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(54) **Aluminium alloy sheet manufacturing method therefor**

(57) An aluminum alloy sheet contains: 2 to 3 wt.% Mg, 0.3 to 0.6 wt.% Cu, 0.08 to 0.15 wt.% Si, 0.005 to 0.15 wt.% Ti, 0.0002 to 0.05 wt.% B, 0.3 wt.% or less Fe as an inevitable impurity, and the balance essentially Al. A manufacturing method comprises the steps of: carrying out at least one homogenization treatment of the ingot at a temperature of from 400 to 580°C; hot-rolling and cold-rolling the ingot to produce a cold-rolled sheet; carrying out at least one heat treatment of the cold-rolled sheet; holding the heat treated cold-rolled sheet at a temperature of from 60 to 150°C for 1 to 48 hours.

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Description**BACKGROUND OF THE INVENTION**

1. Field of the Invention

The present invention relates to an aluminum alloy sheet having excellent bend formability after press-forming and a manufacturing method therefor.

2. Description of the Related Arts

Surface treated cold-rolled steel sheets are used as forming sheets for automobile body panels. Recently, however, aluminum alloy sheets have entered the field responding to the request for reducing weight of the automobile body to improve the fuel consumption of automobile.

Aluminum alloys of 5000 Series containing 4 to 5 wt.% Mg are mainly used as the automobile body panels in Japan owing to their favorable formability. That type of alloys are, however, difficult to prevent the generation of stretcher-strain mark (hereinafter referred to simply as "SSM") caused from dynamic strain aging induced by Mg atoms in the solid solution. Therefore, the productivity of car body panels made of these alloys is low because of the necessity of adjustment by giving grinding the formed product surface after pressing. In addition, when the Mg content becomes to 3 wt.% or more, edge cracks and alligator cracks likely occur during hot-rolling, which deteriorates the yield.

On the other hand, aluminum alloys of 6000 Series contain small amount of Mg, and SSMs are not readily generated, also the hot-rolling property is favorable. The 6000 Series is, however, significantly inferior in the press-formability to the 5000 Series. JP-A-62-177143 (the term "JP-A-" herein referred signifies "unexamined Japanese patent publication") discloses that an aluminum alloy sheet having excellent formability and bake-hardenability is obtained by applying solid solution treatment to a 6000 Series alloy followed by giving low temperature heat treatment at a temperature ranging from 40 to 120 °C for 8 to 36 hours. within 72 hours. after completing the solid solution treatment. The 6000 Series alloys are inherently not a kind of good press-formability, and particularly are considerably poor in bend formability.

To cope with the situation, the inventors had developed an aluminum alloy sheet containing 3 wt.% Mg which suppresses the generation of SSMs, gives good hot-rolling property, and excellent press-formability, which alloy is disclosed in JP-A-4-304339, JP-A-4-365834, JP-A-6-33179. The inventors also developed an aluminum alloy sheet having delayed aging property at room temperature adding to the characteristics described above, which alloy is disclosed in JP-A-6-256917 and JP-A-7-97667.

JP-A-62-27544 and JP-A-2-118049 disclose a technology using similar composition with that given above considering strength, forming workability (bend formability and stretch formability) in T4 heat treatment, SSM characteristic, natural aging property, and SCC resistance.

For these aluminum alloy sheets having a composition range disclosed in prior arts, when Mg content exceeds 3 wt.%, the suppression of SSM generation is difficult. When the Mg content is decreased, there occurs a problem of poor proof stress after the paint-baking treatment following the press-working compared with that of conventional 5000 Series. The proof stress after the paint-baking treatment has a relation to the anti-denting property on a pressed component. The anti-denting property is one of the essential characteristics as the material of automobile body panels. Aluminum alloys having less Mg content give insufficient proof stress after the paint-baking treatment.

Responding to the situation, the inventors took into account of the heat treatment on the above-described aluminum alloy containing 3 wt.% Mg and developed an aluminum alloy which has excellent press-formability, proof stress after the paint-baking treatment, delayed natural aging property, corrosion resistance after the paint-baking treatment, and hot-rolling property, and which does not generate SSM.

That type of alloy sheet satisfies all the characteristics conventionally requested as the automobile aluminum alloy sheets, but the sheet raised a problem of poor bend formability after press-forming.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an aluminum alloy sheet having favorable bend formability after press-forming, while satisfying the necessary conditions of press formability, proof stress after paint-baking treatment, delayed natural aging property, corrosion resistance after coating, and hot rolling property, and no SSM generation.

To attain the object of the present invention, first, the present invention provide an aluminum alloy sheet consisting essentially of:

Mg in an amount of 2 to 3 wt.%, Cu in an amount of 0.3 to 0.6 wt.%, Si in an amount of 0.08 to 0.15 wt.%, Ti in an amount of 0.005 to 0.15 wt.%, B in an amount of 0.0002 to 0.05 wt.%, Fe as an inevitable impurity in an amount of 0.3 wt.% or less, and the balance essentially Al.

Secondly, the present invention provide an aluminum alloy sheet consisting essentially of:

Mg in an amount of 2 to 3 wt.%, Cu in an amount of 0.3 to 0.6 wt.%, Si in an amount of 0.08 to 0.15 wt.%, Ti in an amount of 0.005 to 0.15 wt.%, B in an amount of 0.0002 to 0.05 wt.%, at least one element selected from the group consisting of Mn in an amount of 0.05 to 0.3 wt.%, Cr in an amount of 0.05 to 0.1 wt.% and Zr in an amount of 0.05 to 0.1 wt.%, Fe as an inevitable impurity in an amount of 0.3 wt.% or less, and the balance essentially Al.

Thirdly, the present invention provide a method for manufacturing an aluminum alloy sheet comprising the steps of:

(a) preparing an ingot consisting essentially of:

Mg in an amount of 2 to 3 wt.%, Cu in an amount of 0.3 to 0.6 wt.%, Si in an amount of 0.08 to 0.15 wt.%, Ti in an amount of 0.005 to 0.15 wt.%, B in an amount of 0.0002 to 0.05 wt.%, Fe as an inevitable impurity in an amount of 0.3 wt.% or less, and the balance essentially Al;

(b) carrying out at least one homogenization treatment of the ingot at a temperature of from 400 to 580°C;

(c) hot-rolling and cold-rolling the ingot, to which at least one homogenization treatment was carried out, to produce a cold-rolled sheet;

(d) carrying out at least one heat treatment of the cold-rolled sheet;

(e) holding the heat treated cold-rolled sheet at a temperature of from 60 to 150°C for 1 to 48 hours.

Said heat treatment comprises the steps of:

(i) heating the cold-rolled sheet to a temperature of from 500 to 580°C at a rate of at least 3°C/sec.;

(ii) holding the cold-rolled sheet at the temperature of from 500 to 580°C for at most 60 sec.; and

(iii) cooling the cold-rolled sheet down to 100°C at a rate of at least 2°C/sec.

DESCRIPTION OF THE EMBODIMENT

Against various characteristics requested as the automobile body panels, the 5000 Series containing 5 wt.%Mg shows good strength and press-formability, but has a problem of SSM generation. In an 6000 Series alloy containing 1 wt.%Mg shows good SSM prevention and good strength, but has a problem in the press-formability. That is, 5000 Series and 6000 Series which were conventionally studied as the aluminum alloy for automobile body panels had merits and demerits.

The inventors studied Al-Mg-Cu-Si alloys containing 2 to 3 wt.% Mg, which Mg content is between that of above-described 5000 Series and 6000 Series aluminum alloys, and found that the alloy has favorable SSM characteristic and press-formability, and has rather poor strength compared with that of 5000 Series and 6000 Series alloys. Based on the finding, the inventors improved the strength of the alloy by applying aging heat treatment after the solid solution treatment, which aging heat treatment was not applied for the alloy containing 3 wt.%Mg.

The application of aging heat treatment improved the strength, but the resulted product showed very poor bend formability after press-forming, and a new problem of crack generation on hemming working after press-forming occurred.

In the past, alloys of these types raised no problem of bend formability after press-forming, and no consideration about the bend formability was given at all. Though the bend formability was taken into account of as a part of the press-forming properties, there were occasions of crack generation during the manufacturing process since the bending in actual automobile body panel production line is given after press-forming even when an as-produced alloy sheet is subjected to bending test and when the test showed a successful bending to overlay both folded portions together. That is, bend formability in a simple bending test and the bending workability after press-forming not necessarily agree each other, and the evaluation in a conventional bending test cannot give sufficient evaluation of formability. The disagreement presumably comes from that the deformation mode in press-forming and the deformation modes in the bending after forming differ each other in the interaction of the deformation mode depending on the characteristics of the material.

On the basis of these findings, and on the assumption that an Al-Mg-Cu-Si alloy which positions between 5000 Series and 6000 Series in terms of Mg content is subjected to aging heat treatment after solid solution treatment, the inventors made further studies to improve the bend formability after press-forming without sacrificing the existed requirements as the automobile body panels. And the inventors found that the improvement is achieved, without sacrificing these requirements, by specifying the amount of Mg-Si to a specific narrow range, by further adjusting the amount of Cu, and furthermore, by adding slight amount of Ti and B to improve the balance of whole characteristics.

The present invention is described in more detail in the following.

The aluminum alloy sheet according to the present invention consists essentially of: 2.0 to 3.0 wt.% Mg, 0.30 to 0.60 wt.% Cu, 0.08 to 0.15 wt.% Si, 0.005 to 0.15 wt.% Ti, 0.0002 to 0.05 wt.% B, 0.3 wt.% or less Fe as an inevitable impurity, and balance essentially Al. The alloy sheet may further include at least one element selected from the group of 0.05 to 0.30 wt.% Mn, 0.05 to 0.10 wt.% Cr and 0.05 to 0.10 wt.% Zr.

The alloy composition according to the present invention is based on Al-Mg-Cu-Si alloy. Excellent paint-baking hardenability is obtained by forming a modulated structure (GPB zone) in preceding stage of Al-Cu-Mg compound precipitation. During the manufacturing the alloy, favorable press-formability, proof stress after paint-baking treatment, and delayed natural aging property are obtained by quenching the alloy after the solid solution heat treatment and by applying heat treatment at a low temperature level. Excellent bend formability after press-forming is provided by optimizing the alloy composition.

The following is the reasons of specifying the above-described components to an above-described range.

Magnesium: As a solid solution element, Mg contributes to the increase of work-hardening factor, and to improvement of uniform elongation. Magnesium is also an element to create a modulation structure of Al-Cu-Mg alloy that contributes to bake hardenability. The Mg content less than 2.0 wt.%, however, deteriorates ductility and press-formability, and delays the creation of Al-Cu-Mg modulated structure. When the Mg content exceeds 3.0 wt.%, hot-rolling cracks likely induce, and spot weldability deteriorates. Accordingly, the Mg content is specified in a range of from 2.0 to 3.0 wt.%. From the viewpoint of press-formability (particularly stretch formability) and of bend formability after press-forming, a preferable range of Mg content is 2.5 wt.% or more.

Copper: Copper is a solid solution element to contributes to the increase of strength, and is an element to structure Al-Cu-Mg modulated structure. When the Cu content is less than 0.30 wt.%, however, no modulated structure appears, and both strength and paint-baking hardenability are not sufficient. From the viewpoint of zinc phosphate treatment in coating stage, the Cu content is necessary at or more than 0.3 wt.%. When the Cu content exceeds 0.60 wt.%, crack likely appears during hot-rolling, and corrosion resistance after coating deteriorates. Accordingly, the Cu content is specified to a range of from 0.30 to 0.60 wt.%. For further increasing the strength, the Cu content is preferably at 0.40 wt.% or more. From the point of corrosion resistance, the Cu content is preferably at 0.5 wt.% or less.

Silicon: Silicon is an element to enhance the formation of Al-Cu-Mg modulated structure and to increase the paint-bake hardenability. To perform the function, the Si content is necessary at 0.08 wt.% or more. When the Si content exceeds 0.15 wt.%, coarse Mg_2Si crystals increase, thus significantly deteriorating the bend formability after pressing, and causing the occurrence of defects such as crack generation during hemming. Consequently, the Si content is specified to a range of from 0.08 to 0.15 wt.%.

Iron: Iron is usually contained in aluminum alloys as an inevitable impurity. When the Fe content exceeds 0.3 wt.%, formation of coarse crystals of Al-Fe is significantly enhanced, which then promotes the propagation of cracks during bending after press-forming. Therefore, the Fe content is specified to 0.3 wt.% or less.

Titanium and boron: Titanium and boron form TiB_2 and make the crystal grains in ingot uniform. When, however, Ti and B are less than 0.005 wt.% and 0.0002 wt.%, respectively, the cast structure becomes rough, and Mg_2Si and Al-Fe crystals become coarse, which tends to induce cracks during hot-rolling and to deteriorate the bend formability after press-forming. On the other hand, excess amount of addition of these elements yields coarse intermetallics and deteriorates the formability. Accordingly, the content of Ti and B is specified to a range of from 0.005 to 0.15 wt.% and 0.0002 to 0.05 wt.%, respectively.

Manganese, chromium, zirconium: These elements are added generally to suppress the growth of recrystallized grains. By reducing the size of grains, particularly the rough surface after press-forming is suppressed. The rough surface not only deteriorates the product appearance but also acts as the origin of cracks during hemming after press-forming. Therefore, adequate fineness of grains improves the bend formability after press-forming. The effect is effectively appeared by adding each 0.05 wt.% or more of Mn, Cr, and Zr. When the addition of Mn exceeds 0.30 wt.%, Cr exceeds 0.10 wt.%, and Zr exceeds 0.10 wt.%, the crystal grain size becomes too fine, and SSM appears, and ductility deteriorates. Therefore, it is preferable to add at least one element selected from the group of Mn in an amount of 0.05 to 0.30 wt.%, Cr in an amount of 0.05 to 0.10 wt.%, and Zr in an amount of 0.05 to 0.10 wt.%.

Beryllium may further be added as other element up to 0.01 wt.%. Beryllium is an element to prevent oxidation during casting, to improve hot-rolling property, and to improve formability of alloy sheet. When the Be content exceeds 0.01 wt.%, however, the effect saturates, and the casting work environment may be harmed because Be is an element of strong toxicity, so the excess amount of Be addition is not preferable. Consequently, even when Be is added, the Be

content is limited up to 0.01 wt.%.

Other than these elements, inevitable impurities exist in the alloy as in ordinary aluminum alloys. The amount of these inevitable impurities is allowable within a range that does not deteriorate the effect of the present invention.

An aluminum alloy having above-specified range of components and composition is melted to cast using a known method, and the produced ingot is subjected to single or multistage homogenization treatment at a temperature ranging from 400 to 580 °C. The homogenization treatment enhances the diffusion of eutectic compounds deposited during casting to form a solid solution, and reduces local microscopic segregation. The treatment is also able to precipitate fine compounds of Mn, Cr, and Zr, which elements play an important role to suppress abnormal grain growth in the crystals in finished product and to uniformize the crystal structure. If, however, the treatment temperature is less than 400°C, the above-described effect is insufficient. And if the treatment temperature is above 580° C, eutectic melting occurs. Therefore, the temperature of homogenization treatment is selected to a range of from 400 to 580 °C. When the holding time in the treatment temperature range is less than 1 hour, the above-described effect becomes insufficient, and when the holding time exceeds 72 hours, the effect saturates. So the holding time of the homogenization treatment is preferably in a range of from 1 to 72 hours.

The ingot which was treated by homogenization specified above is hot-rolled and cold-rolled using a known method to obtain a desired sheet thickness. In addition, for the flattening or the surface roughness adjustment, leveling of 5% or less, stretching, or skin-pass rolling maybe applied at both or either of before and after the heat treatment described below.

After rolling, the rolled sheet is subjected to a heat treatment that comprises: heating the sheet to a temperature ranging from 500 to 580 °C at a rate of 3 °C/sec. or more; quenching the sheet to 100 °C at a rate of 2 °C/sec. or more immediately after reaching the sheet to the heating temperature or after holding the sheet at the temperature for 60 sec. or less. The heat treatment is given to dissolve precipitates containing Cu and Mg which are indispensable to the characteristic paint-bake hardenability through formation of the Al-Cu-Mg modulated structure during paint-baking. In that case, if the heating temperature is less than 500 °C, the dissolution of precipitates becomes insufficient, and the amount of paint-bake hardening results in insufficient. If the heating temperature exceeds 580 °C or if the heating speed is less than 3 °C/sec., or if the holding time exceeds 60 sec., then microstructure tends to deteriorate inducing the occurrence of eutectic fusion, abnormal growth of a part of crystal grains, etc., which results in deterioration of formability. In addition, if the cooling rate down to 100 °C is less than 2 °C/sec., Al-Cu-Mg compound deposits during cooling stage to deteriorate the paint-bake hardenability, which is unfavorable. By repeating the heat treatment for one or more times, the paint-bake hardenability is improved, though the productivity reduces. So the heat treatment may be given two or more times, at need.

Immediately after the solid solution treatment or after holding at room temperature, the sheet is subjected to heat treatment at a temperature ranging from 60 to 150 °C for 1 to 48 hours. (low temperature aging). The heat treatment forms Al-Cu-Mg modulated structure to some extent in advance to improve the stability of the characteristics at room temperature level. The modulated structure formed in this stage also contributes to the strengthening during paint-baking by restricting recovery of strain to be introduced by press forming. The Mg atoms which formed the modulated structure lose their contribution to the dynamic strain aging, so the heat treatment suppresses the generation of SSM. If, however, the heat treatment temperature is less than 60 °C or if the holding time is less than 1 hour, then the above-described hardening is not fully attained. If the heating temperature exceeds 150 °C or if the holding time exceeds 48 hours, the modulated structure is formed to an excessive degree, which results in insufficient paint-bake hardenability, and results in precipitation of coarse Al-Cu-Mg compound which has less contribution to the strength.

The application of the above-described treatment process to an aluminum alloy having above-described composition provides an aluminum alloy sheet which is suitable for automobile body panels, and which satisfy the automobile body panel requirements such as paint-bake hardenability and delayed natural aging property, and provides excellent bend formability after press-forming.

Example

The present invention is described in more detail in the following referring to embodiments.

Example 1

Each of alloys having components and composition listed in Table 1 was melted and DC cast to produce an ingot. The produced ingot was subjected to two-stage homogenization treatment: at 440 °C for 4 hours; and at 510 °C for 10 hours. The ingot was then heated to 460°C and hot-rolled to form a sheet having 4 mm of thickness. The finishing temperature of the hot-rolling was 280 °C. The sheet was cooled to room temperature, and was cold-rolled to a final thickness of 1 mm. Thus obtained 1 mm thick sheet was heated to 550 °C at a rate of 10 °C/sec., and was held for 10 sec. at the temperature, followed by accelerated cooling by air to 100 °C at a rate of 20 °C/sec. After the heat treatment, the sheet was allowed to stand at ambient temperature for 2 days. Then the sheet was subjected to heat treatment at 100

°C for 24 hours.

The treated sheet was held at ordinary temperature for 1 week. Then the sheet was cut to a specified shape to prepare specimen. The specimen underwent tensile test (JIS No.5; tensile direction was rolling direction), deep drawing test, and punch stretch forming test.

To evaluate the amount of natural aging, a specimen for tensile test was subjected to an acceleration aging at 40 °C for 90 days, then the specimen underwent the tensile test. The observed proof stress was compared with the proof stress of as-manufactured product. To simulate the paint-baking after press-forming, specimens were treated by separately 2 % and 5 % tensile deformation (corresponding to press-forming condition), then by giving heat treatment at 170 °C for 20 min. (corresponding to paint-baking condition; hereinafter the heat treatment is simply referred to as "BH treatment"). Tensile test was given to the BH-treated specimens.

The punch stretch forming test was carried out by completely locking the circular specimen using a pressing jig with a bead, and by applying forming using a spherical head punch. The minimum height at the occurrence of crack was determined, and the observed minimum height was used as the index of punch stretch forming property. The deep drawing test was conducted by applying a specified pressing force to the circular specimen and by applying forming using a cylindrical punch. Similar with the case of stretch test, the height was determined as the index of deep drawing property.

Bend formability after press-forming was performed by preparing a strip specimen having a size of 20 x 200 mm, by working in advance by a tensile tester, by further bending to 180 ° to overlay both folded portions together to determine the minimum strain amount to induce crack. Higher amount of minimum strain indicates better bend formability after press-forming.

For evaluating SSM, a strip specimen having a size of 40 x 200 mm was used to simulate the SSM generation during press-forming. A tensile tester was applied to draw the specimen at a strain speed of 10^{-2} to 10 %, and the occurrence of parallel bands on the surface of specimen was visually observed.

The test of corrosion resistance after coating was conducted by preparing a specimen through the steps of: cutting a specimen having a size of 70 x 150 mm from the treated coil; degreasing and pickling the specimen; applying chemical conversion treatment in a commercially available zinc phosphate treating solution; washing the specimen with water and drying it; applying primary coating using cation electrodeposition coating method; applying intermediate coating and top coating using spraying method. The prepared total coated paints thickness was about 100 µm. The surface of the specimen was given by cross cut penetrating to the aluminum base material. The cross-cut specimen was subjected to salt solution spray test conforming to JIS Z 2371 for 24 hours. followed by allowing to stand in a wet atmosphere of 50 °C and 95 % RH for 2000 hours. The maximum length of filiform rust generated from the cross-cut section was determined. The maximum length was used as the index for evaluating the corrosion resistance after coating.

These results are shown in Table 2.

[Table 1]

Specimen No.		Mg	Si	Cu	Ti	B	Mn	Cr	Zr	Fe	Al
Example of this invention	Example 1	2.00	0.15	0.50	0.02	0.002	—	—	—	0.10	Balance
	Example 2	2.50	0.08	0.49	0.02	0.002	—	—	—	0.10	Balance
	Example 3	2.50	0.12	0.49	0.02	0.002	—	—	—	0.10	Balance
	Example 4	2.50	0.15	0.49	0.02	0.002	—	—	—	0.10	Balance
	Example 5	3.00	0.08	0.49	0.02	0.002	—	—	—	0.10	Balance
	Example 6	3.00	0.12	0.49	0.02	0.002	—	—	—	0.10	Balance
	Example 7	3.00	0.15	0.49	0.02	0.002	—	—	—	0.10	Balance
	Example 8	3.00	0.08	0.60	0.02	0.002	—	—	—	0.10	Balance
	Example 9	3.00	0.12	0.60	0.02	0.002	—	—	—	0.10	Balance
	Example 10	3.00	0.15	0.60	0.02	0.002	—	—	—	0.10	Balance
	Example 11	2.75	0.12	0.49	0.02	0.002	—	—	—	0.10	Balance
	Example 12	2.75	0.12	0.49	0.02	0.002	0.25	—	—	0.10	Balance
	Example 13	2.75	0.12	0.49	0.02	0.002	—	0.10	—	0.10	Balance
	Example 14	2.75	0.12	0.49	0.02	0.002	—	—	0.10	0.10	Balance
	Example 15	2.75	0.12	0.49	—	—	—	—	—	0.10	Balance
	Example 16	1.90	0.15	0.50	0.02	0.002	—	—	—	0.10	Balance
Comparative example	Example 17	3.10	0.10	0.50	0.02	0.002	—	—	—	0.10	Balance
	Example 18	2.50	0.05	0.50	0.02	0.002	—	—	—	0.10	Balance
	Example 19	2.50	0.16	0.50	0.02	0.002	—	—	—	0.10	Balance
	Example 20	3.00	0.10	0.29	0.02	0.002	—	—	—	0.10	Balance
	Example 21	3.00	0.10	0.70	0.02	0.002	—	—	—	0.10	Balance
	Example 22	3.00	0.16	0.50	0.02	0.002	—	—	—	0.10	Balance
	Example 23	2.75	0.12	0.49	0.02	0.002	0.35	—	—	0.10	Balance
	Example 24	2.75	0.12	0.49	0.02	0.002	—	0.15	—	0.10	Balance
	Example 25	2.75	0.12	0.49	0.02	0.002	—	—	0.15	0.10	Balance
	Example 26	2.75	0.12	0.49	0.02	0.002	—	—	—	0.35	Balance

[Table 2]

Specimen No.	YS (Mpa)	YS at 40°C, after 90 days (Mpa)	YS at 2% elonga- tion after BH (Mpa)	YS at 5 % elonga- tion after BH (Mpa)	TS (Mpa)	Elonga- tion (%)	Punch stretch forming height (mm)	Deep drawing height (mm)	Occurrence of bending crack, rate of preliminary strain (%)	SSM occurrence	Corrosion resistance after coating
Example 1	130	130	170	190	260	31.0	19.0	15.0	15.0	None	○
Example 2	140	140	175	195	260	32.0	19.5	15.0	17.0	None	○
Example 3	130	130	170	190	265	32.0	19.5	15.0	16.0	None	○
Example 4	120	120	160	185	270	32.0	19.5	16.0	15.0	None	○
Example 5	115	115	160	185	270	32.0	19.5	16.0	20.0	None	○
Example 6	115	115	165	190	270	34.0	20.0	16.0	18.0	None	○
Example 7	115	115	170	195	270	34.0	20.0	16.0	16.0	None	○
Example 8	115	120	175	195	270	34.0	20.0	16.0	20.0	None	○
Example 9	115	120	180	200	270	34.0	20.0	16.0	18.0	None	○
Example 10	115	120	185	205	270	34.0	20.0	16.0	16.0	None	○
Example 11	120	120	160	185	265	33.0	19.5	15.5	18.0	None	○
Example 12	120	120	160	185	265	33.0	20.0	15.5	21.0	None	○
Example 13	120	120	160	185	265	33.0	20.0	15.5	21.0	None	○
Example 14	120	120	160	185	265	33.0	20.0	15.5	21.0	None	○
Example 15	120	120	150	170	250	27.0	17.5	13.0	0.0	None	○
Example 16	100	110	130	140	240	27.0	17.5	12.5	5.0	None	○
Example 17	130	130	170	190	260	34.0	20.0	16.0	18.0	Occurred	○
Example 18	100	100	120	130	220	27.0	19.0	13.0	19.0	None	○
Example 19	130	150	180	200	275	32.0	19.0	15.0	5.0	None	○
Example 20	110	110	140	150	220	28.0	19.0	13.5	18.0	None	○
Example 21	120	150	170	195	270	33.0	20.0	15.5	20.0	None	X
Example 22	130	150	185	200	280	24.0	20.0	16.0	5.0	None	○
Example 23	120	120	160	185	265	27.0	15.5	13.0	7.0	Occurred	○
Example 24	120	120	160	185	265	27.0	15.5	13.0	7.0	Occurred	○
Example 25	120	120	160	185	265	27.0	15.5	13.0	5.0	Occurred	○
Example 26	120	120	160	185	265	27.0	15.5	13.0	5.0	Occurred	○

As seen in Table 2, alloy Nos.1 through 14 which had a composition within a range specified in the present invention gave high proof stress after BH treatment after 2 % and 5 % elongation, and generated very little change in proof stress during accelerated aging at 40 °C for 90 days. They also provided favorable stretch formability and deep drawability, and had favorable bend formability after forming generating no crack even after the bending to overlay both folded portions

together after giving 14 % preliminary strain. In addition, they did not generate SSM and they showed excellent corrosion resistance after coating. The alloys containing Cu at 0.5 wt.% or less was identified to be particularly excellent corrosion resistance.

To the contrary, alloy Nos.15 through 26 which had a composition outside of the specified range in the present invention were inferior in either of the above-described characteristics.

For example, alloy Nos. 16, 18, and 20, which contained less amount of either of Mg, Si, and Cu, provided less paint-bake hardenability after BH treatment. Alloy No.15 which did not contain Ti and B generated abnormal grain growth, and gave poor elongation, formability, and bend formability after forming. Alloy No.17 which contained large amount of Mg generated SSMs. Alloy Nos.19 and 22 which contained large amount of Si gave a high degree of aging at normal temperature, and provided significantly poor bend formability after forming. Alloy No.21 which contained large amount of Cu gave high degree of natural aging, and showed significantly poor corrosion resistance. Alloy Nos.23, 24, and 25 which contained excess amount of Mn, Cr, and Zr, respectively, produced too fine crystal grains to generate SSMs, and resulted in poor bend formability after forming. Alloy No.26 which contained large amount of Fe generated large amount of Al-Fe deposit, and resulted in poor formability and bend formability after forming.

Example 2

Among the alloys listed in Table 1, an alloy having the composition of alloy No.11 was used to melt and DC cast to produce an ingot. The produced ingot was subjected to two-stage homogenization treatment: at 440°C for 4 hours; and at 510 °C for 10 hours. The ingot was then heated to 460 °C and hot-rolled to form a sheet having 4 mm of thickness. The sheet was cooled to room temperature, and was cold-rolled to a final thickness of 1 mm. The finishing temperature of the hot-rolling was 280 °C. Thus obtained 1 mm thick sheet was heated to 550 °C at a rate of 10°C/sec., and was held for 10 sec. at the temperature, followed by accelerated cooling by air to 100 °C at a rate of 20 °C/sec. After the heat treatment, the sheet was allowed to stand at ordinary temperature for 2 days. Then the sheet was subjected to heat treatment as shown in Table 3. The obtained alloy sheet was evaluated for each characteristic given in Example 1. The result is given in Table 3.

[Table 3]

Specimen No.	Condition of low temperature aging	Proof stress (MPa)	Proof stress at 40°C after 90 days	Proof stress at 2% elongation after BH	Proof stress at 5% elongation after BH	Tensile strength (MPa)	Elongation (%)	Punch stretch forming height (mm)	Deep drawing height (mm)	Occurrence of bending crack, rate of preliminary strain (%)
Example of this invention	A 80°C X 36h	105	105	150	175	255	34.0	20.5	14.5	20.0
	B 100°C X 12h	110	110	155	180	260	33.5	20.0	15.0	19.0
	C 120°C X 8h	120	120	160	185	265	33.0	19.5	15.5	18.0
	D 125°C X 5h	125	125	165	190	270	32.5	19.0	15.5	17.0
Comparative Example	E No treatment	80	120	120	130	200	34.0	20.5	12.5	25.0
	F 50°C X 48h	90	120	130	140	210	33.0	20.0	13.0	22.0
	G 100°C X 50h	130	130	160	185	270	30.0	18.0	14.0	8.0
	H 170°C X 2h	135	135	160	185	270	29.0	17.0	13.5	7.0

*BH: heat treatment at 170°C for 20 min.

As shown in Table 3, specimens A through D which satisfied the condition of the present invention gave high proof stress after BH treatment after both 2 % and 5 % stretch, gave favorable stretch formability and deep drawability, and had good bend formability after forming giving no crack on bending to overlay both folded portions together after applying 14 % preliminary strain.

To the contrary, specimens E through H which did not satisfy the condition of the present invention were inferior in either of the characteristics described above. For example, both of the specimen E which was not treated by the low temperature aging specified in the present invention and the specimen F which was subjected to the low temperature aging at a lower temperature than the level specified in the present invention gave large proof stress change, or 40 MPa and 30 MPa, respectively, and the proof stress after BH treatment was not sufficient. Both the specimen G which was treated too long period of the low temperature aging and the specimen H which was treated too high temperature of the low temperature aging gave poor elongation and poor formability, and resulted in significantly poor bend formability after press-forming.

Claims

1. An aluminum alloy sheet consisting essentially of:

Mg in an amount of 2 to 3 wt.%, Cu in an amount of 0.3 to 0.6 wt.%, Si in an amount of 0.08 to 0.15 wt.%, Ti in an amount of 0.005 to 0.15 wt.%, B in an amount of 0.0002 to 0.05 wt.%, Fe as an inevitable impurity in an amount of 0.3 wt.% or less, and the balance essentially Al.

2. The aluminum alloy sheet of claim 1, wherein said Mg is 2.5 to 3 wt.%.

3. The aluminum alloy sheet of claim 1, wherein said Cu is 0.4 to 0.6 wt.%.

4. The aluminum alloy sheet of claim 1, wherein said Cu is 0.3 to 0.5 wt.%.

5. An aluminum alloy sheet consisting essentially of:

Mg in an amount of 2 to 3 wt.%, Cu in an amount of 0.3 to 0.6 wt.%, Si in an amount of 0.08 to 0.15 wt.%, Ti in an amount of 0.005 to 0.15 wt.%, B in an amount of 0.0002 to 0.05 wt.%, at least one element selected from the group consisting of Mn in an amount of 0.05 to 0.3 wt.%, Cr in an amount of 0.05 to 0.1 wt.% and Zr in an amount of 0.05 to 0.1 wt.%, Fe as an inevitable impurity in an amount of 0.3 wt.% or less, and the balance essentially Al.

6. The aluminum alloy sheet of claim 5, wherein said Mg is 2.5 to 3 wt.%.

7. The aluminum alloy sheet of claim 5, wherein said Cu is 0.4 to 0.6 wt.%.

8. The aluminum alloy sheet of claim 5, wherein said Cu is 0.3 to 0.5 wt.%.

9. The aluminum alloy sheet of claim 5, wherein said at least one element is Mn in the amount of 0.05 to 0.3 wt.%.

10. The aluminum alloy sheet of claim 5, wherein said at least one element is Cr in the amount of 0.05 to 0.1 wt.%.

11. The aluminum alloy sheet of claim 5, wherein said at least one element is Zr in the amount of 0.05 to 0.1 wt.%.

12. A method for manufacturing an aluminum alloy sheet comprising the steps of:

(a) preparing an ingot consisting essentially of:

Mg in an amount of 2 to 3 wt.%, Cu in an amount of 0.3 to 0.6 wt.%, Si in an amount of 0.08 to 0.15 wt.%, Ti in an amount of 0.005 to 0.15 wt.%, B in an amount of 0.0002 to 0.05 wt.%, Fe as an inevitable impurity in an amount of 0.3 wt.% or less, and the balance essentially Al;

(b) carrying out at least one homogenization treatment of the ingot at a temperature of from 400 to 580°C;

(c) hot-rolling and cold-rolling the ingot, to which at least one homogenization treatment was carried out, to produce a cold-rolled sheet;

(d) carrying out at least one heat treatment of the cold-rolled sheet, said heat treatment comprising the steps of:

(i) heating the cold-rolled sheet to a temperature of from 500 to 580°C at a rate of at least 3°C/sec.,

(ii) holding the cold-rolled sheet at the temperature of from 500 to 580°C for at most 60 sec.; and

(iii) cooling the cold-rolled sheet down to 100°C at a rate of at least 2°C/sec.;

(e) holding the heat treated cold-rolled sheet at a temperature of from 60 to 150°C for 1 to 48 hours.

5 **13.** The method of claim 12, wherein said ingot consisting essentially of:

10 Mg in an amount of 2 to 3 wt.%, Cu in an amount of 0.3 to 0.6 wt.%, Si in an amount of 0.08 to 0.15 wt.%, Ti
 in an amount of 0.005 to 0.15 wt.%, B in an amount of 0.0002 to 0.05 wt.%, at least one element selected from
 the group consisting of Mn in an amount of 0.05 to 0.3 wt.%, Cr in an amount of 0.05 to 0.1 wt.% and Zr in an
 amount of 0.05 to 0.1 wt.%, Fe as an inevitable impurity in an amount of 0.3 wt.% or less, and the balance
 essentially Al.

15 **14.** The method of claim 12, wherein said homogenization treatment is carried out by holding the ingot at the temper-
 ature of from 400 to 580°C for 1 to 72 hours.

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EUROPEAN SEARCH REPORT

Application Number
EP 96 11 7938

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP 0 646 655 A (NIPPON KOKAN KK) 5 April 1995 * page 4, line 31; claims *	1-14	C22C21/08
X	--- DATABASE WPI Section Ch, Week 9343 Derwent Publications Ltd., London, GB; Class M26, AN 93-340063 XP002025514 & JP 05 247 576 A (FURUKAWA ALUMINIUM KK) , 24 September 1993 * abstract *	1-12	
A	--- DATABASE WPI Section Ch, Week 9249 Derwent Publications Ltd., London, GB; Class M26, AN 92-404973 XP002025515 & JP 04 304 339 A (NKK CORP) , 27 October 1992 * abstract *		TECHNICAL FIELDS SEARCHED (Int.Cl.6)
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The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 18 February 1997	Examiner Ashley, G
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	DATABASE WPI Section Ch, Week 9536 Derwent Publications Ltd., London, GB; Class M26, AN 95-273159 XP002025517 & JP 07 173 565 A (NKK CORP) , 11 July 1995 * abstract * -----		
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 18 February 1997	Examiner Ashley, G
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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