the lower limit of a retention time (h) calculated by Equation A described below.

$$\text{Lower limit of retention time}(h)=3(h)\times\text{Cu amount coefficient}\times\text{cooling rate coefficient}\times\text{temperature history coefficient} \quad \text{(Equation A)}$$

[0105] wherein the meanings of the Cu amount coefficient, the cooling rate coefficient, and the temperature history coefficient in Equation A are described as follows:

[0106] Cu amount coefficient: Cu content (%) in aluminum alloy/reference Cu content (0.7%);

[0107] cooling rate coefficient: (average cooling rate (° C./h) in cooling step/reference cooling rate (90° C./h))$^{1/2}$; and

[0108] temperature history coefficient: set at 0.3 or 1.0 based on heat history in (a) or (b) described below:

[0109] (a) temperature history coefficient=0.3 in a case in which the ingot is retained at the pre-rolling heating temperature without cooling the ingot to 320° C. or less in the cooling step; and

[0110] (b) temperature history coefficient=1.0 in a case in which the ingot is cooled to a temperature in a range of 320° C. to room temperature in the cooling step, then heated, and retained at the pre-rolling heating temperature.

[0111] Mg—Si—Cu-based particles can be easily controlled to have appropriate particle sizes by retaining the aluminum alloy for not less than the lower limit of a retention time calculated by the above-described Equation A. The equation is a mathematical expression derived by organizing cooling conditions and the amount of Cu in Al after homogenization treatment on the basis of various kinds of experimental data.

[0112] In the case of retention at a pre-rolling heating temperature without cooling from a temperature after homogenization treatment to 320° C. or less, growth of already precipitated Mg—Si—Cu-based particles is promoted compared with the new precipitation of Mg—Si—Cu-based particles, and therefore, a short time for coarsening to appropriate particle sizes is acceptable. The reason that the heat history coefficient in Equation A is set at 0.3 is because the above is intended. In contrast, in the case of temporally performing cooling to a temperature in a range of 320° C. to room temperature and then performing re-heating to the pre-rolling heating temperature, fine Mg—Si—Cu-based particles are precipitated in a process in a low-temperature region in the cooling after the homogenization treatment and in the process of increasing temperature from room temperature. It is found that long time is needed until control to appropriate particle sizes as compared with the case of retention at a pre-rolling heating temperature without cooling to 320° C. or less after cooling because it is necessary to coarsen the precipitates in the present disclosure. The reason that the heat history coefficient in Equation A is set at 1.0 is because the above is intended.

[0113] The retention time before hot rolling is not particularly restricted as long as being not less than the lower limit of a retention time calculated by Equation A. If the temperature of the ingot is within the range of the pre-rolling heating temperature, the lower limit of the retention time may be achieved by addition of a time for which the ingot is in a furnace, a migration time, and a waiting time on a hot-rolling table. The upper limit of the retention time is not particularly restricted, but hot rolling is performed after retention for 24 hours or less in usual operation.

[0114] Coarse precipitated particles grown by the retention at the pre-rolling heating temperature become the nucleation sites of recrystallization and have the action of promoting the recrystallization. In the material structure of the alloy appropriately retained at the pre-rolling heating temperature, when precipitated particles having a particle diameter of 0.4 μm to 4.0 μm in crystal grains that can be observed with a scanning electron microscope are extracted, the average particle diameter of the precipitated particles is preferably 0.6 μm or more, and more preferably 0.8 μm or more. A reduction in the number of fine particles constituting obstacles to grain boundary migration for recrystallization can also promote the recrystallization. Thus, the total number of precipitated particles having a particle diameter of 0.04 μm to 0.40 μm in crystal grains that can be observed with a scanning electron microscope is preferably 1500 particles/100 μm^2 or less.

[0115] Hot rolling is performed according to a conventional and common method after the homogenization treatment, the cooling, and the retention in the hot rolling in such a manner as described above. A temperature for the hot rolling is set at a temperature within a range of 370° C. to 440° C. The hot-rolling temperature or a winding temperature described later is the temperature of a sheet surface or coil-side wall surface of a workpiece material. Such temperatures can be measured with a contact type thermometer or a non-contact type thermometer.

[0116] In the step of the hot rolling, it is important to set the winding temperature after the hot rolling. In the present disclosure, an appropriate particle distribution is obtained by the cooling and the retention at the pre-rolling heating temperature after the homogenization described above, and an ingot with the action of promoting recrystallization by coarse precipitated particles and in the state of a small number of fine particles obstructing grain boundary migration is hot-rolled. Appropriate setting of the winding temperature of the obtained hot-rolled sheet allows recrystallization to occur due to self-annealing and can result in a recrystallized fine structure on which a material structure for improving ridging resistance is based.

[0117] In the present disclosure, the winding temperature after the hot rolling is set at 310 to 380° C., and preferably at 325 to 365° C. When the winding temperature is less than 310° C., it is impossible to stably obtain a recrystallized structure by self-annealing even if an appropriate particle distribution is obtained before starting the hot rolling. Even if a recrystallized structure is obtained by self-annealing, a winding temperature of more than 380° C. results in the coarse recrystallized grains of the recrystallized structure and therefore in the deterioration of ridging resistance.

[0118] After the self-annealing after the hot rolling, cold rolling is performed until a product sheet thickness is achieved. A total cold rolling reduction from a hot-rolled sheet thickness to the product sheet thickness is preferably 65% or more, and more preferably 75% or more. Such cold rolling allows a rolling texture to be grown, whereby recrystallized grains grow while eroding a rolling texture constituent in solution treatment following the cold rolling, and an aluminum alloy rolled material including a preferred texture can be obtained. The upper limit value of the total cold rolling reduction is not particularly limited, but is set at 85% in the present disclosure.

[0119] The aluminum alloy sheet for molding improved particularly in bendability and ridging resistance can be obtained by further subjecting the aluminum alloy sheet allowed to have a predetermined sheet thickness in such a manner as described above to solution treatment serving as recrystallization treatment. As the conditions of the solution treatment serving as the recrystallization treatment, it is preferable to set a material achieving temperature in a sheet thickness of ¼ part at 500° C. or more and 590° C. or less and to set a retention time at the material achieving temperature at no retention to 5 minutes or less, and it is still more preferable to set a material achieving temperature in a sheet thickness of ¼ part at 530° C. or more and 580° C. or less and to set a retention time at the material achieving temperature at no retention to 1 minute or less.

[0120] In order to impart favorable bake hardenability to the aluminum alloy sheet produced in such a manner as described above, it is possible to perform preliminary ageing treatment by which the aluminum alloy sheet is retained for 1 hour or more in a temperature range of 50 to 150° C. immediately after the solution treatment. However, the preliminary ageing treatment does not essentially influence the texture. Thus, whether or not preliminary ageing treatment is performed is not an essential requirement in the present disclosure aimed at improvement of ridging resistance influenced by a material structure.

EXAMPLES

[0121] More specific examples of the aluminum alloy rolled material for molding according to the present disclosure will now be described. In the examples, plural aluminum alloy rolled sheet materials for molding with different compositions were produced while adjusting production conditions. The mechanical properties and textures of the produced aluminum alloy rolled sheet materials were measured and evaluated, and tests for evaluating the mechanical characteristics (tensile strength and 0.2% proof stress), bending workability, and ridging resistance of the aluminum alloy rolled sheet materials were conducted.

[0122] (i) Production of Aluminum Alloy Rolled Sheet Material

[0123] First, the ingots of aluminum alloys with compositions shown in Table 1 were made by DC casting. The obtained ingot (lateral cross-section dimensions: thickness of 500 mm, width of 1000 mm) was subjected to homogenization treatment at 550° C. for 6 hours, then subjected to a cooling step, retained at a pre-rolling heating temperature, and then subjected to hot rolling. In the present examples, the pre-rolling heating temperature and a hot-rolling temperature were set at the same temperature. As heat histories between the cooling and the hot rolling after the homogenization treatment, two patterns of a case in which after the homogenization treatment, the ingot was cooled to the pre-rolling heating temperature and retained at the pre-rolling heating temperature without being allowed to be at 320° C. or less (direct retention), and a case in which the ingot after the homogenization treatment was cooled to room temperature, re-heated to the pre-rolling heating temperature, and retained at the pre-rolling heating temperature (re-heating) were performed. The cooling rates, the heat histories, and the pre-rolling heating temperatures in the present examples are shown in Table 2. The cooling rate of ¼ part of the ingot was measured using a dummy slab in which a thermocouple was embedded, and which had the same size. The ingot was retained at the pre-rolling heating temperature with reference to the needed retention time calculated from the Equation A described above depending on the heat histories.

[0124] Then, the hot rolling was performed. A temperature at which the hot-rolled sheet after the hot rolling was wound was adjusted as shown in Table 2. After the hot rolling, cold rolling and solution treatment were performed. A rolling reduction in the cold rolling was shown in Table 2. In the solution treatment, solution treatment was performed in a continuous annealing furnace on conditions of 550° C. and 1 minute, and preliminary ageing treatment was performed at 80° C. for 5 hours immediately after forced-air cooling with a fan to around room temperature. The aluminum alloy rolled sheet materials according to disclosure examples and comparative examples were produced by the above steps.

[0125] In the present examples, the state of the distribution of Mg—Si—Cu-based particles in the aluminum alloy ingot before the hot rolling was also examined. In the examination, a small piece sample was cut from a thickness of ¼ part in the center of the width of the ingot at a position of 500 mm from an end of the ingot after the casting of the above-described test material. Samples of which the heat histories (heat histories from homogenization treatment to retention at the hot rolling temperature before hot rolling) equivalent to those of the disclosure examples and the comparative examples in Table 2 were reproduced in a laboratory were generated, mirror-polishing of surfaces of the samples was performed, and the images of the surfaces were then taken with FE-SEM and subjected to image analysis. In the evaluation of the material structures, precipitated particles having a particle diameter of 0.4 μm to 4.0 μm in crystal grains that were able to be observed in the SEM images were extracted, and the average particle diameter of the particles was calculated. In addition, the number of precipitated particles having a particle diameter of 0.04 μm to 0.40 μm in the crystal grains that were able to be observed in the SEM images was quantified. The results are also shown in Table 2.

[0126] Further, the state of recrystallization after the hot rolling was confirmed. In a method of the confirmation, the three outer windings of the hot-rolled sheet were removed, and a sample was then collected from the center in a width direction. The crystal grain structures of cross sections parallel in a rolling direction were photographed, and visual determination was performed whether recrystallization occurred at 100 lattice points obtained by drawing 10 evenly spaced straight lines in a visual field of 2 mm×4 mm in longitudinal and lateral directions, respectively. The number of lattice points corresponding to recrystallized grains was defined as a recrystallization rate, and a case in which the recrystallization rate was 95% or more was defined as generation of a recrystallized structure.

TABLE 1

	Chemical component (mass %)									
Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al	AA
A	0.74	0.16	0.68	0.12	0.68	0.02	0.03	0.02	Bal.	6111
B	0.71	0.17	0.22	0.08	0.70	0.01	0.15	0.03	Bal.	6061
C	0.68	0.10	0.32	0.14	0.72	0.01	0.17	0.01	Bal.	6061
D	0.73	0.18	1.40	0.09	0.70	0.04	0.10	0.02	Bal.	—
E	0.69	0.17	1.61	0.11	0.68	0.02	0.08	0.04	Bal.	—
F	0.27	0.13	0.72	0.14	0.73	0.03	0.23	—	Bal.	—
G	0.34	0.20	0.79	0.12	0.76	0.02	0.26	0.09	Bal.	—
H	1.41	0.13	0.69	0.01	0.70	—	0.16	0.02	Bal.	6110
I	1.61	0.16	0.67	0.13	0.70	0.01	0.21	0.02	Bal.	—
J	0.71	0.02	0.70	0.06	0.26	0.01	0.19	0.03	Bal.	—
K	0.77	0.02	0.78	0.01	0.33	0.03	0.33	0.03	Bal.	—
L	0.72	0.02	0.67	0.04	1.42	—	0.09	0.02	Bal.	—
M	0.67	0.18	0.68	0.09	1.63	0.02	0.11	0.06	Bal.	—
N	0.74	0.01	0.54	0.02	0.49	—	—	0.01	Bal.	—
O	0.65	0.08	0.63	0.43	0.61	0.01	0.01	0.02	Bal.	—
P	0.69	0.15	0.63	0.55	0.64	0.03	0.02	0.02	Bal.	—
Q	0.66	0.06	0.64	0.02	0.63	0.35	0.01	0.02	Bal.	—
R	0.72	0.17	0.68	0.11	0.62	0.43	0.01	0.03	Bal.	—
S	0.69	0.37	0.70	0.11	0.64	0.01	0.01	0.02	Bal.	—
T	0.70	0.45	0.69	0.08	0.64	0.01	0.01	0.02	Bal.	—

The mark "—" shows that a content was not more than a detection limit.

TABLE 2

		Cooling	Retention conditions at pre-rolling heating temperature				Precipitate of ingot before hot rolling Average
Production process	Alloy	rate after homogenization (° C./h)	Heat history*1	Temperature (° C.)*2	Time (h) calculated by Equation A	Actual performance time (h)	particle diameter (μm)
1	A	90	Re-heating	400	2.91	4.0	0.9
2	B	90	Re-heating	400	0.94	2.0	1.2
3	C	90	Re-heating	400	1.37	2.0	0.8
4	D	90	Re-heating	400	6.00	8.0	1.4
5	E	90	Re-heating	400	6.90	8.0	1.0
6	F	90	Re-heating	400	3.09	4.0	0.8
7	G	90	Re-heating	400	3.39	4.0	0.9
8	H	90	Re-heating	400	2.96	4.0	1.2
9	I	90	Re-heating	400	2.87	4.0	1.0
10	J	90	Re-heating	400	3.00	4.0	0.9
11	K	90	Re-heating	400	3.34	4.0	0.8
12	L	90	Re-heating	400	2.87	4.0	1.1

TABLE 2-continued

13	M	90	Re-heating	400	2.91	4.0	1.0
14	N	90	Re-heating	400	2.31	4.0	1.0
15	O	90	Re-heating	400	2.70	4.0	1.1
16	P	90	Re-heating	400	2.70	4.0	1.2
17	Q	90	Re-heating	400	2.74	4.0	0.9
18	R	90	Re-heating	400	2.91	4.0	1.0
19	S	90	Re-heating	400	3.00	4.0	1.2
20	T	90	Re-heating	400	2.96	4.0	1.3
21	A	1800	Direct retention	440	3.91	4.0	1.3
22	A	90	Direct retention	400	0.87	1.0	1.2
23	A	30	Direct retention	370	0.50	1.0	1.0
24	A	90	Re-heating	450	2.91	4.0	1.9
25	A	1800	Re-heating	440	13.03	15.0	1.4
26	A	300	Re-heating	400	5.32	6.0	1.1
27	A	90	Re-heating	370	2.91	4.0	0.7
28	A	90	Re-heating	360	2.91	4.0	0.3
29	A	90	Re-heating	400	2.91	1.0	0.4
30	A	90	Re-heating	400	2.91	4.0	0.9
31	A	90	Re-heating	400	2.91	4.0	0.9
32	A	90	Re-heating	400	2.91	4.0	0.9
33	A	90	Re-heating	400	2.91	4.0	0.9
34	A	90	Re-heating	400	2.91	4.0	0.9

Production process	Precipitate of ingot before hot rolling Number (particles/ 100 μm^2)	Hot-rolling winding temperature (° C.)	Recrystal-lization rate	Inter mediate annealing	Cold rolling reduction (%)	Classification
1	788	346	100%	No	80	Disclosure Example
2	512	311	100%	No	80	Comparative Example
3	1284	358	100%	No	80	Disclosure Example
4	859	326	100%	No	80	Disclosure Example
5	779	351	100%	No	80	Comparative Example
6	462	338	100%	No	80	Comparative Example
7	1411	374	100%	No	80	Disclosure Example
8	982	312	100%	No	80	Disclosure Example
9	783	324	100%	No	80	Comparative Example
10	884	347	100%	No	80	Comparative Example
11	1366	359	100%	No	80	Disclosure Example
12	687	326	100%	No	80	Disclosure Example

TABLE 2-continued

13	769	341	100%	No	80	Comparative Example
14	689	323	100%	No	80	Disclosure Example
15	901	362	100%	No	80	Disclosure Example
16	992	371	100%	No	80	Comparative Example
17	1013	361	100%	No	80	Disclosure Example
18	1097	378	100%	No	80	Comparative Examples
19	863	356	100%	No	80	Disclosure Example
20	928	347	100%	No	80	Comparative Example
21	402	339	100%	No	70	Disclosure Example
22	532	337	100%	No	80	Disclosure Example
23	746	351	100%	No	70	Disclosure Example
24	322	352	100%	No	70	Comparative Example
25	681	341	100%	No	80	Disclosure Example
26	844	356	100%	No	80	Disclosure Example
27	1003	326	100%	No	80	Disclosure Example
28	2133	321	46%	No	80	Comparative Example
29	1724	339	18%	No	70	Comparative Example
30	788	388	100%	No	70	Comparative Example
31	788	305	54%	No	70	Comparative Example
32	788	268	0%	Batch annealing immediately after hot rolling	70	Comparative Example
33	788	291	0%	30% cold rolling + batch annealing	70	Comparative Example
34	788	237	0%	30% cold rolling + CAL	70	Comparative Example

*[1]"Heat history" means a heat history from cooling after homogenization treatment to retention at a pre-rolling heating temperature.
"Direct retention": An ingot was cooled to a pre-rolling heating temperature so as to be prevented from being cooled to 320° C. or less, and was retained.
"Re-heating": An ingot was cooled to room temperature, then re-heated, and retained at a pre-rolling heating temperature.
*[2]Pre-rolling heating temperature, which was set at the same temperature as a hot-rolling temperature in the present embodiment.

[0127] (ii) Mechanical Properties of Aluminum Alloy Rolled Sheet Material, and Measurement and Evaluation of Texture

[0128] For each aluminum alloy sheet material produced in the present examples, a JIS No. 5 test piece was first cut in a direction parallel to a rolling direction, and the tensile strength (ASTS) and 0.2% proof stress (ASYS) of the test piece were measured by a tensile test.

[0129] The states (cube orientation density, and dispersion of average Taylor factors) of the texture of a predetermined plane, defined in the present disclosure, of each sheet material were measured. For the cube orientation density, a plane S**2** at a depth of ¼ of a total sheet thickness was exposed by mechanical polishing and subjected to X-ray diffraction measurement, the orientation information of the texture was acquired by measuring the incomplete pole figures of a (111) plane, a (220) plane, and a (200) plane, and the cube orientation density was calculated using pole figure analysis software, as described above.

[0130] Further, a plane S**3** at a depth of ½ of a total sheet thickness was exposed by mechanical polishing, and SEM-EBSD measurement of the exposed plane was performed by the above-described method, as described above. An area SA was set in the center in a sheet width direction as a representative example of an arbitrary area in the S**3** plane, and the orientation information of the textures of corresponding subareas SA**1**, SA**2**, . . . , SA**10** in the area SA was then acquired. Average Taylor factors were calculated from the obtained orientation information by the above-described method, and the absolute value of the difference between the maximum value and the minimum value of the average Taylor factors between the corresponding subareas in the same plane was calculated.

[0131] (iii) Evaluation of Workability and Ridging Resistance of Aluminum Alloy Rolled Sheet Material

[0132] The workability and ridging resistance of each aluminum alloy sheet material produced in the present examples were evaluated to examine production conditions and the relationships of the configuration of the alloy sheet material, workability, and the like. First, the ridging resistance was evaluated using a conventionally performed simple evaluation technique. Specifically, JIS No. 5 test pieces were collected along a direction at 90° with respect to a rolling direction and subjected to 10% and 15% stretches, respectively. Assuming that a stripe pattern (stripe-shaped recessed and projected pattern) generated on a surface along the rolling direction was regarded as a ridging mark, the presence or absence and degree of generation of the stripe pattern were determined by visual observation. The results are shown in Table 3. In Table 3, "Excellent" shows the absence of a stripe pattern, "Good" shows a state in which a slight stripe pattern was visually observed, "Fair" shows a moderate stripe pattern, and "Poor" shows a state in which a stripe pattern was vivid. In the present embodiment, it was determined that "Excellent" or "Good" showed that ridging resistance was favorable.

[0133] In addition, bending workability was evaluated by a 180-degree bending test. Bending test pieces were collected along a direction at 90° with respect to the rolling direction and subjected to 5% predistortion. Then, the 180-degree bending test of the bending test pieces between which an intermediate plate having a thickness of 1 mm (bend radius: 0.5 mm) was interposed was conducted. The bending workability of the appearance of the bend in each direction was given a point (score) in comparison with the bending workability evaluation samples illustrated in FIG. **2**. The results are shown in Table 3. The higher numerical value of the score in the bending test represents more favorable bending workability. In the present embodiment, it was determined that a point of "6" or more showed favorable bending workability, a point of "7" or more showed high grade bending workability, and a point of "8" or more showed very high grade bending workability.

TABLE 3

		States of texture		Evaluation of ridging resisteance			Tensile test results			
Production process	Alloy	Cube orientation density	Dispersion of Taylor factors	After 10% stretch	After 15% stretch	Bending test score	ASYS (MPa)	ASTS (MPa)	ASTS − ASYS (MPa)	Classification
1	A	12	0.7	Excellent	Excellent	8	116	245	129	Disclosure Example
2	B	26	0.6	Excellent	Excellent	9	105	219	114	Comparative Example
3	C	18	0.8	Excellent	Excellent	8	108	229	121	Disclosure Example
4	D	10	0.7	Excellent	Excellent	7	140	269	129	Disclosure Example
5	E	13	0.6	Excellent	Excellent	5	142	268	126	Comparative Example
6	F	21	0.7	Excellent	Excel lent	8	101	199	98	Comparative Example
7	G	12	0.7	Excellent	Excellent	8	110	233	123	Disclosure Example
8	H	15	0.6	Excellent	Excellent	7	138	261	123	Disclosure Example
9	I	13	0.7	Excellent	Excellent	5	139	266	127	Comparative Example
10	J	20	0.7	Excellent	Excellent	8	100	197	97	Comparative Example
11	K	16	0.7	Excellent	Excellent	8	103	225	122	Disclosure Example
12	L	12	0.7	Excellent	Excellent	7	138	269	131	Disclosure Example
13	M	11	0.7	Excellent	Excellent	5	140	268	128	Comparative Example
14	N	13	0.8	Excellent	Excellent	6	106	228	122	Disclosure Example
15	O	11	1.0	Good	Good	7	110	231	121	Disclosure Example
16	P	11	1.0	Good	Good	5	112	234	122	Comparative Example
17	Q	13	1.0	Good	Good	7	109	232	123	Disclosure Example
18	R	12	1.0	Good	Good	5	113	237	124	Comparative Example
19	S	14	0.7	Excellent	Excellent	6	111	233	122	Disclosure Example
20	T	10	0.6	Excellent	Excellent	5	112	236	124	Comparative Example
21	A	15	0.5	Excellent	Excellent	9	110	241	131	Disclosure Example

TABLE 3-continued

Production process	Alloy	States of texture: Cube orientation density	States of texture: Dispersion of Taylor factors	Evaluation of ridging resisteance: After 10% stretch	Evaluation of ridging resisteance: After 15% stretch	Bending test score	Tensile test results: ASYS (MPa)	Tensile test results: ASTS (MPa)	Tensile test results: ASTS − ASYS (MPa)	Classification
22	A	15	0.6	Excellent	Excellent	8	115	243	128	Disclosure Example
23	A	15	0.7	Excellent	Excellent	8	112	239	127	Disclosure Example
24	A	11	1.2	Fair	Fair	8	109	233	124	Comparative Example
25	A	13	0.7	Excellent	Excellent	8	120	252	132	Disclosure Example
26	A	12	0.6	Excellent	Excellent	9	121	254	133	Disclosure Example
27	A	12	0.8	Excellent	Excellent	8	119	249	130	Disclosure Example
28	A	12	1.6	Poor	Poor	9	121	247	126	Comparative Example
29	A	20	1.6	Poor	Poor	9	122	249	127	Comparative Example
30	A	18	1.5	Fair	Fair	9	115	245	130	Comparative Example
31	A	20	1.6	Poor	Poor	9	116	246	130	Comparative Example
32	A	23	1.8	Poor	Poor	9	113	237	124	Comparative Example
33	A	21	1.6	Fair	Fair	8	112	235	123	Comparative Example
34	A	4	0.1	Excellent	Excellent	5	129	252	123	Comparative Example

[0134] The constituent compositions of all of the aluminum alloy sheet materials of the production processes No. 1, No. 3, No. 4, No. 7, No. 8, No. 11, No. 12, No. 14, No. 15, No. 17, No. 19, Nos. 21 to 23, and Nos. 25 to 27 which are the disclosure examples of the present disclosure are within the ranges defined in the present disclosure. In addition, a cube orientation density in a plane S**2** and the dispersion of average Taylor factors in a plane S**3** satisfy the conditions defined in the present disclosure. The aluminum alloy sheets were confirmed to have favorable ridging resistance and favorable bending workability.

[0135] In contrast, the constituent compositions of the aluminum alloy sheet materials of the production processes No. 2, No. 6, and No. 10 corresponding to the comparative examples are outside the ranges defined in the present disclosure. The results of the aluminum alloy sheet materials comprising an alloy B (No. 2) having a Cu content of less than 0.3%, an alloy F (No. 6) having a Si content of less than 0.3%, and an alloy J (No. 10) having a Mg content of less than 0.3% are shown. In the aluminum alloy sheets, a difference between a tensile strength (ASTS) and a 0.2% proof stress (ASYS) is less than 120 MPa because the contents of Cu, Si, and Mg associated with mechanical characteristics are less than the amounts defined in the present disclosure.

[0136] The constituent compositions of the aluminum alloy sheet materials of the production processes No. 5, No. 9, and No. 13 are also outside the ranges defined in the present disclosure. The results of the aluminum alloy sheet materials comprising an alloy E (No. 5) having a Cu content of more than 1.5%, an alloy I (No. 9) having a Si content of more than 1.5%, and an alloy M (No. 13) having a Mg content of more than 1.5% are shown. Because the contents of Cu, Si, and Mg in the aluminum alloy sheet materials are more than the ranges defined in the present disclosure, coarse particles formed in the production steps also remain in the product sheets and become the origins of cracks in bending working, and therefore, the aluminum alloy sheet materials do not have sufficient bending workability. Scores in the bending test were low in the comparative examples.

[0137] The contents of Mn, Cr, and Fe in the aluminum alloy sheet materials of the production processes Nos. 16, 18, and 20 are more than the preferred ranges. In the bending test, the aluminum alloy sheet materials had low scores, which were results in which it was necessary to regard the aluminum alloy sheet materials as comparative examples.

[0138] Although the ridging resistance and bending workability of the aluminum alloy sheet of the production process No. 14 were acceptable, the contents of Fe, Mn, and Cr in the aluminum alloy sheet were less than the preferred lower limit values (Mn: 0.03% or less, Cr: 0.01% or less, and Fe: 0.03% or less). Therefore, slight surface roughening which can be considered to be caused by coarsening of crystal grains in solution treatment occurred in the aluminum alloy sheet. Thus, the workability of the alloy may be considered to be acceptable to some extent, but the alloy can be considered not to be recommended when importance is particularly placed on working quality.

[0139] The constituent compositions of the aluminum alloy sheets of the production processes No. 24 and Nos. 28 to 34 corresponding to the comparative examples are within the ranges defined in the present disclosure. However, the cube orientation densities and dispersions of average Taylor factors of the final sheets are outside the ranges defined in the present disclosure due to the production process conditions. As a result, the aluminum alloy sheets are inferior in ridging resistance and bending workability.

[0140] These comparative examples will be specifically described. First, Table 2 reveals that the pre-rolling heating temperature in the production process No. 28 is lower than the preferred condition. In this comparative example, retention was performed at the hot rolling temperature for not less than the needed time calculated by Equation A before hot rolling, but any precipitate having a size sufficient for promoting self-annealing was not able to be obtained, and recrystallization after the hot rolling did not sufficiently proceed. In the production process No. 29, the retention time at the pre-rolling heating temperature was shorter than the needed time calculated by Equation A. Therefore, a large number of fine precipitates were formed. As a result, the recrystallization after the hot rolling did not sufficiently proceed. Further, in the production process No. 31, the temperature at which a hot-rolled sheet after hot rolling was wound was less than 310° C., and therefore, recrystallization due to self-annealing did not proceed. The aluminum alloy sheet materials of No. 28, No. 29, and No. 31 are aluminum alloy sheet materials with insufficient recrystallization in states after hot-rolling winding. Table 3 reveals that the differences between the maximum values and the minimum values of the average Taylor factors of the planes **S3** of the final sheets of the aluminum alloy sheet materials of No. 28, No. 29, and No. 31 were more than 1.0, and the aluminum alloy sheet materials were inferior in ridging resistance.

[0141] The aluminum alloy sheet material in the production process No. 24 was produced at a pre-rolling heating temperature set at more than 440° C., and the aluminum alloy sheet material in the production process No. 30 was produced at a winding temperature of more than 380° C. after hot rolling. The textures of the aluminum alloy sheet materials were insufficient controlled, the differences between the maximum values and the minimum values of the average Taylor factors of the planes **S3** of the final sheets of the aluminum alloy sheet materials were more than 1.0, and the aluminum alloy sheet materials were inferior in ridging resistance.

[0142] The production processes Nos. 32 to 34 are production examples in which intermediate annealing was performed after hot rolling while setting a temperature at which a hot-rolled sheet after the hot rolling was wound at less than 310° C. These results reveal that it is particularly important to manage cooling after homogenization treatment, retention at a pre-rolling heating temperature, and a temperature at which a hot-rolled sheet after hot rolling is wound, for improving bending workability and ridging resistance in a good balance. In addition, it is found that when treatment outside the ranges of the preferred conditions is performed in these processes, it is difficult to attain an objective, and intermediate annealing is also ineffective. The low effect of the intermediate annealing is understood from inferior ridging resistance in intermediate annealing (batch annealing at 360° C. for 120 minutes) after hot rolling like No. 32. Like No. 33, even when cold rolling (30%) was performed before intermediate annealing (batch annealing at 360° C. for 120 minutes), only ridging resistance was improved. In No. 34, intermediate annealing (at 500° C. or more for 1 minute or less) was performed in a continuous annealing furnace, and a cube orientation density was outside the definition and bending workability was deteriorated although the dispersion of the Average Taylor factors of the plane **S3** was favorable and ridging resistance was improved. As described above, the performance of intermediate annealing enables a texture to be changed depending on the conditions of the intermediate annealing, but is incapable of allowing both of the cube orientation density of a final sheet and the dispersion of the average Taylor factors of a plane **S3** to fall within preferred ranges.

INDUSTRIAL APPLICABILITY

[0143] As described above, the aluminum alloy rolled material according to the present disclosure is an aluminum alloy rolled material that is based on an Al—Mg—Si-based alloy and is allowed to have compatibility among press formability, ridging resistance, and bending workability by allowing the mechanical properties and texture of the aluminum alloy rolled material to be appropriate in consideration of the content of Cu. The present disclosure can also be utilized for molding-worked components such as the panels and chassis of electronic and electrical instruments and the like as well as automotive applications such as automotive body sheets applied to the body panels of automobiles.

1. An aluminum alloy rolled material for molding, with improved press formability, bending workability, and ridging resistance, the aluminum alloy rolled material comprising:

an aluminum alloy comprising 0.30 to 1.50 mass % Cu, 0.30 to 1.50 mass % Si, 0.30 to 1.50 mass % Mg, at least one of 0.50 mass % or less Mn, 0.40 mass % or less Cr, or 0.40 mass % or less Fe, and a balance of Al and inevitable impurities,

wherein a difference between a tensile strength and a 0.2% proof stress is 120 MPa or more,

wherein a ratio of a cube orientation density to a random orientation is 10 or more in a plane that is perpendicular to a sheet thickness direction and is at a depth of ¼ of a total sheet thickness from a surface, and

wherein an absolute value of a difference between a maximum value and a minimum value of an average Taylor factor in a case in which molding is assumed to cause plane strain deformation having a main strain direction that is a rolling width direction is 1.0 or less, the average Taylor factor being obtained for each of subareas that are obtained by equal division of an area, having a 10 mm width in the rolling width direction and a 2 mm length in a rolling direction, into 10 subareas in the rolling width direction, the subareas being in a plane that is perpendicular to the sheet thickness direction and is at a depth of ½ of the total sheet thickness from the surface.

2. The aluminum alloy rolled material for molding according to claim **1**, wherein the aluminum alloy contains at least one of 0.03 to 0.50 mass % Mn, 0.01 to 0.40 mass % Cr, or 0.03 to 0.40 mass % Fe.

3. The aluminum alloy rolled material for molding according to claim **2**, wherein the aluminum alloy contains at least one of 0.03 to 0.15 mass % Mn, 0.01 to 0.04 mass % Cr, or 0.03 to 0.40 mass % Fe.

4. The aluminum alloy rolled material for molding according to claim **1**, wherein the aluminum alloy contains 0.03 to 0.80 mass % Cu.

5. The aluminum alloy rolled material for molding according to claim **1**, wherein the aluminum alloy contains 0.03 to 0.80 mass % Mg.

6. The aluminum alloy rolled material for molding according to claim **1**, wherein the difference between the tensile strength and the 0.2% proof stress is 121 to 133 MPa.

7. The aluminum alloy rolled material for molding according to claim **1**, wherein the ratio of the cube orientation density to the random orientation is 12 or more.

8. The aluminum alloy rolled material for molding according to claim **7**, wherein the ratio of the cube orientation density to the random orientation is 12 to 18.

9. The aluminum alloy rolled material for molding according to claim **1**, wherein the absolute value of the difference between the maximum value and the minimum value of the average Taylor factor is 0.9 or less.

10. The aluminum alloy rolled material for molding according to claim **9**, wherein the absolute value of the difference between the maximum value and the minimum value of the average Taylor factor is 0.5 to 0.9.

11. The aluminum alloy rolled material for molding according to claim **1**, wherein, in 180-degree bending working, a score given by comparison with workability evaluation samples is 6 or more.

12. The aluminum alloy rolled material for molding according to claim **11**, wherein, in the 180-degree bending working, the score given by comparison with the workability evaluation samples is 7 or more.

13. The aluminum alloy rolled material for molding according to claim **12**, wherein, in the 180-degree bending working, a score given by comparison with the workability evaluation samples is 8 or more.

14. The aluminum alloy rolled material for molding according to claim **1**, wherein the aluminum alloy rolled material is obtained by rolling working including hot rolling working, and an average particle size of precipitated particles having particle diameters of 0.4 to 4.0 μm is 0.6 μm or more in pre-rolling heating and retention prior to the hot rolling working.

15. The aluminum alloy rolled material for molding according to claim **14**, wherein the average particle size of the precipitated particles having particle diameters of 0.4 to 4.0 μm is 0.7 to 1.9 μm.

16. The aluminum alloy rolled material for molding according to claim **14**, wherein a density of the precipitated particles having particle diameters of 0.4 to 4.0 μm is equal to or less than 1500 particles/100 μm^2.

17. The aluminum alloy rolled material for molding according to claim **16**, wherein the density of the precipitated particles having particle diameters of 0.4 to 4.0 μm is 402 particles/100 μm^2 to 1411 particles/100 μm^2.

18. The aluminum alloy rolled material for molding according to claim **1**, wherein a recrystallization rate after the hot rolling working is 95% or more.

19. The aluminum alloy rolled material for molding according to claim **18**, wherein the recrystallization rate after the hot rolling working is 100%.

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