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(54) **High-strength aluminum alloy for pressure casting and cast aluminum alloy comprising the same**

(57) Disclosed is a high-strength cast aluminum alloy obtained by: casting a high-strength aluminum alloy containing 3.5-4.3 % of Cu, 5.0-7.5 % of Si, 0.10-0.25 % of Mg, not more than 0.2 % of Fe, not more than 0.0003 % of P, and the balance comprising Al and unavoidable impurities; and subjecting the alloy thus cast to a T6 treatment. This cast alloy has finer eutectic Si grains by virtue of such a very low P content, enjoys casting and economic merits that are competitive with existing alloys, and satisfies higher mechanical requirements as to tensile strength, elongation, 0.2% proof strength and impact value.

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Description

[0001] This application is based on application No.11-299578 filed in Japan, the entire content of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to a high-strength aluminum alloy for casting which exhibits superior tensile strength, elongation and impact value and which will provide a good surface finish, and to a high-strength cast aluminum alloy comprising the same.

Description of the Prior Art

[0003] Aluminum alloys are widely used as materials for various components of vehicles, industrial machines, airplanes, electric appliances for domestic use and other apparatus of various types. Among such aluminum alloys there are cast aluminum alloys, a representative of which is an AC4CH alloy prescribed by JIS (equivalent to A356.0 prescribed by ASTM (U.S.), G(GK)-AlSi7Mg prescribed by DIN (Germany), or Al-Si7Mg prescribed by ISO). Such cast aluminum alloys are used in important durable parts requiring higher mechanical properties such as vehicle components, metal fittings for stringing and components of hydraulic systems, and in like applications.

[0004] However, such cast alloys as treated by a T6 treatment (a sort of a refining treatment) are inferior in tensile strength, 0.2% proof strength and impact value, though they exhibit a high value of elongation. Typical mechanical property values of the AC4CH alloy as T6-treated are shown in Table 1, and the composition of the AC4CH alloy is shown in Table 2.

Table 1

Tensile strength (MPa)	0.2% Proof Strength (MPa)	Elongation (%)	Impact Value (kJ/m^2)
260	157	16.8	70

Table 2

Composition of AC4CH (%)	
Cu	0.20 or less
Si	6.5-7.5
Mg	0.25-0.45
Zn	0.10 or less
Fe	0.20 or less
Mn	0.10 or less
Ni	0.50 or less
Ti	0.20 or less
Pb	0.05 or less
Sn	0.05 or less
Cr	0.05 or less
Al	balance

SUMMARY OF THE INVENTION

[0005] Accordingly, it is a first object of the present invention to develop a high-toughness cast aluminum alloy which satisfies desired cost efficiency and castability while exhibiting a tensile strength of not less than 380 MPa, an elongation of not less than 9.0 % a 0.2% proof strength of not lees than 200 MPa and an impact value of not less than 90 kJ/m^2 and which can replace the AC4CH alloy.

[0006] It is a second object of the present invention to develop a high-strength aluminum alloy for casting which satisfies the above requirements and will provide a cast product with a good appearance when surface-finished.

[0007] A first feature of the aluminum alloy according to the present invention resides in that the content of P is very low, specifically, not more than 0.0003 %. Alternatively, a second feature of the aluminum alloy resides in that the alloy contains Sb or Sr and optionally Ti or a combination of Ti and B when the alloy has a typical content of P.

[0008] When the content of P is very low, or not more than 0.0003 %, eutectic Si grains in the metallic texture of the cast aluminum alloy as T6-treated becomes finer than those of a corresponding cast aluminum alloy having a typical content of P (P content: 0.0004-0.0030 %). See sample No. 59 with a typical P content in Fig. 1. As a result, the cast aluminum alloy of the present invention satisfies higher mechanical property requirements (i.e., not less than 380 MPa in tensile strength, not less than 9 % in elongation, not less than 200 MPa in 0.2% proof strength and not less than 90 kJ/m^2 in impact value) while exhibiting satisfactory competitiveness against the conventional AC4CH alloy as to castability and cost efficiency (see sample No. 47 with a low P content in Fig. 1). The content ranges of major ingredients including Cu, Si, Mg and Fe will be described by reference to experimental data of examples and comparative examples to be described later.

[0009] Alternatively, even though the content of P is a typical value (P content: 0.0004-0.0030 %, see sample No. 59 with a typical P content in Fig. 1), the addition of 0.05-0.2 % of Sb or 0.005-0.030 % of Sr to such an alloy can make finer eutectic Si grains in the metallic texture of the cast aluminum alloy as T6-treated (see sample No. 62 with a typical P content in Fig. 1) than a corresponding cast alloy having a typical content of P and free of Sb or Sr (see sample No. 60 added with Sr in Fig. 1). As a result, the resulting cast aluminum alloy satisfies higher mechanical property requirements (i.e., not less than 380 MPa in tensile strength, not less than 9 % in elongation, not less than 200 MPa in 0.2% proof strength and not less than 90 kJ/m^2 in impact value) while exhibiting satisfactory competitiveness against the conventional AC4CH alloy as to castability and cost efficiency.

[0010] The addition of 0.05 to 0.35 % of Ti and optionally not more than 0.003 % of B to the above aluminum alloys enables crystal grains to become finer thereby improving the appearance of the resulting cast product as surface-finished, though it does not contribute to an improvement in impact value. In this case, the addition of Ti and B in combination can make resulting crystal grains finer than can the addition of Ti alone (see the photograph of metallic textures shown Fig. 14). It is to be noted that as crystal grains become finer, the tensile strength and 0.2% proof strength are improved.

[0011] For use, any of the foregoing alloys according to the present invention is T6-treated after casting. The alloys of the present invention as cast are not so different from the AC4CH alloy in tensile strength and elongation. However, the T6 treatment allows eutectic Si grains in these alloys to become refined and granular, so that the resulting cast alloys attain the aforementioned mechanical property requirements: not less than 380 MPa in tensile strength, not less than 9 % in elongation, not less than 200 MPa in 0.2% proof strength and not less than 90 kJ/m^2 in impact value.

[0012] The foregoing and other objects, features and attendant advantages of the present invention will become apparent from the reading of the following detailed description with reference to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Fig. 1 is a microscopic photograph showing respective textures of high P-content alloy as a comparative example, low P-content alloy, Sr-added alloy and Sb-added alloy as examples of the present invention;
Fig. 2 is a graph showing the relationship between the Cu content and the mechanical properties;
Fig. 3 is a graph showing the relationship between the Si content and the mechanical properties;
Fig. 4 is a graph showing the relationship between the Mg content and the mechanical properties;
Fig. 5 is a graph showing the relationship between the Fe content and the mechanical properties;
Fig. 6 is a graph showing the relationship among the tensile strength, the P content and the modifying agents;
Fig. 7 is a graph showing the relationship among the 0.2% proof strength, the P content and the modifying agents;
Fig. 8 is a graph showing the relationship among the elongation, the P content and the modifying agents;
Fig. 9 is a graph showing the relationship among the impact value, the P content and the modifying agents;
Fig. 10 is a graph showing the relationship among a low P-content cast alloy, a Ti-added and low P-content cast alloy, and a Ti+B-added and low P-content cast alloy as to tensile strength;

Fig. 11 is a graph showing the relationship among the low P-content cast alloy, the Ti-added and low P-content cast alloy, and the Ti+B-added and low P-content cast alloy as to 0.2% proof strength;

Fig. 12 is a graph showing the relationship among the low P-content cast alloy, the Ti-added and low P-content cast alloy, and the Ti+B-added and low P-content cast alloy as to elongation;

Fig. 13 is a graph showing the relationship among the low P-content cast alloy, the Ti-added and low P-content cast alloy, and the Ti+B-added and low P-content cast alloy as to impact value; and

Fig. 14 is a macrophotograph showing respective textures of the low P-content cast alloy as a basic example of the invention, Ti-added and low P-content cast alloy and Ti+B-added and low P-content cast alloy.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] The present invention will now be described by comparing examples (samples Nos. 47, 53, 63, 51, 54, 55, 60, 62, 57 and 58) of the invention with comparative examples (samples Nos. 49, 46, 48, 44, 43, 50, 52, 56 and 59). The respective compositions and mechanical properties of these examples and comparative examples are shown in the following Table 3.

Table 3

Composition

No.	*	Ingredients (%)								
		Cu	Si	Mg	Fe	Ti	B	Sr	Sb	P
49	T6	3.24	7.04	0.20	0.12	0.00	0.0000	0.000	0.000	< 0.0003
47	T6	4.03	7.02	0.20	0.12	0.00	0.0000	0.000	0.000	< 0.0003
46	T6	4.51	7.08	0.20	0.12	0.00	0.0000	0.000	0.000	< 0.0003
48	T6	5.19	7.08	0.22	0.12	0.00	0.0000	0.000	0.000	< 0.0003
53	T6	3.98	5.08	0.20	0.11	0.00	0.0000	0.000	0.000	< 0.0003
63	T6	4.02	6.03	0.15	0.11	0.00	0.0000	0.000	0.000	< 0.0003
44	T6	4.13	9.12	0.21	0.13	0.00	0.0000	0.000	0.000	< 0.0003
43	T6	4.07	11.0	0.21	0.12	0.00	0.0000	0.000	0.000	< 0.0003
50	T6	4.01	7.20	0.01	0.11	0.00	0.0000	0.000	0.000	< 0.0003
51	T6	4.01	7.14	0.10	0.11	0.00	0.0000	0.000	0.000	< 0.0003
54	T6	3.71	6.80	0.15	0.11	0.00	0.0000	0.000	0.000	< 0.0003
52	T6	3.94	7.05	0.30	0.11	0.00	0.0000	0.000	0.000	< 0.0003
55	T6	4.06	7.15	0.15	0.20	0.00	0.0000	0.000	0.000	< 0.0003
56	T6	4.04	7.10	0.17	0.29	0.00	0.0000	0.000	0.000	< 0.0003
59	T6	4.00	6.97	0.16	0.11	0.00	0.0000	0.000	0.000	0.0007
60	T6	3.92	7.11	0.15	0.11	0.00	0.0000	0.0088	0.000	0.0019
62	T6	3.85	6.91	0.16	0.11	0.00	0.0000	0.000	0.158	0.0010
57	T6	3.94	7.08	0.17	0.11	0.12	0.0000	0.000	0.000	< 0.0003
58	T6	3.92	7.07	0.14	0.11	0.15	0.0004	0.000	0.000	< 0.0003

Note: the asterisk "*" indicates the type of a refining treatment.

Mechanical properties

No.	Tensile strength	Proof strength	Elongation	Impact value
49	364	202	11.8	118
47	395	229	10.4	109
46	338	256	5.2	66
48	331	265	3.8	38
53	390	233	11.1	131
63	385	244	9.3	119
44	345	291	3.0	47
43	399	263	4.0	45
50	371	202	8.9	111
51	391	219	11.7	138
54	386	226	11.2	125
52	398	294	5.4	75
55	383	223	9.9	98
56	377	223	8.5	88
59	388	236	7.6	70
60	381	228	10.5	131

62	382	216	11.2	108
57	387	235	9.1	93
58	397	231	11.0	90

[0015] A first example of a high-strength aluminum alloy for casting (samples Nos. 47, 53, 63, 51, 54 and 55, see the microscopic photograph of sample No. 47 with a low P content in Fig. 1) according to the first example of the present invention has the following composition:

Cu: 3.5-4.3 %;
Si: 5.0-7.5 %;
Mg: 0.10-0.25 %;
Fe ≤ 0.2 %;
P ≤ 0.0003 %; and
balance: Al and unavoidable impurities.

[0016] This example is characterized in that the content of P is lower than a typical P content (0.0004-0.0030 %), specifically not more than 0.0003 %. If the P content is higher than 0.0003 %, eutectic Si grains resulting from the T6 treatment are large and elongate. Such large and elongate grains give rise to a notching effect, which in turn causes the mechanical properties, especially the impact resistance, of the alloy to lower. However, by reducing the P content to a value not more than 0.0003 %, which was lower than the typical P content, eutectic Si grains after having undergone the T6 treatment became refined and globular, and the mechanical properties, especially impact resistance, of the alloy were improved.

[0017] A second example of a high-strength aluminum alloy for casting (see the microscopic photograph of sample No. 62 added with Sb in Fig. 1) according to the present invention has the following composition:

Cu: 3.5-4.3 %;
Si: 5.0-7.5 %;
Mg: 0.10-0.25 %;
Fe ≤ 0.2 %;
P: 0.0004-0.0030 %;
Sb: 0.05-0.2 %; and
balance: Al and unavoidable impurities.

[0018] This example is characterized in that the alloy is added with Sb in an amount as small as 0.05 to 0.2 % though the content of P is within the range of the typical P content. This alloy as T6-treated after casting had finer eutectic Si grains in the metallic texture thereof than did a corresponding alloy not added with Sb.

[0019] A third example of a high-strength aluminum alloy for casting (see the microscopic photograph of sample No. 60 added with Sr) according to the present invention has the following composition:

Cu: 3.5-4.3 %;
Si: 5.0-7.5 %;
Mg: 0.10-0.25 %;
Fe ≤ 0.2 %;
P: 0.0004-0.0030 %;
Sr: 0.005-0.030 %; and
balance: Al and unavoidable impurities.

[0020] Like the second example, this example is characterized in that the alloy is added with Sr in an amount as small as 0.005 to 0.030 % though the content of P is within the typical P content range of 0.0004 to 0.0030 %. This alloy as T6-treated after casting had finer eutectic Si grains in the metallic texture thereof than did a corresponding alloy not added with Sr.

[0021] A fourth example of a high-strength aluminum alloy for casting (sample No. 57) according to the present invention is prepared by adding 0.05 to 0.35 % of Ti to any one of the alloys of the first to third examples. On the other hand, a fifth example of a high-strength aluminum alloy for casting (sample No. 58) according to the present invention is prepared by adding 0.05 to 0.35 % of Ti and not more than 0.003 % of B to any one of the alloys of the first to third examples. The addition of a small amount of Ti or of a combination of Ti and B enables refinement of crystal grains of each alloy as T6-treated thereby contributing to improved surface finish, though it does not contribute to an improvement in the impact resistance.

[0022] Any of the alloys according to the first and fifth examples of the present invention, as cast, is not largely different from the conventional AC4CH alloy in tensile strength and elongation. However, such mechanical properties of the alloys of the present invention are modified by a subsequent heat treatment called "T6 treatment". The T6 treatment is performed under the following conditions. That is, a solution treatment is performed at 500°C to 520°C for 4 to 12 hours, followed by an aging treatment at 140°C to 180°C for 2 to 7 hours. In fact, the alloys of the present invention, after having undergone the T6 treatment, each exhibited a tensile strength of not less than 380 MPa, elongation of not less than 9 %, 0.2% proof strength of not less than 200 MPa, and an impact value of not less than 90 kJ/m^2.

[0023] The alloys of the present invention were compared with comparative examples. Samples Nos. 47, 53, 63, 51, 54 and 55 according to the first example of the invention and samples Nos. 49, 46, 48, 44, 43, 50, 52 and 56 as comparative examples each had a low P content, specifically not more than 0.0003 %. By varying the contents of Cu, Si, Mg and Fe, these samples were tested for the influence from the varying contents.

[0024] Sample No. 59 as a comparative example contained Cu, Si, Mg and Fe in amounts within the respective specified ranges of the present invention and had a P content of 0.0007 %, which was beyond the specified range, and was tested for the influence from the increased P content.

[0025] Samples Nos. 60 and 62 according to the second and third examples of the present invention had P contents of 0.0019 % and 0.0010 %, respectively, which were higher than the specified content range, and were added with Sr and Sb, respectively, to determine the respective effects of Sr and Sb.

[0026] Sample No. 57 according to the fourth example of the invention had necessary ingredients including P within respective specified content ranges and was added with Ti to determine the influence of Ti. On the other hand, sample No. 58 according to the fifth example of the invention had necessary ingredients including P within respective specified content ranges and was added with Ti and B to determine the influence of the combination of Ti and B. Any one of the alloys shown in Table 1 had undergone the T6 treatment under the conditions: solution treatment at 520°C for 12 hours, then aging treatment at 160°C for 5 hours after water cooling, followed by air cooling.

[0027] The addition of Cu causes a Cu-Al intermetallic compound such as $CuAl_2$ to precipitate at the aging treatment following the solution treatment thereby strengthening the α-Al phase, hence, improving the tensile strength of the resulting T6-treated cast aluminum alloy. In the case where the Cu content was as low as 3.24 % and the contents of other ingredients were within the respective specified ranges (sample No. 49 as a comparative example), the tensile strength of the cast alloy was as low as 364 MPa. On the other hand, in the case where the Cu content was as high as 4.51 % (sample No. 46 as a comparative example), the elongation and impact value of the resulting cast alloy were as low as 5.2 % and 66 kJ/m^2, respectively. Sample No. 48 as a comparative example exhibited a similar tendency. By contrast, in the case where the Cu content was 4.03 % which was within the specified range (sample No. 47 according to the first example), the resulting cast alloy exhibited a tensile strength of 395 MPa, elongation of 10.4 %, 0.2% proof strength of 229 MPa and impact value of 109 kJ/m^2, all of which attained the respective target values. A variation in each mechanical property with varying content of Cu is shown in Fig. 2. As can be seen from Fig. 2, the intended mechanical properties were attained when the Cu content was about 4 % (within the specified range of 3.5 to 4.3 %) in a Al-X%Cu-7%Si-0.2%Mg-0.1%Fe-low P alloy as T6-treated.

[0028] The addition of Si provides molten metal with sufficient fluidity to ensure improved castability. In the case where the Si content was not less than 9 %, which was higher than the specified range, and the contents of other ingredients were within the respective specified ranges (samples Nos. 44 and 43 as comparative examples), the elongation and impact value of the resulting cast alloy were as low as 3-4 % and 45-47 kJ/m^2, respectively. On the other hand, in the case where the Si content was less than 5 %, the fluidity of the alloy was so low that the alloy is not adaptable for casting. By contrast, in the case where the Si content was 5 to 7 % (samples Nos.53 and 63 as examples of the invention), which was within the specified range, the resulting cast alloy exhibited a tensile strength of not less than 380 MPa, elongation of 10.4 %, 0.2% proof strength of 229 MPa and impact value of 109 kJ/m^2, all of which attained the respective target values. A variation in each mechanical property with varying content of Si is shown in Fig. 3. As can be seen from Fig. 3, the intended mechanical properties were attained when the Si content was about 7 % (within the specified range of 5.0 to 7.5 %) in an Al-4%Cu-X%Si-0.2%Mg-0.1%Fe-low P alloy as T6-treated.

[0029] Like the addition of Cu, the addition of Mg causes Mg-Si intermetallic compounds such as Mg_2Si and an Al-Cu-Mg compound to precipitate when the alloy is subjected to the solution treatment and the subsequent aging treatment thereby strengthening the α-Al phase. In the case where the Mg content was as low as 0.01 % and the contents of other ingredients were within the respective specified ranges (sample No. 50 as a comparative example), the tensile strength and elongation of the resulting cast alloy was lower than 380 MPa and as low as 8.9 %, respectively. On the other hand, in the case where the Mg content was as high as 0.30 % (sample No. 52 as a comparative example), the elongation and impact value of the resulting cast alloy were as low as 5.4 % and 75 kJ/m^2, respectively. By contrast, in the case where the Mg content was 0.10 to 0.20 % (samples Nos. 51 and 54 as examples of the invention), the resulting cast alloy exhibited a tensile strength of not less than 386 MPa, elongation of not less than 10.4 %, 0.2% proof strength of not less than 219 MPa and impact value of 109 kJ/m^2, all of which attained the respective target values. A variation in each mechanical property with varying content of Mg is shown in Fig. 4. As can be seen from Fig. 4, the intended mechanical properties were attained when the Mg content was about 0.15 % (within the specified range of 0.10 to 0.25 %) in an Al-4%Cu-7%Si-X%Mg-0.1%Fe-low P alloy as T6-treated.

[0030] Fe is an element that causes the mechanical properties of a cast alloy to lower and, hence, the addition of a smaller amount of Fe is more preferable. In the case where the Fe content was as high as 0.29 % and the contents of other ingredients were within the respective specified ranges (sample No. 56 as a comparative example), the tensile strength, elongation and impact value of the resulting cast alloy was as low as 377 MPa, 8.5 % and 88 kJ/m^2, respectively. By contrast, in the case where the Fe content was not more than 0.20 % (sample No. 55 as an example of the invention), the resulting cast alloy exhibited a tensile strength of not less than 383 MPa, elongation of not less than 9.9 %, 0.2% proof strength of not less than 223 MPa and impact value of 98 kJ/m^2, all of which attained the respective target values. A variation in each mechanical property with varying content of Fe is shown in Fig. 5. As can be seen from Fig. 5, the intended mechanical properties were attained when the Fe content was not more than 0.2 % (i.e., the specified range) in an Al-4%Cu-7%Si-0.15%Mg-X%Fe-low P alloy as T6-treated.

[0031] Sample No. 59 was a comparative example having a higher P content and exhibited elongation and impact value as low as 7.6 % and 70 kJ/m^2, respectively. This is because eutectic Si grew into large and elongate grains in the T6-treated cast alloy as shown in the macrophotograph of the texture of sample No. 59 in Fig. 1. By reducing the P content to the specified value or lower it is possible to make eutectic Si grains finer and granular thereby attaining the target tensile strength, 0.2% proof strength, elongation and impact value.

[0032] Samples Nos. 60 and 62 as examples of the invention were added with Sr and Sb, respectively, and each had a higher P content than the specified P content. Without addition of Sr or Sb, such a high P-content alloy would exhibit lower elongation and impact value. However, the addition of Sr or Sb to such an alloy causes eutectic Si grains to become refined and granular thereby making it possible to improve the elongation and impact value. In fact, sample No. 60 containing 0.0019 % of P and added with 0.0088 % of Sr attained the intended mechanical properties, and sample No. 62 containing 0.0010 % of P added with 0.158 % of Sb attained the intended mechanical properties.

[0033] Figs. 6 to 10 show the relationship between the mechanical properties and the modifying agents. Alloys used were T6-treated Al-4%Cu-7%Si-0.15%Mg-0.1%Fe alloys added with P in a high content (sample No. 59 as a comparative example), with P in a low content (not more than 0.0003 %), with Sb and with Sr, respectively.

[0034] Specifically, Fig. 6 shows the relationship between the tensile strength and the modifying agents. As shown, in any one of the cases the average value exceeded the respective target value. It should be noted that the measured values of Sr-added alloys tended to be relatively widely scattered.

[0035] Fig. 7 shows the relationship between the 0.2% proof strength and the modifying agents. As shown, in any one of the cases the average value exceeded the respective target value. Although Sb-added alloys were found to exhibit a relatively narrow scatter of measured values, other three types of alloys were found to exhibit a relatively wide scatter of measured values.

[0036] Fig. 8 shows the relationship between the elongation and the modifying agents. As shown, the average value of the high P-content alloys was 7.4 %, which was significantly lower than the target value of 9 %. The respective average value of any one of other three types of alloys was 10 % or higher, which was beyond the target value.

[0037] Fig. 9 shows the relationship between the impact value and the modifying agents. As shown, the average value of the high P-content alloys was 70 kJ/m^2, which was significantly lower than the target value of 90 kJ/m^2. The respective average value of any one of the other three types of alloys was 100 kJ/m^2 or higher, which was beyond the target value.

[0038] Figs. 10 to 13 each show a variation in each mechanical property of a low P-content alloy when this alloy was added with Ti or with Ti and B. An Al-4%Cu-7%Si-0.15%Mg-0.1%Fe-low P alloy was used as a reference example, and Ti or a combination of Ti and B was added to this type of alloy. A macrophotograph of the texture of each alloy as T6-treated is shown in Fig. 14. As shown, the alloy added with Ti was found to have finer crystal grains than the reference example not added with Ti or with a combination of Ti and B, and the alloy added with a combination of Ti and B was found to have still finer crystal grains than the alloy added with Ti alone.

[0039] Specifically, Fig. 10 shows a comparison between the low P-content alloy not added with Ti or with a combination of Ti and B and the low P-content alloy added with Ti or with a combination of Ti and B as to tensile strength. The average values of these alloys were not so different from each other but tended to become higher as grains became finer. Specifically, the tensile strength of the low P-content alloy added with Ti was higher than that of the low P-content alloy not added with Ti or with a combination of Ti and B, and the tensile strength of the low P-content alloy added with a combination of Ti and B was higher than that of the low P-content alloy added with Ti alone.

[0040] Fig. 11 shows a comparison between the low P-content alloy not added with Ti or with a combination of Ti and B and the low P-content alloy added with Ti or with a combination of Ti and B as to 0.2% proof strength. The average values of these alloys were not so different from each other, and the low P-content alloy added with a combination Ti and B exhibited the highest value, and the low P-content alloy added with Ti alone exhibited a higher value than the low P-content alloy not added with Ti or with a combination of Ti and B.

[0041] Fig. 12 shows a comparison between the low P-content alloy not added with Ti or with a combination of Ti and B and the low P-content alloy added with Ti or with a combination of Ti and B as to elongation. The low P-content alloy added with a combination of Ti and B and the low P-content alloy without addition exhibited substantially equal values of elongation, while the low P-content alloy added with Ti alone exhibited an elongation that was lower than those of the former two alloys and slightly higher than the target value.

[0042] Fig. 13 shows a comparison between the low P-content alloy not added with Ti or with a combination of Ti and B and the low P-content alloy added with Ti or with a combination of Ti and B as to impact value. The low P-content alloy added with a combination of Ti and B and the low P-content alloy added with Ti alone exhibited impact values that were significantly lower than that of the low P-content alloy without addition and slightly higher than the target value.

[0043] While certain presently preferred embodiments of the present invention have been described in detail, as will be apparent for those skilled in the art, various changes and modifications may be made in embodiment without departing from the scope of the present invention as defined in the following claims.

Claims

1. A high-strength aluminum alloy for casting comprising 3.5 to 4.3 % of Cu, 5.0 to 7.5 % of Si, 0.10 to 0.25 % of Mg, not more than 0.2 % of Fe, not more than 0.0003 % of P, and the balance comprising Al and unavoidable impurities.

2. A high-strength aluminum alloy for casting comprising 3.5 to 4.3 % of Cu, 5.0 to 7.5 % of Si, 0.10 to 0.25 % of Mg, not more than 0.2 % of Fe, 0.0004 to 0.0030 % of P, 0,05 to 0.2 % of Sb, and the balance comprising Al and unavoidable impurities.

3. A high-strength aluminum alloy for casting comprising 3.5 to 4.3 % of Cu, 5.0 to 7.5 % of Si, 0.10 to 0.25 % of Mg, not more than 0.2 % of Fe, 0.0004 to 0.0030 % of P, 0.005 to 0.0030 % of Sr, and the balance comprising Al and unavoidable impurities.

4. A high-strength aluminum alloy for casting as set forth in any one of claims 1 to 3, further comprising 0.05 to 0.35 % of Ti.

5. A high-strength aluminum alloy for casting as set forth in any one of claims 1 to 3, further comprising 0.05 to 0.35 % of Ti and not more than 0.003 % of B.

6. A high-strength cast aluminum alloy comprising a high-strength aluminum alloy for casting as recited in claim 1, which is in a state as cast and then treated by a T6 treatment.

7. A high-strength cast aluminum alloy comprising a high-strength aluminum alloy for casting as recited in claim 2, which is in a state as cast and then treated by a T6 treatment.

8. A high-strength cast aluminum alloy comprising a high-strength aluminum alloy as recited in claim 3, which is in a state as cast and then treated by a T6 treatment.

9. A high-strength cast aluminum alloy obtained by: casting a high-strength aluminum alloy for casting comprising 3.5 to 4.3 % of Cu, 5.0 to 7.5 % of Si, 0.10 to 0.25 % of Mg, not more than 0.2 % of Fe, 0.05 to 0.35 % of Ti, not more than 0.0003 % of P, and the balance comprising Al and unavoidable impurities; and subjecting the alloy thus to a T6 treatment.

10. A high-strength cast aluminum alloy obtained by: casting a high-strength aluminum alloy for casting comprising 3.5 to 4.3% of Cu, 5.0 to 7.5% of Si, 0.10 to 0.25% of Mg, not more than 0.2 % of Fe, 0.0004 to 0.0030 % of P, 0.05 to 0.2 % of Sb, 0.05 to 0.35 % of Ti, and the balance comprising Al and unavoidable impurities; and subjecting the alloy thus cast to a T6 treatment.

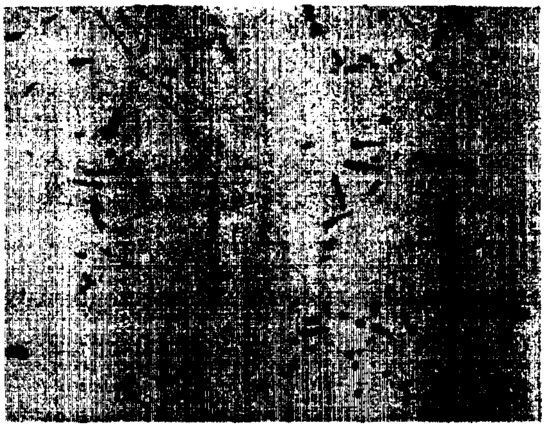
11. A high-strength cast aluminum alloy obtained by: casting a high-strength aluminum alloy for casting comprising 3.5 to 4.3 % of Cu, 5.0 to 7.5 % of Si, 0.10 to 0.25 % of Mg, not more than 0.2 % of Fe, 0.0004 to 0.0030 % of P, 0.005 to 0.030 % of Sr, 0.05 to 0.35 % of Ti, and the balance comprising Al and unavoidable impurities; and subjecting the alloy thus cast to a T6 treatment.

12. A high-strength cast aluminum alloy obtained by: casting a high-strength aluminum alloy for casting comprising 3.5 to 4.3 % of Cu, 5.0 to 7.5 % of Si, 0.10 to 0.25 % of Mg, not more than 0.2 % of Fe, 0.05 to 0.35 % of Ti, not more than 0.003 % of B, not more than 0.0003 % of P, and the balance comprising Al and unavoidable impurities; and subjecting the alloy thus cast to a T6 treatment.

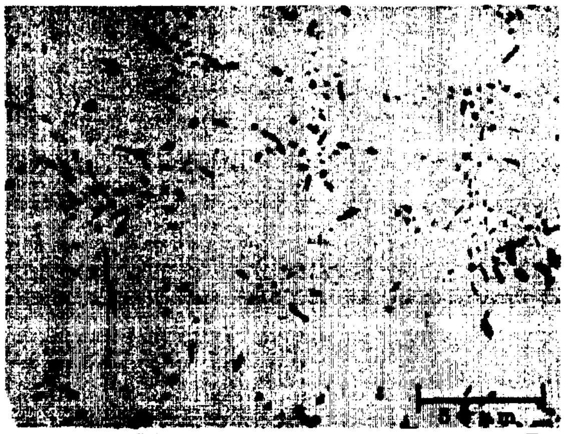
13. A high-strength cast aluminum alloy obtained by: casting a high-strength aluminum alloy for casting comprising 3.5 to 4.3 % of Cu, 5.0 to 7.5 % of Si, 0.10 to 0.25 % of Mg, not more than 0.2 % of Fe, 0.0004 to 0.0030 % of P, 0.05 to 0.2 % of Sb, 0.05 to 0.35 % of Ti, not more than 0.003 % of B, and the balance comprising Al and unavoidable impurities; and subjecting the alloy thus cast to a T6 treatment.

14. A high-strength cast aluminum alloy obtained by: casting a high-strength aluminum alloy for casting comprising 3.5 to 4.3% of Cu, 5.0 to 7.5% of Si, 0.10 to 0.25% of Mg, not more than 0.2 % of Fe, 0.0004 to 0.0030 % of P, 0.005 to 0.030 % of Sr, 0.05 to 0.35 % of Ti, not more than 0.003 % of B, and the balance comprising Al and unavoidable impurities; and subjecting the alloy thus cast to a T6 treatment.

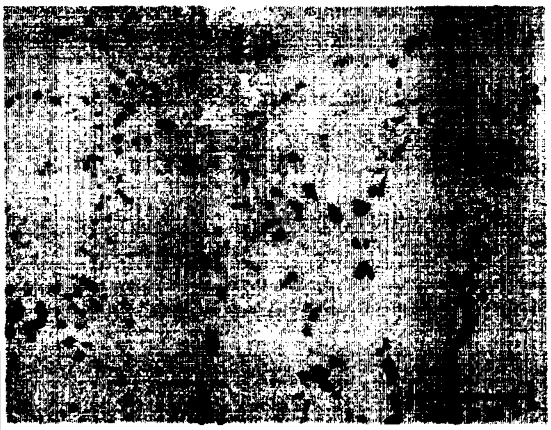
Fig.1



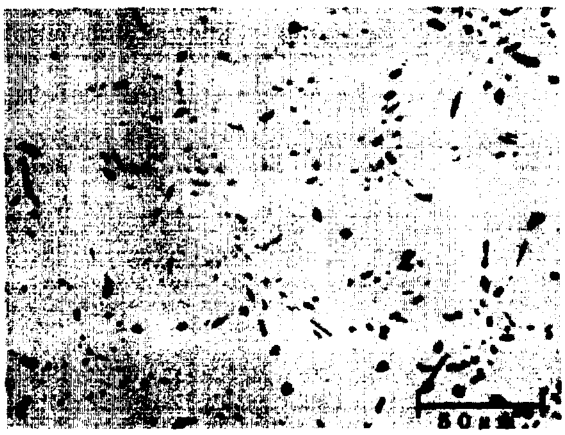
Sample No.59 with a typical P content



Sample No.47 with a low P content



Sample No.60 added with Sr



Sample No.62 added with Sb

Fig.2

Al-X% Cu-7% Si-0.2% Mg-0.1% Fe-low P alloy

Cu content(%)	Tensile strength(MPa)	0.2% proof strength(MPa)	Elongation(%)	Impact value(kJm^2)
3.24	364	202	11.8	118
4.03	395	229	10.4	109
4.51	338	256	5.2	66
5.19	331	265	3.8	38

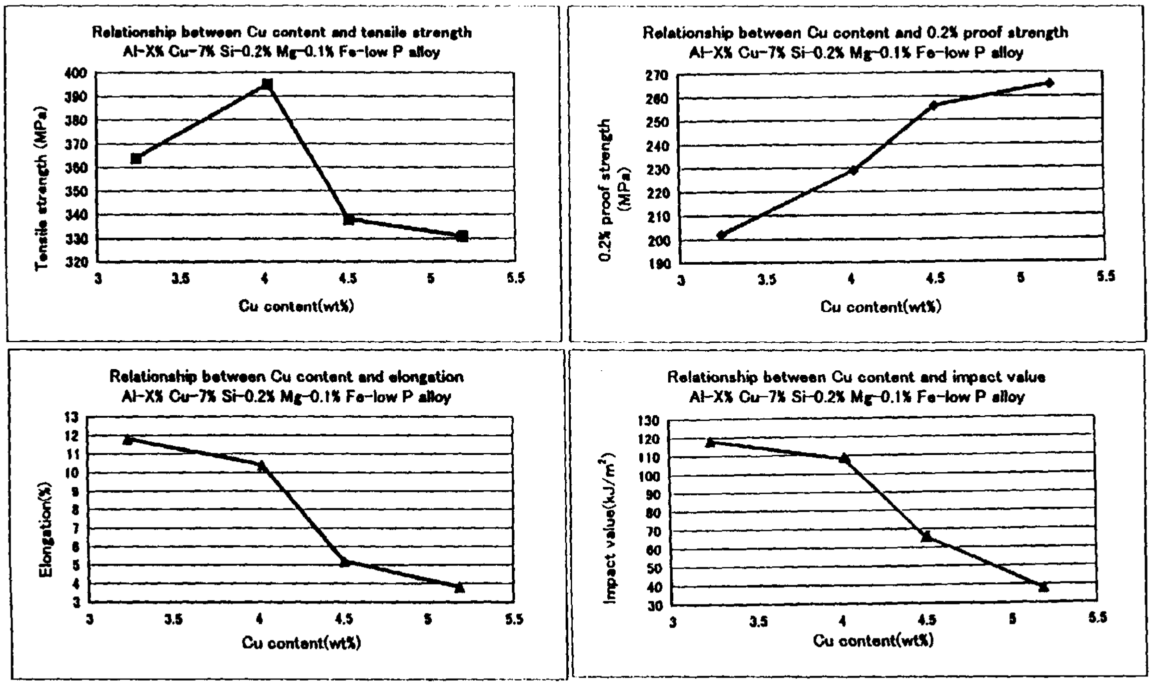


Fig.3

Al-4% Cu-X% Si-0.2% Mg-0.1% Fe-low P alloy

Si content(%)	Tensile strength(MPa)	0.2% proof strength(MPa)	Elongation(%)	Impact value(kJ/m^2)
5.08	390	233	11.1	131
7.02	395	229	10.4	109
9.12	345	291	3.0	47
11.0	399	263	4.0	45

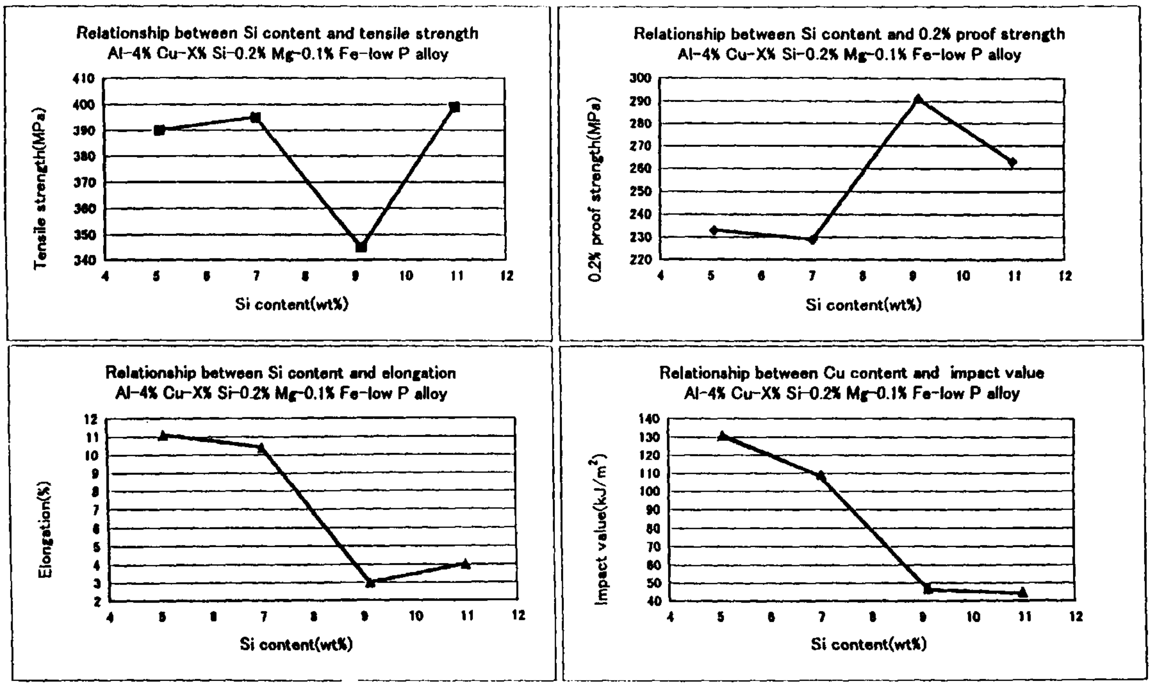


Fig.4

Al-4% Cu-7% Si-X% Mg-0.1% Fe-low P alloy

Mg content(%)	Tensile strength(MPa)	0.2% proof strength(MPa)	Elongation(%)	Impact value(kJ/m^2)
0.01	371	202	8.9	111
0.10	391	219	11.7	138
0.15	386	226	11.2	125
0.20	395	229	10.4	109
0.30	398	294	5.4	75

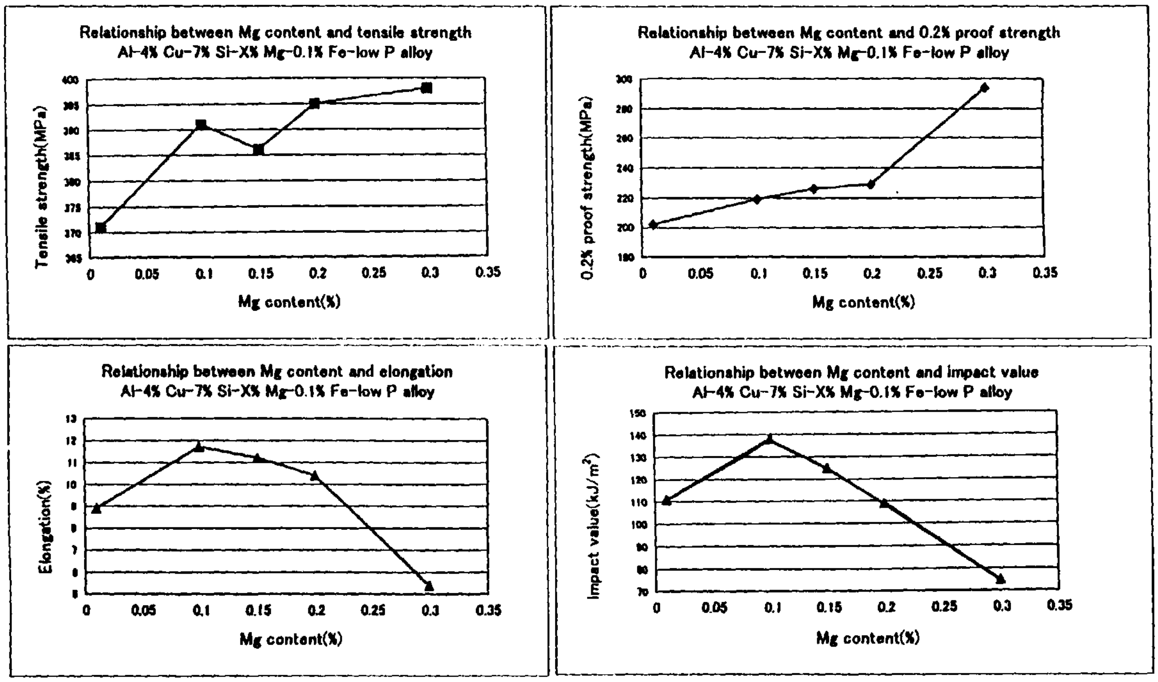


Fig.5

Al-4% Cu-7% Si-0.15% Mg-X% Fe-low P alloy

Fe content(%)	Tensile strength(MPa)	0.2% proof strength(MPa)	Elongation(%)	Impact value(kJ/m²)
0.11	386	226	11.2	125
0.20	383	223	9.9	98
0.29	377	223	8.5	88

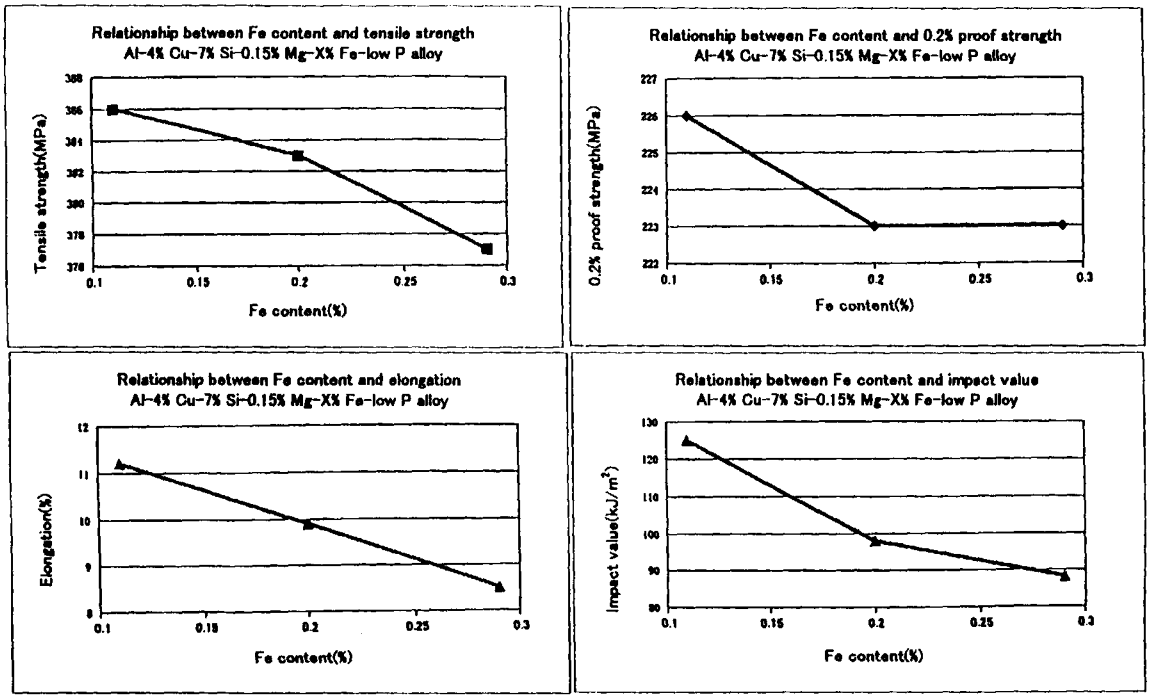


Fig.6

Al-4% Cu-7% Si-0.15% Mg-0.1% Fe alloy
Tensile strength(MPa)

	High P-content alloy	Low P-content alloy	Sb-added alloy	Sr-added alloy
1	399	388	388	381
2	385	395	373	383
3	386	387	381	403
4	385	381	383	376
5	385	380	387	363
Average	388	386	382	381

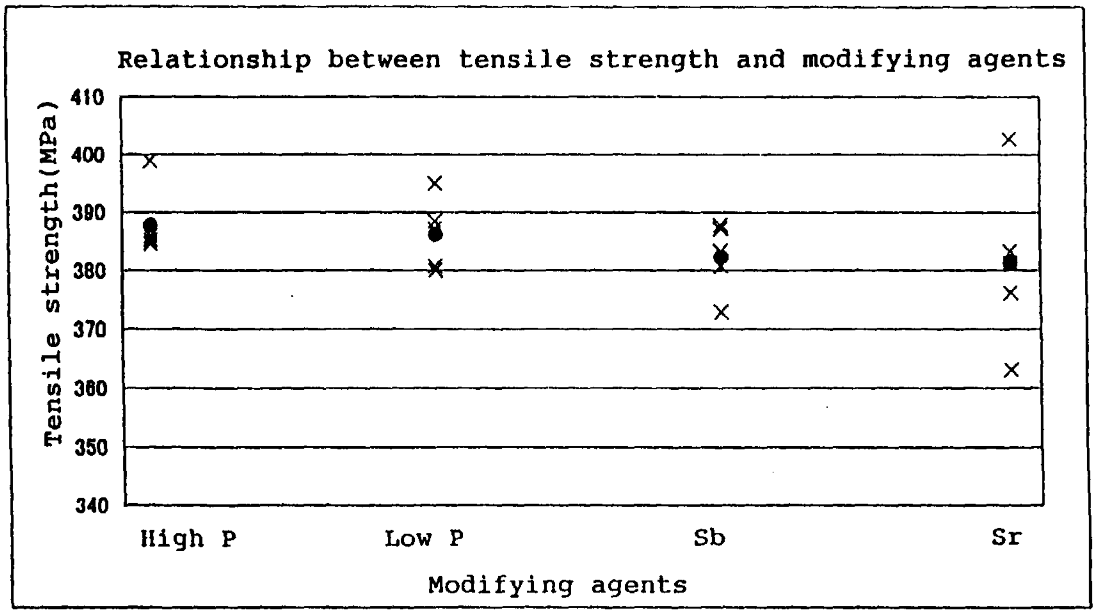


Fig.7

Al-4% Cu-7% Si-0.15% Mg-0.1% Fe alloy
0.2 proof strength(MPa)

	High P-content alloy	Low P-content alloy	Sb-added alloy	Sr-added alloy
1	254		212	234
2	242	233	218	233
3	222	237	218	242
4	229	219	214	226
5	234	216	219	205
Average	236	226	216	228

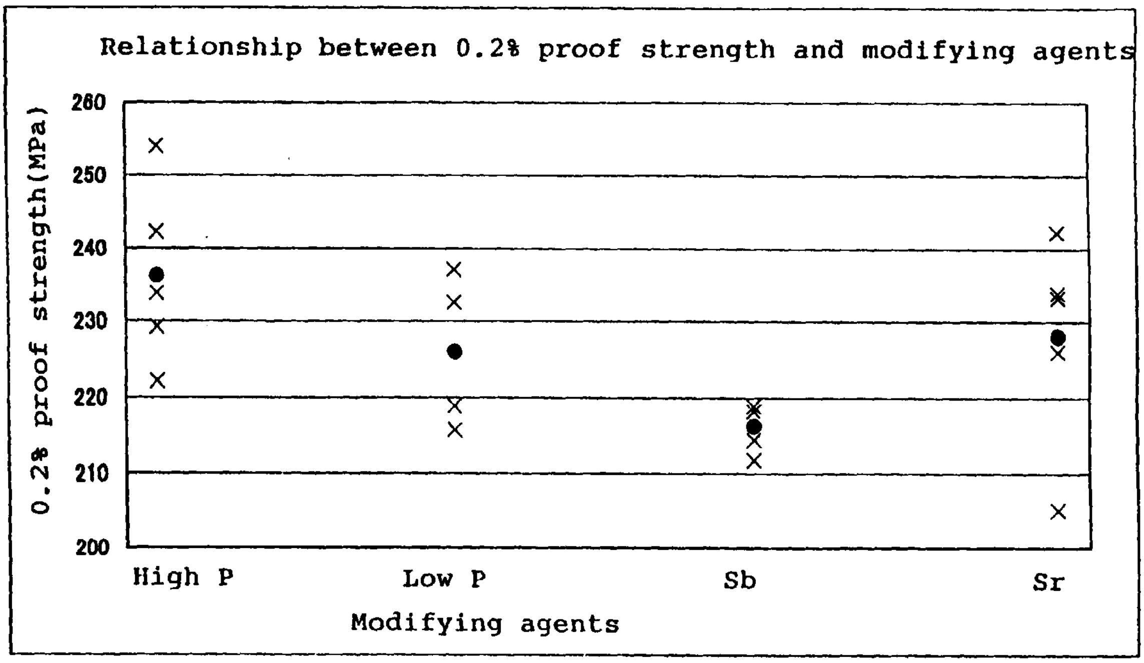


Fig.8

Al-4% Cu-7% Si-0.15% Mg-0.1% Fe alloys
Elongation(%)

	High P-content alloy	Low P-content alloy	Sb-added alloy	Sr-added alloy
1	7.1	11.4	12.2	10.3
2	6.2	12.5	9.3	9.2
3	8.8	10.6	11.0	12.5
4	7.7	10.2	11.8	9.8
5	7.2	11.1	11.7	10.5
Average	7.4	11.2	11.2	10.5

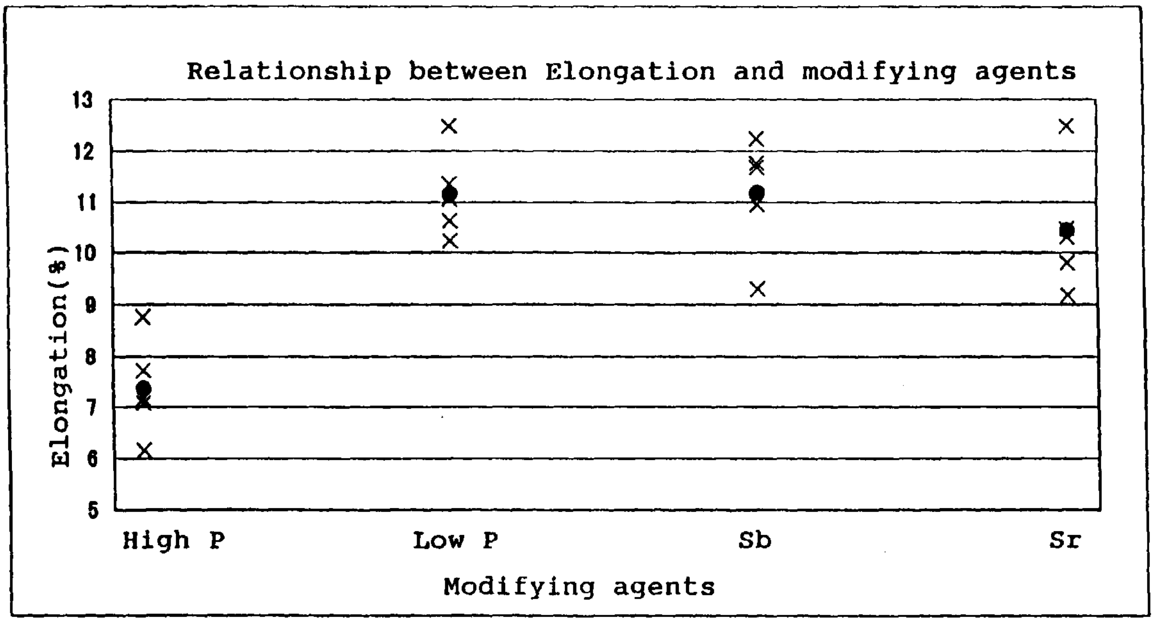


Fig.9

Al-4% Cu-7% Si-0.15% Mg-0.1% Fe alloys

Impact value(kJ/m^2)

	High P-content alloy	Low P-content alloy	Sb-added alloy	Sr-added alloy
1	65	112	115	123
2	67	127	111	153
3	68	131	107	121
4	81	130	100	127
Average	70	125	108	131

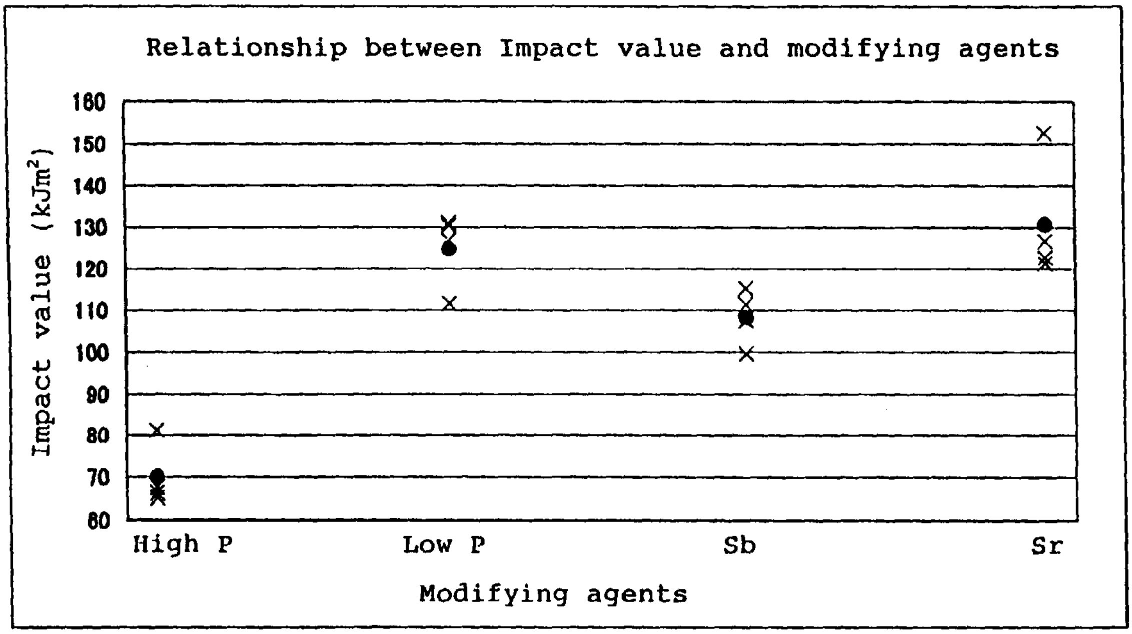


Fig.10

Al-4% Cu-7% Si-0.15% Mg-0.1% Fe-Low P alloy
Tensile strength (MPa)

	Low P	Low P + Ti	Low P + Ti -B
2	388	377	390
3	395	398	400
4	387	392	392
6	381	389	399
7	380	381	404
Average	386	387	397

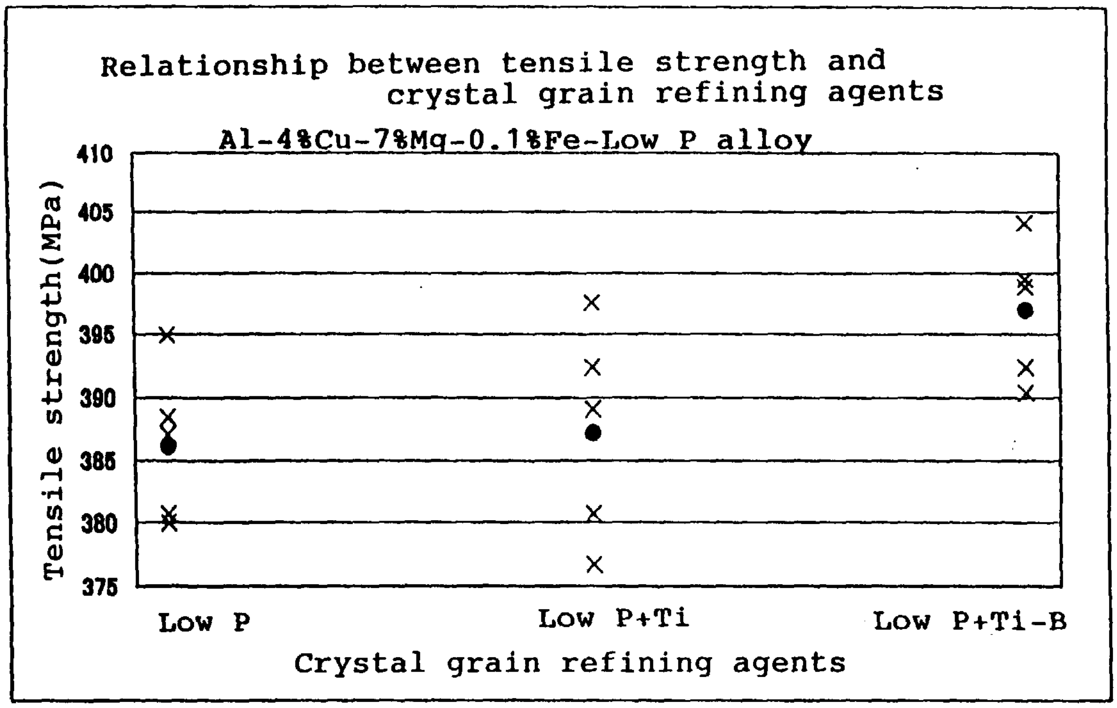


Fig.11

Al-4% Cu-7% Si-0.15% Mg-0.1% Fe-Low P alloy
0.2% proof strength (MPa)

	Low P	Low P + Ti	Low P + Ti -B
2		237	231
3	233	240	235
4	237	237	236
6	219	234	222
7	216	225	230
Average	226	235	231

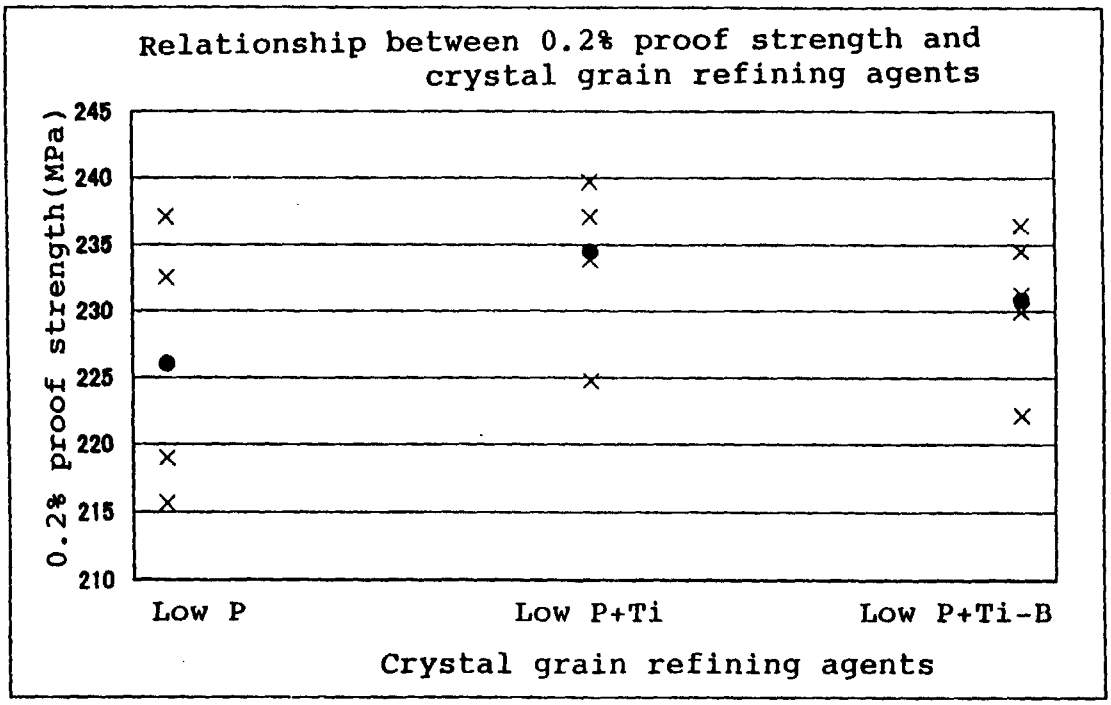


Fig.12

Al-4% Cu-7% Si-0.15% Mg-0.1% Fe-Low P alloy
Elongation (%)

	Low P	Low P + Ti	Low P + Ti -B
2	11.36	7.40	9.22
3	12.48	10.06	11.76
4	10.64	8.80	9.38
6	10.24	9.76	11.94
7	11.06	9.24	12.52
Average	11.16	9.05	10.96

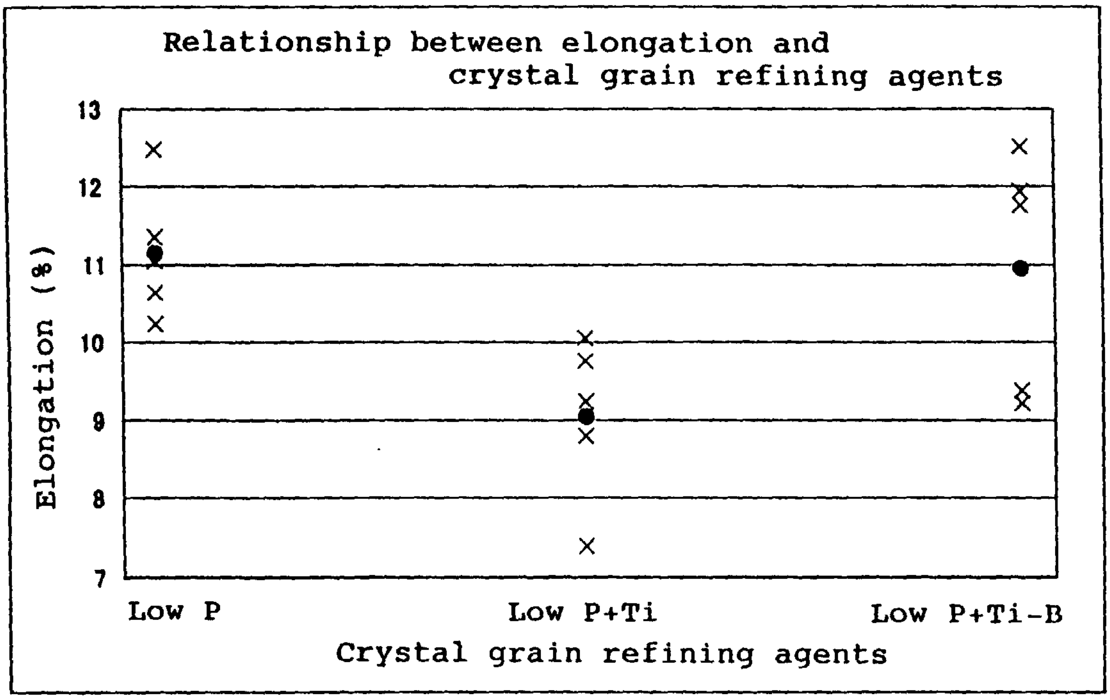


Fig.13

Al-4% Cu-7% Si-0.15% Mg-0.1% Fe-Low P alloy
Impact value (kJ/m^2)

	Low P	Low P + Ti	Low P + Ti -B
2	112	88	85
3	127	86	98
4	131	101	88
6	130	97	90
Average	125	93	90

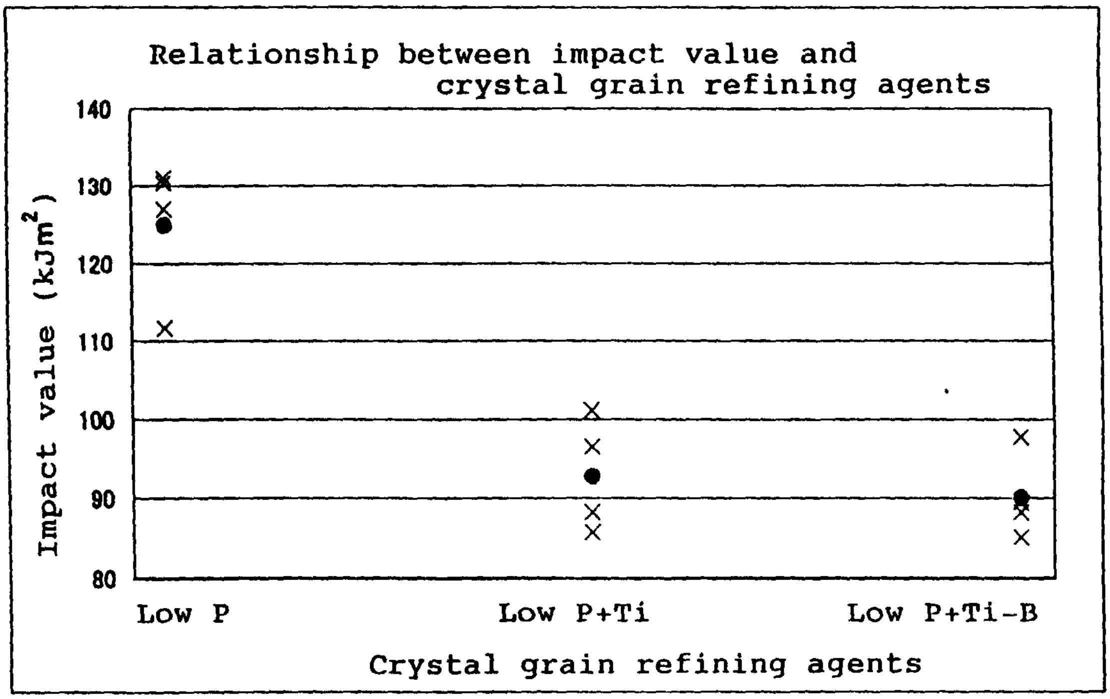


Fig.14