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(54) METHOD OF MANUFACTURING ALUMINUM ALLOY PLATE FOR MOLDING

(57) An aluminum alloy ingot containing not less than 0.4 % by weight and less than 1.7 % by weight of Si, not less than 0.2 % by weight and less than 1.2 % by weight of Mg, and Al and unavoidable impurities for the remainder is homogenized at a temperature of not lower than 500 °C; the resultant product being cooled from a temperature of not lower than 500 °C to a temperature in the range of 350-450 °C and started to be hot rolled; the hot rolling step being finished at a temperature in the range of 200-300 °C; the resultant product being subjected to cold rolling at a reduction ratio of not less than 50 % immediately before it has been solution-treated; the cold rolled product being then solution-treated in which it is retained at a temperature in the range of 500-580 °C at a temperature increasing rate of not less than 2 °C/s for not more than 10 minutes; the resultant product being subjected to hardening in which it is cooled to a temperature of not higher than 100 °C at a cooling rate of not less than 5 °C/s. Thus, a method of manufacturing an aluminum alloy plate for molding is provided which has high strength and moldability and an excellent external appearance of a post-molding surface thereof, and which is suitably used as a material for transportation equipment parts, such as an outer plate for automobiles.

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Description

FIELD OF THE INVENTION

The present invention relates to a method for manufacturing aluminum alloy plate for forming, specifically to a method for manufacturing aluminum alloy plate for forming with favorable press-forming properties, giving excellent appearance after forming, and being suitable for vehicle materials such as automobile external body panels.

DESCRIPTION OF PRIOR ART

From the viewpoint of recent concern about global environmental conservation, weight reduction of vehicles such as automobiles has been positively promoted. Weight reduction by switching from iron and steel materials to aluminum materials is a typical example of an attempt to reduce vehicle weight. Responding to this need, various types of aluminum alloy have been developed. For the aluminum alloy used in automobile external body panels, the Japanese metal industry developed the 5000-Series Al-Mg-Zn-Cu alloys (disclosed in JP-A-103914(1978) and in JP-A-171547(1983)) and Al-Mg-Cu alloys (disclosed in JP-A-219139(1989)) (the term "JP-A-" referred to herein signifies "unexamined Japanese patent publication"), and some of these alloys have already been brought into practical use.

In Western countries, the 6000-Series Al-Mg-Si alloys such as 6009, 6111, and 6016 alloys were produced. Although the 6000-Series aluminum alloys are somewhat inferior to the 5000-Series aluminum alloys in their forming properties, they have sufficient forming characteristics to permit them to be used as automobile external body panels, and they feature high strength due to the application of heat treatment during the coating and baking stage. Accordingly, the 6000-Series aluminum alloys are expected to further reduce plate thickness and applied weight over the 5000-Series. The 6000-Series aluminum alloys have, however, the disadvantage of poor appearance after forming compared with the 5000-Series aluminum alloys.

Typical defects occurring during the forming process include stretcher strain marks (hereinafter referred to simply as "SS marks"), "orange peel" (hereinafter referred to as "rough surface"), and ridging marks. SS marks are likely appear on a material which undergoes large yield elongation during plastic working. SS marks often raise problems, particularly in the 5000-Series alloys. A rough surface is known to appear readily in a material containing coarse crystal grains. Ridging marks are surface irregularities which appear even when the crystal grains are sufficiently fine not to induce a rough surface, but only under conditions where crystal grains with nearly equal crystalline plane orientation to each other are grouped, inducing a significant difference in deformation behavior at the boundary of the group.

Countermeasures such as leveler-correction and preparation of fine crystal grains are applied to counteract SS marks and rough surfaces. As for ridging marks, however, no sufficient study of preventive means has so far been conducted because this type of defect becomes a problem only when extremely high surface quality is needed after the forming of the plate, as in the case of external automobile body panels. The generation of ridging marks, which cause problems, is also often observed during the formation of 6000-Series aluminum alloy plates as external automobile body panels.

DISCLOSURE OF THE INVENTION

The present invention was completed by focusing on the 6000-Series aluminum alloys which are expected to further reduce plate thickness and weight as the materials of vehicles such as external automobile body panels compared with the 5000-Series alloys, and by performing detailed study on the relations among the chemical ingredients, the manufacturing conditions, and the post-forming surface defects (particularly ridging marks) to solve the above-described problems experienced in the 5000-Series alloys. The object of the present invention is to provide a method for manufacturing aluminum alloy plate for forming with high strength and favorable forming properties, and further providing excellent appearance after forming.

The method for manufacturing aluminum alloy plate for forming to achieve the above-described object embodies the first aspect of the present invention which comprises: applying solid solution treatment to an aluminum alloy ingot consisting of between 0.4% and 1.7% of Si, between 0.2 % and 1.2% of Mg, by weight, and heating the remaining Al and inevitable impurities from a temperature range of 500°C to below the melting point of the aluminum alloy; cooling the aluminum alloy ingot from a temperature of 500°C or above to a temperature range between 350 and 450°C; starting hot-rolling the aluminum alloy and ending the hot-rolling at a temperature range between 200 and 300°C; applying cold-rolling to the hot-rolled aluminum alloy to 50% or more of draft immediately before applying solid-solution treatment; heating the cold-rolled aluminum alloy to a temperature range between 500 and 580°C at a rate of 2°C/s or more, followed by holding the heated aluminum alloy for 10 minutes or less to conduct solid-solution treatment; then cooling the aluminum alloy to a temperature of 100°C or below at a rate of 5°C/s or more to effect hardening.

The second aspect of the present invention comprises: aluminum alloy consisting of between 0.4% and 1.7% of Si, between 0.2% and 1.2% of Mg, and at least one element selected from the group of 1.0% or less of Cu, 1.0% or less of Zn, 0.5% or less of Mn, 0.2% or less of Cr, 0.2% or less of Zr, and 0.2% or less of V, by weight, and the remaining Al and inevitable impurities.

The third and fourth aspects of the present invention comprise: soaking an aluminum alloy ingot consisting of 0.8 to 1.3% of Si, 0.3 to 0.8% of Mg, by weight, and the remaining Al and inevitable impurities, or consisting of 0.8 to 1.3% of Si, and 0.3 to 0.8% of Mg, and at least one element selected from the group of 1.0% or less of Cu, 1.0% or less of Zn, 0.5% or less of Mn, 0.2% or less of Cr, 0.2% or less of Zr, and 0.2% or less of V, by weight, and the balance of Al and inevitable impurities, at a temperature range of 500°C to below the melting point of the aluminum alloy; cooling the soaked aluminum alloy ingot from a temperature of 500°C or above to a temperature range of between 350 and 400°C; starting hot-rolling the aluminum alloy and ending the hot-rolling at a temperature range between 200 and 250°C; applying cold-rolling to the hot-rolled aluminum alloy to 80% or more of draft immediately before applying solid-solution treatment; heating the cold-rolled aluminum alloy to a temperature range between 500 and 580°C at a rate of 2°C/s or more, followed by holding the heated aluminum alloy for 1 minute or less to conduct solid-solution treatment; then cooling the aluminum alloy to a temperature of 100°C or below at a rate of 5°C/s or more to effect hardening.

The present invention was derived on the basis of findings that the suppression of ridging mark generation in the 6000-Series aluminum alloys without degrading the forming property needs to specify the alloy composition and requires strict control of soaking conditions, hot-rolling conditions, cold-rolling conditions, and final solid solution treatment conditions. The alloy composition contains essential elements of Si in a range of between 0.4% and 1.7% and of Mg in a range between 0.2% and 1.2%. Silicon and Mg coexist to form Mg_2Si, increasing the strength of the alloy. If the Si content is below 0.4%, sufficient strength cannot be obtained. If the Si content is 1.7% or more, the proof stress during the press-forming of the alloy becomes too high and degrades the forming properties, and the corrosion resistance also degrades. If the Mg content is less than 0.2%, satisfactory strength cannot be attained. If the Mg content is 1.2% or more, the proof stress rises, and the forming properties and the characteristic of precisely producing the press-mold shape during press-forming, or what is called the shape-freezing property, is degraded. To confer further improved anti-denting properties and shape-freezing property after forming to the aluminum alloy plate of the present invention, it is preferable to limit the content of the essential elements to between 0.8 and 1.3% for Si and between 0.3 and 0.8% for Mg.

Other than the above-described essential alloying components, addition of Cu as a selective component to a content of 1.0% or less further increases the strength of the alloy. If the Cu content exceeds 1.0%, corrosion resistance degrades and anti-filiform corrosion properties also degrade. Addition of Zn also improves the strength of alloy. If the Zn content exceeds 1.0%, however, corrosion resistance degrades, and the aging properties at room temperature increase. Therefore, the addition of Zn is limited to 1.0% or less. The addition of 0.5% or less of Mn, 0.2% or less of Cr, 0.2% or less of Zr, and 0.2% or less of V further increases the strength of the alloy and decreases the crystal grain size, inducing favorable effects by preventing rough surface occurrence during the forming process. If these additives are added at above their respective upper limits, generation of coarse intermetallic compounds increases, degrading the forming properties.

According to the present invention, 0.05% or less of Ti, or 0.05% or Ti and 100 ppm or less of B may be added other than the above-specified elements. If the added amount of Ti and B exceeds the respective upper limit, generation of coarse intermetallic compounds increases, degrading the forming properties. The inclusion of Fe as an inevitable impurity is allowed up to 0.3%. If the Fe content exceeds 0.3%, the forming properties, particularly bend-forming property, tend to degrade.

Regarding the manufacturing condition of aluminum alloy of the present invention, an ingot of aluminum alloy having the composition described above is prepared using a semi-continuous casting process, and the ingot is soaked in a temperature range between 500°C and the melting point of the alloy. When the soaking temperature is below 500°C, the removal of ingot segregation and the homogenizing of alloy structure cannot be fully achieved, and the formation of solid solution of Mg_2Si which contributes to the strength of alloy becomes insufficient, which may result in poor forming properties. After soaking, the alloy is not cooled to room temperature but is instead subjected to hot-rolling at a starting temperature range of 350 to 450°C, preferably in a range between 350 and 400°C. If the soaked ingot is cooled to room temperature followed by heating to the temperature of hot-rolling, coarse Mg_2Si deposits appear during the heating process, making the formation of solid solution difficult during the solid solution treatment process, which results in degraded forming properties. If the ingot is cooled to room temperature after being soaked, the ingot needs to be heated to 500°C or above again, then to be cooled to a temperature range between 350 and 450°C, preferably to a range between 350 and 400°C, before beginning hot-rolling.

Hot-rolling begins at a temperature ranging between 350 and 450°C, preferably ranging between 350 and 400°C, and ends at a temperature ranging between 200 and 300°C, preferably ranging between 200 and 250°C. When the starting temperature of hot-rolling is below 350°C, the deformation resistance of the material rises. When the starting temperature exceeds 450°C, the structure grows excessively during the hot-rolling process with a high probability of forming groups of grains having similar crystalline plane orientation in the alloy plate after cold-rolling and after solid solution treatment, and ridging marks are likely appear on the plate surface after press-forming. If the hot-rolling is concluded at a temperature of 300°C or above, secondary recrystallization tends to occur after the rolling, and the structure becomes coarse, resulting in the generation of ridging marks. If the ending temperature of hot-rolling is below 200°C, water-soluble rolling oil stains are likely to remain on the surface of the alloy plate, degrading the surface quality.

After the completion of hot-rolling, intermediate annealing and cold-rolling are carried out, when necessary, to prepare a plate having a specified thickness. Immediately before the solid solution treatment, the plate is cold-rolled to 50% or more of draft, preferably to 80% or more of draft, then the plate is subjected to solid solution treatment. If the draft of the cold-rolling immediately before the solid solution treatment is less than 50%, the crystal grains tend to become coarse after the solid solution treatment, and may result in a rough surface. Furthermore, the decomposition of the hot-rolled structure cannot be fully achieved, easily generating ridging marks, and the forming property degrades.

The solid solution treatment is implemented by heating the material to a temperature ranging between 500 and 580°C at a rate of 2°C/s or more. If the temperature rise speed is less than 2°C/s, the crystal grains become coarse, tending to cause a rough surface during the press-forming process. If the heating temperature is lower than 500°C, the solid solution of deposit becomes insufficient, and the specified strength and forming properties cannot be attained. Even if the specified strength and forming properties are obtained, the heat treatment requires an extremely long period, which is unfavorable from the industrial point of view. If the material is heated to above 580°C, local eutectic fusing is likely to occur, degrading the forming properties. A preferable holding time is 10 minutes or less. Longer than 10 minutes of holding time degrades productivity, which is unfavorable from the point of industrial application. The most preferable holding time is 1 minute or less. After heating, the material is cooled to 100°C or below at a rate of 5°C/s or more. When the cooling speed is less than 5°C/s, coarse compounds deposit at the grain boundary and degrade ductility, thus degrading strength and forming properties.

According to the present invention, a material's composition is selected to provide optimal strength and forming properties, and a combination of ingot soaking, hot-rolling, cold-rolling, and solid solution treatment is applied under specified conditions. Thus a good surface condition after forming is provided by ensuring fine crystal grain size to prevent rough surface generation with random crystal plane orientation while preventing degradation of forming properties.

OPTIMAL MODE FOR CARRYING OUT THE INVENTION

The present invention is described in more detail referring to Examples and Comparative Examples.

Example 1

An aluminum alloy ingot comprising 1.2% of Si, 0.6% of Mg, 0.1% of Mn, 0.2% of Fe, by wt., and the remainder of Al was manufactured using a semi-continuous casting process. The obtained ingot was surface machined, then treated under the conditions given in Table 1 to form a plate 1 mm thick. The prepared plate was subjected to a tensile test. A 200 mm square panel was cut from the plate for press-forming. The formed alloy was visually observed to check for the generation of ridging marks, rough surface, and SS marks, and was tested for intergrain corrosion. Based on the assumption that the plate was coated and baked in the same way as would be an external automobile body panel, heat treatment at 200°C for 30 minutes was given, then the proof stress (post-BH proof stress) was determined. Table 2 shows the test and observed result. As seen in Table 2, all the test materials conforming to the present invention showed excellent strength characteristics such as 100 MPa or more of pre-forming proof stress and 28% or more of elongation, had excellent post-BH proof stress, favorable appearance after being formed, and provided superior corrosion resistance up to 0.1 mm deep.

Table 1

Condition No.	Soaking °C × h	Hot-rolling		Cold-rolling draft %	Solid solution treatment		
		Start °C	End °C		Heating speed °C/s	Holding °C × min	Cooling speed °C/s
1	540 × 8	420	280	80	10	540 × 1	30
2	540 × 8	420	280	80	10	520 × 5	30
3	500 × 8	420	280	80	10	550 × 0.5	100
4	500 × 8	420	280	80	10	540 × 1	15

Table 2

Condition No.	Tensile properties			Post-BH proof stress σ0.2 MPa	Ridging marks	Rough surface	SS mark
	σB MPa	σ0.2 MPa	δ %				
1	236	122	31	233	None	None	None
2	230	114	30	229	None	None	None
3	235	120	31	242	None	None	None
4	229	112	30	231	None	None	None

Comparative Example 1

An aluminum alloy ingot having the same composition as that of Example 1 was manufactured using the semi-continuous casting process. The ingot was treated according to the conditions given in Table 3 to form a plate 1 mm thick. The plate was subjected to the test given in Example 1. The result is shown in Table 4. The values with underline are outside of the condition of the present invention.

Table 3

Condition No.	Soaking °C × h	Hot-rolling		Cold-rolling draft %	Solid solution treatment		
		Start °C	End °C		Heating speed °C/s	Holding °C × min	Cooling speed °C/s
1	540 × 8	520	230	80	10	540 × 1	30
2	540 × 8	480	230	80	10	540 × 1	30
3	540 × 8	420	380	80	10	540 × 1	30
4	540 × 8	420	280	20	10	540 × 1	30
5	540 × 8	420	280	80	0.2	540 × 1	30
6	540 × 8-RT	380	280	80	10	540 × 1	30
7	540 × 8	420	280	80	10	470 × 1	30
〈Note〉 The soaking of 540x8-RT means that the sample was heated to 540°C for 8 hrs., and cooled to room temperature, then re-heated from room temperature to 380°C.							

Table 4

Condition No.	Tensile properties			Post-BH proof stress σ0.2 MPa	Ridging marks	Rough surface	SS mark
	σB MPa	σ0.2 MPa	δ %				
1	238	126	32	235	Present	None	None
2	234	122	31	230	Present	None	None
3	225	119	30	231	Present	None	None
4	226	115	29	227	Present	Present	None
5	237	127	31	235	None	Present	None
6	220	114	26	196	None	None	None
7	162	86	24	119	None	None	None

As seen in Table 4, Conditions No. 1 and No. 2 applied excessively high starting temperature for hot-rolling, and Condition No. 3 applied excessively high hot-rolling ending temperature, so the specimens thus prepared generated ridging marks after forming. Condition No. 8 applied less cold-rolling draft and insufficient decomposition of the specimen's hot-rolled structure so that ridging marks appeared after forming, and a rough surface appeared owing to the formation of coarse crystal grains. Condition No. 9 provided insufficient heating rate in the solid solution treatment so that the crystal grains became too coarse, and press-forming induced a rough surface. Condition No. 10 experienced cooling to room temperature after soaking followed by re-heating to the hot-rolling temperature so that the specimen had insufficient penetration of alloying elements during the solid solution treatment, and the elongation became low and the forming property degraded. Condition No. 11 applied excessively low solid solution treatment temperature so that the deposits were unable to undergo sufficient solid solution formation, so the strength and elongation were poor.

Example 2

An aluminum alloy ingot having the composition given in Table 5 was manufactured by a semi-continuous casting process. After machining the surface, the ingot was treated by Condition No. 1 of Table 1 to form a plate 1 mm thick. The plate was subjected to the test given in Example 1. The result is shown in Table 6. As seen in Table 6, all the specimens A through G, which were manufactured in accordance with the present invention, had a high strength of 100 MPa or more and high elongation of 28% or more, and showed excellent forming properties and appearance after forming. They also showed superior corrosion resistance in intergrain corrosion tests, giving a maximum of 0.1 mm of corrosion depth.

Table 5

Alloy No.	Composition (wt %)								
	Si	Mg	Cu	Mn	Cr	Zn	Zr	V	Fe	Al
A	1.2	0.6	-	0.1	-	-	-	-	0.2	Balance
B	0.8	0.8	-	-	-	-	-	-	0.2	Balance
C	0.6	1.0	0.3	-	0.2	-	-	-	0.2	Balance
D	1.0	0.5	0.6	-	-	-	-	-	0.2	Balance
E	1.2	0.7	-	-	-	0.3	-	-	0.2	Balance
F	1.0	0.6	0.5	-	-	-	0.05	-	0.2	Balance
G	1.0	0.8	-	0.1	-	-	-	0.03	0.2	Balance

Table 6

Alloy No.	Tensile properties			Post-BH proof stress σ0.2 MPa	Ridging marks	Rough surface	SS mark
	σB MPa	σ0.2 MPa	δ %				
A	236	122	31	237	None	None	None
B	233	110	29	229	None	None	None
C	265	143	28	249	None	None	None
D	260	128	30	235	None	None	None
E	241	130	30	245	None	None	None
F	262	129	30	237	None	None	None
G	267	131	29	240	None	None	None

Comparative Example 2

An aluminum alloy ingot having the composition given in Table 7 was manufactured using a semi-continuous casting process. After machining the surface, the ingot was treated according to Condition No. 1 of Table 1 to form a plate 1 mm thick. The plate was subjected to the test given in Example 1. The result is shown in Table 8. As seen in Table 8, the specimen of alloy H contained less Si and Mg so that the strength was low and crystal grains were coarse, generating a rough surface during the forming stage. Alloy I contained less Mg, so that the strength was insufficient, and the content of Cu was excessive so that the corrosion depth increased significantly during the intergrain corrosion test to degrade the corrosion resistance. The alloy J contained an excessive amount of Si so that the strength increased and the elongation decreased, causing unsatisfactory forming properties. The alloy K was A5182 alloy, and it generated SS marks during the forming process, degrading its appearance. In Table 7, underlined values are outside of the conditions of the present invention.

Table 7

Alloy No.	Composition (wt %)					
	Si	Mg	Cu	Mn	Fe	Al
H	<u>0.3</u>	0.2	-	-	0.2	Balance
I	0.8	0.2	<u>1.2</u>	-	0.2	Balance
J	<u>2.0</u>	0.9	-	-	0.2	Balance
K	0.1	<u>4.5</u>	-	0.3	0.2	Balance

Table 8

Alloy No.	Tensile properties			Post-BH proof stress σB MPa	Ridging marks	Rough surface	SS mark
	σB MPa	σ0.2 MPa	δ %				
H	130	63	32	88	None	Present	None
I	162	89	25	106	None	None	None
J	286	173	24	280	None	None	None
K	284	130	29	132	None	None	Present

INDUSTRIAL APPLICABILITY

As described above, the present invention provides a method for manufacturing aluminum alloy plate for forming with excellent strength and forming properties, particularly excellent press-forming properties, with a good appearance after forming, and suitable for vehicle materials such as automobile external body panels.

Claims

1. A method for manufacturing aluminum alloy plate for forming comprising: soaking an aluminum alloy ingot consisting of between 0.4% and 1.7% of Si, between 0.2 % and 1.2% of Mg, by weight, and the balance of Al and inevitable impurities at a temperature range between 500°C and below the melting point of the aluminum alloy; cooling the soaked aluminum alloy ingot from 500°C or above to a temperature range between 350 and 450°C; starting hot-rolling the aluminum alloy and ending the hot-rolling in a temperature range between 200 and 300°C; applying cold-rolling to the hot-rolled aluminum alloy to 50% or more of draft immediately before applying solid-solution treatment; heating the cold-rolled aluminum alloy to a temperature range between 500 and 580°C at a rate of 2°C/s or more, followed by holding the heated aluminum alloy for 10 minutes or less to conduct solid-solution treatment; then cooling the aluminum alloy to a temperature of 100°C or below at a rate of 5°C/s or more to effect hardening.

2. A method for manufacturing aluminum alloy plate for forming of Claim 1, wherein the aluminum alloy consists of between 0.4% and 1.7% of Si, between 0.2% and 1.2% of Mg, and at least one element selected from the group of 1.0% or less of Cu, 1.0% or less of Zn, 0.5% or less of Mn, 0.2% or less of Cr, 0.2% or less of Zr, and 0.2% or less of V, by weight, and balance of Al and inevitable impurities.

3. A method for manufacturing aluminum alloy plate for forming comprising: soaking an aluminum alloy ingot consisting of between 0.8 and 1.3% of Si, between 0.3 and 0.8% of Mg, by weight, and balance of Al and inevitable impurities at a temperature range between 500°C and below the melting point of the aluminum alloy; cooling the soaked aluminum alloy ingot from a temperature of 500°C or above to a temperature range between 350 and 400°C; starting hot-rolling the aluminum alloy and ending the hot-rolling at a temperature range between 200 and 250°C; applying cold-rolling to the hot-rolled aluminum alloy to 80% or more of draft immediately before applying solid-solution treatment; heating the cold-rolled aluminum alloy to a temperature range between 500 and 580°C at a rate of 2°C/s or more, followed by holding the heated aluminum alloy for 1 minute or less to carry out solid-solution treatment; then cooling the aluminum alloy to a temperature of 100°C or below at a rate of 5°C/s or more to effect hardening.

4. A method for manufacturing aluminum alloy plate for forming of Claim 3, wherein the aluminum alloy consists of between 0.8 and 1.3% of Si, and between 0.3 and 0.8% of Mg, and at least one element selected from the group of 1.0% or less of Cu, 1.0% or less of Zn, 0.5% or less of Mn, 0.2% or less of Cr, 0.2% or less of Zr, and 0.2% or less of V, by weight, and the balance of Al and inevitable impurities.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP95/00200

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl6 C22F1/05, C22C21/02

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)

Int. Cl6 C22F1/05, C22F1/04, C22C21/02

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

Jitsuyo Shinan Koho 1926 - 1994
Kokai Jitsuyo Shinan Koho 1971 - 1994

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.
Y	JP, A, 64-11937 (Sky Aluminum K.K.), January 17, 1989 (17. 01. 89), Line 6, lower left column, page 1 to line 9, lower left column, page 2 & US, A, 4897124	1 - 4
Y	JP, A, 3-170635 (Sky Aluminum K.K.), July 24, 1991 (24. 07. 91), Line 16, lower right column, page 1 to line 15, lower left column, page 2 (Family: none)	1 - 4
Y	JP, A, 3-294456 (Kobe Steel, Ltd.), December 25, 1991 (25. 12. 91), Line 6, lower left column to line 3, lower right column, page 1 (Family: none)	1 - 4
Y	JP, A, 5-43974 (NKK Corp.), February 23, 1993 (23. 02. 93), Lines 19 to 32, column 1 (Family: none)	1 - 4

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
April 28, 1995 (28. 04. 95)	May 23, 1995 (23. 05. 95)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)