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(54) **HEAT-RESISTANT ALUMINUM ALLOY AND PROCESS FOR ITS PRODUCTION.**

(57) A heat-resistant aluminum alloy, which contains 5 to 10 wt % of iron, 0.5 to 3 wt % of molybdenum 0.5 to 3 wt % of at least one element selected from among chromium, zirconium and vanadium, with the sum of iron, molybdenum, chromium, zirconium and vanadium being 6 to 16 wt %, and the balance of substantially aluminum, and which has a tensile strength at 300°C of 26kg/mm^2 or more. This alloy can be produced by preparing an aluminum alloy powder of the above-described formulation according to the melt atomizing process and solidifying and molding the product at temperatures of 400 to 580°C.

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TITLE MODIFIED see front page

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SPECIFICATION

HEAT RESISTANT ALUMINUM ALLOY AND PREPARATION THEREOF

FIELD OF THE INVENTION

The present invention relates to a heat resistant aluminum ally which can be used in automobile engine parts and aircraft parts.

CONVENTIONAL ART

Hitherto, as heat resistant aluminum alloys, 2218, 2219, 2618 and the like are known. However, the aluminum alloys are required to have much better heat resistance in accordance with the technological progress.

To provide highly heat resistant aluminum alloys, recently, it is proposed to improve high-temperature strength by the addition of a considerable amount of a transition metal such as iron, which has been avoided since it deteriorates the properties of the alloys, to the alloys.

Since such kinds of aluminum alloys contain the considerable amount of the transition metal such as iron, they cannot be produced by the conventional casting method. Therefore, they are produced by consolidating the alloy powder prepared by the melt atomizing method.

In fact, such the aluminum alloys have improved heat resistance as reported in "Advanced in Powder Technology"; "Advanced P/M Aluminum Alloys", 213-214, 1981: ASM Material Science Seminor published by AMERICAN SOCIETY FOR

METALS, and some of them are reported to have tensile strength of about 30 kg/mm^2 at 300°C. However, such alloys cannot be prepared with good reproducibility and have not been practically used.

For parts which are exposed to high temperatures such as the aircraft engine parts, impellers of gas turbine engines and engine pistons, materials are required to have tensile strength of 25 kg/mm^2 or larger, preferably larger than 30 kg/mm^2 at 300°C. However, none of the already developed heat resistant aluminum alloys satisfies this requirement practically.

DISCLOSURE OF THE INVENTION

In view of the above circumstances, an object of the present invention is to provide a heat resistant aluminum alloy which has high tensile strength of larger than 26 kg/mm^2 at high temperature of 300°C.

The heat resistant aluminum alloy of the present invention comprises 5 to 10 % by weight of iron, 0.5 to 3 % by weight of molybdenum, 0.5 to 3 % by weight of at least one element selected from the group consisting of chromium, zirconium and vanadium and rest of aluminum, provided that the total amount of iron, molybdenum, chromium, zirconium and vanadium is from 6 to 16 % by weight, and has the tensile strength of larger than 26 kg/mm^2 at 300°C.

Such the heat resistant aluminum alloy can be produced from powder of an aluminum alloy comprising 5 to 10

% by weight of iron, 0.5 to 3 % by weight of molybdenum, 0.5 to 3 % by weight of at least one element selected from the group consisting of chromium, zirconium and vanadium and rest of aluminum with the proviso that the total amount of iron, molybdenum, chromium, zirconium and vanadium is from 6 to 16 % by weight. The powder is produced by a melt atomizing method and consolidated by hot working method at a temperature of 400 to 580°C.

The "melt atomizing method" herein used includes all the methods which comprise spraying metal alloy melt having a desired alloy composition and solidifying it quickly, and an air atomizing method, a gas atomizing method, a centrifugal atomizing method and a rotational roll atomizing method are exemplified.

As the method for consolidating the aluminum alloy powder, extrusion, forging, hot press and HIP are exemplified.

As described above, in the conventional techniques for improving the heat resistance of the aluminum alloy, the transition metal element such as iron is added to the aluminum alloy so as to increase the strength of matrix and also to form a thermally stable intermetallic compound.

According to the study by the present inventors, it was found that the transition metals have two kinds of the effects on the strength of the alluminum alloys. One is increase of the strength of the aluminum alloy and another is maintenance and improvement of the thermal stability of the aluminum alloys. Then, the combination of these two kinds of the transition elements will provide the aluminum alloy with much higher heat resistance.

It is generally known that, among the additive elements, the addition of iron gives the largest strength and heat resistance among the transition elements. The iron atoms form the intermetallic compound: Al_3Fe, the precipitates are dispersed in the matrix, and then increases the strength of the matrix. Since said intermetallic compound has large heat resistance, it effectively improve the high-temperature strength of the alloy.

Molybdenum contributes to the improvement of the strength of the alloy. Molydbenum forms an Al-Fe-Mo base compound, which is uniformly dispersed in the matrix and improves not only the strength of the matrix but also the heat resistance of the alloy.

To further increase the thermal stability, at least one element selected from the group consisting of chromium, zirconium and vanadium is added to the aluminum alloy, and metallic compounds consisting of these elements are precipitated on grain boundaries and will inhibit the excessive growth of crystal grains and the dispersed Al-Fe-Mo compound at high temperatures. Thereby, they significantly improve the high-temperature strength of the aluminum alloy.

The contents of these elements in the aluminum alloy are as specified above. If any one of the additive elements is contained in an amount of less than the above lower limit, the strength and heat resistance of the aluminum alloy are insufficiently improved. If any one of the additive element is used in an amount of larger than the above upper limit, plastic working of the aluminum alloy becomes difficult and toughness and ductility of the aluminum alloy are greatly decreased so that the aluminum alloy cannot be practically used, although the strength and heat resistance of the aluminum alloy are highly improved.

The aluminum alloy powder produced by the melt atomizing method is more fine and homogeneous and has less segregation than those produced by casting. However, when the cooling rate during solidification is less than 10^2 °C/sec., the additive element such as iron, molybdenum, vanadium, zirconium or chromium is segregated to make the structure uniform, so that the compacting and plastic deformation of the aluminum alloy powder become difficult. Even if the compacting is possible, the strength and elongation of the aluminum alloy are undesirably decreased.

During hot plastic working of the aluminum alloy powder for consolidating, at a temperature of lower than 400°C, deformation resistance is too high to produce alloys with sufficient strength, while at a temperature of higher than 580°C, the precipitates and the crystal grains grow so large that sufficient high-temperature strength of the aluminum alloy is not achieved.

The present invention will be illustrated by following Examples.

Examples

Aluminum alloy powder having the composition of Table 1 was prepared by the air atomizing method and screened to 100 mesh or less. The alloy powder was consolidated by zone hot plastic working method at the temperature specified in Table 1. In extrusion, the alloy was consolidated at the extrusion ratio of 13 to form a rod of 21 mm in diameter.

Table 1

Sample No.	Composition (wt%)	Molding method	Temperature (°C)
1	Al-8Fe-2Mo-2Cr	Extrusion	480
2	Al-8Fe-2Mo-2V	Extrusion	480
3	Al-8Fe-2Mo-2Zr	Extrusion	480
4	Al-8Fe-2Mo-1V-1Cr	Extrusion	450
5	Al-8Fe-2Mo-2Cr	Forging	520
6	Al-8Fe-2Mo-2Cr	HIP, 4 ton/cm^2	550
7	Al-8Fe-2Mo-2Cr	HIP, 2 ton/cm^2	500
8*	Al-10Fe-5Mo-5Cr	Extrusion	550
9*	Al-4Fe-0.2Mo-0.2Cr	Extrusion	450
10*	Al-8Fe-2Mo-2Cr	Extrusion	620
11*	Al-8Fe-2Mo	Extrusion	480
12*	Al-8Fe-1Zr	Extrusion	480
13*	Al-8Fe-3Cr	Extrusion	480
14*	Al-10Fe-2Cr	Extrusion	500

Note: Sample Nos. with * were the comparative examples.

With the produced aluminum alloy, tensile strength at room temperature and at 300°C was measured. The results are shown in Table 2. The tensile strength at 300°C was measured after keeping the aluminum alloy sample at 300°C for 100 hours.

Table 2

Sample No.	Tensile strength (kg/mm^2)		Remarks
	At room temp.	At 300°C	
1	57	33	Elongation, 2.3 %
2	55	31	Elongation, 3.6 %
3	58	30	Elongation, 2.1 %
4	53	27	
5	56	29	
6	55	27	
7	55	28	
8*	58	34	Elongation less than 1 % Extrusion clog at 500°C
9*	42	22	
10*	52	24	
11*	40	21	
12*	31	16	
13*	36	21	
14*	43	24	
15*	52	26	
16*	45	29	

Note: Sample Nos. with * were the comparative examples.

Sample Nos. 15 and 16 had the compositions of Al-8Fe-3.4Ce and Al-8Fe-2Mo, respectively and corresponded to the conventional alloys disclosed in Advanced P/M Aluminum Alloys, pages 213-214.

The tensile strength of the aluminum alloys of examples according to the present invention was larger than 50 kg/mm^2 at room temperature and larger than 26 kg/mm^2 at 300°C. From these results, it is understood that the aluminum alloys of the present invention have excellent high-temperature strength. On the contrary, the aluminum alloys of the comparative examples had inferior high-temperature strength in particular. Although Sample No. 8 had good strength, it had poor plastic workability and considerably small elongation so that it cannot be processed practically.

According to the present invention, there is provided the heat resistant aluminum alloy having not only the good room temperature strength but also such excellent high-temperature strength that its tensile strength exceeds 26 kg/mm^2 at 300°C.

Therefcre, the heat resistant aluminum alloy can be used for the production of automobile engine parts, aircraft parts, gas turbine engine parts, etc, which are conventionally produced from iron base alloys or nickel base alloys, whereby it is possible to make those parts light and highly efficient.

What is claimed is:

1. A heat resistant aluminum alloy which comprises 5 to 10 % by weight of iron, 0.5 to 3 % by weight of molybdenum, 0.5 to 3 % by weight of at least one element selected from the group consisting of chromium, zirconium and vanadium and rest of aluminum, provided that the total amount of iron, molybdenum, chromium, zirconium and vanadium is from 6 to 16 % by weight, which alloy has tensile strength of larger than 26 kg/mm^2 at 300°C.

2. A process for producing a heat resistant aluminum alloy, which comprises preparing powder of an aluminum alloy comprising 5 to 10 % by weight of iron, 0.5 to 3 % by weight of molybdenum, 0.5 to 3 % by weight of at least one element selected from the group consisting of chromium, zirconium and vanadium and rest of aluminum with the proviso that the total amount of iron, molybdenum, chromium, zirconium and vanadium is from 6 to 16 % by weight by a melt atomizing method, and solidifying said aluminum alloy powder at a temperature of 400 to 580°C.

3. The process according to claim 1, wherein the cooling rate in the solidification of the aluminum alloy powder is not less than 10^2 °C/sec.

INTERNATIONAL SEARCH REPORT

International Application No PCT/

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl[4] C22C21/00, 1/04, B22F9/08

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	C22C1/04, 21/00, B22F1/00, 9/08

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	JP, A, 60-234936 (Sumitomo Light Metal Industries, Ltd.) 21 November 1985 (21. 11. 85) Claim, page 2, lower right column, lines 4 to 14, page 3, Table 1, Gokin No. 3, 6 of Table 2 (Family: none)	1-3
X	JP, A, 61-48551 (Sumitomo Light Metal Industries, Ltd.) 10 March 1986 (10. 03. 86) Claim 2, page 2, lower right column, lines 8 to 19, page 3, Table 1, Gokin No. 5, 10 of Table 2 (Family: none)	1-3
X	JP, A, 61-52343 (Sumitomo Light Metal Industries, Ltd.) 15 March 1986 (15. 03. 86) Claim, page 2, lower right column, lines 12 to 20, page 3, Table 1, Gokin No. 2, 5 of Table 2, page 3, lower right column, lines 3 to 10	1-3

* Special categories of cited documents: [10]

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

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

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

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

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
January 23, 1989 (23. 01. 89)	January 30, 1989 (30. 01. 89)
International Searching Authority	**Signature of Authorized Officer**
Japanese Patent Office	

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

	(Family: none)	
X	JP, A, 62-33738 (Toyo Aluminium Kabushiki Kaisha) 13 February 1987 (13. 02. 87) Claims 1, 2, page 4, Table 1 and page 5, Sample No. 1 of Table 2 (Family: none)	1-3
X	JP, A, 62-47447 (Toyo Aluminium Kabushiki Kaisha) 2 March 1987 (02. 03. 87) Claims 1, 2 (Family: none)	1-3

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ...., because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers ...., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim numbers ...., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

International Application No. PCT/JP88/01037

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

P	JP, A, 62-250145 (Toyo Aluminium Kabushiki Kaisha) 31 October 1987 (31. 10. 87) Claims 1, 2, Table 1 of page 3 and Sample No. 2, 3 of page 4, Table 2, (Family: none)	1-3
X	JP, A, 60-248860 (Allied Corp.) 9 December 1985 (09. 12. 85) Claims 1, 6, page 3, lower right column, lines 1 to 5, page 8, upper left column, lines 8 to 9 & EP, A2, 136,508	1-3

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

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