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(54) **Title:** METHOD OF PRODUCING ALUMINUM ALLOY SHEET

(57) **Abstract:** A method of production of aluminum alloy sheet having the 6000 series as its basic composition and superior in bake-hardenability, bendability, and prevention of orange peel surface is provided. A method of production of aluminum alloy sheet superior in bake-hardenability, bendability, and prevention of orange peel surface comprising continuously casting an alloy melt of a composition consisting of essential elements comprised of, by mass%, Mg: 0.40 to 0.70%, Si: 0.50 to 1.00%, Mn: 0.05 to 0.30%, Fe: 0.10 to 0.50%, Ti: 0.005 to 0.10%, and B: 0.0005 to 0.01% and optional elements comprised of one or two of Zr: 0.05% or less and Cr: 0.05% or less and the balance of Al and unavoidable impurities using a twin belt type caster to a thin slab of a thickness of 5 to 15 mm, directly winding this up into a coil, then successively performing first cold rolling, intermediate solution heat treatment, secondary cold rolling, final solution heat treatment, and preaging, in which the secondary cold rolling is performed at a final cold rolling rate of 15 to 30%.

DESCRIPTION

METHOD OF PRODUCING ALUMINUM ALLOY SHEET

TECHNICAL FIELD

[0001]

The present invention relates to a method of production of aluminum alloy sheet superior in bake-hardenability, bendability, and prevention Of an orange peel surface. The 6000-series alloy sheet according to the present invention, by making use of these superior properties, can be widely used as external sheet materials for automobiles and other vehicles, household electrical products, etc. or building materials etc.

BACKGROUND ART

[0002]

As a method of production of 6000-series aluminum alloy sheet, the method of using semi-continuous casting etc. to produce a cast ingot, scalping the surface or heat treating the ingot for homogenization, then successively hot rolling, cold rolling, annealing, and otherwise processing it is generally used.

[0003]

However, in recent years, to -further reduce the weight of automobiles, further higher strength tends to be sought. Not only this, but also further improvement of the bake-hardenability, that is, the bake-hardenability, and bendability are desired. Further, improving productivity to reduce costs is also being increasingly demanded.

[0004]

To meet these requirements, for example Japanese Patent Publication (A) No. 62-207851 proposes aluminum alloy sheet for forming obtained by continuously casting an aluminum alloy melt containing Si: 0.4 to 2.5%, Mg: 0.1 to 1.2%, and one or more of Cu: '1.5% or less, Zn: . 2'.5% or less, Cr: 0.3% or less, Mn: 0.6% or less, and Zr:

0.3% or less into a sheet of a thickness of 3 to 15 mm, then cold rolling it, and solution heat treating and quenching it so as to reduce the maximum size of the intermetallic compound in the matrix to 5 μm or less and a method of production of the same.

[0005]

Further, Japanese Patent Publication (A) No. 07-286251 proposes, in order to obtain aluminum alloy sheet superior in formability and bake-hardenability, a method of production of aluminum alloy sheet superior in formability and bake-hardenability .comprising homogenizing an Al alloy cast ingot .containing for example, by wt%, Si: 0.2% or more and Mg: 0.3% or more, with the Si and Mg in the range of Si+0.7Mg: 0.7 to 1.5%, further one or more of Cu: 0.05 to 1%, Zr: 0.01 to 0.15%, Mn: 0.01 to 0.15%, Be: 0.001 to 0.2%, Ti: 0.001 to 0.03%, and B : 0.0001 to 0.01%, and the balance of Al and Fe and unavoidable impurities limited to 0.2% or less, hot rolling this homogenized Al alloy cast ingot to produce hot rolled sheet, cold rolling the obtained hot rolled sheet to produce cold rolled sheet, then heat treating this cold rolled sheet for final solution heat treatment, characterized by dividing the cold rolling into at least two operations and interposing intermediate solution heat treatment and intermediate aging between the at least two cold rolling operations

[0006]

Similarly, Japanese Patent Publication (A) No. 2003-328095 proposes, in order to obtain aluminum alloy thin-gauge sheet superior in press formability and bake-hardenability, the method of production of aluminum alloy sheet for forming comprising, for example, continuously casting an aluminum alloy melt of a composition falling under the 6000 series defined by the JIS, cold rolling the obtained cast sheet material, or not, heating to over 450°C to 570°C, holding the sheet at this temperature for 30 minutes or less, then heat-treating it for intermediate solution heat treatment under conditions of cooling by a cooling rate of 5 to 500°C/sec, cold rolling it further to prepare a cold rolled sheet, heating this cold rolled sheet at a heating rate of 5 to 500°C/sec to 500 to 580°C, holding at this temperature for 60 seconds or less, then cooling by 5 to 500°C/sec for solution heat treatment, then allowing the sheet to stand at room temperature for 135 minutes to 6 days, then heating by 4 to 500°C/sec to 220 to 320°C, then holding at this temperature for 60 seconds or less, then gradually cooling it for reversion.

[0007]

Japanese Patent Publication (A) No. 07-286251 discloses a treatment method applying intermediate solution heat treatment in the middle of cold rolling, but describes that to stabilize the crystal grain size, the final cold rolling rate has to be 50% or more. Further, the casting method in this case is the usual DC casting.

Further, Japanese Patent Publication (A) No. 2003-328095 also discloses a treatment method applying intermediate solution heat treatment in the middle of cold rolling, but the final cold rolling rate is not particularly limited and as an example, only one describing (3 mm thick-*1 mm thick) 66.6% can be found. Further, the casting method in this case is twin-roll casting.

Further, in a 6000-series alloy sheet used for an automobile body sheet, much superior formability and higher strength properties are being sought. In particular, in a continuously cast material, the bake-hardenability, bendability and prevention of an orange peel surface have to be further improved.

[Patent Document 1] Japanese Patent Publication (A) No. 62-207851

[Patent Document 2] Japanese Patent Publication (A)

No. 07-286251

[Patent Document 3] Japanese Patent Publication (A) No. 2003-328095

DISCLOSURE OF THE INVENTION

[0008]

The object of the present invention is to provide a method of production of aluminum alloy sheet having the 6000 series as its basic composition and improved in bake-hardenability, bendability, and prevention of an orange peel surface.

[0009]

The inventors engaged in intensive research and as a result newly discovered that in a treatment method treating sheet by intermediate solution heat treatment in the middle of cold rolling, if making the final cold rolling reduction in the cold rolling performed after the intermediate solution heat treatment over 30%, the strain accumulation due to the cold rolling becomes larger and the dislocation density becomes higher, whereby the recrystallized grains become less than 20 µm in size, the yield strength in the final sheet (T4P treated material) becomes high, and the bendability is reduced.

[0010]

The present invention was completed based on the above novel discovery and provides a method of production of aluminum alloy sheet superior in bake-hardenability, bendability, and prevention of orange peel surface comprising continuously casting an alloy melt of a composition consisting of essential elements comprised of, by mass%, Mg: 0.40 to 0.70%, Si: 0.50 to 1.00%, Mn: 0.05 to 0.30%, Fe: 0.10 to 0.50%, Ti: 0.005 to 0.10%, and B: 0.0005 to 0.01% and optional elements comprised of one or two of Zr: 0.05% or less and Cr: 0.05% or less and the balance of Al and unavoidable impurities- using a twin belt type caster to a thin slab of a thickness of 5 to 15 mm, directly winding this up into a coil, then successively performing first cold rolling, intermediate solution heat treatment, secondary cold rolling, final solution heat treatment, and preaging (T4P-treating), in which the secondary cold rolling is performed at a final cold rolling reduction of 15 to 30%.

[0011]

According to the present invention, by continuously casting an aluminum alloy melt of a predetermined composition based on a 6000-series composition and including a suitable quantity of Mn etc. using a twin belt type casting machine to a thin slab of a thickness of 5 to 15 mm, a cooling rate at the time of solidification at a position of 1/4 of the slab thickness of 40 to 150°C/s can be secured.

Due to this, it is possible to cast a thin slab maintained high in the amounts of Mg and Si in solid solution in the matrix and having a fine intermetallic compound precipitated in it. Further, when cold rolling this slab, by performing the intermediate solution heat treatment in the middle of the cold rolling, at the same time as the transformation from the needle-shaped β-AlFeSi phase to the spherical α-Al(Fe-Mn)Si, the Mg_2Si dissolves into the matrix, whereby the amounts of Mg and Si in solid solution in the matrix increases. Further, by cold rolling by a final cold rolling reduction of 15 to 30% and thereby limiting the strain accumulation in the final cold rolling process to a suitable range to control the dislocation density, a recrystallized grain size of 20 to 30 μm is achieved and the bake-hardenability, bendability, and prevention of orange peel surface in the final sheet (T4P treated material) can be improved. After the final solution heat treatment, the needle-shaped β-AlFeSi phase transforms to the spherical α-Al(Fe·Mn)Si phase, Si dissolves from the β-AlFeSi phase into the matrix, and the amount of Si in solid solution in the matrix increases. By treating this sheet for preaging, the clusters forming the nuclei for aging precipitation at the time of baking uniformly finely disperse in the matrix resulting in a sheet superior in bake-hardenability. Further, the compound is made spherical and suitable sizes of crystal grains are realized to improve the bendability. Due to this, a 6000 series alloy sheet superior in bake-hardenability, bendability, and prevention of orange peel surface can be produced.

BEST MODE FOR WORKING THE INVENTION

[0012]

The twin belt casting method is the method of pouring a melt between a pair of water cooled rotating belts facing each other in the vertical direction and solidifying the melt by the cooling from the belt surfaces to cast a thin slab. In the present invention, the twin belt casting method is used to case a slab of a thickness of 5 to 15 mm. If the slab thickness exceeds 15 mm, it becomes difficult to wind the thin slab in a coil, while if the slab thickness is less than 5 mm, a drop in the productivity is inevitable and casting of a thin slab becomes difficult.

[0013]

By using the twin belt casting method to cast a slab of a thickness of 5 to 15 mm, the cooling rate at the time of solidification at 1/4 of the slab thickness can be made 40 to 150°C/s. If the cooling rate is less than 40°C/s, the microstructure occurring at the time of solidification at the center part of the slab will become coarse and a deterioration in the bendability will be inevitable, while if the cooling rate during solidification exceeds 150°C/s, the β-AlFeSi phase and α-Al(Fe-Mn)Si phase will become finer, the recrystallization nuclei will become sparser, the size of the recrystallized grains will become coarser to 30 μm or more, and the bendability and prevention of orange peel surface will deteriorate.

[0014]

After winding the thin slab, by cold rolling (first cold rolling) the slab and, during this cold rolling, treating it in a continuous annealing line for intermediate solution heat treatment, it is possible to cause recrystallization to remove the accumulated strain and soften the slab, then control the strain accumulation by the subsequent cold rolling process of the final cold rolling reduction of 15 to 30% (secondary cold rolling) to reduce the size of the recrystallized grains to 20 to 30 μm. Further, by intermediate solution heat treatment, it is possible to make the β-AlFeSi phase spherical, promote the transformation from the β-AlFeSi phase to the α-Al(Fe-Mn)Si phase, and thereby obtain a coil in a state with the Mg and Si of the relatively fine Mg2Si remaining in the cast structure in solid solution in the matrix, improve the effect of the final solution heat treatment after the final cold rolling, and improve the bake-hardenability and bendability.

[0015]

As the solution heat treatment, it is preferable to use a continuous annealing line to heat the sheet by a temperature elevation rate of 10°C/s or more to 540 to 580°C and hold it there for within 30 seconds.

[0016]

In the solution heat treatment, the reason for limiting the temperature elevation rate up to the solution heat treatment temperature to 10°C/s or more is that in the case of a temperature elevation rate of less than 10°C/s, the coil feed rate becomes extremely slow and as a result the treatment time becomes long and the costs increase. Further, in particular in the final solution heat treatment, in the case of a temperature elevation rate of less than 10°C/s, the crystal grain size would end up exceeding 30 μm and the prevention of an orange peel surface during forming would deteriorate.

[0017]

The reason for making the solution heat treatment temperature 540 to 580°C in range is that in the case of a temperature of less than 540°C, the β-AlFeSi phase does not become sufficiently spherical and the Mg_2Si precipitating at the time of casting will not sufficiently dissolve in solid solution in the matrix, while in the case of a temperature of over 580°C, the intermetallic compounds present at the grain boundaries will melt and end up causing burning.

[0018]

The reason for limiting the solution heat treatment time to within 30 seconds is that if performing the solution heat treatment for within 30 seconds, the Mg_2Si precipitating at the time of casting or during cooling of the thin slab will sufficiently dissolve in the matrix in solid solution. Even if performing the solution heat treatment for 30 seconds or more, the Mg and Si in the matrix will end up becoming satµrated and the coil feed rate will become too slow resulting in a long treatment time and increased costs.

[0019]

This solution heat treatment is preferably usually-performed on a continuous annealing line (CAL) . A "continuous annealing line (CAL) " is a facility for continuous solution heat treatment of a coil and is characterized by being provided with an induction heating system for heat treatment, water nozzles and tanks for water cooling, air nozzles for air cooling, etc.

[0020]

After the solution heat treatment, the sheet is rapidly cooled. This "rapid cooling" is cooling by a cooling rate not allowing precipitation of Mg_2Si or another precipitate for aging hardening during cooling. In particular, .this is cooling so that the curve of temperature drop from the solution heat treatment temperature passes through the side at the short time side from the precipitation nose of the TTT diagram. In the case of the 6000 series composition, the front end of the precipitation nose is near 350°C. Therefore, the rapid cooling from the solution heat treatment temperature is generally sufficient if performed at a rate (for example 50°C/s) avoiding the front end of the precipitation nose near 350°C down until close to 250°C.

The specific method for rapid cooling after solution heat treatment may be air cooling using air nozzles, cooling using water mist spray, quenching by cold water by passing through a water tank, or quenching by warm water. Further, these cooling methods may be combined.

[0021]

The final cold rolling reduction in the secondary cold rolling (final cold rolling) is limited to 15 to 30%. If the final cold rolling reduction is less than 15%, the strain accumulation during the secondary cold rolling becomes smaller, so the dislocation density is low, the nuclei of the recrystallized grains become sparser, the recrystallized grains exceed 30 μm in size, and the prevention of an orange peel surface deteriorates.

If the final cold rolling rate exceeds 30%, the strain accumulation during the secondary cold rolling phase becomes larger and the dislocation density becomes higher, so the recrystallized grains become less than 20 μm in size, the yield strength in the final sheet (T4P treated material) becomes high, and the bendability is reduced. A more preferable final cold rolling rate is 15 to 25%. A still more preferable final cold rolling reduction is 17 to 23%.

[0022]

When cooling the coil after the final solution heat treatment, then rewinding it up at a high temperature, the rewinding temperature is made 70 to 110°C. If the rewinding temperature is less than 70°C, the effect of preaging is not sufficiently obtained. If the rewinding temperature exceeds 110°C, an intermediate phase of Mg_2Si called the β" which should inherently precipitate at the time of the main baking of the coating or a similar reinforcing phase ends up precipitating, so the yield strength becomes high and the bendability deteriorates.

[0023]

Specifically, it is possible to use a continuous annealing line to perform the final solution heat treatment and water cool the sheet by a cooling rate of 10°C/s or more down to 250°C or less, then cool by air by a cooling rate of 1 to 20°C/s down to 70 to H O°C, rewind the sheet, then cool it down to room temperature.

[0024]

After the high temperature rewinding, the coil is inserted into a thermal insulation box or annealing furnace etc. and gradually cooled by a cooling rate of 10°C/hr or less down to room temperature. This is because if the cooling rate exceeds 10°C/h, the effect of preaging cannot be sufficient.

[0025]

When cooling the sheet down to room temperature after the final solution heat treatment, then applying preaging treatment, the preaging temperature is made 60 to 110°C. If the holding temperature is less than 60°C, a long time is required to obtain the effect. If the holding temperature exceeds 110°C, an intermediate phase of Mg_2Si called the β" which should inherently precipitate at the time of the main baking of the coating or a similar reinforcing phase ends up precipitating, so the yield strength becomes high and the bendability deteriorates.

[0026]

The holding time during the preaging treatment after the final solution heat treatment is made 3 to 12 hours., If the holding time is less than 3 hours, the effect cannot be obtained, while if the holding time is over 12 hours, an intermediate phase of Mg_2Si called the β" which should inherently precipitate at the time of the main baking of the coating or a similar reinforcing phase ends up precipitating, so the yield strength becomes high and the bendability deteriorates.

[0027]

Next, the significance and reasons for limitation of the alloying elements of the present invention will be explained. The essential element Mg dissolves in the matrix after the final solution heat treatment and, at the time of heating for baking the coating, precipitates together with the Si as a strengthening phase so as to improve the strength. The amount of addition of Mg is limited to 0.4 to 0.7% because if less than 0.4%, the effect is small, while if over 0.7%, the bendability after the solution heat treatment deteriorates. The more preferable range of Mg content is 0.4 to 0.6%.

[0028]

The essential element Si precipitates as an Mg_2Si intermediate phase called β" together with Mg or its similar strengthening phase and improves the. strength at the time of baking the coating. The content of Si is limited to 0.5 to 1.0% because if less than 0.5%, the effect is small, while if over 1.0%, the bendability after the final solution heat treatment deteriorates. The more preferable range of Si content is 0.5 to 0.9%.

[0029]

The essential element Fe, in presence together with Si and Mn, forms large numbers of needle-shaped β-AlFeSi phase and α-Al (Fe-Mn) Si phase of a size of 5 µm or less during casting. Due to the increase in recrystallization nuclei, refinement of the recrystallized grains is promoted and the sheet becomes superior in formability.

If the Fe content is less than 0.1%, the effect is not remarkable. If over 0.5%, during casting, a coarse needle-shaped β-AlFeSi phase and spherical α-Al (Fe -Mn) Si phase are produced. Not only is the bendability at the final sheet reduced, but also the amount of Si in solid solution in the matrix in the thin slab is reduced, so the bake-hardenability of the final sheet is reduced. Therefore, the preferable range of Fe content is 0.1 to 0.5%. The more preferable range of Fe content is 0.1 to 0.3%.

[0030]

The essential element Mn is added as an element which promotes the transformation from the needle-shaped β-AlFeSi phase to the spherical α-Al (Fe-Mn) Si phase and refines the recrystallized grains. In the present invention, the two solution heat treatment operations promote the transformation from the needle-shaped β-AlFeSi phase to the spherical α-Al (Fe-Mn) Si phase. The Si dissolves and diffuses from the β-AlFeSi phase into the matrix, and the amount of Si in solid solution in the matrix is increased,; whereby a sheet with a superior bake-hardenability can be obtained.

If the Mn content is less than 0.05%, the effect is not sufficient, the recrystallized grains end up exceeding 30 μm in size, and the orange peel surface is obvious. If over 0.30%, the recrystallized grains become finer to less than 20 μm in size and the yield strength in the final sheet (T4P treated material) rises, so the bendability deteriorates. Not only this, the amount of precipitation of the Al(Fe-Mn)Si phase at the time of casting becomes higher and the amount of solid solution of Si in the matrix becomes lower, so the bake-hardenability in the final sheet deteriorates. Therefore, the preferable range of Mn content is 0..05 to 0.30%. The more preferable range of the Mn content is 0.05 to 0.20%.

[0031]

Even if the essential element Ti is contained, if 0.10% or less, it will not impair the effect of the present invention, will act as a crystal grain refining agent of the thin slab, and can reliably prevent slab cracks and other casting defects. If the Ti content is less than 0.005%, the effect is not sufficient, while if the Ti content is over 0.10%, at the time of casting, $TiAl_3$ and other coarse intermetallic compounds are produced, so the bendability remarkably deteriorates. Therefore, the preferable range of the Ti content is 0.005 to 0.10%. The more preferable range of the Ti content is 0.005 to 0.05%.

[0032]

The essential element B is inevitably included by addition of a rod hardener (for example, Al-5%Ti-l%B) as a crystal grain refining agent of a cast ingot. The element B, by the mixture with the essential element Ti in the melt, is strikingly improved in the crystal grain refinement effect of the cast ingot. If the B content is less than 0.0005%, the crystal grain refinement effect is not sufficient and it is difficult to reliably prevent slab cracks and other casting defects. When the B content exceeds 0.01%, not only does the crystal grain refinement effect of the cast ingot become .saturated, but sometimes the clusters of the excess TiB_2 act as inclusions in the final sheet (T4P treated material) and cause surface scratches during forming and otherwise reduce the formability.

[0033]

The optional element Cr is added as an element for refining the recrystallized grains. For this reason, if over 0.05%, the recrystallized grains become fine sizes of less than 20 µm and the yield strength in the final sheet becomes higher, so as a result not only does the bake-hardenability deteriorates, but also the amount of precipitation of the Al(Fe-Cr)Si phase at the time of casting becomes high and the amount of Si in solid solution is reduced, so the bake-hardenability of the final sheet deteriorates. Therefore, the preferable range of Cr content is 0.05% or less. The more preferable range of Cr content is 0.03% or less.

[0034]

The optional element Zr is added as an element for refining the recrystallized grains. If the Zr content is over 0.05%, the slab at the time of casting is formed with a coarse Al_3Zr phase and the bendability deteriorates. Therefore, the more preferable range of Zr content i's 0.05% or less. The more preferable range of Zr content is 0.03% or less.

[0035]

As explained above, according to the present invention, it becomes possible to produce 6000 series alloy sheet for automobile body sheet superior in bake-hardenability, bendability, and prevention of orange peel surface at a low cost using T4P treated material after final solution heat treatment. While intermediate solution heat treatment becomes necessary, the surface scalping, hot rolling, and other processes before that are greatly simplified, so the total production costs are greatly reduced.

EXAMPLES

[0036]

An alloy melt of the composition shown in Table 1 was prepared, degassed, allowed to settle in the furnace, then cast by a twin belt caster to a thin slab of a thickness of 7 mm. This thin slab was cold rolled to the sheet thickness shown by the "sheet thickness before intermediate solution heat treatment" in Table 2, then cut to a sheet of predetermined dimensions. However, as described in Table 2, the sample C was not treated by intermediate solution heat treatment.

[0037]

[Table 1]

Table 1. Alloy Composition (mass%)

Mg	Si	Mn	Fe	Ti	B
0.60	0.80	0.12	0.21	0.02	0.001

[0038]

The samples A, B, D/ E, and F were held in a salt bath at 560°C for 15 seconds (intermediate solution heat treatment), then quickly quenched in cold water, then cold rolled to the final sheet thickness of 1 mm. The sample G was held in an annealer at 350°C for 1 hour, then quickly quenched in cold water, then cold rolled to the final sheet thickness of 1 mm.

[0039]

These cold rolled sheets (samples A to G) were held in a salt bath at 560°C for 15 seconds (final solution heat treatment), quickly quenched in 85°C warm water, and heat treated as is in an annealer at 85°C for 8 hours (preaging), then allowed to cool to room temperature, then allo.wed to stand at room temperature for one week. This material was used as the final sheet before the baking (T4P treated material). Further, this T4P treated material was aged in an annealer at 180°C for 30 minutes to simulate the thermal history at the time of baking the coating. This material was used as the T6P treated material.

[0040]

A room temperature tensile test was conducted on both the T4P treated material and the T6P treated material. The results are shown in Table 2. The difference in the 0.2% yield strengths of the T4P treated material and T6P treated material was evaluated as the bake-hardenability. If this value is 100 MPa or more, the bake-hardenability is evaluated as being superior. Further, the results of evaluation of the bendability, crystal grain size, and orange peel surface of the T4P material are also shown in Table 2.

[0041]

[Table 2]

Table 2. Method of Production and Structure and Properties

Sample	Sheet thickness before intermediate solution heat treatment	Final cold rolling rate (%)	Intermediate solution heat treatment temperature/ hours	T4P			T6P			Bake-hardenability	Bendability	GS (µm)	Evaluation of prevention of range peel surface (*1)	
				YS (MPa)	UTS (MPa)	EL (%)	YS (MPa)	UTS (MPa)	EL (%)	(MPa)	-5%PS 180°			
A	1.3 mm	23	560°Cx15s	110	229	27	217	288	22	107	2.5	27	Good	Invention example
B	1.2 mm	17	560°Cx15s	105	227	27	215	285	21	110	2	29	Good	Invention example
C	1.0 mm (*2)	-	-	121	231	30	212	283	24	91	3	13	Good	Comparative example
D	2 mm	50	560°Cx15s	119	233	28	225	295	21	106	3	21	Good	Comparative example
E	1.5 mm	33	560°Cx15s	117	233	25	229	297	20	112	3	24	Good	Comparative example
F	1.1 mm	9	560°Cx15s	102	225	25	213	284	19	111	2	73	Poor	Comparative example
G	1.3 mm	23	350°Cx1h	97	207	27	187	257	21	90	2	52	Fair	Comparative example

(*1) Evaluation of prevention of orange peel surface: Observation of broken surface after tensile test.

(*2) No intermediate solution heat treatment.

[0042]

The bendability was evaluated by giving 5% prestrain to a T4P treated material, then bending it by r/t=0.5 (bending radius r, sheet thickness t) at 180° and visually examining it for the extent of cracks at the surface of the bent part. The evaluation was scored at seven levels of 1, 1.5., 2, 2.5, 3, 4, and 5. A score of 2.5 or less was evaluated as meaning superior bendability.

[0043]

The crystal grain size was measured by the intercept line meth'od at a location of 1/4 the thickness in a cross-section of a direction parallel to the rolling.

[0044]

The prevention of an orange peel surface was evaluated in three ranks of "Good", "Fair", and "Poor" by visual examination of the surface near the break in a test piece after a tensile test of a T4P treated material.

[0045]

The examples (products of the present invention) constituted as the sample A and sample B were treated during the cold rolling by intermediate solution heat treatment and had final cold rolling reduction of 23% and 17%, so were superior in both bake-hardenability and bendability, had crystal grain sizes of 20 to 30 µm, and were superior in prevention of orange peel surface as well.

[0046]

As opposed to this, the comparative examples constituted as the sample D and sample E were treated during the cold rolling by intermediate solution heat treatment and had final cold rolling reduction of 50% and 33%, so were inferior in bendability. The comparative example constituted by the sample F had a final cold rolling rate of 9%, so ended up with coarse crystal grains and inferior prevention of orange peel surface. The comparative example constituted by the sample C was not treated by intermediate solution heat treatment, so was inferior in both bake-hardenability and bendability. The comparative example constituted by the sample G was treated by intermediate annealing instead of intermediate solution heat treatment, so was superior in bendability, but was inferior in both bake-hardenability and orange peel surface.

INDUSTRIAL APPLICABILITY

[0047]

According to the present invention, there is provided a method of production of aluminum alloy sheet having the 6000 series as its basic composition and improved .in bake-hardenability, bendability, and prevention of orange peel surface.

CLAIMS

1. A method of production of aluminum alloy sheet superior in bake-hardenability, bendability and prevention of orange peel surface comprising continuously casting an alloy melt of a composition consisting of essential elements comprised of, by mass%, Mg: 0.40 to 0.70%, Si: 0.50 to 1.00%, Mn: 0.05 to 0.30%, Fe: 0.10 to 0.50%, Ti: 0.005 to 0.10%, and B: 0.0005 to 0.01% and optional elements comprised of one or two of Zr: 0.05% or less and Cr: 0.05% or less and the balance of Al and unavoidable impurities using a twin belt type caster to a thin slab of a thickness of 5 to 15 mm, directly winding this up into a coil, then successively performing first cold rolling, intermediate solution heat treatment, secondary cold rolling, final solution heat treatment, and preaging, in which the secondary cold rolling is performed at a final cold rolling reduction of 15 to 30%.

2. A method as set forth in claim 1, characterized by performing the intermediate solution heat treatment by holding the sheet in a continuous annealing line in a temperature range of 540 to 580°C for within 30 seconds.

3. A method as set forth in claim 1 or 2, characterized by performing the preaging by any one of the following (1) and (2):

(1) treatment for gradual cooling from the 70 to 110°C temperature range of the cooling process after the final solution heat treatment by a cooling rate of 10°C/hr or less down to room temperature or

(2) treatment for cooling once after the final solution heat treatment, then reheating to 60 to 110°C and holding the sheet for 3 to 12 hours.

4. A method as set forth in any one of claims 1 to 3, characterized by heating until a temperature of an intermediate solution heat treatment and final solution heat treatment by a heating rate of 10°C/seconds or more.

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2006/326316

A. CLASSIFICATION OF SUBJECT MATTER
INV. C22F1/04 C22F1/043 C22F1/053 C22C21/00 C22C21/02
C22C21/10

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22F C22C

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

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

EPO-Internal , WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
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Y	US 3 490 955 A (WINTER JOSEPH ET AL) 20 January 1970 (1970-01-20) claims 1-10; examples I–IV	1-4
A	WO 2006/011242 A (NIPPON LIGHT METAL CO [JP]; HONDA MOTOR CO LTD [JP]; ALCAN INT LTD [CA) 2 February 2006 (2006-02-02) claims 1,2	1-4
A	EP 1 715 067 A (NIPPON LIGHT METAL CO [JP]) 25 October 2006 (2006-10-25) claims 1,2	1-4

☐ Further documents are listed in the continuation of Box C

☒ See patent family annex

* Special categories of cited documents

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

'E' earlier document but published on or after the international filing date

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

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

'T' later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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

'Y' document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

'&' document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 August 2007	05/09/2007

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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