

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11)

EP 1 331 281 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
18.05.2005 Bulletin 2005/20

(51) Int Cl.7: **C22C 21/02, C22C 21/04**

(21) Application number: **03000610.0**

(22) Date of filing: **14.01.2003**

(54) **Aluminum alloy for die casting, die casting method using same alloy, and die casting product by same method**

Aluminiumlegierung zum Druckgiessen, Herstellungsverfahren durch Druckgiessen dieser Legierung, und durch dieses Verfahren hergestelltes druckgegossenes Produkt

Alliage d'aluminium pour moulage sous pression, méthode de moulage sous pression avec cet alliage, et produit moulé sous pression obtenu par cette méthode

(84) Designated Contracting States:
DE FR GB

(30) Priority: **18.01.2002 JP 2002009839**

(43) Date of publication of application:
30.07.2003 Bulletin 2003/31

(73) Proprietors:
• **NISSAN MOTOR COMPANY, LIMITED**
Yokohama-shi, Kanagawa 221-0023 (JP)
• **Nippon Light Metal, Co. Ltd.**
Shinagawa-ku, Tokyo 140-0002 (JP)

(72) Inventors:
• **Kitaoka, Sanji**
Fuji-shi, Shizuoka 416-0907 (JP)
• **Kuramasu, Yukio**
Shizuoka-shi, Shizuoka 422-8044 (JP)
• **Sumi, Shinichiro**
Ihara-gun, Shizuoka 421-3203 (JP)
• **Tsushima, Kenji**
Yokohama-shi, Kanagawa 236-0057 (JP)
• **Kambe, Hiroshi**
Miura-shi, Kanagawa 238-0114 (JP)

• **Shioda, Masahiko**
Yokohama-shi, Kanagawa 240-0024 (JP)

(74) Representative: **Grünecker, Kinkeldey,**
Stockmair & Schwanhäusser Anwaltssozietät
Maximilianstrasse 58
80538 München (DE)

(56) References cited:
EP-A- 0 687 742

• **PATENT ABSTRACTS OF JAPAN** vol. 1999, no. 04, 30 April 1999 (1999-04-30) -& JP 11 012705 A (SUMITOMO LIGHT METAL IND LTD), 19 January 1999 (1999-01-19)
• **PATENT ABSTRACTS OF JAPAN** vol. 1997, no. 09, 30 September 1997 (1997-09-30) -& JP 09 125181 A (SUMITOMO LIGHT METAL IND LTD), 13 May 1997 (1997-05-13)
• **PATENT ABSTRACTS OF JAPAN** vol. 017, no. 648 (M-1518), 2 December 1993 (1993-12-02) -& JP 05 208296 A (KOBE STEEL LTD), 20 August 1993 (1993-08-20)

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 1 331 281 B1

Description**BACKGROUND OF THE INVENTION**

[0001] This invention relates to improvements in aluminum alloy for a die casting which alloy can obtain excellent mechanical properties upon die casting, and more particularly to the aluminum alloy for a die casting which alloy is excellent in static and dynamic mechanical performances and suitable to be applicable to vehicle body parts of an automotive vehicle such as various pillars, a roof, a joint of a space frame and an installation section of a suspension, and suspension parts of the automotive vehicle such as a suspension arm, a sub-frame, link parts of a suspension and an engine cradle, and further relates to a die casting product using the aluminum alloy and to a production method for the die casting product.

[0002] The die casting has been hitherto extensively used for producing parts of an engine and parts of a transmission of an automotive vehicle for the reasons why a casting having thin walls can be obtained, a dimensional accuracy is high, a productivity is high, and freedom in selecting a shape is high, and the like. In recent years, a joint of a space frame, a center pillar and the like constituting a vehicle body have become formed of an aluminum alloy die casting which is adjusted in mechanical properties such as tensile strength, 0.2 % proof stress, elongation and the like by applying a heat treatment on a die casting which has been produced by a vacuum die casting. As such an aluminum alloy for die casting, "365 alloy" according to Aluminum Association Standard is extensively used in Europe and the United States of America as disclosed in Japanese Patent Provisional Publication No. 8-41575.

[0003] Now, it is expected in the future that environmental protective measures and excellent fuel economy are further strictly required for vehicles. In order to meet this requirement, weight-lightening of the vehicle is a very important technique. In this regard, it is further required to achieve the weight-lightening technique at low cost from the viewpoint of cost competitiveness. In view of these, application of the aluminum alloy die casting seems to be one of favorable measures for coping with the requirements.

SUMMARY OF THE INVENTION

[0004] However, conventional aluminum alloys for die casting have not so high balance between strength and elongation, and therefore there are limits in kinds of parts to which the alloys are applicable and in effect for weight-lightening. Accordingly, it is eagerly desired to develop an aluminum alloy for die casting having a high balance between strength and elongation.

[0005] Vehicle body parts of an automotive vehicle such as various pillars, joint sections of space frames are required to stably have high strength and elongation even in a high speed deformation region for the purpose of securing safety in the event of vehicle collision. In this regard, discussion of static strength and elongation has been made on the conventional aluminum alloys for die casting. However, no discussion has been made on measures for stably obtaining high strength and elongation in a high strain rate region at a level of 1000/s in connection with the conventional aluminum alloys. Thus, the conventional aluminum alloys for die casting have a theme to solve the above problems.

[0006] It is, therefore, an object of the present invention to provide an improved aluminum alloy for a die casting which alloy can overcome drawbacks encountered in conventional aluminum alloys for die casting.

[0007] Another object of the present invention is to provide an improved aluminum alloy for a die casting which alloy can stably exhibit high strength and elongation in a high strain rate region in case of application as parts of an automotive vehicle, thereby enabling the body part to be further weight-lightened.

[0008] A further object of the present invention is to provide an improved aluminum alloy for a die casting, in which primary crystal α -phase is fined by single and large amount addition of B thereby ensuring an excellent balance between strength and elongation, while eutectic Si particle is fined by addition of Sb thereby ensuring further improved elongation and toughness.

[0009] A still further object of the present invention is to provide an improved method of producing a die casting product using the improved aluminum alloy, by which method the die casting product can be effectively obtained without lowering the excellent mechanical properties or performances (particularly the elongation and toughness) possessed by the improved aluminum alloy.

[0010] A still further object of the present invention is to provide an improved die casting product such as parts of an automotive vehicle, which product is high in strength and elongation in a high strain rate region such as vehicle collision, thereby enabling the parts to be further weight-lightened.

[0011] An aspect of the present invention resides in an aluminum alloy for a die casting, comprising or consisting essentially of Si in an amount ranging from 10 to 12 % by weight, Mg in an amount ranging from 0.15 to 0.50 % by weight, Mn in an amount ranging from 0.5 to 1.0 % by weight, Fe in an amount of not more than 0.15 % by weight, Ti in an amount of not more than 0.1 % by weight, Sb in an amount ranging from 0.05 to 0.20 % by weight, B in an amount ranging from 0.005 to 0.02%, and balance consisting of aluminum and inevitable impurities.

[0012] Another aspect of the present invention resides in a method of producing a die casting product. The method comprises forming an aluminum alloy into a die casting by high vacuum die casting to obtain the die casting product. The aluminum alloy comprises or consists essentially of Si in an amount ranging from 10 to 12 % by weight, Mg in an amount ranging from 0.15 to 0.50 % by weight, Mn in an amount ranging from 0.5 to 1.0 % by weight, Fe in an amount of not more than 0.15 % by weight, Ti in an amount of not more than 0.1 % by weight, Sb in an amount ranging from 0.05 to 0.20 % by weight, B in an amount ranging from 0.005 to 0.02%, and balance consisting of aluminum and inevitable impurities.

[0013] A further aspect of the present invention resides in a die casting product produced by the method comprising forming an aluminum alloy into a die casting by high vacuum die casting to obtain the die casting product. The aluminum alloy comprises or consists essentially of Si in an amount ranging from 10 to 12 % by weight, Mg in an amount ranging from 0.15 to 0.50 % by weight, Mn in an amount ranging from 0.5 to 1.0 % by weight, Fe in an amount of not more than 0.15 % by weight, Ti in an amount of not more than 0.1 % by weight, Sb in an amount ranging from 0.05 to 0.20 % by weight, B in an amount ranging from 0.005 to 0.02%, and balance consisting of aluminum and inevitable impurities.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

Fig. 1 is a sectional view of a cavity (corresponding to a product) of dies of a high vacuum die casting machine, the product being used for evaluation of mechanical properties in Experiment 1;

Fig. 2 is a plan view of a specimen used in a static tensile test for an aluminum alloy die casting in Experiment 1;

Fig. 3 is a plan view of a specimen used in a dynamic tensile test for the aluminum alloy die casting in Experiment 1;

Fig. 4 is a schematic illustration showing the principle of a One-Bar Method high speed tensile tester used for the dynamic tensile test in connection with Fig. 3;

Fig. 5A is a plan view of a specimen used for macrography of an aluminum alloy die casting in Experiment 2;

Fig. 5B is a front view of the specimen of Fig. 5A;

Fig. 5C is a side view of the specimen of Fig. 5A;

Fig. 6A is a photograph showing the macro-structure of the aluminum alloy die casting of Example 1;

Fig. 6B is a photograph showing the macro-structure of the aluminum alloy die casting of Comparative Example 3;

Fig. 6C is a photograph showing the macro-structure of the aluminum alloy die casting of Comparative Example 4;

Fig. 6D is a photograph showing the macro-structure of the aluminum alloy die casting of Comparative Example 5; and

Fig. 7 is a graph showing changes of the concentration of B with lapsed time, in the molten metals of Example 4, Comparative Example 6 and Comparative Example 7 in connection with Experiment 2.

DETAILED DESCRIPTION OF THE INVENTION

[0015] According to the present invention, an aluminum alloy for a die casting, comprises or consists essentially of Si in an amount ranging from 10 to 12 % by weight, Mg in an amount ranging from 0.15 to 0.50 % by weight, Mn in an amount ranging from 0.5 to 1.0 % by weight, Fe in an amount of not more than 0.15 % by weight, Ti in an amount of not more than 0.1 % by weight, Sb in an amount ranging from 0.05 to 0.20 % by weight, B in an amount ranging from 0.005 to 0.02 % by weight, and balance consisting of aluminum and inevitable impurities. In the aluminum alloy, Sb in the amount ranging from 0.05 to 0.20 % by weight may be replaced with Sr in an amount ranging from 0.005 to 0.020 % by weight.

[0016] A method of producing a die casting product according to the present invention comprises forming the aluminum alloy into a die casting by high vacuum die casting to obtain the die casting product. In the producing method, the obtained die casting product is preferably subjected to a solution treatment at a temperature of not lower than 530 °C for a time of not longer than 1 hr., and thereafter subjected to an aging treatment.

[0017] The die casting product according to the present invention is preferably a vehicle body part of an automotive vehicle, such as a so-called A pillar, a so-called B pillar, a so-called C pillar, a roof, a joint of a space frame or an installation section of a suspension, or a suspension part of an automotive vehicle such as a suspension arm, a sub-frame, a link part of a suspension or an engine cradle. The A pillar is, for example, a pillar located between the window glass of a front windshield and a front door in a sedan-type passenger car. The B pillar is, for example, a pillar located between the window glass of a front door and the window glass of a rear door in the sedan-type passenger car. The C pillar is, for example, a pillar located between the window glass of the rear door and a rear window glass in the sedan-type passenger car. The space frame is a frame structure which is constituted by connecting pipes or the like and usually used in a vehicle body of aluminum.

[0018] Hereinafter, discussion will be made on composition of the aluminum alloy according to the present invention

and reasons for determining conditions of treatments and the like along with effects obtained by the compositions and the conditions.

(1) Si: 10 to 12 % by weight

[0019] Si is an element effective for improving the flowability of molten metal during die casting. If the content of Si is less than 10 % by weight, the effect is little. If the amount of Si exceeds 12 % by weight, the crystallization amount of eutectic Si increases or the primary crystal Si crystallizes thereby lowering the elongation and toughness in a high strain rate region such as during vehicle collision. Accordingly, the Si content is within the range of from 10 to 12 % by weight.

(2) Mg: 0.15 to 0.5 % by weight

[0020] Mg is an element contributable for improving the strength by crystallization of Mg_2Si during the aging treatment upon coexistence of Si. If the content of Mg is less than 0.15 % by weight, the effect of improving the strength is little. If the content of Mg exceeds 0.5 % by weight, the crystallization amount of Mg_2Si increases thereby lowering the elongation and toughness. Consequently, the Mg content is set within the range of from 0.15 to 0.5 % by weight.

(3) Mn: 0.5 to 1.0 % by weight

[0021] Mn is an element contributable for improving the strength by forming fine intermetallic compound upon coexistence of Fe and Si. Additionally, Mn is an element contributable for preventing burning of a product to a die during die casting. If the content of Mn is less than 0.5 % by weight, the sufficient effect cannot be obtained. If the content of Mn exceeds 1.0 % by weight, coarse Al-Mn-Fe-Si-based intermetallic compounds crystallize thereby lowering the elongation (particularly, elongation in the high strain rate region). Consequently, the Mn content is set within the range of from 0.5 to 1.0 % by weight.

(4) Fe: not more than 0.15 % by weight

[0022] Fe is an element for preventing burning of the product to the die during die casting. If the content of Fe exceeds 0.15 % by weight, the crystallization amount of needle-like Fe-based intermetallic compound increases thereby lowering the elongation and toughness. Consequently, the Fe content is set at a value of not more than 0.15 % by weight.

(5) Ti: not more than 0.1 % by weight

B: 0.005 to 0.02 % by weight

[0023] It has been hitherto said that Ti and B are elements effective for improving the mechanical properties of aluminum casting because TiB_2 formed upon addition of Ti and B serves as a heterogeneous nuclear of aluminum solid solution thereby fining the primary crystal $\alpha(Al)$ -phase. However, as a result of research and development of the inventors, it has newly become apparent in the alloy of the present invention that composite addition of Ti and B provides no effect for fining the primary crystal α -phase, and that addition of a large amount of only B fines the primary crystal α phase thereby improving the mechanical properties of the alloy. Additionally, it has also become apparent that a change of B concentration upon lapse of time is not found in case of addition of only B, whereas sedimentation of TiB_2 occurs to lower the concentration of B thereby reducing the effect of fining the primary crystal α phase in case of the composite addition of Ti and B.

[0024] In view of the above, in the alloy according to the present invention, Ti seems to be an impurity element for impeding fining of the primary crystal α -phase, and therefore the content of Ti is set within a range of not more than 0.1 % by weight. B is the element for improving the mechanical properties of the alloy by fining the primary crystal α phase, in which the content of B is set within a range of from 0.05 to 0.02 % by weight because the effect is little if the B content is less than 0.05. The effect of fining the primary crystal α -phase upon addition of B will be discussed in detail with reference to Examples after.

(6) Sb: 0.05 to 0.20 % by weight

Sr: 0.005 to 0.020 % by weight

[0025] Sb and Sr are elements contributable for improving the elongation and toughness by fining eutectic Si particle

crystallized in Al-Si based die casting. If the contents of Sb and Sr are respectively less than 0.05 and less than 0.005 % by weight, the effects are little. If the contents of Sb and Sr respectively exceed 0.20 and 0.020 % by weight, inter-metallic compound of Al is formed thereby lowering the elongation and toughness. Consequently, the contents of Sb and Sr are respectively set within the range of from 0.05 to 0.20 % by weight and the range of from 0.005 to 0.020 % by weight. It has become apparent in the alloy of the present invention that Sb is larger in effect than Sr.

(7) Solution treatment temperature: not lower than 530 °C

Solution treatment time: not longer than 1 hour

[0026] In order to obtain a die casting having further improved elongation and toughness by using the aluminum alloy for a die casting, it is effective to fine and granulate eutectic Si particle crystallized during die casting. For this purpose, the solution treatment is a very effective measure. However, if the solution treatment is carried out at a temperature exceeding 530 °C and a time exceeding 1 hour, spheroidization of eutectic Si progresses while coarsening the eutectic Si. If the solution treatment is carried out at a temperature lower than 530 °C, it is difficult to accomplish both the fining and granulating the eutectic Si particle. Consequently, the solution treatment temperature is set at a value not lower than 530 °C, and the solution treatment time is set at a value not longer than 1 hour.

EXAMPLES

[0027] The present invention will be more readily understood with reference to the following Examples in comparison with Comparative Examples; however, these Examples are intended to illustrate the invention and are not to be construed to limit the scope of the invention.

EXPERIMENT 1

[1] Composition of Aluminum Alloy for Die Casting

[0028] Aluminum alloys of Examples 1 to 3 and Comparative Examples 1 to 3 and raw materials for the aluminum alloys had respectively compositions shown in Table 1. The Comparative Examples 1 and 2 corresponded to the "365 alloy" according to Aluminum Association Standard.

Table 1

Items		Chemical composition (wt.%)								
		Si	Mg	Mn	Fe	Ti	Sb	Sr	B	Al
Example	1	10.7	0.24	0.73	0.04	0.001	0.10	-	0.009	Balance
	2	10.9	0.27	0.72	0.05	0.0009	0.10	-	0.005	Balance
	3	11.0	0.26	0.68	0.05	0.001	-	0.010	0.010	Balance
Comparative Example	1	10.5	0.25	0.67	0.07	0.10	-	0.009	-	Balance
	2	10.4	0.27	0.70	0.06	0.11	-	0.011	0.002	Balance
	3	10.6	0.25	0.71	0.04	0.15	0.09	-	0.006	Balance

[2] Melting and Die Casting

[0029] Each aluminum alloy of Examples and Comparative Examples shown in Table 1 was produced upon melting at 750 °C, thus preparing molten metal of the aluminum alloy. The aluminum alloy molten metal was subjected to a bubbling treatment with argon gas for the purpose of removal of inclusions and degasification.

[0030] The molten metal of the aluminum alloy underwent die casting by using a high vacuum die casting machine having a clamping force of 320 tons, after coating a mold releasing agent onto the cavity of dies, under the following conditions: a casting pressure was 60 MPa, a high speed injection rate was 3.5 m/s, a degree of vacuum within a sleeve through which the molten metal flowed was 0.96 atmosphere, and a degree of vacuum of a vacuum valve section was 0.95 atmosphere. The temperature of the molten metal during die casting was 680 °C. The cavity of the dies had such a cross-sectional shape shown in Fig. 1, which corresponded to a product (specimen material) having a thickness of 2 mm and a length of 410 mm.

[3] Heat Treatment

[0031] The product or die casting produced as discussed above was subjected to the solution treat at 540 °C for 30 minutes and immediately thereafter underwent the aging treatment at 160 °C for 45 minutes, thus forming the specimen material corresponding to the shape of Fig. 1.

[4] Tensile Test

[0032] A specimen of the shape of JIS 13B as shown in Fig. 2 was cut out from the above specimen material and had a thickness (t) of 2 mm. The shape of JIS 13B was according to JIS (Japanese Industrial Standard) Z 2201. The specimen was subjected to a static tensile test at a strain rate of 0.001/s by using an Instron universal tester (AG-10TC) produced by Shimadzu Corporation. Additionally, a specimen of the shape as shown in Fig. 3 was cut out from the above specimen material. The specimen was subjected to a dynamic tensile test at a strain rate of about 1000/s by using a so-called One-Bar Method high speed tensile tester as illustrated in Fig. 4. The principle of the dynamic tensile test using the One-Bar Method high speed tensile tester had been discussed in "Proc. Symp. HDPIUTAM (1968), page 313". The dynamic tensile test was conducted as follows: With reference to Fig. 4, the specimen 10 as shown in Fig. 3 was disposed between an output rod 12 and an impact block 14. The output shaft 12 was fixed at its one end. The specimen 10 was connected to the impact block 14 at a position A and connected to the other end of the output rod 12 at a position B. A hammer 16 was impacted against the impact block 14 at a rate or velocity of $V_0(t)$. At this time, a displacement rate or velocity $V(t)$ at the position A was measured by an optical displacement meter (not shown), while a strain was measured by the strain gauge 18 attached to the output rod 12.

[0033] Then, a nominal stress ($\sigma(t)$) was determined according to following equation:

$$\sigma(t) = \frac{S_0}{S} \cdot E_0 \cdot \varepsilon_g(t)$$

where S is the cross-sectional area of the specimen; S_0 is the cross-sectional area of the output rod; E_0 is the Young's modulus of the output rod; and ε_g is the strain measured by the strain gauge.

[0034] The thus determined nominal stress corresponds to a tensile strength (MPa).

[0035] Additionally, a nominal strain ($\varepsilon(t)$) was determined according to the following equation:

$$\varepsilon(t) = \frac{U_A(t) - U_B(t)}{L} = \frac{1}{L} \cdot \int_0^t [V(t) - C \cdot \varepsilon_g(t)] dt$$

where $U_A(t)$ is the displacement at the position A; $U_B(t)$ is the displacement at the position B; L is the distance of the specimen between the positions A and B; and $V(t)$ is the speed of the impact block.

[0036] The thus determined nominal strain ($\varepsilon(t)$) was converted to an elongation (%) according to the following equation:

$$\varepsilon(t) = \left(\frac{U_A(t) - U_B(t)}{L} \right) \times 100 = \left(\frac{1}{L} \cdot \int_0^t [V(t) - C \cdot \varepsilon_g(t)] dt \right) \times 100$$

[0037] Each of the above static and dynamic tensile tests was repeated 5 times to obtain five values of the tensile strength (MPa) and five values of the elongation (%). An average value of the five values of the tensile strength was determined and shown in Table 2. An average value of the five values of the elongation (%) was determined and shown in Table 2.

Table 2

Items		Static tensile test			Dynamic tensile test	
		Tensile strength (MPa)	0.2% proof stress (MPa)	Elongation (%)	Tensile strength (MPa)	Elongation (%)
Example	1	273	160	18.8	283	17.9
	2	270	160	17.9	279	17.4
	3	271	158	16.6	283	15.7
Comparative Example	1	243	145	14.5	255	13.8
	2	245	145	14.3	258	13.9
	3	255	151	15.3	271	14.0

[0038] As apparent from the test results shown in Table 2, it has been confirmed that the aluminum die castings formed of the alloys of Examples are excellent in static and dynamic mechanical properties as compared with the 365 alloy used in Europe and the United States of America. This may be assumed to be caused under the effect of fined primary crystal α phase upon single addition of B. In comparison in effect between Sb and Sr as fining agents for eutectic Si, it has become apparent that the single addition of Sb is more effective than the addition of Sr from the viewpoint of improving the balance between the strength and the elongation since the alloy containing Sb is larger in elongation than the alloy containing Sr.

EXPERIMENT 2

[0039] In order to prove the effectiveness of the single and large amount addition of B, macrography and inspection of change of the B concentration in molten metal with time lapse were conducted.

[1] Macrography

(a) Test Method

[0040] Each aluminum alloy of Examples and Comparative Example shown in Table 3 was produced upon melting at 750 °C, thus preparing molten metal of the aluminum alloy. The aluminum alloy molten metal was subjected to a bubbling treatment with argon gas for the purpose of removal of inclusions and degasification. Immediately thereafter, the molten metal of aluminum alloy was cast into a wedge-shaped specimen as shown in Figs. 5A to 5C by using a gravity casting, in which the temperature of the molten metal was 700 °C during casting.

Table 3

Items	Chemical composition (wt.%)								
	Si	Mg	Mn	Fe	Ti	Sb	Sr	B	Al
Example 1	10.7	0.24	0.73	0.04	0.001	0.10	-	0.009	Balance
Comparative Example 3	10.6	0.25	0.71	0.04	0.15	0.09	-	0.006	Balance
Comparative Example 4	10.9	0.28	0.67	0.06	0.11	0.09	-	-	Balance
Comparative Example 5	10.8	0.27	0.71	0.06	0.15	0.11	-	0.002	Balance

(b) Test Result

[0041] A slowly cooled section (indicated as "Observed Position" in Fig. 5C) of the wedge-shaped specimen formed by the gravity casting was cut out and ground, and thereafter was etched by using an etching reagent of cupric chloride, followed by observation of the macro-structure thereof. The result of the observation is shown in Figs. 6A to 6D. Figs. 6A, 6B, 6C and 6D which are respectively photographs showing the macro-structures of Example 1, Comparative Example 3, Comparative Example 4 and Comparative Example 5. As apparent from these photographs, it has been demonstrated that the alloy (Example 1) of the B single and large amount addition type has finer macro-structure than

the alloy (Comparative Example 4) of the Ti addition type and the alloys (Comparative Examples 3 and 5) of the Ti-B addition type which have been conventionally considered effective for fining the primary crystal α phase. From this test result, the reason why the aluminum alloy according to the present invention possesses an excellent balance between the strength and the elongation resides in the fact that the primary crystal α phase is fined by the single and large amount addition of B.

[2] Inspection of Change of B Concentration with Time Lapse

(a) Test Method

[0042] Each aluminum alloy of Examples and Comparative Example shown in Table 4 was produced in an amount of 8 kg upon melting at 750 °C, thus preparing molten metal of the aluminum alloy. The aluminum alloy molten metal was subjected to a bubbling treatment with argon gas for the purpose of removal of inclusions and degasification. Thereafter, the molten metal was cooled to 700 °C and kept at a constant temperature as it was in a crucible. During keeping at the constant temperature, the molten metal was sampled at every predetermined time lapse. The sampled molten metal was subjected to an ICP (induction couple plasma) emission spectral analysis according to JIS H 1307, in which the concentration of B in the sampled molten metal was measured.

Table 4

Items	Chemical composition (wt.%)								
	Si	Mg	Mn	Fe	Ti	Sb	Sr	B	Al
Example 4	10.7	0.24	0.73	0.04	-	0.10	-	0.01	Balance
Comparative Example 6	10.6	0.25	0.74	0.06	0.11	0.09	-	0.01	Balance
Comparative Example 7	10.7	0.25	0.75	0.04	0.11	0.10	-	0.002	Balance

(b) Test Result

[0043] The result of the inspection of change of the B concentration in molten metal (kept at the constant temperature) with time lapse is shown in Fig. 7 in which a line a represents the result of Example 4, a line b represents the result of Comparative Example 6, and a line c represents the result of Comparative Example 7. As apparent from Fig. 7, in case of the molten metal (Comparative Example 6) of the conventional Ti-B addition type, the B concentration in the molten metal lowers with lapse of time. In case of the molten metal (Example 4) of the B single addition type, lowering of the B concentration with lapse of time is hardly found. This demonstrates that the B concentration in the molten metal lowers with lapse of time so that the effect of fining the macro-structure disappears in the molten metal of the Ti-B addition type, whereas no disappear of the effect of fining the macro-structure occurs with lapse of time in the molten metal of the B single addition type. As a cause for lowering the B concentration in the molten metal of the Ti-B addition type, it is considered that TiB_2 is formed in the molten metal and then sediments in the molten metal.

[0044] As discussed above, in the aluminum alloy for a die casting according to the present invention, the primary crystal α phase is fined by the single and large amount addition of B, thereby ensuring an excellent balance between strength and elongation. Additionally, the eutectic Si particle is fined by addition of Sb, thereby ensuring further improved elongation and toughness.

[0045] Moreover, in the production method of a die casting product according to the present invention, by employing a high vacuum die casting, entanglement of gas into the die casting can be suppressed thereby obtaining the die casting product without lowering the excellent mechanical properties or performances (particularly the elongation and toughness) possessed by the alloy according to the present invention. Further, by accomplishing the heat treatment after the die casting, the balance between the strength and the elongation can be adjusted at a desired value, and therefore the alloy of the present invention can be applied, for example, to the vehicle body parts of an automotive vehicle such as the A pillar, the B pillar, the C pillar, the roof, the joint of a space frame, the installation section of a suspension, and additionally the suspension parts of an automotive vehicle such as the suspension arm, the sub-frame, the link parts of the suspension and the engine cradle.

[0046] Although the invention has been described above by reference to certain embodiments and examples of the invention, the invention is not limited to the embodiments and examples described above.

Claims

1. An aluminum alloy for a die casting, comprising Si in an amount ranging from 10 to 12 % by weight, Mg in an amount ranging from 0.15 to 0.50 % by weight, Mn in an amount ranging from 0.5 to 1.0 % by weight, Fe in an amount of not more than 0.15 % by weight, Ti in an amount of not more than 0.1 % by weight, Sb in an amount ranging from 0.05 to 0.20 % by weight, B in an amount ranging from 0.005 to 0.02%, and balance consisting of aluminum and inevitable impurities.
2. An aluminum alloy as claimed in Claim 1, wherein Sb in the amount ranging from 0.05 to 0.20 % by weight is replaced with Sr in an amount ranging from 0.005 to 0.020 % by weight.
3. A method of producing a die casting product, comprising:
forming an aluminum alloy of Claim 1 or 2 into a die casting by high vacuum die casting to obtain the die casting product.
4. A method as claimed in Claim 3, further comprising:
accomplishing a solution treatment on the die cast product; and
accomplishing an aging treatment on the die cast product after the solution treatment.
5. A method as claimed in Claim 4, wherein the solution treatment is accomplished at a temperature of not lower than 530 °C for a time of not longer than 1 hr.
6. A die casting product produced by the method of any of Claims 3 to 5.
7. A die casting product as claimed in Claim 6, wherein the die casting product is one selected from the group consisting of a A pillar, a B pillar, a C pillar, a roof, a joint of a space frame, and an installation section of a suspension of an automotive vehicle.
8. A die casting product as claimed in Claim 6, wherein the die casting product is one selected from the group consisting of a suspension arm, a sub-frame, a link part of a suspension, and an engine cradle of an automotive vehicle.

Patentansprüche

1. Aluminiumlegierung für ein Druckgießen, die aufweist Si in einer Menge im Bereich von 10 bis 12 Gew.-%, Mg in einer Menge im Bereich von 0,15 bis 0,50 Gew.-%, Mn in einer Menge im Bereich von 0,5 bis 1,0 Gew.-%, Fe in einer Menge von nicht mehr als 0,15 Gew.-%, Ti in einer Menge von nicht mehr als 0,1 Gew.-%, Sb in einer Menge im Bereich von 0,05 bis 0,20 Gew.-%, B in einer Menge im Bereich von 0,005 bis 0,02 Gew.-%, und den Rest bestehend aus Aluminium und unvermeidlichen Verunreinigungen.
2. Aluminiumlegierung nach Anspruch 1, wobei Sb in der Menge im Bereich von 0,05 bis 0,20 Gew.-% durch Sr in einer Menge im Bereich die von 0,005 bis 0,020 Gew.-%, ersetzt ist.
3. Verfahren zur Herstellung eines Druckgusserzeugnisses, das aufweist:
Bilden einer Aluminiumlegierung von Anspruch 1 oder 2 in einem Druckgießen unter Hochvakuum- Druckgießen, um ein Druckgusserzeugnis zu erhalten.
4. Verfahren nach Anspruch 3, das außerdem aufweist:
Durchführen einer Lösungsbehandlung an dem Druckgusserzeugnis und
Durchführen einer Alterungsbehandlung an dem Druckgusserzeugnis nach der Lösungsbehandlung.
5. Verfahren nach Anspruch 4, wobei die Lösungsbehandlung bei einer Temperatur von nicht niedriger als 530° C für eine Zeit von nicht länger als 1 Std. ausgeführt wird.

6. Druckgusserzeugnis, hergestellt durch das Verfahren nach einem der Ansprüche 3 bis 5.
7. Druckgusserzeugnis nach Anspruch 6, wobei das Druckgusserzeugnis eines ist, ausgewählt aus der Gruppe, enthaltend eine A- Säule, eine B- Säule, eine C- Säule, ein Dach, eine Verbindung eines Raumrahmens und einen Installationsabschnitt einer Aufhängung eines Kraftfahrzeuges.
8. Druckgusserzeugnis nach Anspruch 6, wobei das Druckgusserzeugnis eines ist, ausgewählt aus der Gruppe, enthaltend einen Aufhängungsarm, einen Sub- Rahmen, ein Verbindungsteil einer Aufhängung und ein Motorge- stell eines Kraftfahrzeuges.

Revendications

1. Un alliage d'aluminium pour un moulage sous pression, comprenant Si dans une quantité dans la gamme de 10 à 12% en poids, Mg dans une quantité dans la gamme de 0,15 à 0,50% en poids, Mn dans une quantité dans la gamme de 0,5 à 1,0% en poids, Fe dans une quantité de pas plus de 0,15% en poids, Ti dans une quantité de pas plus de 0,1% en poids, Sb dans une quantité dans la gamme de 0,05 à 0,20% en poids, B dans une quantité dans la gamme de 0,005 à 0,02% en poids, et le reste se composant d'aluminium et d'impuretés inévitables.
2. Un alliage d'aluminium tel que revendiqué à la revendication 1, dans lequel Sb dans la quantité dans la gamme de 0,05 à 0,20% en poids est remplacé par Sr dans une quantité dans la gamme de 0,005 à 0,020% en poids.
3. Un procédé de production d'un produit moulé sous pression, comprenant l'étape consistant à :
former un alliage d'aluminium de la revendication 1 ou 2 dans un moulage sous pression par une technique de moulage sous pression sous vide élevée afin d'obtenir le produit moulé sous pression.
4. Un procédé tel que revendiqué à la revendication 3, comprenant en outre les étapes consistant à
effectuer un traitement de recuit sur le produit moulé sous pression ; et
effectuer un traitement de vieillissement sur le produit moulé sous pression après le traitement de recuit.
5. Un procédé tel que revendiqué à la revendication 4, dans lequel le traitement de recuit est effectué à une température non inférieure à 530°C pendant une durée non inférieure à 1 heure.
6. Un produit moulé sous pression réalisé par le procédé d'une quelconque des revendications 3 à 5.
7. Un produit sous pression tel que revendiqué à la revendication 6, dans lequel le produit moulé sous pression est un produit choisi dans le groupe se composant d'un montant A, d'un montant B, d'un montant C, d'un toit, d'une articulation d'un châssis de type treillis, et d'une portion d'installation d'une suspension d'un véhicule automobile.
8. Un produit moulé sous pression tel que revendiqué à la revendication 6, dans lequel le produit moulé sous pression est un produit choisi dans le groupe se composant d'un bras de suspension, d'un faux châssis, d'une partie de liaison d'une suspension, et d'un berceau de moteur d'un véhicule automobile.

FIG.1

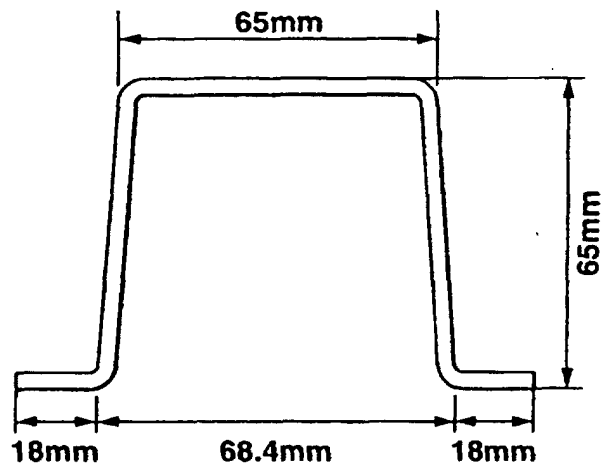


FIG.2

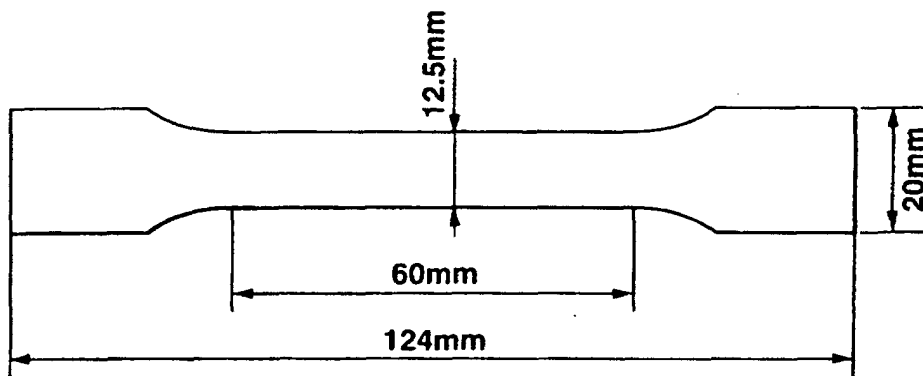


FIG.3

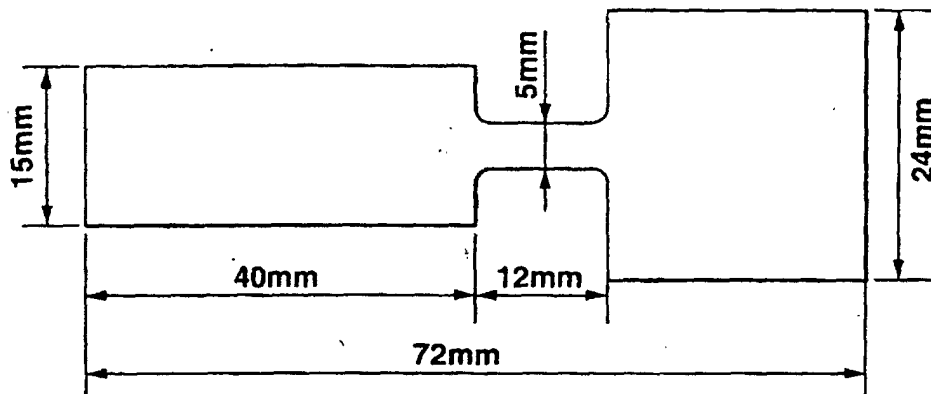


FIG.4

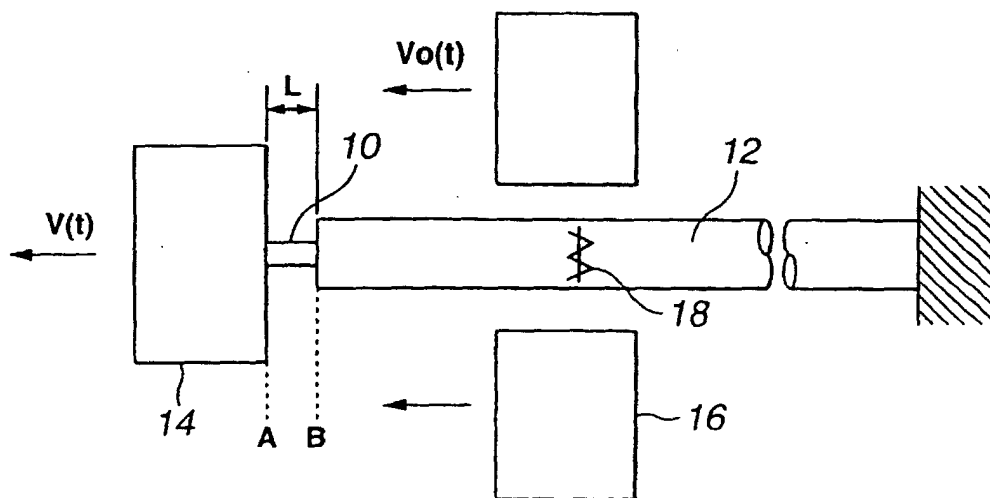


FIG.5A

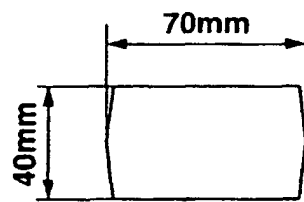


FIG.5B

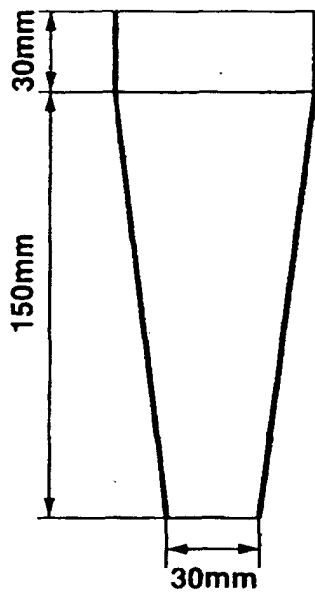


FIG.5C

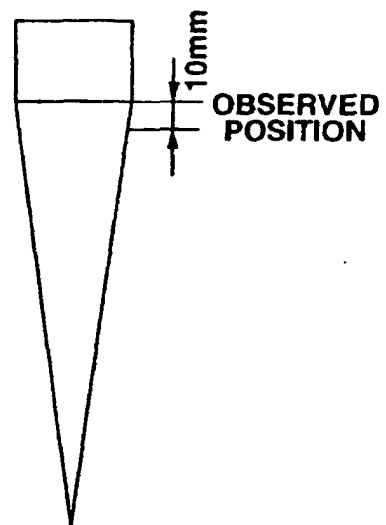


FIG.6A

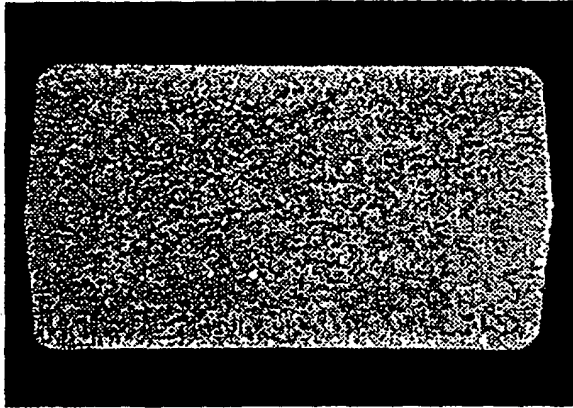


FIG.6B

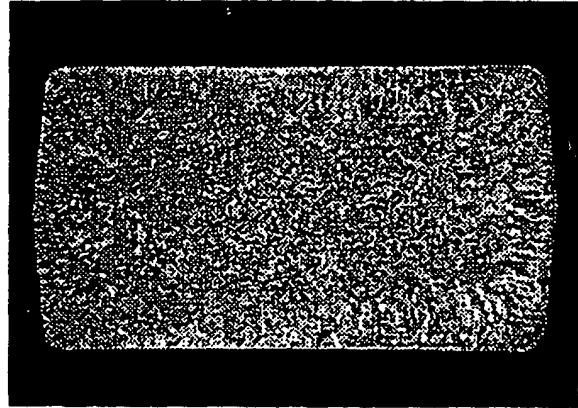


FIG.6C

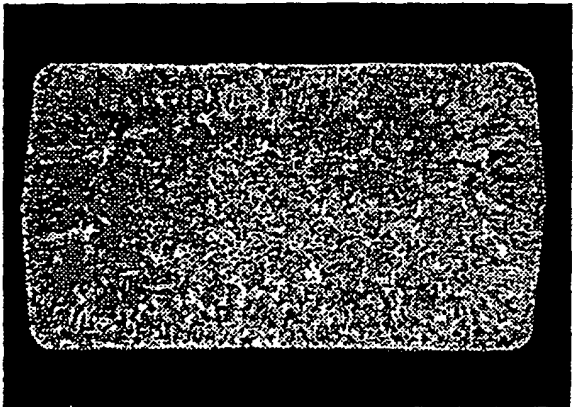


FIG.6D

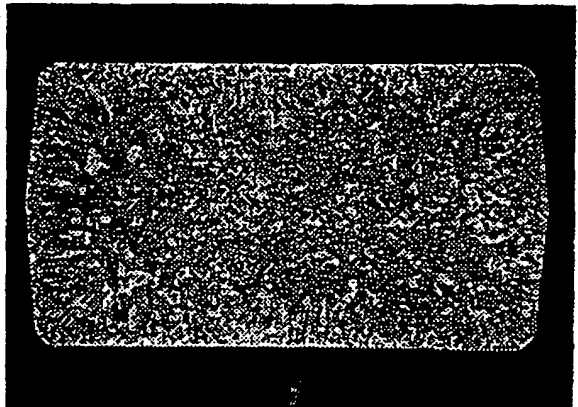


FIG.7

