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(54) HIGH-STRENGTH ALUMINUM ALLOY EXTRUDATE WITH EXCELLENT CORROSION RESISTANCE, DUCTILITY, AND HARDENABILITY AND PROCESS FOR PRODUCING SAME

(57) An Al-Mg-Si-based high-strength aluminum alloy extruded shape exhibits excellent corrosion resistance and ductility, and exhibits excellent hardenability during extrusion (i.e., ensures high productivity). A method for producing the same is also disclosed. The high-strength aluminum alloy extruded shape includes 0.65 to 0.90 mass% of Mg, 0.60 to 0.90 mass% of Si, 0.20 to 0.40 mass% of Cu, 0.20 to 0.40 mass% of Fe, 0.10 to 0.20 mass% of Mn, and 0.005 to 0.1 mass% of Ti, with the balance being Al and unavoidable impurities, the aluminum alloy, extruded shape having a stoichiometric Mg_2Si content of 1.0 to 1.3 mass%, an excess Si content relative to stoichiometric Mg_2Si of 0.10 to 0.30 mass%, and a total content of Fe and Mn of 0.35 mass% or more.

FIG. 1

Alloy		Alloy component (mass%)								Mg_2Si	exSi	Mn +Fe
		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti			
1	Example	0. 70	0. 30	0. 30	0. 15	0. 75	0. 00	0. 00	0. 02	1. 18	0. 14	0. 45
2	Example	0. 66	0. 37	0. 25	0. 20	0. 70	0. 00	0. 00	0. 02	1. 10	0. 10	0. 57
3	Example	0. 76	0. 34	0. 36	0. 19	0. 80	0. 00	0. 00	0. 02	1. 26	0. 15	0. 53
4	Example	0. 76	0. 25	0. 36	0. 10	0. 81	0. 00	0. 00	0. 02	1. 28	0. 20	0. 35
5	Example	0. 70	0. 30	0. 30	0. 20	0. 75	0. 00	0. 00	0. 02	1. 18	0. 13	0. 50
6	Example	0. 70	0. 20	0. 32	0. 15	0. 72	0. 00	0. 02	0. 02	1. 14	0. 19	0. 37
7	Example	0. 65	0. 35	0. 25	0. 20	0. 69	0. 00	0. 02	0. 02	1. 09	0. 10	0. 57
8	Example	0. 67	0. 26	0. 25	0. 10	0. 69	0. 00	0. 00	0. 02	1. 09	0. 17	0. 36
9	Example	0. 84	0. 35	0. 35	0. 20	0. 81	0. 00	0. 00	0. 02	1. 28	0. 22	0. 55
10	Example	0. 90	0. 36	0. 36	0. 20	0. 79	0. 00	0. 00	0. 02	1. 25	0. 29	0. 56
1	Comparative Example	0. 55	0. 18	0. 00	0. 00	0. 75	0. 00	0. 00	0. 01	1. 18	0. 07	0. 18
2	Comparative Example	0. 52	0. 25	0. 00	0. 00	0. 70	0. 00	0. 00	0. 02	1. 10	0. 05	0. 25
3	Comparative Example	0. 60	0. 25	0. 00	0. 00	0. 80	0. 00	0. 00	0. 02	1. 26	0. 07	0. 25
4	Comparative Example	0. 70	0. 15	0. 20	0. 20	0. 60	0. 02	0. 00	0. 01	0. 95	0. 26	0. 37
5	Comparative Example	0. 70	0. 17	0. 26	0. 00	1. 02	0. 10	0. 00	0. 01	1. 61	0. 06	0. 27
6	Comparative Example	0. 78	0. 18	0. 10	0. 00	0. 48	0. 00	0. 00	0. 02	0. 76	0. 45	0. 18
7	Comparative Example	0. 80	0. 17	0. 10	0. 10	0. 50	0. 00	0. 00	0. 02	0. 79	0. 44	0. 27
8	Comparative Example	0. 90	0. 17	0. 10	0. 10	0. 50	0. 00	0. 00	0. 02	0. 79	0. 54	0. 27
9	Comparative Example	0. 61	0. 25	0. 31	0. 00	0. 78	0. 00	0. 00	0. 02	1. 23	0. 09	0. 25
10	Comparative Example	0. 66	0. 06	0. 30	0. 00	0. 75	0. 00	0. 00	0. 02	1. 18	0. 21	0. 06
11	Comparative Example	0. 70	0. 05	0. 30	0. 00	0. 75	0. 00	0. 00	0. 02	1. 18	0. 25	0. 05
12	Comparative Example	0. 70	0. 24	0. 30	0. 00	0. 73	0. 00	0. 00	0. 03	1. 15	0. 21	0. 24
13	Comparative Example	0. 70	0. 19	0. 32	0. 05	0. 74	0. 00	0. 02	0. 02	1. 17	0. 21	0. 26
14	Comparative Example	1. 01	0. 16	0. 49	0. 00	0. 51	0. 00	0. 00	0. 01	0. 80	0. 67	0. 16
15	Comparative Example	0. 83	0. 72	0. 41	0. 16	1. 21	0. 28	0. 00	0. 01	1. 91	0. 00	1. 16

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Description

TECHNICAL FIELD

[0001] The present invention relates to an extruded shape produced using an Al-Mg-Si-based aluminum alloy.

BACKGROUND ART

[0002] In recent years, a reduction in weight of automobiles aimed to improve driving performance and reduce fuel consumption has been desired from the viewpoint of environment protection.

[0003] Use of an aluminum alloy extruded shape as an automotive structural material has been studied in order to meet the requirements for reducing fuel consumption by way of a reduction in weight.

[0004] An automotive structural material is required to exhibit high strength, high bendability, and high corrosion resistance, and a JIS 7000 series aluminum alloy (Al-Zn-Mg-based aluminum alloy) and a JIS 6000 series aluminum alloy (Al-Mg-Si-based aluminum alloy) have attracted attention. However, a 7000 series aluminum alloy (natural age hardening alloy) has a drawback in that processing becomes difficult due to hardening when the time elapsed from extrusion to bending is long. Moreover, a 7000 series aluminum alloy shows a decrease in corrosion resistance under a stress environment.

[0005] Therefore, a 6000 series aluminum alloy has been considered to be a promising heat-treatable alloy that does not undergo natural age hardening, and exhibits excellent corrosion resistance.

[0006] An extruded shape formed of a known high-strength 6000 series aluminum alloy exhibits high tensile strength, but exhibits insufficient elongation, and easily produces cracks during bending.

[0007] In order to obtain high strength, water-cooling press quenching is performed immediately after extrusion.

[0008] The water-cooling press quenching treatment has an advantage in that properties similar to those obtained by solution/quenching treatment that reheats the extruded alloy after extrusion can be obtained. However, since a difference in cooling rate occurs between each cross-sectional area due to the cross-sectional shape of the extruded shape, the difference in thickness, and the like, the extruded shape shows a non-uniform temperature distribution during cooling, and strain occurs. Therefore, the dimensional accuracy deteriorates, and it is difficult to reduce the thickness of the cross-sectional profile. The degree of freedom of the cross-sectional shape decreases as a result of preventing occurrence of such strain.

[0009] The water-cooling press quenching treatment has another disadvantage in that an increase in cost occurs as compared with an air-cooling quenching treatment.

[0010] On the other hand, the air-cooling quenching treatment has an advantage in that cost can be reduced as compared with the water-cooling press quenching treatment. However, since the cooling rate is limited, high strength may not be obtained depending on the alloy composition, and a deterioration in ductility may occur although high strength can be obtained.

[0011] Patent Document 1 discloses an aluminum alloy extruded shape that exhibits excellent axial crush properties and corrosion resistance, and includes 0.4 to 0.8% of Mg, 0.3 to 0.9% of Si, 0.05% or less of Cu, and 0.095% or less of Mn, Cr, Zr in total, wherein the number of Mg_2Si moieties having a length of 3 μm in the extrusion direction is 50 or more per mm^2. However, it is considered that the alloy composition disclosed in Patent Document 1 provides excellent corrosion resistance, but achieves a proof stress of only about 220 MPa (i.e., cannot sufficiently contribute to a reduction in weight of the product). Since a water-cooling press quenching treatment is normally used in Patent Document 1, it is considered that the extrusion productivity is low.

[0012] Since Cu, Mn, Cr, and Zr are considered to be impurities, and the content thereof is limited, it is considered that an improvement in ductility cannot be achieved.

[0013] Patent Document 2 discloses an aluminum alloy extruded shape that exhibits excellent hardenability and axial crush properties, and includes 0.45 to 0.75% of Mg, 0.45 to 0.80 of Si, 0.1 to 0.4% of excess Si, 0.15 to 0.40% of Mn, and 0 to 0.1 % of Cr, wherein Mn and Cr compounds are finely dispersed. Patent Document 2 achieves good productivity by utilizing an air-cooling press quenching treatment. However, the aluminum alloy extruded shape disclosed in Patent Document 2 has a proof stress of only about 220 MPa.

[0014] Since it is necessary to add Cr that achieves sharp quench sensitivity, it is difficult to improve the proof stress using an air-cooling means.

Patent Document 1: JP-A-2002-285272
Patent Document 2: JP-A-2004-225124

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0015] An object of the invention is to provide an Al-Mg-Si-based high-strength aluminum alloy extruded shape that exhibits excellent corrosion resistance and ductility, and exhibits excellent hardenability during extrusion (i.e., ensures high productivity), and a method for producing the same.

SOLUTION TO PROBLEM

[0016] According to one aspect of the invention, there is provided a high-strength aluminum alloy extruded shape that exhibits excellent corrosion resistance, ductility, and hardenability, the aluminum alloy extruded shape including 0.65 to 0.90 mass% of Mg, 0.60 to 0.90

mass% of Si, 0.20 to 0.40 mass% of Cu, 0.20 to 0.40 mass% of Fe, 0.10 to 0.20 mass% of Mn, and 0.005 to 0.1 mass% of Ti, with the balance being Al and unavoidable impurities, the aluminum alloy extruded shape having a stoichiometric Mg_2Si content of 1.0 to 1.3 mass%, an excess Si content relative to stoichiometric Mg_2Si of 0.10 to 0.30 mass%, and a total content of Fe and Mn of 0.35 mass% or more. Note that the unit "mass%" may be hereinafter referred to as "%".

[0017] The extruded shape is obtained by extruding an aluminum alloy having the above composition, cooling the extruded aluminum alloy at an average cooling rate of 100°C/min or less immediately after the extrusion, and subjecting the cooled aluminum alloy to artificial aging.

[0018] When the average cooling rate is 100°C/min or less, it suffices to air-cool the aluminum alloy using a fan immediately after the extrusion instead of water-cooling the aluminum alloy, and press quenching by air-cooling can be implemented.

[0019] For example, a cooling rate of 50 to 100°C/min can be achieved by cooling the extruded shape extruded from an extrusion press using a fan.

[0020] The extruded shape thus produced has a structure in which crystal grains having an aspect ratio of 4.0 or more have an average crystal grain size of 80 μm or less, and has a 0.2% proof stress (σ) of 280 MPa or more.

[0021] The term "aspect ratio" used herein refers to the ratio (L_1/L_2) of the length L_1 of the crystal grains of the recrystallized structure in the extrusion direction to the length L_2 of the crystal grains in the direction orthogonal to the extrusion direction.

[0022] The term "average crystal grain size" used herein refers to the average diameter of circles respectively circumscribed to the crystal grains.

[0023] The extruded shape according to one aspect of the invention has an impact strength determined by a Charpy impact test of 20 J/cm^2 or more.

[0024] The content range of each component is selected for the following reasons. Mg and Si

[0025] Mg and Si contribute to an improvement in the strength of the extruded shape through formation of Mg_2Si precipitates.

[0026] Since a decrease in extrudability occurs if the Mg content and/or the Si content is too high, the upper limit of the Mg content is set to 0.90%, and the upper limit of the Si content is set to 0.90%.

[0027] The Mg_2Si content is set to 1.0 to 1.3% in order to obtain a 0.2% proof stress of 280 MPa or more while taking account of extrudability.

[0028] Excess Si relative to stoichiometric Mg_2Si can improve the 0.2% proof stress without significantly impairing extrudability.

[0029] However, a decrease in ductility may occur if the excess Si content relative to stoichiometric Mg_2Si is too high. Therefore, the excess Si content relative to stoichiometric Mg_2Si is set to 0.10 to 0.30%.

[0030] It is preferable to control the excess Si content relative to stoichiometric Mg_2Si within the range of 0.10 to 0.20% from the viewpoint of ensuring excellent ductility.

Cu

[0031] Cu contributes to solid solution hardening, and ensures elongation when the Cu content is within a given range.

[0032] Since a decrease in corrosion resistance and extrudability occurs if the Cu content is too high, the Cu content is set to 0.2 to 0.4%.

Fe

[0033] One aspect of the invention is characterized in that the Fe content is set to 0.20 to 0.40%.

[0034] Fe refines the crystal grains of the extruded metal structure, and improves ductility.

[0035] Known refinement components such as Mn, Cr, and Zr increase quench sensitivity even during air-cooling using a fan immediately after extrusion. In contrast, Fe does not increase quench sensitivity, and makes it possible to perform quenching at a cooling rate of 100°C/min or less.

Mn

[0036] It is known that Mn affects quench sensitivity during air-cooling using a fan immediately after extrusion. The inventor of the invention conducted extensive studies, and found that Mn does not significantly affect quench sensitivity during air-cooling using a fan when the Mn content is 0.20% or less. The inventor also found that, when the Mn content is 0.10 to 0.20%, a recrystallized structure that extends in the extrusion direction is obtained in which propagation of cracks is suppressed as compared with a spherical recrystallized structure, and the crystal grains have a small average crystal grain size.

[0037] Therefore, the total content of Fe and Mn is set to 0.35% or more.

Ti

[0038] Ti refines the crystal grains when casting a billet subjected to extrusion. The Ti content is preferably 0.005 to 0.10%.

[0039] If the Ti content exceeds 0.10%, coarse intermetallic compounds may be easily produced, and may not disappear during extrusion. As a result, the strength of the extruded shape may decrease.

Additional components

[0040] Additional components (e.g., Cr, Zr, and Zn) other than the above components may be included in the extruded shape as unavoidable impurities as long as the content of each additional component is 0.05% or less, and the total content of additional components is 0.15% or less.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0041] According to one aspect of the invention, the proof stress can be improved while ensuring extrudability by setting the stoichiometric Mg_2Si content to 1.00 to 1.30%, and setting the excess Si content relative to stoichiometric Mg_2Si to 0.10 to 0.30%. It is possible to achieve high strength and high ductility by press quenching via air-cooling in case that the Fe content is set to 0.20 to 0.40%, and the Mn content is set to 0.10 to 0.20% so that "Fe+Mn≥0.35 mass%" is satisfied.

[0042] It is also possible to improve the impact strength.

BRIEF DESCRIPTION OF DRAWINGS

[0043]

FIG. 1 shows the composition of each billet used for experiments and evaluations.
FIG. 2 shows the production conditions used for experiments and evaluations.
FIG. 3 shows evaluation results.
FIG. 4 shows an example of a comparison of the metal structure of an extruded shape.

DESCRIPTION OF EMBODIMENTS

[0044] Billets that differ in chemical composition were cast, extruded, and evaluated as described below.

[0045] A molten metal including the alloy components shown in FIG. 1 was prepared, and cast at a casting speed 60 mm/min or more to obtain a cylindrical billet having a diameter of 8 inches.

[0046] FIG. 2 shows the subsequent production conditions.

[0047] The cast billet was homogenized at 565 to 595°C for 2 to 6 hours (see "HOMO conditions").

[0048] The billet was preheated to 480 to 520°C, and extruded to obtain an extruded shape having a hollow cross-sectional shape (single-hollow cross-sectional shape) (W=50 mm, H=40 mm, t (thickness)=3 mm).

[0049] FIG. 2 shows the extrusion speed and the cooling rate.

[0050] The cooling rate was set to 50 to 100°C/min in order to achieve press quenching by air-cooling using a fan. Note that the cooling rate was set to 200°C/min in Comparative Example 5.

[0051] The extruded shape was cooled to room temperature, and subjected to artificial aging at 185 to 200°C for 3 to 3.5 hours (see "Heat treatment conditions").

[0052] FIG. 3 shows the property evaluation results for the extruded shape thus produced.

Evaluation items and evaluation methods

[0053]

(1) Tensile strength, 0.2% proof stress, and elongation: A JIS No. 4 tensile test specimen was prepared from the extruded shape in accordance with JIS Z 2241. The specimen was subjected to a tensile test using a tensile tester compliant to the JIS standard.

(2) Microstructure: A specimen was cut from the extruded shape, mirror-finished, and etched at 40°C for 3 minutes using a 3% NaOH aqueous solution. The surface of the specimen was observed using an optical microscope.

[0054] FIG. 4 shows a photograph of the metal structure of Comparative Example 1 (see "RELATED-ART ALLOY"), and a photograph of the metal structure of Example 1 (see "INVENTIVE ALLOY").

[0055] The aspect ratio was determined by calculating the average value (n=5 to 10) of the ratios (L_1/L_2) of the length L_1 of the crystal grains in the extrusion direction to the length L_2 of the crystal grains in the direction orthogonal to the extrusion direction.

[0056] The crystal grain size was determined by calculating the average value (n=5 to 10) of the diameters of circles respectively circumscribed to the crystal grains.
(3) Corrosion resistance: The stress corrosion cracking resistance (SCC resistance) was evaluated.

[0057] A No. 1 specimen was prepared in accordance with JIS H 8711, and subjected to the following cycle test in a state in which a stress equal to 100% of the 0.2% proof stress was applied.

[0058] A cycle (3.5% NaCl aqueous solution, 25°C, 10 min → air-drying (25°C, 40% (humidity), 50 min)) is repeated 720 times, and a case where no cracks were observed was evaluated as acceptable.

(4) Impact strength: A JIS V-notch No. 4 tensile test specimen was prepared from the extruded shape in accordance with JIS Z 2242. The impact strength was measured using a Charpy impact tester compliant to the JIS standard.

[0059] The target impact strength was set to 20 J/cm^2 or more.

Evaluation results

[0060] The extruded shapes of Examples 1 to 10 had a flat recrystallized metal structure (microstructure) in which crystal grains having an aspect ratio of 4.0 or more had an average crystal grain size of 80 μm or less.

[0061] The extruded shapes of Examples 1 to 10 had a proof stress of 280 MPa or more (i.e., exhibited high strength), and had an elongation (ductility) of 8% or more.

[0062] The extruded shapes of Examples 1 to 10 had a Charpy impact strength of 20 J/cm^2 or more.

[0063] The extruded shapes of Comparative Examples 1 to 5 showed high elongation, but had low proof stress.

[0064] The extruded shapes of Comparative Examples 1 to 3 had low proof stress since the Cu content and the excess Si content were low.

[0065] The extruded shape of Comparative Example 4 had low proof stress since the Mg_2Si content was low, and the extruded shape of Comparative Example 5 had low proof stress since the excess Si and the total content of Mn and Fe were low.

[0066] The extruded shapes of Comparative Examples 6 to 8 are poor in both of proof stress and elongation.

[0067] This is because the Fe content, the Cu content, and the Mg content were low.

[0068] The extruded shapes of Comparative Examples 9 to 13 achieved the target proof stress, but had low elongation and low impact strength.

[0069] This is because the total content of Fe and Mn was low.

[0070] The extruded shape of Comparative Example 14 had low proof stress, low elongation, and low impact strength since the excess Si content and the total content of Fe and Mn were low.

[0071] The extruded shape of Comparative Example 15 had low proof stress since the excess Si content was low although the Si content and the Mg content were sufficient.

INDUSTRIAL APPLICABILITY

[0072] Since the aluminum alloy extruded shape according to the embodiments of the invention exhibits excellent corrosion resistance, ductility, and hardenability, the aluminum alloy extruded shape may be widely used as structural materials for vehicles, machines, and the like.

Claims

1. A high-strength aluminum alloy extruded shape that exhibits excellent corrosion resistance, ductility, and hardenability, the aluminum alloy extruded shape comprising 0.65 to 0.90 mass% of Mg, 0.60 to 0.90 mass% of Si, 0.20 to 0.40 mass% of Cu, 0.20 to 0.40 mass% of Fe, 0.10 to 0.20 mass% of Mn, and 0.005 to 0.1 mass% of Ti, with the balance being Al and unavoidable impurities, the aluminum alloy extruded shape having a stoichiometric Mg_2Si content of 1.0 to 1.3 mass%, an excess Si content relative to stoichiometric Mg_2Si of 0.10 to 0.30 mass%, and a total content of Fe and Mn of 0.35 mass% or more.

2. The high-strength aluminum alloy extruded shape as defined in claim 1, wherein crystal grains of the aluminum alloy extruded shape having an aspect ratio of 4.0 or more have an average crystal grain size of 80 μm or less.

3. The high-strength aluminum alloy extruded shape as defined in claim 1 or 2, wherein the aluminum alloy extruded shape has a proof stress of 280 MPa or more.

4. The high-strength aluminum alloy extruded shape as defined in claim 1 or 2, wherein the aluminum alloy extruded shape has an impact strength determined by a Charpy impact test of 20 J/cm^2 or more.

5. A method for producing a high-strength aluminum alloy extruded shape that exhibits excellent corrosion resistance, ductility, and hardenability, the method comprising extruding an aluminum alloy, cooling the extruded aluminum alloy at an average cooling rate of 100°C/min or less immediately after the extrusion, and subjecting the cooled aluminum alloy to artificial aging, the aluminum alloy comprising 0.65 to 0.90 mass% of Mg, 0.60 to 0.90 mass% of Si, 0.20 to 0.40 mass% of Cu, 0.20 to 0.40 mass% of Fe, 0.10 to 0.20 mass% of Mn, and 0.005 to 0.1 mass% of Ti, with the balance being Al and unavoidable impurities, the aluminum alloy having a stoichiometric Mg_2Si content of 1.0 to 1.3 mass%, an excess Si content relative to stoichiometric Mg_2Si of 0.10 to 0.30 mass%, and a total content of Fe and Mn of 0.35 mass% or more.

FIG. 1

Alloy		Alloy component (mass%)								Mg_2Si	exSi	Mn +Fe
		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti			
1	Example	0. 70	0. 30	0. 30	0. 15	0. 75	0. 00	0. 00	0. 02	1. 18	0. 14	0. 45
2	Example	0. 66	0. 37	0. 25	0. 20	0. 70	0. 00	0. 00	0. 02	1. 10	0. 10	0. 57
3	Example	0. 76	0. 34	0. 36	0. 19	0. 80	0. 00	0. 00	0. 02	1. 26	0. 15	0. 53
4	Example	0. 76	0. 25	0. 36	0. 10	0. 81	0. 00	0. 00	0. 02	1. 28	0. 20	0. 35
5	Example	0. 70	0. 30	0. 30	0. 20	0. 75	0. 00	0. 00	0. 02	1. 18	0. 13	0. 50
6	Example	0. 70	0. 20	0. 32	0. 15	0. 72	0. 00	0. 02	0. 02	1. 14	0. 19	0. 37
7	Example	0. 65	0. 35	0. 25	0. 20	0. 69	0. 00	0. 02	0. 02	1. 09	0. 10	0. 57
8	Example	0. 67	0. 26	0. 25	0. 10	0. 69	0. 00	0. 00	0. 02	1. 09	0. 17	0. 36
9	Example	0. 84	0. 35	0. 35	0. 20	0. 81	0. 00	0. 00	0. 02	1. 28	0. 22	0. 55
10	Example	0. 90	0. 36	0. 36	0. 20	0. 79	0. 00	0. 00	0. 02	1. 25	0. 29	0. 56
1	Comparative Example	0. 55	0. 18	0. 00	0. 00	0. 75	0. 00	0. 00	0. 01	1. 18	0. 07	0. 18
2	Comparative Example	0. 52	0. 25	0. 00	0. 00	0. 70	0. 00	0. 00	0. 02	1. 10	0. 05	0. 25
3	Comparative Example	0. 60	0. 25	0. 00	0. 00	0. 80	0. 00	0. 00	0. 02	1. 26	0. 07	0. 25
4	Comparative Example	0. 70	0. 15	0. 20	0. 20	0. 60	0. 02	0. 00	0. 01	0. 95	0. 26	0. 37
5	Comparative Example	0. 70	0. 17	0. 26	0. 00	1. 02	0. 10	0. 00	0. 01	1. 61	0. 06	0. 27
6	Comparative Example	0. 78	0. 18	0. 10	0. 00	0. 48	0. 00	0. 00	0. 02	0. 76	0. 45	0. 18
7	Comparative Example	0. 80	0. 17	0. 10	0. 10	0. 50	0. 00	0. 00	0. 02	0. 79	0. 44	0. 27
8	Comparative Example	0. 90	0. 17	0. 10	0. 10	0. 50	0. 00	0. 00	0. 02	0. 79	0. 54	0. 27
9	Comparative Example	0. 61	0. 25	0. 31	0. 00	0. 78	0. 00	0. 00	0. 02	1. 23	0. 09	0. 25
10	Comparative Example	0. 66	0. 06	0. 30	0. 00	0. 75	0. 00	0. 00	0. 02	1. 18	0. 21	0. 06
11	Comparative Example	0. 70	0. 05	0. 30	0. 00	0. 75	0. 00	0. 00	0. 02	1. 18	0. 25	0. 05
12	Comparative Example	0. 70	0. 24	0. 30	0. 00	0. 73	0. 00	0. 00	0. 03	1. 15	0. 21	0. 24
13	Comparative Example	0. 70	0. 19	0. 32	0. 05	0. 74	0. 00	0. 02	0. 02	1. 17	0. 21	0. 26
14	Comparative Example	1. 01	0. 16	0. 49	0. 00	0. 51	0. 00	0. 00	0. 01	0. 80	0. 67	0. 16
15	Comparative Example	0. 83	0. 72	0. 41	0. 16	1. 21	0. 28	0. 00	0. 01	1. 91	0. 00	1. 16

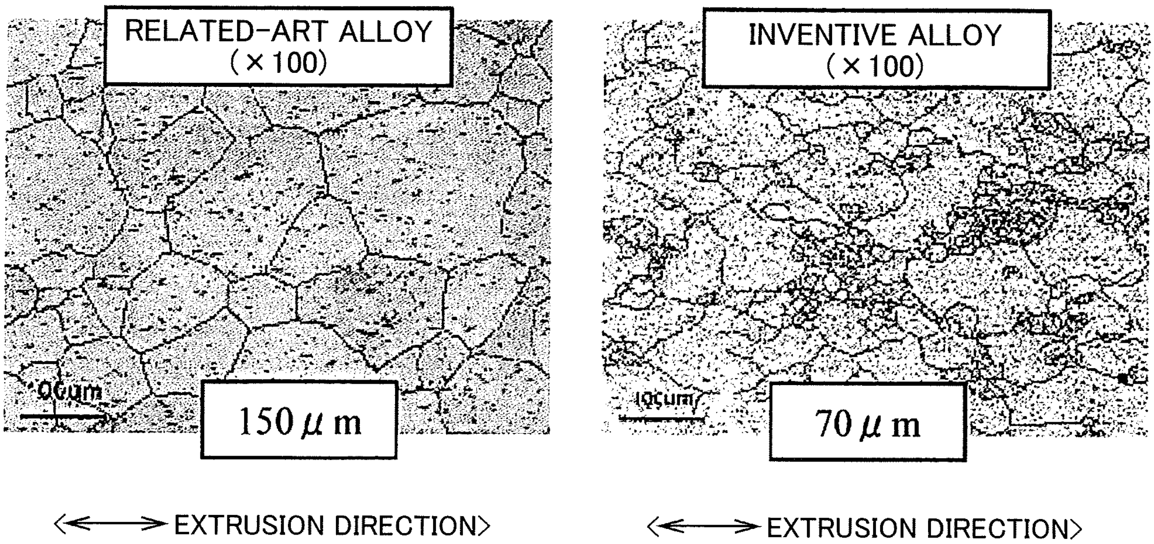
FIG. 2

Alloy		Casting speed	HOMO conditions	BLT temperature	Extrusion speed	Cooling rate	Heat treatment conditions
		60 mm/min or more	565 to 595°C for 2 to 6 hr	480°C or more	10 m/min or more	100°C/min or less	185～200℃
1	Example	70	575℃×3h	500	12	80	195℃×3h
2	Example	70	565℃×3h	480	10	70	190℃×3h
3	Example	70	585℃×5h	520	14	90	200℃×3. 5h
4	Example	70	585℃×5h	520	14	90	200℃×3. 5h
5	Example	70	575℃×3h	500	12	80	195℃×3h
6	Example	70	575℃×3h	500	12	80	195℃×3h
7	Example	70	565℃×3h	480	12	70	195℃×3h
8	Example	70	565℃×3h	480	12	70	190℃×3h
9	Example	70	585℃×5h	520	15	90	200℃×3h
10	Example	70	585℃×5h	520	15	90	200℃×3h
1	Comparative Example	65	575℃×3h	500	12	80	195℃×3h
2	Comparative Example	65	565℃×3h	480	10	70	190℃×3h
3	Comparative Example	65	585℃×5h	520	14	90	200℃×3. 5h
4	Comparative Example	60	565℃×2h	500	12	80	195℃×3h
5	Comparative Example	60	565℃×2h	500	10	200	185℃×6h
6	Comparative Example	70	575℃×3h	500	12	80	195℃×3h
7	Comparative Example	70	575℃×3h	500	12	80	195℃×3h
8	Comparative Example	70	595℃×3h	500	12	80	195℃×3h
9	Comparative Example	70	575℃×3h	500	12	80	195℃×3h
10	Comparative Example	70	575℃×3h	500	12	80	195℃×3h
11	Comparative Example	70	575℃×3h	500	12	80	195℃×3h
12	Comparative Example	70	575℃×3h	500	12	80	195℃×3h
13	Comparative Example	70	575℃×3h	500	12	80	195℃×3h
14	Comparative Example	60	565℃×6h	500	10	80	195℃×3h
15	Comparative Example	60	565℃×2h	500	10	150	185℃×6h

FIG. 3

	Alloy	Tensile strength [MPa]		Proof stress [MPa]		Elongation [%]		Microstructure					Corrosion resistance	Charpy impact strength [J/cm^2]		Overall evaluation
								Crystal grain size		Aspect ratio		Shape				
		300 MPa or more		280 MPa or more		8% or more		80 μm or less		4.0 or more		—	No SCC	20J/cm^2 or more		
1	Example	320	○	301	○	11. 0	○	70	○	4. 5	○	Flat recrystal-lized structure	○	23. 8	○	○
2	Example	305	○	286	○	11. 6	○	60	○	4. 1	○	Flat recrystal-lized structure	○	34. 4	○	○
3	Example	342	○	318	○	10. 6	○	60	○	4. 9	○	Flat recrystal-lized structure	○	22. 5	○	○
4	Example	347	○	325	○	9. 4	○	75	○	5. 2	○	Flat recrystal-lized structure	○	35. 4	○	○
5	Example	319	○	299	○	11. 7	○	70	○	4. 1	○	Flat recrystal-lized structure	○	30. 7	○	○
6	Example	331	○	308	○	9. 2	○	70	○	4. 1	○	Flat recrystal-lized structure	○	25. 4	○	○
7	Example	310	○	288	○	11. 5	○	60	○	4. 0	○	Flat recrystal-lized structure	○	34. 4	○	○
8	Example	315	○	295	○	11. 2	○	65	○	4. 5	○	Flat recrystal-lized structure	○	32. 4	○	○
9	Example	335	○	322	○	9. 2	○	70	○	4. 5	○	Flat recrystal-lized structure	○	22. 5	○	○
10	Example	340	○	327	○	8. 9	○	70	○	4. 5	○	Flat recrystal-lized structure	○	21. 4	○	○
1	Comparative Example	258	×	233	×	11. 4	○	150	×	1. 1	×	Granular recrys-tallized structure	○	22. 8	○	×
2	Comparative Example	247	×	220	×	13. 1	○	150	×	1. 2	×	Granular recrys-tallized structure	○	38. 5	○	×
3	Comparative Example	271	×	247	×	12. 0	○	150	×	1. 2	×	Granular recrys-tallized structure	○	18. 5	×	×
4	Comparative Example	285	×	265	×	10. 0	○	150	×	1. 5	×	Granular recrys-tallized structure	○	19. 5	×	×
5	Comparative Example	245	×	180	×	13. 0	○	120	×	1. 1	×	Granular recrys-tallized structure	○	20. 0	○	×
6	Comparative Example	297	×	269	×	7. 5	×	150	×	2. 1	×	Granular recrys-tallized structure	○	19. 7	×	×
7	Comparative Example	293	×	265	×	8. 3	×	130	×	2. 3	×	Granular recrys-tallized structure	○	18. 8	×	×
8	Comparative Example	292	×	264	×	6. 3	×	130	×	2. 2	×	Granular recrys-tallized structure	○	18. 6	×	×
9	Comparative Example	327	○	309	○	7. 7	×	150	×	2. 4	×	Granular recrys-tallized structure	○	18. 7	×	×
10	Comparative Example	338	○	322	○	3. 4	×	180	×	1. 5	×	Granular recrys-tallized structure	○	19. 6	×	×
11	Comparative Example	345	○	332	○	4. 1	×	180	×	1. 8	×	Granular recrys-tallized structure	○	17. 6	×	×
12	Comparative Example	327	○	308	○	6. 2	×	150	×	2. 4	×	Granular recrys-tallized structure	○	18. 6	×	×
13	Comparative Example	334	○	310	○	7. 2	×	150	×	2. 4	×	Granular recrys-tallized structure	○	18. 9	×	×
14	Comparative Example	308	○	277	×	4. 6	×	150	×	2. 5	×	Granular recrys-tallized structure	○	19. 9	×	×
15	Comparative Example	225	×	165	×	13. 0	○	120	×	1. 1	×	Granular recrys-tallized structure	○	20. 5	○	×

FIG. 4


RELATED-ART ALLOY
(×100)
150μm
<←→ EXTRUSION DIRECTION>
INVENTIVE ALLOY
(×100)
70μm
<←→ EXTRUSION DIRECTION>

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/052002

A. CLASSIFICATION OF SUBJECT MATTER
C22C21/06(2006.01)i, *B21C29/00*(2006.01)i, *C22C21/02*(2006.01)i, *C22F1/05*(2006.01)i, *C22F1/00*(2006.01)n

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22C21/00-21/18, C22F1/00-1/18

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 9-202933 A (Nippon Steel Corp.), 05 August 1997 (05.08.1997), table 1 (Family: none)	1-5
A	JP 10-219381 A (Nippon Steel Corp.), 18 August 1998 (18.08.1998), table 1 (Family: none)	1-5
A	JP 8-60285 A (The Furukawa Electric Co., Ltd.), 05 March 1996 (05.03.1996), table 1 & EP 0687743 A1	1-5

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

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Date of the actual completion of the international search
01 April, 2013 (01.04.13)

Date of mailing of the international search report
09 April, 2013 (09.04.13)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/052002

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2002-256368 A (Kobe Steel, Ltd.), 11 September 2002 (11.09.2002), table 1 (Family: none)	1-5
A	R.K.Wyss, L.W.Blazek, Influence of Excess Si on Strength and Toughness in Al-Mg-Si Alloys, Materials Science Forum, Vol.217-222, 1996, Page.1783-1788	1-5

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Patent documents cited in the description

- JP 2002285272 A **[0014]**
- JP 2004225124 A **[0014]**