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(54) **ALUMINUM ALLOY EXCELLENT IN MACHINABILITY AND ALUMINUM ALLOY MATERIAL AND METHOD FOR PRODUCTION THEREOF**

ALUMINIUMLEGIERUNG MIT HERVORRAGENDER ZERSPANBARKEIT UND  
ALUMINIUMLEGIERUNGSMATERIAL UND HERSTELLUNGSVERFAHREN DAFÜR

ALLIAGE D'ALUMINIUM PRESENTANT UNE EXCELLENTE USINABILITE, ET MATERIAU  
D'ALLIAGE D'ALUMINIUM ET SON PROCEDE DE PRODUCTION

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**Description****Technical Field**

5 **[0001]** The present invention relates to Al-Mg-Si series aluminum alloys excellent in machinability, and methods for manufacturing an aluminum alloy material.

**Background Art**

10 **[0002]** In cutting aluminum alloy materials, there are problems that it is required to perform steps of disposing chips which is long and continuous and removing burrs generated at a corner of a product at the time of lathing or burrs generated at around a drilled hole at the time of drilling.

**[0003]** In order to solve these problems, an easy-to-cut aluminum alloy capable of suppressing cutting ability and burr generation by adding low fusing point elements such as Pb, Bi and Sn to enhance chip fractionizing nature, is proposed.

15 **[0004]** However, these low fusing point elements are often segregated at a crystal grain boundary. As a result, these elements tend to be partially fused by heat generated during, for example, heavy machining processing, which in turn results in crack generation. Furthermore, manufacturing and using such easy-to-cut aluminum alloy materials containing Pb that is a toxic element causes a serious problem from a viewpoint of earth environmental protection and also deteriorates recycling of aluminum products.

20 **[0005]** Accordingly, an easy-to-cut aluminum alloy containing Si or Cu as an alternative element of the aforementioned low fusing point element is developed.

**[0006]** For example, Japanese Unexamined Laid-open Patent Publication No. 11-12705 discloses an aluminum alloy to be forged containing Si: 3-11 mass%, Japanese Unexamined Laid-open Patent Publication No. 9-249931 discloses a high corrosion resistant aluminum alloy containing Si: 1.5 - 12.0 mass%, and Japanese Unexamined Laid-open Patent  
25 Publication No. 2-97638 discloses an aluminum alloy for magnetic tape contact component use containing Si: 2.0 - 12.5 mass% and Cu: 1.0 - 6.5 mass%. In these aluminum alloy materials, hard Si particles are dispersed in the aluminum matrix so that the Si particles can be ground at the time of cutting or the Si particles and the matrix interface thereof can be exfoliated to thereby break the chips into small pieces. Since these aluminum alloy materials do not contain low fusing point elements, they are excellent in recycling nature, and also excellent in corrosion resistance and heat resist-  
30 ance.

**[0007]** Furthermore, these aluminum alloy materials are manufactured by homogenizing a cast extruding billet of predetermined compositions, then extruding the billet at 400 - 600 °C, into an extruded article at 350 - 550 °C, and then quenching the extruded article at a die exit or performing a solution treatment after cutting the extruded article into a long cut article of 1 - 5 m length.

35 **[0008]** In the aforementioned conventional easy-to-cut aluminum alloy, however, if the alloy contains 5% or more of Si, since a large amount of Si particles are dispersed therein, there is a drawback that the Si particles having acute-angle portions attack a cutting edge of a cutting tool, and therefore the cutting tool will be heavily worn down or the cutting tool will be damaged, thereby shortening the life. On the other hand, in an aluminum alloy containing a large amount of Cu, there is a drawback that the alloy is poor in corrosion resistance.

40 **[0009]** Furthermore, in the aforementioned manufacturing process, although the Si particle may sometimes become 1  $\mu\text{m}$  or less at the time of casting the billet, the particle tends to grow up to a size exceeding 1  $\mu\text{m}$  due to a heat treatment of 300 °C or more, which is performed after the casting. Accordingly, the Si particle grows during each processing, i.e., homogenizing processing, extruding processing, quenching processing at a die exit and solution treatment processing, and finally grows up to a size of 5 - 10  $\mu\text{m}$ . As a result, the alloy material obtained by performing the aforementioned series of processing is poor in cutting ability as compared to a cast member, which causes heavy abrasion or damage  
45 of a cutting tool. Concretely, if large Si particles with a mean particle diameter exceeding 5  $\mu\text{m}$  exist in the aluminum matrix, tool damage such as tool abrasion or tool chipping will become serious. Furthermore, the tool damage deteriorates the quality of the machined surface obtained by a long and continuous cutting processing. Furthermore, if alumite processing is executed to the aluminum alloy materials containing such large and rough Si particles, there is a problem  
50 that the alumite coating thickness becomes uneven since the generation rate of alumite coat differs between the Si particles exposed to the surface and the aluminum matrix.

**[0010]** US-A 5 123 973 describes a wrought extruded rod product comprised of 11 to 13.5 wt.% Si, 0.5 to 2.0 wt.% Cu, 0.8 to 2 wt.% Mg, 0.5 to 3.0 wt.% Ni, max. 1 wt.% Fe, max. 0.1 wt.% Cr, max. 0.25 wt.% Zn, the balance aluminum, incidental elements and impurities.  
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**Disclosure of Invention**

**[0011]** In view of the aforementioned technical background, the present invention aims to provide aluminum alloys

excellent in cutting ability, capable of suppressing abrasion and damage such as chipping of a cutting tool and having better alumite processability, and manufacturing methods for manufacturing an aluminum alloy material. To this aid, the present invention provides an aluminum alloy according to claim 1 and an aluminum alloy according to claim 31 as well a method for manufacturing an aluminum alloy material according to claim 23 and a method for manufacturing an aluminum alloy material according to claim 65. Further embodiments of the aluminium alloys and manufacturing methods according to the present invention are described in the dependent claims.

**[0012]** The present invention includes aluminum alloys roughly classified by chemical composition into two types and two methods for manufacturing an aluminum alloy material.

**[0013]** A first aluminum alloy consists of Mg: 0.3 - 6 mass%, Si: 0.3 - 10 mass%, Zn: 0.05 - 1 mass%, Sr: 0.001 - 0.3 mass%, one or more of selective additional elements selected from the group consisting of Cu: 0.01% or more but less than 1 mass%, Fe: 0.01 - 1 mass%, Mn: 0.01 - 1 mass%, Cr: 0.01 - 1 mass%, Zr: 0.01 - 1 mass%, Ti: 0.01 - 1 mass%, Na: 0.001 - 0.5 mass%, Ca: 0.001 - 0.5 mass%; and the balance being Aluminum and impurities.

**[0014]** In the first aluminum alloy, it is preferable that the content of Mg is 0.5 - 1.1 mass%. It is preferable that the content of Si is 1.5 - 5 mass%. It is preferable that the content of Zn is 0.1 - 0.3 mass%. It is preferable that the content of Sr is 0.005 - 0.05 mass%.

**[0015]** In the first aluminum alloy, it is preferable that the selective additional element is Cu. It is preferable that the selective additional element is Fe. It is preferable that the selective additional element is one or more elements selected from the group consisting of Cr and Mn. It is preferable that the selective additional element is Zr. It is preferable that the selective additional element is Ti. It is preferable that the selective additional element is one or more elements selected from the group consisting of Na and Ca.

**[0016]** Furthermore, in the first aluminum alloy, it is preferable that the content of Cu is 0.1 - 0.3 mass%. It is preferable that the content of Fe is 0.1 - 0.3 mass%. It is preferable that the content of Mn is 0.1 - 0.3 mass%. It is preferable that the content of Cr is 0.1 - 0.3 mass%. It is preferable that the content of Zr is 0.1 - 0.3 mass%. It is preferable that the content of Ti is 0.1 - 0.3 mass%. It is preferable that the content of Na is 0.005 - 0.3 mass%. It is preferable that the content of Ca is 0.005 - 0.3 mass%. For example, in the first aluminum alloy a mean particle diameter of Si particle is 1 - 5  $\mu\text{m}$  and a mean aspect ratio of Si particle is 1 - 3, as an alloy texture of the aluminum alloy.

**[0017]** In this aluminum alloy, it is preferable that the mean particle diameter of the Si particle is 3  $\mu\text{m}$  or less. The mean aspect ratio of the Si particle is preferably 2 or less.

**[0018]** A first method for manufacturing an aluminum alloy material according to the present invention comprises: making a billet composed of the first aluminum alloy as recited in any one of claims 1 -19 at a casting rate of 10-180 mm/min., homogenizing the billet at 400 - 570°C for 6 hours or more to obtain a homogenized billet; extruding the homogenized billet at a billet temperature of 300 - 550 °C, an extrusion rate of 0.5 - 100 m/min. and an extrusion ratio of 10 - 200 into an extruded article having a predetermined configuration; executing a solution treatment to the extruded article at 400 - 570 °C for 1 hour or more; and aging the solution treated extruded article at 90 - 300 °C for 1 - 30 hours.

**[0019]** In the aforementioned aluminum alloy material manufacturing method, it is preferable that the casting rate is 30 - 130 mm/min. The homogenization is preferably performed at 500 - 545°C for 10 hours or more. The extrusion is preferably performed at the billet temperature of 350 - 500°C, the extrusion rate of 2 - 30 m/min. and the extrusion ratio of 20 - 85. The solution treatment is preferably performed at 500 - 545°C for 3 hours or more. The aging is preferably performed at 140 - 200°C for 3 - 20 hours. It is preferable that the solution treated extruded article is drawn at a reduction rate of 5 - 30% into a predetermined configuration, and thereafter the aging is performed. Especially, the reduction rate of the drawing is preferably 10 - 20%.

**[0020]** A second aluminum alloy comprises: Mg: 0.1 - 6 mass%; Si: 1.2-8.5 mass%; Cu: 0.01 mass% or more but less than 1 mass%; Zn: 0.01 - 3 mass%; Sr: 0.001 - 0.5 mass%; optionally one or more of selective additional elements selected from the group consisting of Ti: 0.001 - 1 mass%, B: 0.0001 - 0.03 mass%, C: 0.0001 - 0.5 mass%, Fe: 0.01 - 1 mass%, Cr: 0.01 - 1 mass%, Mn: 0.01 - 1 mass%; Zr: 0.01 - 1 mass%, V: 0.01 - 1 mass%, Sc: 0.0001 - 0.5 mass%, Ni: 0.005 - 1 mass%, Na: 0.001 - 0.5 mass%, Sb: 0.001 - 0.5 mass%, Ca: 0.001 - 0.5 mass%, Sn: 0.01 - 1 mass%, Bi: 0.01 - 1 mass%, In: 0.001 - 0.5 mass%; and the balance being Aluminum and impurities.

**[0021]** In the second aluminum alloy, it is preferable that the content of Mg is 0.3 - 5 mass%. . The content of Cu is preferably 0.1 - 0.8 mass%. The content of Zn is preferably 0.05 - 1.5 mass%. The content of Sr is preferably 0.005 - 0.3 mass%.

**[0022]** In the second aluminum alloy, it is preferable that the selective additional element is one or more elements selected from the group consisting of Ti, B, C and Sc. The selective additional element is preferably Fe. The selective additional element is preferably one or more elements selected from the group consisting Cr and Mn. The selective additional element is preferably one or more elements selected from the group consisting Zr and V. The selective additional element is preferably Ni. The selective additional element is preferably one or more elements selected from the group consisting Na, Sb and Ca. The selective additional element is preferably one or more elements selected from the group consisting Sn, Bi and In.

**[0023]** In the second aluminum alloy, it is preferable that the content of Ti is 0.003 - 0.5 mass%. The content of B is

preferably 0.0005 - 0.01 mass%. The content of C is preferably 0.001 - 0.3 mass%. The content of Fe is preferably 0.05 - 0.7 mass%. The content of Cr is preferably 0.03 - 0.7 mass%. The content of Mn is preferably 0.03 - 0.7 mass%. The content of Zr is preferably 0.03 - 0.7 mass%. The content of V is preferably 0.03 - 0.7 mass%. The content of Sc is preferably 0.01 - 0.3 mass%. The content of Ni is preferably 0.03 - 0.7 mass%. The content of Na is preferably 0.005 - 0.3 mass%. The content of Sb is preferably 0.005 - 0.3 mass%. The content of Ca is preferably 0.005 - 0.3 mass%. The content of Sn is preferably 0.05 - 0.5 mass%. The content of Bi is preferably 0.05 - 0.5 mass%. The content of In is preferably 0.01 - 0.3 mass%. For example, in metal texture, a mean dendrite arm spacing is 1 - 200  $\mu\text{m}$ , a dendrite boundary zone includes eutectic Si particles of 0.01 - 5  $\mu\text{m}$  of mean particle diameters and other second phase particles, and an eutectic lamella texture in which a mean skeleton line length ( $L_m$ ) in a longitudinal direction is 0.5  $\mu\text{m}$  or more and a mean width ( $W_m$ ) is 0.5  $\mu\text{m}$  or more is formed in a shape of a network.

**[0024]** In the second aluminum alloy, it is preferable that, in the eutectic lamella texture, the eutectic Si particles and other second phase particles exist 500 pieces/ $\text{mm}^2$  or more in total, and the area share of these particles is 0.1 - 50%. The mean dendrite arm spacing is preferably 3-100  $\mu\text{m}$ . The mean particle diameter of the eutectic Si particle is preferably 0.1 - 3  $\mu\text{m}$ . Preferably, the eutectic lamella texture has a mean skeleton line length ( $L_m$ ) of 3  $\mu\text{m}$  or more and a mean width ( $W_m$ ) of 1  $\mu\text{m}$  or more. The mean ratio ( $L/W_m$ ) of the skeleton line length to the skeleton width in the eutectic lamella texture is preferably 3 or more.

**[0025]** Furthermore, it is preferable that the eutectic Si particles and other second phase particles exist 1,000 pieces/ $\text{mm}^2$  or more in total. The area share of the eutectic Si particles and other second phase particles is preferably 0.3 - 40%.

**[0026]** A second method for manufacturing an aluminum alloy material comprises: continuously casting molten the second aluminum alloy as recited in any one of claims 31-58 to obtain a shape member having a prescribed cross section at a casting rate of 30 - 5000 mm/min. and a cooling rate of 10 - 600  $^{\circ}\text{C}/\text{sec.}$ , the molten aluminum alloy and held at the solidus temperature or more; thereafter aging the shape member at 100 - 300 $^{\circ}\text{C}$  for 0.5 - 100 hours.

**[0027]** In the aforementioned second method for manufacturing an aluminum alloy material, it is preferable that the casting rate is 100 - 2000 mm/min. The cooling rate is preferably 30 - 300  $^{\circ}\text{C}/\text{sec.}$  The aging is preferably performed at 120 - 220 $^{\circ}\text{C}$  for 1 - 30 hours. Preferably, the shape member is a non-hollow member. It is preferable that the shape member circumscribes to a circle with a diameter of 10 - 150 mm in cross section. It is preferable that the method further comprises a step of removing a surface layer portion of a 0.1 - 10 mm depth from the continuously cast shape member. The removed surface layer portion is preferably 0.2 - 5 mm in depth.

**[0028]** It is preferable that the second method further comprises the step of performing a secondary forming processing of a cross-sectional area decreasing ratio of 30% or less to the shape member after the continuous casting at a temperature of 400  $^{\circ}\text{C}$  or below. The processing temperature is preferably 250  $^{\circ}\text{C}$  or below. The cross-sectional area decreasing ratio is preferably 20% or less.

**[0029]** In the following explanation, the aforementioned two types of aluminum alloys will be detailed by classifying them into the first aluminum alloy containing Mg, Si, Zn and Sr as common indispensable elements and the second aluminum alloy containing Mg, Si, Cu, Zn and Sr as common indispensable elements. Following the explanation of each aluminum alloy composition, the aluminum alloy materials and the manufacturing methods thereof corresponding to these compositions will be explained.

#### I. The first aluminum alloy, and the first manufacturing method (Claims 1 - 30)

**[0030]** The first aluminum alloy and the alloy materials having the chemical compositions thereof suppress abrasion and damage of a cutting tool by rounding and fining Si particles while securing good cutting ability caused by the enhanced chip breakable nature due to the Si particles. Furthermore, in addition to the strengthening by the main deposit,  $\text{Mg}_2\text{Si}$ , the strength of the alloys are notably improved by the excessive Si particles, as compared to conventional alloys.

**[0031]** Hereinafter, the reasons for adding each element and for limiting the amount of each element in the aluminum alloys and the alloy materials will be detailed.

**[0032]** In the composition of the aforementioned aluminum alloy, four elements of Mg, Si, Zn and Sr are essential elements. The first aluminum alloy (claims 1 - 22) according to the present invention comprises these 4 elements.

**[0033]** Mg is dissolved in an alloy matrix and dispersed as deposits such as  $\text{Mg}_2\text{Si}$  created by bonding with excessive Si, etc. in the matrix, to thereby enhance the mechanical property, especially proof strength and further improve the cutting ability of the alloy by the synergistic effect with other solid solution type elements. If the Mg content is less than 0.3 mass%, the aforementioned effects cannot be obtained sufficiently. To the contrary, if the Mg content exceeds 6.0 mass%, oxidation of an alloy molten metal is promoted and plastic-working nature deteriorates. Accordingly, the Mg content should be 0.3 - 6 mass%. Preferably, the Mg content is 0.5 - 1.1 mass%.

**[0034]** Since only few amount of Si can be dissolved in an aluminum, Si is dispersed in the matrix as a single particle of Si except for the amount required for compound formation. In the alloy texture in which Si particles are dispersed, since the Si particles are ground by a cutting tool and/or the Si particle and the aluminum base phase are peeled at the interface, the chips can be easily broken, resulting in improved cutting ability. Furthermore, the Si particles become

round and fine by Sr added as an essential element, or Na and Ca added as an arbitrary element, which also improves the cutting ability. If Si content is less than 0.3 mass%, sufficient chip breaking effects cannot be obtained. To the contrary, if Si content exceeds 10 mass%, although the chip breaking effects can be improved, a cutting tool will be abraded heavily, causing deteriorated productivity. Accordingly, it is necessary that Si content is 0.3 - 10 mass%. From this point of view, the preferable Si content is 1.5 - 5 mass%.

**[0035]** Zn dissolves in an alloy matrix, while Zn bonds with Mg and disperses in a matrix as deposit of  $MgZn_2$ . This improves the mechanical property of the aluminum alloy and the cutting ability of the alloy by the synergistic effects of other dissolve type elements. If Zn content is less than 0.05 mass%, the aforementioned effects cannot be obtained sufficiently. To the contrary, if Zn content exceeds 1 mass%, the corrosion resistance may deteriorate. Accordingly, it is necessary that Zn content is 0.05 - 1 mass%. Furthermore, if the Zn content falls within the range, it is effective in improving an alumite coat generation rate, and therefore the alloy can be suitably used for a product to which alumite processing is performed for the purpose of improving the abrasion resistance. The preferable Zn content is 0.1 - 0.3 mass%.

**[0036]** Sr makes eutectic Si at the time of solidification and proeutectic Si round and fine when Sr coexists with Si. This indirectly improves the chip breaking nature, which in turn improves the cutting ability and suppresses abrasion and damage on a cutting tool. Furthermore, Sr has effects of making Si particles disperse uniformly and finely at the steps of continuous casting, extrusion, drawing, etc., thereby further improving the cutting ability. If Sr content is less than 0.001 mass%, the aforementioned effects cannot be obtained sufficiently and the Si particle cannot be rounded, causing acute portions, which results in heavy abrasion of a cutting tool. To the contrary, if Sr exceeds 0.3 mass%, the aforementioned effects will be saturated, resulting in fruitless addition. Accordingly, Sr should be 0.001 - 0.3 mass%. Preferably, the Sr content is 0.005 - 0.05 mass%.

**[0037]** The first aluminum alloy according to the present invention (Claims 1 - 22) is an aluminum alloy containing the aforementioned four essential elements as basic compositions and optionally containing one or more arbitrary combined elements selected from the group consisting of eight elements, Cu, Fe, Mn, Cr, Zr, Ti, Na and Ca for the purpose of further improving various characteristics of the alloy.

**[0038]** Cu dissolves in an alloy matrix, while Cu bonds with Al and disperses in a matrix as deposit of  $CuAl_2$ . This improves the mechanical property and cutting ability of an aluminum alloy by the synergistic effects with other dissolve type elements. If Cu content is less than 0.01 mass%, the aforementioned effects cannot be obtained sufficiently. To the contrary, if Cu content exceeds 1 mass%, there is a possibility that corrosion resistance deteriorates. Accordingly, it is preferable that Cu content is 0.01 or more but less than 1 mass%. More preferably, the Cu content is 0.1 - 0.3 mass%.

**[0039]** Fe is an inevitable element contained in an aluminum alloy. The content falling within the range of 0.01 - 1 mass% is a normal amount contained during manufacturing an aluminum alloy. Therefore, no special step for decreasing Fe content is required. Furthermore, if Fe content falls within the aforementioned range, since only a few amount of Fe bonds with Si, which is effective to improve chip breaking effect, can be distributed as an individual particle, which can maintain outstanding chip breaking nature. In order to decrease the Fe content less than 0.01 mass%, the cost increases. To the contrary, if Fe content exceeds 1 mass%, Fe compounds with Si increase and Si individual particles decrease, resulting in deteriorated chip breaking nature. It is preferable that Fe content is 0.1 - 0.3 mass%.

**[0040]** Mn and Cr are elements to be added in order to improve mechanical strength by suppressing recrystallization in an aluminum alloy and enhance corrosion resistance. If Mn content and Cr content is less than 0.01 mass% respectively, it is difficult to obtain sufficient recrystallization inhibition effect and improve mechanical property and corrosion resistance. Furthermore, the chip breaking nature in the cross-sectional direction becomes unstable because of the recrystallized large particles. To the contrary, if the content exceeds 1 mass%, the hot deformation resistance at the time of extrusion increases, resulting in deteriorated productivity. Therefore, it is preferable that Mn content and Cr content are 0.01 - 1 mass% respectively. Furthermore, if Mn and Cr content falls within the aforementioned range, since only a few amount thereof bonds with Si, which is effective in improving chip breaking effect, can be distributed as an individual particle, which can maintain outstanding chip breaking nature. More preferable Mn content and Cr content are 0.1 - 0.3 mass%, respectively.

**[0041]** Zr is an elements to be added in order to improve mechanical strength by suppressing generation of large particle due to recrystallization in an aluminum alloy and enhance corrosion resistance. Furthermore, intermetallic compounds are formed by Zr and Al, and dispersed in a matrix. This improves cutting ability. If Zr content is less than 0.01 mass%, it is difficult to obtain sufficient recrystallization inhibition effect and improve mechanical property and corrosion resistance. Furthermore, the chip breaking nature in the cross-sectional direction becomes unstable because of the recrystallized large particles, and the cutting improvement effect is poor. To the contrary, if the content exceeds 1 mass%, the extrusion nature and/or castability deteriorates remarkably. Therefore, it is preferable that Zr content is 0.01 - 1 mass%. From this view point, more preferable Zr content is 0.1 - 0.3 mass%.

**[0042]** Ti is, similar to Zr, an elements to be added in order to improve mechanical strength by suppressing generation of large particle due to recrystallization in an aluminum alloy and enhance corrosion resistance. If Ti content is less than 0.01 mass%, it is difficult to obtain sufficient recrystallization inhibition effect and improve mechanical property and

corrosion resistance. Furthermore, the chip breaking nature in the cross-sectional direction becomes unstable because of the recrystallized large particles, and the cutting improvement effect is poor. To the contrary, if the content exceeds 1 mass%, the extrusion nature and/or castability deteriorates remarkably. Therefore, it is preferable that Ti content is 0.01 - 1 mass%. From this view point, more preferable Ti content is 0.1 - 0.3 mass%.

5 **[0043]** Na and Ca are elements to be added, similar to the aforementioned Sr, in order to round Si particle and disperse Si particles uniformly. If Na content is less than 0.001 mass%, the aforementioned effects cannot be obtained sufficiently. To the contrary, if Na content exceeds 0.5 mass%, the effects will be saturated. Accordingly, it is preferable that Na content is 0.001 - 0.5 mass%. If Ca content is less than 0.001 mass%, the aforementioned effects cannot be obtained sufficiently. To the contrary, if Ca content exceeds 0.5 mass%, the effects will be saturated. Accordingly, it is preferable that Ca content is 0.001 - 0.5 mass%. More preferably, Mg content is 0.005 - 0.3 mass%, Ca content is 0.005 - 0.3 mass%.

10 **[0044]** In the aluminum alloy and alloy material according to the present invention, since Sr, which is effective in rounding Si individual particle and dispersing Si particles uniformly, is contained as an essential element, an addition of Na and Ca is arbitrary. Therefore even if these elements are not added, the rounding of Si particle and uniform dispersibility of Si particles are secured.

15 **[0045]** As for the aforementioned eight elements to be arbitrarily selected, the aforementioned effects can be obtained by adding at least one element or two or more arbitrarily combined elements to the essential four elements. The aluminum alloys as recited in claims 6 - 11 include selective additional element (s) in order to obtain a predetermined effect. In cases where two or more elements are added, it is also preferable to selectively combine two or more elements different in effect. For example, these selective additional elements are classified into: A group element (Cu) which improves mechanical property by deposit such as  $\text{CuAl}_2$ ; B group element (Fe) which distributes Si as individual particles; C group element (Cr, Mn) which improves mechanical strength by suppressing recrystallization; D group element (Ti) which improves mechanical strength by suppressing generation of large and rough particles due to recrystallization and also improves corrosion resistance; E group element (Zr) which improves mechanical strength by suppressing generation of large and rough particles due to recrystallization, improves corrosion resistance and also improves cutting ability by forming intermetallic compounds; and F group elements (Na, Ca) which are effective in rounding Si particle and making Si particle into small pieces. Then, one or two or more arbitrarily combined groups are added to the essential elements. As for the group comprising plural elements, one or more elements are arbitrarily selected within the group. In cases where arbitrary additional elements are selected per one group, the content of each element should fall within the aforementioned range.

20 **[0046]** The aluminum alloy according to any of claims 20-22 defines the chemical compositions of an alloy falling within the range of the aforementioned aluminum alloys (claims 1 - 19) and the mean particle diameter and mean aspect ratio of Si particle in an alloy texture.

25 **[0047]** Although Si particles improve cutting ability by serving as chip breaking origins at the time of cutting, it is required that Si particle is fine and spherical in order to suppress abrasion of a tool and that the mean particle diameter is 1 - 5  $\mu\text{m}$  and the mean aspect ratio is 1 - 3. Si particle has a tendency that the mean particle diameter and the mean aspect ratio become larger as the Si content increases. Although good cutting ability can be obtained even if the mean particle diameter exceeds 5  $\mu\text{m}$ , a tool will be abraded heavily if the mean aspect ratio becomes larger. Accordingly, in this invention, in order to realize both good cutting ability and suppressed abrasion of a tool, the mean particle diameter and mean aspect ratio of Si particle are specified within the aforementioned range. From the viewpoint of obtaining outstanding cutting ability and suppressing abrasion of a tool, the preferable mean particle diameter of Si particle is 3  $\mu\text{m}$  or less, and the preferable mean aspect ratio is two or less.

30 **[0048]** The aluminum alloys mentioned above can be manufactured by the method according to any of claims 23-30. That is, the alloy material in which fined and rounded Si particles are distributed uniformly can be manufactured by using an alloy having predetermined chemical compositions and specifying the processing conditions of from a casting and extrusion of a billet to a drawing of the extruded article and heat treatment conditions.

35 **[0049]** A billet is formed at the casting rate of 10-180 mm/min. During this casting, the Si-Sr compound in a molten metal serves as a nucleus, and rounded proeutectic Si and eutectic Si are dispersed in the aluminum. As a result, fined and rounded Si particles can be obtained by the following heat treatment and extruding processing, or the drawing processing. Furthermore, since Si particles are rarely partially segregated at the crystal grain boundary and uniformly distributed in a cross-section, stable chip breaking nature can be obtained. If the casting rate is less than 10 mm/min., Si particle becomes larger and the particle distribution becomes rough. Therefore, stable chip breaking nature cannot be obtained. To the contrary, if the casting rate exceeds 180 mm/min., a casting surface may become bad or solidification crack may occur. The preferable casting rate is 30-130 mm/min.

40 **[0050]** The homogenization processing of the billet is performed by holding the billet at 400 - 570°C for 6 hours or more. Since this homogenization processing causes stable growth of Si particles and dissolving of other dissolve type elements, no partial segregation at the dendrite boundary zone or the crystal grain boundary occurs. Accordingly, the cutting ability, mechanical property and corrosion resistance of the finally obtained alloy material become good. If the homogenization processing performed at less than 400 °C, or for less than 6 hours, Si particle does not stably grows,

and dissolve type elements are not dispersed, and not dissolved in the aluminum. Accordingly, corrosion resistance deteriorates at the segregated portion, and stable chip breaking nature cannot be obtained. To the contrary, if the temperature exceeds 570 °C, voids are formed in the alloy texture by the eutectic fusion of aluminum and other each element, causing a deterioration of mechanical property. The preferable homogenization processing condition is to hold the billet at 500 - 545°C for 10 hours or more.

**[0051]** The extrusion is performed at the billet temperature of 300 - 550°C, the extrusion product rate of 0.5 - 100 m/min. and the extrusion ratio of 10 - 200. By performing the extrusion under the conditions, Si particles will be dispersed uniformly at the crystal grain boundary without causing partial segregation, which does not spoil the cutting ability, mechanical property and corrosion resistance of the finally obtained alloy material. Furthermore, the productivity will be also good. If the billet temperature is less than 300 °C, the extrusion rate will deteriorate, resulting in poor productivity. The productivity will also deteriorate when the extrusion product rate is less than 0.5 m/min. Furthermore, if the extrusion ratio is less than 10, the distributed state of Si particles will not become uniform, and Si particles will be partially segregated at the old dendrite boundary zone. This causes unstable cutting ability and deteriorated mechanical property and corrosion resistance. To the contrary, if the billet temperature exceeds 550°C, the extrusion product rate exceeds 100 m/min. or the extrusion ratio exceeds 200, tears, pickups and the like arise on the surface of the extruded member, resulting in deteriorated surface quality. The preferable billet temperature is 350 - 500°C, the preferable extrusion product rate is 2 - 30 m/min., and the preferable extrusion ratio is 20 - 85.

**[0052]** The solution treatment after the extrusion is performed by holding the billet at 400 - 570°C for 1 hour or more. This solution treatment rounds Si particle, and therefore stable chip breaking nature can be obtained. Furthermore, the solution treatment decreases the partial segregation at the crystal grain boundary of the additional element, and therefore high mechanical property and high corrosion resistance can be obtained. If the solution treatment condition is less than 400 °C or less than 1 hour, mechanical strength becomes insufficient and chip breaking nature becomes poor. To the contrary, if the temperature exceeds 570°C, partial fusion at the crystal grain boundary occurs, and mechanical property deteriorates remarkably. The preferable solution treatment is performed by holding the billet at 500 - 545 °C at 3 hours or more.

**[0053]** The aging treatment is performed by holding the billet at 90 - 300°C for 1 - 30 hours. This causes the maximum strength and good chip breaking nature of the aluminum alloy material. If the aging temperature is less than 90 °C or the holding time is less than 1 hour, the aging becomes insufficient, the finished surface at the time of cutting becomes rough and the mechanical property deteriorates. To the contrary, if the aging temperature exceeds 300°C or the aging time exceeds 30 hours, the aging becomes excessive, which deteriorates chip breaking nature and mechanical property. The preferable aging is performed by holding the billet at 140 - 200 °C for 3 - 20 hours.

**[0054]** The extruded member after the solution treatment is preferably drawn at a reduction rate of 5 - 30% into a predetermined configuration. This drawing forms a predetermined configuration, and also can improve the mechanical property by fining the recrystallized structure of the surface formed at the time of extrusion. Furthermore, high dimensional accuracy in the longitudinal direction can be obtained. If the drawing reduction rate is less than 5%, the aforementioned effect becomes poor. To the contrary, if it exceeds 30%, tension breaks may occur at the time of drawing. The preferable reduction is 10 - 20%.

**[0055]** Other manufacturing conditions follow those for a conventional method.

II. The second aluminum alloy, and the second manufacturing method (claims 31 - 77)

**[0056]** The second aluminum alloy and the aluminum alloy materials including the chemical compositions thereof can further enhance the cutting ability due to Si particles obtained by the predetermined chemical compositions by further specifying the metal texture, and can suppress abrasion and damage on a cutting tool by controlling Si particle size.

**[0057]** Hereinafter, the reasons for adding each element and for limiting the amount of each element in the aluminum alloys and the alloy materials will be detailed.

**[0058]** In the composition of the aforementioned aluminum alloy, five elements of Mg, Si, Cu, Zn and Sr are essential elements. The second aluminum alloy (claims 31- 66) according to the present invention comprises these five elements.

**[0059]** Mg is dissolved in an alloy matrix and dispersed as deposits such as Mg<sub>2</sub>Si created by bonding with Si, etc. in the matrix, to thereby enhance the mechanical property, especially proof strength and further improve the cutting ability of the alloy by the synergistic effect with other solid solution type elements. If the Mg content is less than 0.1 mass%, the aforementioned effects cannot be obtained sufficiently. To the contrary, if the Mg content exceeds 6 mass%, oxidation of an alloy molten metal is promoted and plastic-working nature also deteriorates. Accordingly, the Mg content should be 0.1 - 6 mass% . Preferably, the Mg content is 0.3 - 5 mass%.

**[0060]** Since only a few amount of Si can be dissolved in an aluminum, Si is dispersed in the matrix as a single particle of Si except for the amount required for compound formation. Especially, the eutectic Si particles solidified and formed by the quick cooling at the time of the continuous casting of this invention become fine particles of 5 μm or less, and form eutectic lamella texture together with other second phase particles at the dendrite boundary zone. At the time of

cutting, a cutting tool causes separation of the eutectic lamella texture, grinding of the eutectic Si particles, and/or interfacial peeling between the eutectic Si particles and the aluminum host phase. As a result, the chips become easy-to-break, which improves cutting ability remarkably. Furthermore, the Si particles are rounded and fined by Sr added as an essential element or Na, Sb and Ca added as an arbitrary element, which also improves the cutting ability. If Si content is less than 0.3 mass%, chip breaking nature, i.e., cutting ability improving effects, cannot be obtained sufficiently. To the contrary, if Si content exceeds 12.5 mass%, although the cutting ability can be improved, many big and rough eutectic Si particles are formed. Therefore, cutting tool damages such as abrasion and/or chipping occur heavily, causing deteriorated productivity. According to the invention the Si content is 1.2 - 8.5 mass%.

**[0061]** Cu dissolves in an alloy matrix, while Cu bonds with Al and disperses in a matrix as deposit of  $\text{CuAl}_2$ , etc. This improves the mechanical property and cutting ability of an aluminum alloy by the synergistic effects with other dissolve type elements. Furthermore, the  $\text{CuAl}_2$  also exists in the eutectic lamella texture, and improves cutting ability by participating the separation of the eutectic lamella texture at the time of cutting. If Cu content is less than 0.01 mass%, the aforementioned effects cannot be obtained sufficiently. To the contrary, if Cu content exceeds 1 mass%, corrosion resistance may deteriorate. Accordingly, the Cu content is 0.01 or more but less than 1 mass%. More preferably, the Cu content is 0.1 - 0.8 mass%.

**[0062]** Zn dissolves in an alloy matrix, while Zn bonds with Mg and disperses in a matrix as deposit of  $\text{MgZn}_2$ , etc. This improves the mechanical property of the aluminum alloy and the cutting ability of the alloy by the synergistic effects of other dissolve type elements. If Zn content is less than 0.01 mass%, the aforementioned effects cannot be obtained sufficiently. To the contrary, if Zn content exceeds 3 mass%, there is a possibility that corrosion resistance deteriorates. Accordingly, it is necessary that Zn content is 0.01 - 3 mass%. Furthermore, if the Zn content falls within the range, it is effective in improving an alumite coat generation rate, and therefore the alloy can be suitably used for a product to which alumite processing is performed for the purpose of improving the abrasion resistance. The preferable Zn content is 0.05 - 1.5 mass%.

**[0063]** Sr makes eutectic Si at the time of solidification and proeutectic Si round and fine when Sr coexists with Si. This indirectly improves the chip breaking nature, which in turn improves the cutting ability and suppresses abrasion and damage such as chipping on a cutting tool. Furthermore, Sr has effects of making Si particles disperse uniformly and finely at the steps of continuous casting and/or the following secondary forming processing, thereby further improving the cutting ability. If Sr content is less than 0.001 mass%, the aforementioned effects cannot be obtained sufficiently, and the Si particle cannot be rounded, causing acute portions, which results in heavy abrasion or damage such as chipping of a cutting tool. To the contrary, if Sr exceeds 0.5 mass%, the aforementioned effects will be saturated, resulting in fruitless addition. The preferable Sr content is 0.005 - 0.3 mass%.

**[0064]** The second aluminum alloy according to the present invention (Claim 31-66) is an aluminum alloy containing the aforementioned five essential elements as basic compositions and optionally containing one or more arbitrary combined elements selected from the group consisting of sixteen elements, Ti, B, C, Fe, Cr, Mn, Zr, V, Sc, Ni, Na, Sb, Ca, Sn, Bi and In for the purpose of further improving various characteristics of the alloy.

**[0065]** Ti makes an ingot texture fine, and suppresses appearance of macro patterns and/or solidification cracks, which will be generated on the cut surface when the ingot texture is rough. If Ti content is less than 0.001 mass%, an ingot fining effect is poor. To the contrary, if it exceeds 1 mass%, rough Ti-Al series compounds will be formed, which may deteriorate castability and/or ductility of the aluminum alloy. Accordingly, it is preferable that Ti content is 0.001 - 1 mass%. The more preferable Ti content is 0.003 - 0.5 mass%.

**[0066]** B makes an ingot texture fine like Ti, and suppresses appearance of macro patterns and/or solidification cracks, which will be generated on the cut surface when the ingot texture is rough. If B content is less than 0.0001 mass%, an ingot fining effect is poor. To the contrary, if it exceeds 0.03 mass%, hard particles will be formed, which may increase abrasion and/or damages such as chipping. Accordingly, it is preferable that B content is 0.0001 - 0.03 mass%. The more preferable Ti content is 0.0005 - 0.01 mass%.

**[0067]** Fe is an element inevitably contained in an aluminum alloy. The content falling within the range of 0.01 - 1 mass% is a normal amount contained during manufacturing an aluminum alloy. Therefore, no special step for decreasing Fe content is required. Furthermore, if Fe content falls within the aforementioned range, since only a few amount of Fe bonds with Si, which is effective to improve chip breaking effect, can be distributed as an individual particle, which can maintain outstanding chip breaking nature. In order to decrease the Fe content less than 0.01 mass%, the cost increases. To the contrary, if Fe content exceeds 1 mass%, Fe compounds with Si increase and Si individual particles decrease, resulting in deteriorated chip breaking nature. The more preferable Fe content is 0.05 - 0.7 mass%.

**[0068]** Zr and V make an ingot texture fine, and suppresses appearance of macro patterns and/or solidification cracks, which will be generated on the cut surface when the ingot texture is rough, like Ti and B. Furthermore, an intermetallic compound is formed between aluminum and cutting ability improves because they disperse to a matrix. If the content of each element is less than 0.01 mass%, the aforementioned effect is poor. To the contrary, if it exceeds 1 mass%, castability deteriorates. Accordingly, it is preferable that the content of each element is 0.01 - 1 mass%. The preferable content is 0.03 - 0.7 mass%. Furthermore, Zr has an effect of improving mechanical strength by suppressing the recryst-

tallization and enhancing corrosion resistance, like below-mentioned Cr and Mn. As for these effects, if Zr content is less than 0.01 mass%, the mechanical property and corrosion resistance cannot be improved, and the chip breaking nature in the cross-sectional direction becomes unstable since large and rough particles are formed by recrystallization. To the contrary, if it exceeds 1 mass%, the hot deformation resistance at the time of secondary forming processing increases, resulting in deteriorated productivity. Accordingly, it is preferable that Zr content is 0.01 - 1 mass%, more preferably 0.03 - 0.7 mass%.

**[0069]** Cr and Mn are elements to be added in order to improve mechanical strength by suppressing recrystallization in an aluminum alloy and enhance corrosion resistance. If Cr content and Mn content are less than 0.01 mass% respectively, it is difficult to obtain sufficient recrystallization inhibition effect and improve mechanical property and corrosion resistance. Furthermore, the chip breaking nature in the cross-sectional direction becomes unstable because of the recrystallized large particles. To the contrary, if the content exceeds 1 mass%, the hot deformation resistance at the time of extrusion increases, resulting in deteriorated productivity. Therefore, it is preferable that Mn content and Cr content are 0.01 - 1 mass% respectively. Furthermore, if Mn and Cr content fall within the aforementioned range, since only a few amount thereof bonds with Si, which is effective in improving chip breaking effect, can be distributed as an individual particle, which can maintain outstanding chip breaking nature. More preferable Mn content and Cr content are 0.03 - 0.7 mass%, respectively.

**[0070]** Sc and C make an ingot texture fine, and suppresses appearance of macro patterns and/or solidification cracks, which will be generated on the cut surface when the ingot texture is rough, like Zr, V, B and Ti. If these elements are less than 0.0001 mass% respectively, the aforementioned effect cannot be obtained sufficiently. To the contrary, if they exceed 0.5 mass% respectively, they bond with aluminum or other elements to form hard particles, which causes heavy abrasion or damage on a cutting tool. Accordingly, it is preferable that the contents are 0.0001 - 0.5 mass%. Their more preferable contents are 0.01 - 0.3 mass%, respectively.

**[0071]** Ni forms Ni-Al series intermetallic compounds to improve cutting ability. If Ni content is less than 0.005 mass%, the aforementioned effect cannot be obtained sufficiently. To the contrary, if the content exceeds 1 mass%, castability and corrosion resistance deteriorates. Accordingly, it is preferable that Ni content is 0.005 - 1 mass%, more preferably 0.03 - 0.7 mass%.

**[0072]** Na, Sb and Ca make eutectic Si at the time of solidification and proeutectic Si round and fine when they coexist with Si, like Sr. This indirectly improves the chip breaking nature, which in turn improves the cutting ability and suppresses abrasion and damage such as chipping on a cutting tool. If the content of each of these elements is less than 0.001 mass%, the aforementioned effects cannot be obtained sufficiently. To the contrary, if it exceeds 0.5 mass%, the aforementioned effects will be saturated, resulting in fruitless addition. Accordingly, it is preferable that each content is 0.001 - 0.5 mass%, more preferably 0.005 - 0.3 mass%.

**[0073]** Sn, Bi and In further improve cutting ability when they coexist with Si. The content thereof should be Sn: 0.01 - 1 mass%, Bi: 0.01 - 1 mass% and In: 0.001 - 0.5 mass%. If each content is below the lower limit, the aforementioned effects cannot be obtained sufficiently. To the contrary, if it exceeds the upper limit, the corrosion resistance deteriorates, and the quality of the finished surface also deteriorates since tears will be generated at the time of cutting, especially at the time of deep cutting. Furthermore, cracks will be induced at the time of the hot deformation. Their preferable content is Sn: 0.05 - 0.5 mass%, Bi: 0.05 - 0.5 mass%, and In: 0.01 - 0.3 mass%.

**[0074]** As for the aforementioned sixteen elements to be arbitrarily selected, the aforementioned effects can be obtained by adding at least one element or two or more arbitrarily combined elements to the essential five elements. The aluminum alloys as recited in claims 38-42 include selective additional element(s) in order to obtain predetermined effects. In cases where two or more elements are added, it is also preferable to selectively combine two or more elements different in effect. For example, these selective additional elements are classified into: A group element (Ti, B, C and Sc) which has an effect of fining an ingot texture and suppressing an appearance of a macro pattern and solidification cracks; B group element (Fe) which distributes Si as individual particles; C group element (Cr and Mn) which improves mechanical strength by suppressing recrystallization; D group element (Zr and V) which has effects of fining an ingot texture and of suppressing an appearance of a macro pattern and solidification cracks, and further improves cutting ability due to the formation of intermetallic compounds; E group element (Ni) which improves cutting ability by forming intermetallic compounds; F group element (Na, Sb and Ca) which has an effect of rounding and fining Si particle; and G group element (Sn, Bi and In) which improves cutting ability when it coexists with Si. Then, one or more arbitrarily combined groups are added to the essential elements. As for the group comprising plural elements, one or more elements are arbitrarily selected within the group. In cases where arbitrary additional elements are selected per one group, the content of each element should fall within the aforementioned range.

**[0075]** The aluminum alloys as recited in claims 59-66 define the chemical compositions of an alloy so as to fall within the range of the aforementioned aluminum alloys as recited in claims 31-58, and specify the metal texture.

**[0076]** Figs. 1 and 2 show an example of metal texture of an aluminum alloy material manufactured by casting according to the present invention. Fig. 3 shows an example of metal texture of an aluminum alloy material manufactured by performing processing such as heat treatment and extrusion after casting. The aluminum alloy material shown in Fig.

3 corresponds to the alloy material mentioned in the paragraph entitled "BACKGROUND ART" and pointed out that a further improvement is required in respect of cutting ability and abrasion of a tool.

5 [0077] In Figs. 1 and 2, the portion shown with light color (in Fig. 1, the portion indicated as proeutectic  $\alpha$ -Al) is a dendrite. At the boundary zone thereof, eutectic lamella texture (shown as dark colored portion) including eutectic Si particles (indicated as eutectic Si in Fig. 1) and other second phase particles is distributed in the shape of a three dimensional network. To the contrary, Fig. 3 showing the conventional aluminum alloy material reveals that the second phase of the dendrite boundary zone has been divided and Si particles have been changed to an independently distributed texture form.

10 [0078] The aluminum alloy according to the present invention is made by considering the fact that the differences of the aforementioned metal textures influence cutting ability and abrasion and/or damage on a cutting tool. Concretely, the aluminum alloy material defines the dendrite arm spacing (hereinafter referred as "DAS") and the eutectic lamella texture formed at the dendrite boundary zone.

15 [0079] In the metal texture, it is required that the average DAS (see Fig. 1) is 1 - 200  $\mu\text{m}$ . The reason for limiting the average DAS within the aforementioned range is as follows. If the average DAS is less than 1  $\mu\text{m}$ , although the cooling rate at the time of casting should be 1,000  $^{\circ}\text{C}/\text{sec}$ . or more, the cooling rate exceeds the manufacture limitation as an ingot member. To the contrary, if the average DAS exceeds 200  $\mu\text{m}$ , cutting ability and mechanical property will remarkably deteriorate. The preferable average DAS is 3 - 100  $\mu\text{m}$ .

20 [0080] At the dendrite boundary zone, an eutectic lamella texture containing the eutectic Si particles each having a mean particle diameter of 0.01 - 5  $\mu\text{m}$  and other second phase particles is formed in the aluminum host phase. At the time of cutting, the eutectic Si particles, even a single Si particle, become chip breaking origins, which improves cutting ability. Furthermore, the eutectic Si particles form layer-like eutectic lamella texture, and the eutectic lamella texture can be separated as if the eutectic lamella texture is peeled off, which improves cutting ability. Since such eutectic lamella texture is distributed in a continuous three-dimensional network, the aforementioned separation occurs continuously. As a result, cutting ability can be improved and abrasion of a cutting tool can be suppressed. To the contrary, in the metal texture form shown in Fig. 3, since Si particles as chip breaking origins are independently distributed, the cutting ability and abrasion of a cutting tool is inferior to those of the metal texture distributed in the shape of a network as shown in Figs. 1 and 2.

25 [0081] If the mean particle diameter of the eutectic Si particle is less than 0.01  $\mu\text{m}$ , the cutting ability improvement effect is poor. Furthermore, The eutectic Si particle tends to increase in size as the Si content increases. If the mean particle diameter exceeds 5  $\mu\text{m}$ , although good cutting ability can be obtained, a tool will be heavily abraded or damaged such as chipped as the grain size becomes larger. Accordingly, in order to realize both good cutting ability and suppression of tool damage, the mean particle diameter of eutectic Si particle is limited to 0.01 - 5  $\mu\text{m}$ . Especially, from the viewpoint of suppressing tool damage, the preferable mean particle diameter is 0.1 - 3  $\mu\text{m}$ .

30 [0082] The aforementioned other second phase particles are particles generated between Al, such as a  $\text{CuAl}_2$  and Al-Fe-Si series, Al-Mn-Si series, Al-Cr-Si series and Al-Fe series, and an additional element. The preferable mean particle diameter is 0.1 - 0.3  $\mu\text{m}$ .

35 [0083] As shown in Fig. 1, the size the eutectic lamella texture is represented by the skeleton line length (L) in the longitudinal direction and the width (W). The skeleton line length (L) is the length of the skeleton line showing the frame of the eutectic lamella texture, and the width (W) is the maximum width in the direction perpendicular to the skeleton line. In the present invention, the eutectic lamella texture is defined by the mean values of the aforementioned length and width and the ratio thereof, wherein the mean skeleton line length ( $L_m$ ) is 0.5  $\mu\text{m}$  or more, and the mean width ( $W_m$ ) is 0.5  $\mu\text{m}$  or more. If the mean skeleton line length ( $L_m$ ) and mean width ( $W_m$ ) are less than 0.5  $\mu\text{m}$ , respectively, good cutting ability cannot be obtained. The preferable average skeleton line length ( $L_m$ ) is 3  $\mu\text{m}$  or more, and the preferable average width ( $W_m$ ) is 1  $\mu\text{m}$  or more. Furthermore, it is preferable to be a long and slender configuration in which the mean value ( $L/W_m$ ) of the ratio (L/W) of the skeleton line length (L) to the mean width (W) is 3 or more, because this configuration is excellent in continuous separation.

40 [0084] In the aforementioned eutectic lamella texture, if the number of particles of the eutectic Si particles and the other second phase particles constituting the eutectic lamella texture and the area share are specified, more excellent cutting ability can be obtained. That is, in the eutectic lamella texture, it is preferable that the eutectic Si particles and other second phase particles exist 500 pieces/ $\text{mm}^2$  or more in total, and the area share of these particles is 0.1 - 50%. If the total number of particles is less than 500 pieces/ $\text{mm}^2$  or the area share is less than 0.1%, the cutting ability improving effect becomes poor. Furthermore, the number of eutectic Si particles and the area share tend to become larger as the Si content increases, and even if the area share exceeds 50%, good cutting ability can be obtained. However, if the area share exceeds 50%, the mechanical strength of the alloy material, especially the ductility ability (tensile strength) and the corrosion resistance, deteriorates. Therefore, the upper limit of the area share should be 50%. From the viewpoint of suppressing deterioration of mechanical strength and corrosion resistance while keeping cutting ability, the especially preferable total number of the eutectic Si particles and other second phase particles is 1,000 pieces/ $\text{mm}^2$  or more, and the especially preferable area share is 0.3 - 40%.

**[0085]** The aluminum alloy material having the aforementioned metal texture is manufactured by the methods according to claims 67-77. That is, the alloy material having network-shaped eutectic lamella texture can be manufactured by using an alloy having a predetermined chemical compositions and specifying the terms and conditions of casting.

**[0086]** A molten aluminum alloy having predetermined chemical compositions and held at not less than the solidus temperature is continuously cast at the casting rate of 30 - 5,000 mm/min. and the cooling rate of 10 - 600 °C/sec. to form a shape member having a predetermined cross-section. In the solidification process, fine and rounded eutectic Si particles each having a nucleus of Si-Sr compound in a molten metal are dispersed in the aluminum, and dendrite grows up to mean DAS in the aforementioned range. At the dendrite boundary zone, eutectic lamella texture containing eutectic Si particles and other second phase particles is formed in the shape of a network of a certain size.

**[0087]** If the casting rate is below 30 mm/min., eutectic Si particles become rough to cause a low-density distribution of particles, resulting in poor cutting ability and heavy damage of cutting tool. To the contrary, if the casting rate exceeds 5,000 mm/min., a shape member having a predetermined cross-section cannot be obtained. Furthermore, casting defects such as solidification cracks and pores occur, which may cause poor casting surface. The preferable casting rate is 50 - 3,000 mm/min., more preferably 100 - 2,000 mm/min.

**[0088]** If the cooling rate is less than 10 °C/sec., eutectic Si particles become rough to cause a low-density distribution of particles, causing heavy damage of cutting tool. To the contrary, in order to attain the cooling rate exceeding 600 °C/sec., special equipment and special process control are required, which deteriorates productivity. Furthermore, a cost problem will also arise. The preferable cooling rate is 30 - 500 °C/sec., more preferably 30 - 300 °C/sec.

**[0089]** The continuous casting method is not limited to a specific one as long as the aforementioned casting conditions can be attained. A vertical-type continuous casting process and a horizontal continuous casting process can be exemplified. Furthermore, direct cooling can be recommended in order to attain the aforementioned cooling rate.

**[0090]** The cross-sectional configuration of the shape member to be cast is not limited at all. A circular cross-section configuration, a polygonal cross-sectional configuration and, other heteromorphic cross-sectional configuration can be exemplified. A non-hollow member can be recommended. Furthermore, a hollow member which includes a hollow portion in a cross section is also included in the present invention.

**[0091]** In case of a non-hollow member, it is preferable that the member has a cross section circumscribed to a circle with a diameter of 10 - 150 mm. If the diameter of the circumscribed circle is less than 10 mm, the molten metal flow deteriorates remarkably, which makes it difficult to form a predetermined configuration. To the contrary, if the diameter exceeds 150 mm, the cooling becomes insufficient due to the increased cross-section, which makes it difficult to attain the aforementioned cooling rate. As a result, it becomes difficult to form a network-shaped eutectic lamella texture, which in turn may cause deterioration of cutting ability.

**[0092]** The aging treatment to the continuously cast shape member is performed by holding the member at 100 - 300 °C for 0.5 - 100 hours. During this period, the element dissolved at the time of casting is deposited in the host phase, causing maximum mechanical strength and excellent cutting ability. If the aging temperature is less than 100 °C or the holding time is less than 0.5 hours, the aging becomes insufficient. Thus, the quality of the finished surface at the time of cutting deteriorates, and neither cutting ability nor mechanical strength increases. Furthermore, if the aging temperature exceeds 300 °C or the holding time exceeds 100 hours, the aging will be excessive, resulting in deteriorated cutting ability and decreased mechanical strength. The preferable aging conditions are to hold the member at 120 - 220 °C for 1 - 30 hours.

**[0093]** The surface layer of the cast shape member includes heterogeneous layers, such as an inverse-segregation layer, a chill layer and a rough cell layer, which are formed at the time of solidification. Since the heterogeneous layers deteriorate the quality of shape member, it is preferable to remove the heterogeneous layers by eliminating the surface depth of 0.1 - 10 mm. If the elimination amount of the surface layers is less than 0.1 mm, the heterogeneous layer cannot be removed sufficiently. The elimination of 10 mm depth can exclude the heterogeneous layers assuredly. Elimination of more than 10 mm depth has no significance, and the materials will be wasted. The preferable elimination amount is 0.2 - 5 mm in depth. The surface layer elimination may be performed after the casting but before the aging, or after the aging but before the secondary-forming processing. Furthermore, the elimination method is not limited, and peeling processing and scalping processing can be exemplified.

**[0094]** If necessary, the cast shape member may be subjected to secondary forming processing to form a predetermined shape before or after the aging. The secondary forming processing method is not limited to a specific so long as the method is a plastic working method by which a cross-section area decreases. Drawing, extruding and rolling can be exemplified. It is preferable that the processing is performed under the conditions of: the working temperature of 400 °C or less; and the cross-sectional area reduction ratio (i.e., cross-sectional area before processing/ cross-sectional area after processing) is 30% or less. If the working temperature exceeds 400 °C, the eutectic Si particles dispersed in the eutectic lamella texture condenses to become rough and spherical shape, which deteriorates cutting ability. Furthermore, if the processing is performed so that the cross-sectional area reduction ratio exceeds 30%, the eutectic lamella texture is fractured, which deteriorates cutting ability and alloy material quality. The preferable conditions of the secondary forming processing are: the working temperature of 250 °C or less and the cross-sectional area reduction

ratio of 20% or less.

**[0095]** Furthermore, the heat treatment, such as homogenization processing and solution treatment, before the aging treatment or before the secondary forming processing may be performed appropriately.

5 **[0096]** The aluminum alloy material cast according to the present invention or the member to which the secondary forming processing was performed after the casting is cut by a saw, a shear, etc. For example, although the member may be cut into a short member less than 1 m in length, a long member 1 - 10 m in length or a blank member, these cut members are included in this invention irrespective of length.

**[0097]** Other manufacturing conditions follow a conventional method.

**[0098]** Each invention has the following effects.

10 **[0099]** According to the invention as recited in claim 1, since Si particles are fined and rounded by Sr, an aluminum alloy that is excellent in chip breaking nature and causes less abrasion or damage of a cutting tool can be obtained. Furthermore, since the aluminum alloy contains Mg and Zn, the aluminum alloy is excellent in alumite processability and plastic-working nature.

15 **[0100]** According to the invention as recited in claim 2, an aluminum alloy more excellent in mechanical property can be obtained.

**[0101]** According to the invention as recited in claim 3, an aluminum alloy more excellent in cutting ability can be obtained.

**[0102]** According to the invention as recited in claim 4, an aluminum alloy more excellent in mechanical property and alumite processability can be obtained.

20 **[0103]** According to the invention as recited in claim 5, since Si particles are further rounded and fined, an aluminum alloy which is excellent in chip breaking nature and causes less damage or abrasion of a cutting tool can be obtained.

25 **[0104]** According to the invention as recited in claim 1, since Si particle can be further rounded and fined by Sr, or by Sr, Na and Ca, an aluminum alloy which is excellent in chip breaking nature and causes less damage or abrasion of a cutting tool can be obtained. An aluminum alloy excellent in mechanical property, corrosion resistance, alumite processability and plastic-working nature because of the existence of Mg and Zn can be obtained. Cu improves mechanical property. Fe promotes dispersion of Si as an individual particle, which improves cutting ability. Cr and Mn enhance mechanical strength. Zr enhances mechanical strength, corrosion resistance and cutting ability. Furthermore, Ti enhances mechanical strength and corrosion resistance.

30 **[0105]** According to the invention as recited in claim 6, an aluminum alloy more excellent in mechanical property can be obtained.

**[0106]** According to the invention as recited in claim 7, since Si are dispersed as an individual particle, more excellent chip-breaking nature can be maintained.

**[0107]** According to the invention as recited in claim 8, an aluminum alloy more excellent in mechanical property and corrosion resistance can be obtained.

35 **[0108]** According to the invention as recited in claim 9, an aluminum alloy more excellent in mechanical property, corrosion resistance and cutting ability can be obtained.

**[0109]** According to the invention as recited in claim 10, an aluminum alloy more excellent in mechanical property and corrosion resistance can be obtained.

40 **[0110]** According to the invention as recited in claim 11, since Si particle can be further rounded and fined, an aluminum alloy which is excellent in chip breaking nature and causes less damage or abrasion of a cutting tool can be obtained.

**[0111]** According to the invention as recited in claim 12, an aluminum alloy more excellent in mechanical property can be obtained.

**[0112]** According to the invention as recited in claim 13, since Si can be dispersed as an individual particle, more excellent chip-breaking nature can be maintained.

45 **[0113]** According to the invention as recited in claim 14 or 15, an aluminum alloy more excellent in mechanical property and corrosion resistance can be obtained.

**[0114]** According to the invention as recited in claim 16, an aluminum alloy more excellent in mechanical property, corrosion resistance and cutting ability can be obtained.

50 **[0115]** According to the invention as recited in claim 17, an aluminum alloy more excellent in mechanical property and corrosion resistance can be obtained.

**[0116]** According to the invention as recited in claim 18 or 19, since Si particle can be further rounded and fined, an aluminum alloy which is excellent in chip breaking nature and causes less damage or abrasion of a cutting tool can be obtained.

55 **[0117]** According to the invention as recited in claim 20, since Si particle is fined and rounded, the aluminum alloy has good chip breaking nature, and causes less abrasion and damage on a cutting tool. Furthermore, it is also excellent in mechanical property, alumite processability and plastic working nature by other additional elements.

**[0118]** According to the invention as recited in claim 21, since the aforementioned Si particle is fined, there are still less abrasion and damage on a cutting tool.

**[0119]** According to the invention as recited in claim 22, since the aforementioned Si particle is rounded, there are still less abrasion and damage on a cutting tool.

**[0120]** According to the invention as recited in claim 23, it is possible to manufacture the aluminum alloy material which has fined and rounded Si particles, has good chip breaking nature, causes less abrasion and damage on a cutting tool, and is excellent in mechanical property, alumite processability and plastic working nature.

**[0121]** According to the invention as recited in claim 24, an aluminum alloy material with the best cutting ability can be manufactured.

**[0122]** According to the invention as recited in claim 25, an aluminum alloy material with the best cutting ability, mechanical property and corrosion resistance can be manufactured.

**[0123]** According to the invention as recited in claim 26, an aluminum alloy material with the best cutting ability, mechanical property and corrosion resistance can be manufactured. Furthermore, productivity is also excellent.

**[0124]** According to the invention as recited in claim 27, an aluminum alloy material with the best mechanical property and corrosion resistance can be manufactured.

**[0125]** According to the invention as recited in claim 28, an aluminum alloy material with the best mechanical property can be manufactured.

**[0126]** According to the invention as recited in claim 29, an aluminum alloy material which has fined surface recrystallized structure, and is excellent especially in mechanical property can be manufactured.

**[0127]** According to the invention as recited in claim 30, an aluminum alloy material whose mechanical property is further improved can be manufactured.

**[0128]** According to the invention as recited in claim 31, since Si particle is fined and rounded by Sr, and eutectic lamella texture is formed at the dendrite boundary zone, it is possible to obtain an aluminum alloy material comprised of this alloy which is excellent in cutting ability and causes less abrasion and damage on a cutting tool. Furthermore, it is possible to obtain an aluminum alloy which is excellent in mechanical property, especially tensile property, corrosion resistance, alumite processability and plastic working nature because of the existence of Mg, Cu and Zn.

**[0129]** According to the invention as recited in claim 31, since Si particle is fined and rounded by Sr, or Sr and any one of Na, Sb and Ca, and eutectic lamella texture is formed at the dendrite boundary zone, it is possible to obtain an aluminum alloy material comprised of this alloy which is excellent in cutting ability and causes less abrasion and damage on a cutting tool. Furthermore, Mg, Zn and Cu improve mechanical property, especially tensile characteristics, corrosion resistance, alumite processability and plastic working nature. Furthermore, any one of Ti, B, C and Sc causes fined ingot texture and suppresses appearance of macro patterns and solidification cracks. Fe promotes dispersion of Si as an individual particle, which improves cutting ability. Cr and Mn improve mechanical strength. Zr or V fines ingot texture, suppresses appearance of macro patterns and solidification cracks, and further improves cutting ability by forming intermetallic compounds. Ni forms intermetallic compounds, which improves cutting ability. Any one of Sn, Bi and In improves cutting ability.

**[0130]** According to the invention as recited in claim 32, an aluminum alloy more excellent in mechanical property can be obtained.

**[0131]** According to the invention as recited in claim 33, an aluminum alloy more excellent in mechanical property and cutting ability can be obtained.

**[0132]** According to the invention as recited in claim 34, an aluminum alloy more excellent in mechanical property and alumite processability can be obtained

**[0133]** According to the invention as recited in claim 35, since Si particle can be further rounded and fined, an aluminum alloy which is excellent in chip breaking nature and causes less damage or abrasion of a cutting tool can be obtained.

**[0134]** According to the invention as recited in claim 36, an aluminum alloy in which ingot texture is fined and appearance of macro patterns and solidification cracks are suppressed can be obtained.

**[0135]** According to the invention as recited in claim 37, since Si can be dispersed as an individual particle, more excellent chip-breaking nature can be maintained.

**[0136]** According to the invention as recited in claim 38, an aluminum alloy more excellent in mechanical property and corrosion resistance can be obtained.

**[0137]** According to the invention as recited in claim 39, an aluminum alloy in which ingot texture is fined, appearance of macro patterns and solidification cracks are suppressed and cutting ability is excellent, can be obtained.

**[0138]** According to the invention as recited in claim 40, an aluminum alloy more excellent in cutting ability can be obtained.

**[0139]** According to the invention as recited in claim 41, since Si particle can be further rounded and fined, an aluminum alloy which is excellent in chip breaking nature and causes less damage or abrasion of a cutting tool can be obtained.

**[0140]** According to the invention as recited in claim 42, an aluminum alloy more excellent in cutting ability can be obtained.

**[0141]** According to the invention as recited in any one of claims 43 - 45, an aluminum alloy in which ingot texture is fined and appearance of macro patterns and solidification cracks are suppressed can be obtained.

[0142] According to the invention as recited in claim 46, since Si can be dispersed as an individual particle, more excellent chip-breaking nature can be maintained.

[0143] According to the invention as recited in claim 47 or 48, an aluminum alloy more excellent in mechanical property and corrosion resistance can be obtained.

5 [0144] According to the invention as recited in claim 49 or 50, an aluminum alloy in which ingot texture is fined, appearance of macro patterns and solidification cracks are suppressed and cutting ability is excellent, can be obtained

[0145] According to the invention as recited in claim 51, an aluminum alloy in which ingot texture is fined and appearance of macro patterns and solidification cracks are suppressed can be obtained.

10 [0146] According to the invention as recited in claim 52, an aluminum alloy more excellent in cutting ability can be obtained.

[0147] According to the invention as recited in any one of claims 53-55, since Si particle can be further rounded and fined, an aluminum alloy which is excellent in chip breaking nature and causes less damage or abrasion of a cutting tool can be obtained.

15 [0148] According to the invention as recited in any one of claims 57-58, an aluminum alloy more excellent in cutting ability can be obtained.

[0149] According to the invention as recited in claim 59, since eutectic Si particles can be served as chip breaking origins independently, cutting ability is improved. Furthermore, since eutectic lamella texture can be continuously separated, cutting ability is improved. Furthermore, since the eutectic Si particles are fined and rounded, abrasion and damage on a cutting tool can be suppressed. Furthermore, this aluminum alloy is also excellent in mechanical property, especially tensile characteristics, corrosion resistance, alumite processability and plastic-working nature.

20 [0150] According to the invention as recited in claim 60, an aluminum alloy material which is more excellent in cutting ability and capable of suppressing abrasion and damage on a cutting tool can be obtained.

[0151] According to the invention as recited in claim 61, an aluminum alloy material which is further improved in cutting ability and mechanical characteristics can be obtained.

25 [0152] According to the invention as recited in claim 62, abrasion and damage on a cutting tool can be suppressed while keeping excellent cutting ability.

[0153] According to the invention as recited in claim 63, an aluminum alloy material which is further improved in cutting ability can be obtained.

30 [0154] According to the invention as recited in claim 64, an aluminum alloy material which is further improved in cutting ability can be obtained.

[0155] According to the invention as recited in claim 65, cutting ability can be further improved, and abrasion and damage on a cutting tool can be suppressed.

[0156] According to the invention as recited in claim 66, cutting ability can be further improved, and abrasion and damage on a cutting tool can be suppressed.

35 [0157] According to the invention as recited in claim 67, it is possible to manufacture the aluminum alloy material that has eutectic Si particles and eutectic lamella texture, causes less abrasion and damage on a cutting tool while keeping outstanding cutting ability, and is excellent in mechanical property, especially tensile characteristics, corrosion resistance, alumite processability and plastic-working nature.

40 [0158] According to the invention as recited in claim 68 or 69, especially, the aforementioned eutectic Si particles and aforementioned eutectic lamella texture can be formed assuredly.

[0159] According to the invention as recited in claim 70, since the elements dissolved can fully deposited at the time of casting, an aluminum alloy material excellent especially in cutting ability and mechanical property can be manufactured.

[0160] According to the invention as recited in claim 71, a non-hollow member having the aforementioned eutectic Si particles and eutectic lamella texture can be manufactured.

45 [0161] According to the invention as recited in claim 72, especially the molten metal flow is good, and the aforementioned cooling rate can be easily achieved.

[0162] According to the invention as recited in claim 73, surface heterogeneous layers can be eliminated, and therefore a high quality aluminum alloy material can be obtained.

[0163] According to the invention as recited in claim 74, heterogeneous layers can be eliminated assuredly.

50 [0164] According to the invention as recited in claim 75, aggregation of eutectic Si particles and/or destruction of eutectic lamella texture can be prevented, and therefore an aluminum alloy material can be processed into any desired configuration while maintaining excellent cutting ability.

[0165] According to the invention as recited in claim 76 or 77, cutting ability can be maintained assuredly even if a secondary forming processing is performed.

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### Brief Description of Drawings

[0166]

Fig. 1 is a photograph showing metal texture of an aluminum alloy corresponding to claims 59-63 of the present invention.

Fig. 2 is a photograph showing other metal texture of other aluminum alloy material corresponding to claims 59-63 of the present invention.

Fig. 3 is a photograph showing metal texture of a conventional aluminum alloy material.

Fig. 4 is a photograph showing a cut surface of 98.2% peel rate to evaluate the quality of the machined surface of Example IIA.

Fig. 5 is a photograph showing the cut surface 3.4% peel rate to evaluate the quality of the machined surface of Example IIA.

Fig. 6 is a cross-sectional view of a principal part of a gas pressurization type hot top casting apparatus used in Examples IIA, IIB and IIC.

Fig. 7 is a cross-sectional view of a principal part of a horizontal continuous casting apparatus used in Example IIB.

## Examples

### I. FIRST ALUMINUM ALLOY AND FIRST MANUFACTURING METHOD (examples corresponding to claims 1 - 30)

**[0167]** Aluminum alloys of compositions of Al Nos. I-1 - I-17 shown in Table 1 were prepared. The alloy Nos. I-1 and I-2 include Mg, Si, Zn and Sr, and the balance being aluminum and impurities, and the compositions correspond to claims 1 - 5 of the present invention. The alloys Nos. I-3 to I-12 include eight optional selective elements of the aforementioned elements, and the compositions correspond to claims 6 -19. The alloys Nos. I-13 to I-17 are comparative compositions.

**[0168]** From these aluminum alloy materials, round bars were made by billet casting, extrusion, and drawing.

**[0169]** First, a billet was made at the casting rate of 80 mm/min. by DC casting. The billet was homogenized by holding at 520 °C for 10 hours, and then extruded into a round bar with a diameter of 15 mm at the billet temperature of 450 °C, the extrusion product rate of 12 m/min., and the extrusion ratio of 35. This extruded member is held at 540 °C for 3 hours for a solution treatment, then drawn at the reduction rate of 25%, and aged by holding at 160 °C for 5 hours to thereby obtain a test piece.

**[0170]** On each prepared test piece (drawn member), the proof strength of 0.2%, the tensile strength and the fracture elongation were measured. Further, the chip breaking nature, the corrosion resistance, the abrasion of a tool, the alumite processability and the plastic-working nature were evaluated by the following method.

[Chip breaking nature, tool abrasion]

**[0171]** Each test piece was wet cut using a superhard chip at the cutting rate of 150 m/min., the feeding rate of 0.2 mm/rev. to form a slit of 1.0 mm depth. The chip breaking nature was evaluated by chip number/100g.

[Corrosion Resistance]

**[0172]** A salt spray test based on JIS Z2371 was performed, and the corrosion resistance was measured by the corrosion weight loss due to 1,000 hours spray.

[Tool Abrasion]

**[0173]** Continuous cutting for 5 minutes is performed under the conditions of cutting rate of 200 m/min., feeding rate of 0.2 mm/rev., and slitting of 10 mm by dry type cutting using a high-speed slab cutting-edge byte, and the abrasion width of the byte's flank was measured.

[Alumite Processability]

**[0174]** Sulfuric acid alumite processing was conducted by a conventional method, and evaluation was performed by the thickness of the generated alumite coat.

[Plastic-working Nature]

**[0175]** This was evaluated by the rate of the limit lump rate obtained by a lump nature examination. In this examination, The crack generating limitation by cold working (forging) was investigated and evaluated by this result.

**[0176]** These results are collectively shown in Table 1. Regarding the chip breaking nature, the corrosion resistance,

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the abrasion of a tool, the alumite processability and the plastic-working nature, they were evaluated relatively on the basis of comparison alloy No. I-13. "O" denotes a performance equivalent to the comparison alloy No. I-13, "⊙" denotes a performance superior to the comparison alloy, "Δ" denotes a performance inferior to the comparison alloy, and "×" denotes a performance further inferior to the comparison alloy.

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Table 1

Alloy No. (I-n)	Chemical compositions of Al-Mg-Si series alloy (mass%, balance being Al and impurities)												Characteristics								
	Mg	Si	Zn	Sr	Cu	Fe	Mn	Cr	Zr	Ti	Na	Ca	Other	Tensile characteristics		Cutting division nature	Corrosion resistance	Tool Abrasion	Alumite processability	Plastic-working nature	
	0.2% proof strength N/mm <sup>2</sup>	Tensile strength N/mm <sup>2</sup>	Fracture elongation %																		
Invention	1	1.0	1.8	0.3	0.03	-	-	-	-	-	-	-	-	-	290	315	15.5	○	○	○	○
	2	0.6	4.8	0.2	0.05	-	-	-	-	-	-	-	-	-	315	338	9.0	○	○	○	○
	3	1.0	1.8	0.3	0.03	0.2	0.2	0.01	-	-	-	-	-	-	305	335	14.0	○	○	○	○
	4	1.0	2.8	0.3	0.03	0.2	0.2	0.01	-	-	-	-	-	-	312	340	12.0	○	○	○	○
	5	1.0	4.8	0.3	0.03	0.2	0.2	0.01	-	-	-	-	-	-	328	348	11.0	○	○	○	○
	6	1.0	2.8	0.3	0.01	0.2	0.2	0.01	-	-	-	-	-	-	310	339	12.5	○	○	○	○
	7	1.0	2.8	0.3	0.03	0.2	0.2	0.01	-	-	-	-	-	-	315	336	12.6	○	○	○	○
	8	1.0	2.8	0.3	0.03	0.2	0.2	0.01	0.2	-	-	-	-	-	320	345	13.5	○	○	○	○
	9	1.0	2.8	0.3	0.03	0.2	0.2	0.01	-	0.2	-	-	-	-	315	340	13.5	○	○	○	○
	10	1.0	2.8	0.3	0.03	0.2	0.2	0.01	-	-	0.2	-	-	-	318	340	12.5	○	○	○	○
	11	1.0	2.8	0.3	0.03	0.2	0.2	0.01	-	-	-	0.005	-	-	310	340	13.0	○	○	○	○
	12	1.0	2.8	0.3	0.03	0.2	0.2	0.01	-	-	-	-	0.005	-	305	335	13.5	○	○	○	○
	13	1.0	0.8	-	-	0.2	0.2	0.10	-	-	-	-	-	Pb:0.5 Bi:0.5	280	310	16.0	○	○	○	○
	14	1.0	2.8	0.3	-	0.2	0.2	0.01	-	-	-	-	-	-	322	342	12.1	○	○	△	○
	15	1.0	4.8	0.3	-	0.2	0.2	0.01	-	-	-	-	-	-	327	339	11.6	○	○	△	○
	16	1.0	<u>11.5</u>	0.3	0.03	0.2	0.2	0.01	-	-	-	-	-	-	295	315	9.5	○	△	○	○
	17	1.0	<u>11.5</u>	0.3	-	0.2	0.2	0.01	-	-	-	-	-	-	290	309	7.9	○	△	○	○
Comparative																					

In this Table, the underlined numeral is out of the scope of the invention.

[0177] Furthermore, on the invention alloys Nos. I-1, I-3 to I-5, I-11, I-12 and comparison alloys Nos. I-14 to I-17, the

mean particle diameter of Si particle, the particle diameter range, the mean aspect ratio thereof were examined. The results are shown in Table 2 which also shows the Si content, Sr content, Na content, Ca content, chip-breaking nature and abrasion of a tool which affect the above.

Table 2

Alloy No. (I-n)	Si, Sr, Na, Ca content (mass%)				Si particle			Other Character	
	Si	Sr	Na	Ca	Mean particle diameter (μm)	Range of Particle diameter (μm)	Mean aspect ratio	Cutting division nature	Tool Abrasion
1	1.8	0.03	-	-	1.2	0.3 - 3.3	1.5	○	⊙
3	1.8	0.03	-	-	1.2	0.3 - 3.2	1.3	○	⊙
4	2.8	0.03	-	-	3.1	0.8 - 4.2	2.3	○	○
5	4.8	0.03	-	-	4.9	1.2 - 6.6	2.8	⊙	○
11	2.8	0.03	0.005	-	3.0	0.7 - 4.2	2.3	○	⊙
12	2.8	0.03	-	0.005	3.1	0.7 - 4.1	2.1	○	⊙
14	2.8	-	-	-	3.3	0.1 - 5.5	4.1	○	△
15	4.8	-	-	-	4.2	0.1 - 6.9	4.2	○	△
16	11.5	0.03	-	-	6.5	0.5 - 12.1	3.6	⊙	×
17	11.5	-	-	-	6.8	0.3 - 11.2	4.9	⊙	×
Invention									
Comparative									

[0178] From the results shown in Tables 1 and 2, it was confirmed that the aluminum alloy materials of the invention

alloy Nos. I-1 to I-12 are excellent in chip breaking nature and abrasion of a tool since the particles are fined and rounded irrespective of Si addition.

## II. SECOND ALUMINUM ALLOY, AND SECOND MANUFACTURING METHOD

(Examples corresponding to claims 31-77)

### A. Compositions of Aluminum alloy

**[0179]** Aluminum alloys having compositions of alloy Nos. IIA-1 to IIA-129 shown in Tables 3 - 8 were prepared. Each of the alloy Nos. IIA-1 to IIA-30 includes Mg, Si, Cu, Zn, Sr and the balance being aluminum and impurities. Alloys Nos. IIA-31 to IIA-40 are comparative compositions. Alloys Nos. IIA-41 to IIA-108 (except for IIA-93, 94 and 97) have the basic compositions of Alloy No. IIA-30, and Alloys Nos. IIA-109 to IIA-129 have the basic compositions of Alloy No. IIA-10. Furthermore, sixteen optional selective elements are added to the above alloys. Alloy No. IIA-94 has basic compositions of Alloy No. IIA-7 (Mg: 1 mass%, Si: 0.8 mass%, Cu: 0.2 mass%, Zn: 0.2 mass%, Sr: 0.03 mass%), Alloys Nos. IIA-93 and 97 have basic compositions of Alloy (Mg: 1 mass%, Si: 1.5 mass%, Cu: 0.2 mass%, Zn: 0.2 mass%, Sr: 0.03 mass%). Optional additional elements are added to the above alloys. Alloy Nos. IIA-6,7,11,12,94, do not form part of the invention.

**[0180]** Using these aluminum alloys as the casting materials, a non-hollow member of a round cross-section with a diameter of 53 mm was cast vertically and continuously by the below-mentioned gas pressurization type hot top casting method.

[Gas Pressurization Type Hot Top Casting]

**[0181]** In the gas pressurization type hot top casting apparatus shown in Fig. 6, the reference numeral "1" denotes a mold for forming the external periphery of an ingot, and "2" denotes a cylindrical molten metal receiving tub disposed at the upper portion of the mold 1.

**[0182]** The mold 1 has an annular cavernous portion 3 for circulating a cooling medium such as water therein. This cavernous portion 3 is provided with a plurality of port mouths 4 opening toward the outside. The cooling medium C introduced into the cavernous portion 3 through an introductory tubing which is not illustrated performs a primary cooling of the cast member S by cooling the mold 1, and is spouted from the port mouths 4 to perform a secondary cooling of the casting S. Furthermore, the inner upper surface 1a of the mold 1 is lower than the exterior upper surface 1b, to thereby form a gap 6 opened to a gas passage 5 between the inner upper surface 1a and the lower surface of the molten metal tub 2.

**[0183]** The lower inner part of the molten metal tub 2 is protruded horizontally toward the inner side of the mold 1 to form an over hang portion 7. Accordingly, the pressurized gas F introduced into the gas passage 5 through the gas introduction passage 8 from the exterior is introduced under the overhang portion 7 from the gap 6. This excludes the molten metal from the region immediately under the over hang portion 7 to thereby make the molten metal contact to the inner peripheral surface of the mold 1 at the position far below the upper end of the mold 1. The contact distance between the molten metal and the mold 1 is controlled by the flow rate of the pressurized gas F, which in turn controls the primary cooling time and the solidification process to obtain a cast member S excellent in metal texture. In the figure, "M" shows the overhang amount of the overhang portion 7.

**[0184]** Furthermore, lubricating oil is introduced into a supply passage 9 from the exterior through a passage which is not illustrated, and supplied to the inner peripheral surface of the mold 1 through numeral fine feed mouths 10 branched from the supply passage 9. "11" denotes a heat-resistant packing member fitted in the slot cut in the upper surface of the mold 1 to prevent the leak of the gas passing through the gap 6.

**[0185]** According to the vertical-type continuous casting apparatus, the casting rate and cooling rate of the present invention can be attained, and a cast member with outstanding characteristics, such as cutting ability, can be manufactured.

**[0186]** The casting conditions were the casting conditions b shown in the following Table 9, and all of the alloys were continuously cast successfully.

**[0187]** Subsequently, the surface portion of the cast non-hollow member of 1.5 mm depth was eliminated. Thereafter, aging was performed by holding the member at 170 °C for 11 hours, to thereby obtain a test piece.

**[0188]** About each test piece, the mechanical properties, such as 0.2% proof strength, tensile strength, fracture elongation (tensile characteristics), were measured, and the homogeneity of metal texture, plastic-working nature, cutting ability, abrasion of a tool, quality of the machined surface, corrosion resistance, alumite processability were examined by the following method. Then, except for the mechanical properties, they were evaluated relatively by comparing with various characteristics of the extruded member consist of JIS A6262 alloy in the five following grades.

◎◎ : Extremely excellent

◎ : Excellent

○ : Equivalent

△ : Slightly poor

× : Very poor

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[Homogeneity of metal texture]

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**[0189]** It is evaluated by size of dendrite texture, measured result on space, size of eutectic lamella texture, form, continuity and homogeneity in a test piece cross-section.

[Plastic-working nature]

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**[0190]** It is evaluated by drawing at the cross-sectional area reduction ratio of 20% and using the change rate of characteristics from the results of the cutting ability examination and the tensile test.

[Cutting ability]

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**[0191]** Wet cutting was performed by using a superhard chip at the cutting rate of 150 m/min., feeding rate of 0.2 mm/rev. to form a slit of 1.0 mm depth, and the chip breaking nature is examined from chips number/100g. Then, the cutting ability is evaluated by the chip breaking nature.

[Abrasion of a tool]

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**[0192]** Continuous cutting for 5 minutes is performed under the conditions of cutting rate of 200 m/min. , feeding rate of 0.2 mm/rev. , and slitting of 10 mm by dry type cutting using a high-speed slab cutting-edge byte, and the abrasion width of the byte's flank was measured.

[Quality of finished surface]

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**[0193]** It was evaluated by the rate (%) of the peeled portion existing in a unit area (1 mm<sup>2</sup>) on the cut surface of the test piece cut by the aforementioned cutting test. As examples of cut surfaces, Fig. 3 shows the cut surface of 98.2% peeled rate, and Fig. 4 shows the cut surface of 3.4% peeled rate.

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[Cutting crack nature]

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**[0194]** Wet cutting was performed by using a superhard chip at the cutting rate of 150 m/min. and feeding rate of 0.2 mm/rev. to form a slit of 3.0 mm depth. Then, the Cutting crack nature was evaluated by the incidence rate (%) of the cutting cracks within a unit area (1 mm<sup>2</sup>).

[Corrosion resistance]

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**[0195]** A salt spray test based on JIS Z2371 was performed, and the corrosion resistance was measured by the corrosion weight loss due to 1,000 hours spray.

[Alumite Processability]

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**[0196]** Sulfuric acid alumite processing was conducted by a conventional method, and evaluation was performed by the thickness of the generated alumite coat.

**[0197]** These results are shown in Tables 3 - 8.

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Table 3

Alloy No. (IIA-n)	Compositions of Al alloy (mass%, balance being Al and impurities)					Various characteristics										
	Mg	Si	Cu	Zn	Sr	Mechanical property			Texture homogeneity	Plastic-working nature	Cutting ability	Tool abrasion	Quality of finished surface	Cutting crack nature	Corrosion resistance	Alumite processability
						0.2% proof strength N/mm <sup>2</sup>	Tensile strength N/mm <sup>2</sup>	Fracture elongation %								
1	0.3	2.8	0.2	0.2	0.03	285	320	7.2	◎	○	◎	◎	◎	◎	◎	◎
2	2.0	2.8	0.2	0.2	0.03	305	330	8.6	○	○	◎	◎	◎	◎	◎	◎
3	4.0	2.8	0.2	0.2	0.03	307	330	8.0	○	○	◎	◎	◎	◎	◎	◎
4	5.0	2.8	0.2	0.2	0.03	300	325	8.0	○	○	◎	◎	◎	◎	◎	◎
5	6.0	2.8	0.2	0.2	0.03	290	320	7.8	○	○	◎	◎	◎	◎	◎	◎
6	1.0	0.3	0.2	0.2	0.03	280	315	14.5	◎	○	◎	◎	◎	◎	◎	◎
7	1.0	0.8	0.2	0.2	0.03	305	330	13.0	◎	○	◎	◎	◎	◎	◎	◎
8	1.0	4.0	0.2	0.2	0.03	326	340	12.1	◎	○	◎	◎	◎	◎	◎	◎
9	1.0	6.0	0.2	0.2	0.03	320	330	9.6	○	○	◎	◎	◎	◎	◎	◎
10	1.0	8.0	0.2	0.2	0.03	305	325	9.0	○	○	◎	◎	◎	◎	◎	◎
11	1.0	10.0	0.2	0.2	0.03	290	310	8.0	○	○	◎	◎	◎	◎	◎	◎
12	1.0	12.0	0.2	0.2	0.03	290	315	8.1	○	○	◎	◎	◎	◎	◎	◎
14	1.0	2.8	0.05	0.2	0.03	280	310	12.6	◎	○	◎	◎	◎	◎	◎	◎
15	1.0	2.8	0.1	0.2	0.03	280	320	13.0	◎	○	◎	◎	◎	◎	◎	◎
16	1.0	2.8	0.3	0.2	0.03	308	340	13.9	◎	○	◎	◎	◎	◎	◎	◎
17	1.0	2.8	0.5	0.2	0.03	340	376	14.2	◎	○	◎	◎	◎	◎	◎	◎
18	1.0	2.8	0.8	0.2	0.03	350	395	13.0	◎	○	◎	◎	◎	◎	◎	◎
19	1.0	2.8	0.2	0.01	0.03	305	330	14.5	◎	○	◎	◎	◎	◎	◎	◎
20	1.0	2.8	0.2	0.05	0.03	308	325	15.0	◎	○	◎	◎	◎	◎	◎	◎

Alloy Nos. IIA-6, IIA-7, IIA-11, IIA-12 do not form part of the invention.

Table 4

Alloy No. (IIA-n)	Compositions of Al alloy (mass%, balance being Al and impurities)					Various characteristics										
	Mg	Si	Cu	Zn	Sr	Mechanical property			Texture homogeneity	Plastic-working nature	Cutting ability	Tool Abrasion	Quality of finished surface	Cutting crack nature	Corrosion resistance	Alumite processability
						0.2% proof strength N/mm <sup>2</sup>	Tensile strength N/mm <sup>2</sup>	Fracture elongation %								
Invention	21	1.0	2.8	0.2	0.1	0.03	315	335	14.3	◎	○	◎	◎	◎	◎	○
	22	1.0	2.8	0.2	0.5	0.03	332	356	11.2	◎	○	◎	◎	◎	◎	○
	23	1.0	2.8	0.2	1.0	0.03	335	350	12.6	◎	○	◎	◎	◎	◎	○
	24	1.0	2.8	0.2	1.5	0.03	340	355	10.9	◎	○	◎	◎	◎	◎	○
	25	1.0	2.8	0.2	0.2	0.005	306	319	12.6	◎	○	◎	◎	◎	◎	○
	26	1.0	2.8	0.2	0.2	0.01	310	332	15.6	◎	○	◎	◎	◎	◎	○
	27	1.0	2.8	0.2	0.2	0.05	308	327	16.2	◎	○	◎	◎	◎	◎	○
	28	1.0	2.8	0.2	0.2	0.1	301	320	15.8	◎	○	◎	◎	◎	◎	○
	29	1.0	2.8	0.2	0.2	0.2	301	322	15.1	◎	○	◎	◎	◎	◎	○
	30	1.0	2.8	0.2	0.2	0.03	303	326	14.6	◎	○	◎	◎	◎	◎	○
Comparative	31	<u>0.01</u>	2.8	0.2	0.2	0.03	265	305	8.2	◎	○	○	×	△	○	○
	32	7.0	2.8	0.2	0.2	0.03	280	300	7.5	○	○	○	×	△	○	△
	33	1.0	<u>0.1</u>	0.2	0.2	0.03	272	298	17.6	◎	○	△	○	◎	○	○
	34	1.0	<u>14.0</u>	0.2	0.2	0.03	335	358	4.1	△	○	△	△	○	△	△
	35	1.0	2.8	=	0.2	0.03	285	310	10.6	◎	○	△	◎	○	◎	○
	36	1.0	2.8	<u>1.2</u>	0.2	0.03	358	396	12.6	○	○	○	○	○	△	○
	37	1.0	2.8	0.2	=	0.03	290	316	13.1	◎	○	◎	◎	◎	◎	△
	38	1.0	2.8	0.2	<u>4.0</u>	0.03	390	421	10.6	○	○	◎	◎	◎	△	○
	39	1.0	2.8	0.2	0.2	=	270	295	8.2	△	○	◎	△	◎	○	○
	40	1.0	2.8	0.2	<u>0.2</u>	<u>0.8</u>	305	321	14.6	○	○	◎	○	◎	△	○

In this Table, the underlined numeral is out of the scope of the invention.

Table 5

Alloy No. (IIA-n)	Al alloy compositions (mass%) Basic compositions Mg:1.0, Si:2.8, Cu:0.2, Zn:0.2, Sr:0.03, balance:Al and impurities	Mechanical property				Various characteristics						
		0.2% proof strength N/mm <sup>2</sup>	Tensile strength N/mm <sup>2</sup>	Fracture elongation %	Texture homogeneity	Plastic-working nature	Cutting ability	Tool Abrasion	Quality of finished surface	Outing crack nature	Corrosion resistance	Alumite processability
41	Tl: 0.003	298	319	12.8	⊙	○	⊙	⊙	⊙	⊙	⊙	○
42	Tl: 0.02	302	320	14.6	⊙	○	⊙	⊙	⊙	⊙	⊙	○
43	Tl: 0.3	308	325	13.1	⊙	○	⊙	⊙	⊙	⊙	⊙	○
44	B: 0.0005	302	330	15.1	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
45	B: 0.005	305	320	15.2	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
46	B: 0.01	308	329	14.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
47	C: 0.01	305	320	15.1	⊙	○	⊙	⊙	⊙	⊙	⊙	○
48	C: 0.15	295	315	14.0	⊙	○	⊙	⊙	⊙	⊙	⊙	○
49	Fe: 0.05	285	318	16.2	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
50	Fe: 0.2	296	325	15.1	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
51	Fe: 0.7	291	323	13.6	○	○	⊙	⊙	⊙	⊙	⊙	○
52	Cr: 0.03	305	318	14.1	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
53	Cr: 0.2	302	325	16.2	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
54	Cr: 0.7	308	330	15.1	○	○	⊙	⊙	⊙	⊙	⊙	○
55	Mn: 0.1	309	328	14.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
56	Mn: 0.3	319	338	12.5	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
57	Zr: 0.1	310	329	13.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
58	Zr: 0.3	312	329	12.9	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
59	Zr: 0.7	309	336	14.9	○	○	⊙	⊙	⊙	⊙	⊙	○
60	V: 0.1	296	318	10.2	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
61	V: 0.3	296	322	11.2	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙

Invention

Table 6

Alloy No. (IIA-n)	Al alloy compositions (mass%) Basic compositions Mg:1.0, Si:2.8, Cu:0.2, Zn:0.2, Sr:0.03, balance:Al and impurities	Various characteristics										
		Mechanical property			Texture homogeneity	Plastic-working nature	Cutting ability	Tool Abrasion	Quality of finished surface	Cutting crack nature	Corrosion resistance	Alumite processability
		0.2% proof strength N/mm <sup>2</sup>	Tensile strength N/mm <sup>2</sup>	Fracture elongation %								
62	Sc: 0.07	300	325	14.6	⊙	○	⊙	⊙	⊙	⊙	⊙	○
63	Sc: 0.16	310	330	13.1	⊙	○	⊙	⊙	⊙	⊙	⊙	○
64	Ni: 0.003	302	320	15.2	⊙	○	⊙	⊙	⊙	⊙	⊙	○
65	Ni: 0.2	315	340	11.6	⊙	○	⊙	⊙	⊙	⊙	⊙	○
66	Ni: 0.7	318	342	10.9	○	○	⊙	⊙	⊙	⊙	⊙	○
67	Na: 0.01	300	320	13.6	⊙	○	⊙	⊙	⊙	⊙	⊙	○
68	Na: 0.1	302	328	13.1	⊙	○	⊙	⊙	⊙	⊙	⊙	○
69	Sb: 0.01	305	325	13.0	⊙	○	⊙	⊙	⊙	⊙	⊙	○
70	Sb: 0.1	304	326	12.9	⊙	○	⊙	⊙	⊙	⊙	⊙	○
71	Ca: 0.01	301	322	14.6	⊙	○	⊙	⊙	⊙	⊙	⊙	○
72	Ca: 0.1	298	320	12.6	⊙	○	⊙	⊙	⊙	⊙	⊙	○
73	Ca: 0.3	300	325	12.4	○	○	⊙	⊙	⊙	⊙	⊙	○
74	Sn: 0.05	315	335	13.2	⊙	○	⊙	⊙	⊙	⊙	⊙	○
75	Sn: 0.2	308	330	14.2	⊙	○	⊙	⊙	⊙	⊙	⊙	○
76	Sn: 0.4	310	328	13.9	⊙	○	⊙	⊙	⊙	⊙	⊙	○
77	Bi: 0.05	305	332	14.1	⊙	○	⊙	⊙	⊙	⊙	⊙	○
78	Bi: 0.2	300	326	14.8	⊙	○	⊙	⊙	⊙	⊙	⊙	○
79	Bi: 0.4	305	328	12.9	⊙	○	⊙	⊙	⊙	⊙	⊙	○
80	In: 0.01	300	320	16.2	⊙	○	⊙	⊙	⊙	⊙	⊙	○
81	In: 0.1	302	330	12.6	⊙	○	⊙	⊙	⊙	⊙	⊙	○
82	In: 0.3	305	328	14.1	⊙	○	⊙	⊙	⊙	⊙	⊙	○

Invention

Table 7

Alloy No. (IIA-n)	Al alloy compositions (mass%) Basic compositions Mg:1.0, Si:2.8, Cu:0.2, Zn:0.2, Sr:0.03, balance Al and impurities	Various characteristics										
		Mechanical property			Texture homogeneity	Plastic-welding nature	Cutting ability	Tool Abrasion	Quality of finished surface	Cutting crack nature	Corrosion resistance	Alumite processability
		0.2% Proof strength N/mm <sup>2</sup>	Tensile strength N/mm <sup>2</sup>	Fracture elongation %								
88	Ti: 0.1, Fe: 0.1	306	321	12.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
89	Ti: 0.1, Mn: 0.1	302	320	12.8	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
90	Ti: 0.1, Cr: 0.1	310	321	10.9	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
91	Cr: 0.1, Ni: 0.1	308	320	11.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
92	Sn: 0.3, Bi: 0.1	309	330	14.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
93	Si:1.5, Sn:0.4, In:0.02 **	298	323	12.9	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
94	Si:0.8, Sn:0.5, Bi:0.5 *	289	319	11.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
95	Ti: 0.1, Sn: 0.1	292	320	12.1	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
96	Fe: 0.2, Cr: 0.1	299	323	14.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
97	Si:1.5, Sn:0.3, In:0.05 **	316	331	12.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
98	Fe: 0.2, Ca: 0.1	301	320	13.9	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
99	Ti:0.1, Fe:0.2, Cr:0.1	302	326	14.1	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
100	Fe:0.2, Zr:0.1, Ni: 0.1	300	315	10.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
101	Fe:0.2, Zr:0.1, Bi:0.1	305	319	10.8	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
102	Ti:0.1, Fe:0.2, Cr:0.1, Sb:0.05	295	322	14.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
103	Ti:0.1, Fe:0.2, Mn:0.1, Cr:0.1	290	320	15.1	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
104	Ti:0.1, Fe:0.2, V:0.1, Ca:0.1, Sn:0.1	295	319	14.0	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
105	Cr:0.1, Fe:0.2, Mn:0.1, Er:0.1, Nb:0.1	290	315	12.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
106	Bi:0.1, Fe:0.2, Mn:0.1, Zr:0.1, In:0.1	286	310	12.1	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
107	Bi:0.1, Fe:0.2, Mn:0.1, Ni:0.1, In:0.1	292	318	14.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙
108	Fe:0.2, B, Mn, Er, Ni, Sb, In: 0.1 respectively	290	320	12.6	⊙	○	⊙	⊙	⊙	⊙	⊙	⊙

Note: (\*)denotes:Si:0.8 mass%, (\*\*)denotes:Si:1.5 mass%, Mg,Cu,Zn,Sr: same mass%

Alloy No. IIA-94 does not form part of the invention.

Table 8

Alloy No. (IIA-n)	Al alloy compositions (mass%) Basic compositions Mg:1.0, Si:8.0, Cu:0.2, Zn:0.2, Sr:0.03, balance:Al and impurities	Various characteristics											
		Mechanical Property				Texture homogeneity	Plastic-working nature	Cutting ability	Tool Abrasion	Quality of finished surface	Cutting crack nature	Corrosion resistance	Alumite processability
		0.2% proof strength N/mm <sup>2</sup>	Tensile strength N/mm <sup>2</sup>	Fracture elongation %									
109	Ti: 0.02	302	319	11.6	○	○	○	○	○	○	○	○	○
110	B: 0.005	302	318	10.9	○	○	○	○	○	○	○	○	○
111	C: 0.1	298	319	12.1	○	○	○	○	○	○	○	○	○
112	Fe: 0.2	302	321	12.0	○	○	○	○	○	○	○	○	○
113	Cr: 0.2	303	319	10.1	○	○	○	○	○	○	○	○	○
114	Mn: 0.1	302	322	14.6	○	○	○	○	○	○	○	○	○
115	Zr: 0.3	305	320	13.6	○	○	○	○	○	○	○	○	○
116	V: 0.1	302	319	12.0	○	○	○	○	○	○	○	○	○
117	Sc: 0.07	305	322	11.8	○	○	○	○	○	○	○	○	○
118	Ni: 0.2	300	318	10.1	○	○	○	○	○	○	○	○	○
119	Na: 0.1	305	321	13.9	○	○	○	○	○	○	○	○	○
120	Sb: 0.1	300	322	14.1	○	○	○	○	○	○	○	○	○
121	Ca: 0.1	300	320	13.6	○	○	○	○	○	○	○	○	○
122	Sn: 0.2	308	329	13.2	○	○	○	○	○	○	○	○	○
123	Bi: 0.2	307	320	14.9	○	○	○	○	○	○	○	○	○
124	In: 0.1	302	318	12.6	○	○	○	○	○	○	○	○	○
125	Ti: 0.1, Fe:0.2	298	319	10.6	○	○	○	○	○	○	○	○	○
126	Ti: 0.1, Ni: 0.1	297	316	10.1	○	○	○	○	○	○	○	○	○
127	Ti: 0.03, Fe: 0.2, Cr: 0.1	289	316	11.1	○	○	○	○	○	○	○	○	○
128	B:0.1, Fe:0.2, Mn:0.1, Ni:0.1, In:0.1	280	314	11.0	○	○	○	○	○	○	○	○	○
129	Fe:0.2, B:Mn,Zr,Ni,Sb,Sc:0.1 respectively	282	316	10.9	○	○	○	○	○	○	○	○	○

Table 9

	Casting condition a	Casting condition b
Molten metal temperature	730 °C	730 °C
Amount of cooling water	40 little/min.	40 little/min.
Casting diameter	Diameter 120 mm	Diameter 53 mm
Casting rate	150 mm/min.	300 mm/min.
Lubricating oil	Castor oil	Castor oil
Amount of Lubricating oil	1 cc/min.	1 cc/min.
Gas	Air	Air
Gas flow rate	0.5 litter/min.	0.5 litter/min.
Protruded amount of overhang portion (M)	10mm	10mm

**[0198]** From the results of Tables 3 - 8, it was confirmed that the aluminum alloy of compositions according to the present invention has outstanding homogeneity of metal texture, plastic-working nature, cutting ability (including quality of finished surface and cutting crack nature), corrosion resistance and alumite processability, and that abrasion of a tool can also be suppressed at the time of cutting.

#### B. Metal texture and Manufacture conditions

**[0199]** The manufacturing test of aluminum alloy materials were performed using IIA-30 (Table 4) and IIA-127 (Table 8) among the alloys of the above-mentioned compositions.

**[0200]** As for the casting Nos. IIB-1, IIB-2, IIB-5 and IIB-6, they were cast by the vertical-type continuous casting method. As for the casting Nos. IIB-3, IIB-4, IIB-7 and IIB-8, they were cast by the horizontal continuous casting method. Each cast member was formed into a non-hollow member (round bar) having a round cross-section. The detail of the casting method and casting conditions are as follows. Furthermore, as comparative examples, casting Nos. IIB-9, IIB-10 were cast by a metal mold.

[Vertical-type continuous casting]

**[0201]** Two types of non-hollow members having of round cross-section were made under the casting conditions a and b shown in Table 9 by the same gas pressurizing type hot top casting method as employed in the aforementioned example of "A. Aluminum alloy chemical compositions."

[Horizontal continuous casting]

**[0202]** In the horizontal continuous casting apparatus shown in Fig. 7, the reference numeral "20" denotes a mold, "21" denotes a tundish, "22" denotes a fire resistance conductor for introducing molten metal into the mold 20 from the tundish 21. Furthermore, "23" and "24" denote fire resistance plates for specifying the opening diameter of the molten metal inlet 32 from the conductor 22 to the mold 20.

**[0203]** The mold 20 has an annular cavernous portion 25 in which cooling medium C such as water circulates, and is provided with a plurality of port mouths 26 opened from the cavernous portion 25 toward the outside. The mold 20 has the annular cavernous portion 25 which circulates cooling mediums C, such as water, to the inside, and a plurality of port mouths 26 which perform opening outside from this cavernous portion 25 are formed. The cooling medium C introduced into the cavernous portion 25 through an introductory tubing which is not illustrated performs a primary cooling of the cast member S by cooling the mold 20, and is blown off from the port mouth 26 to perform a secondary cooling of the casting S.

**[0204]** Furthermore, lubricating oil is introduced into a supply passage 28 via a passage 27 from the exterior, and is supplied to the inner peripheral surface 20a of the mold 20 via a number of supply canaliculus 29 branched from the supply passage 28.

**[0205]** In Fig. 7, "31" denotes an exit of the tundish 21, and "32" denotes a molten metal inlet.

**[0206]** According to the horizontal continuous casting apparatus, the casting rate and cooling rate of the present invention can be attained, and a cast member having outstanding characteristics, such as cutting ability, can be manufactured.

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[0207] Two kinds of non-hollow members having round cross-section were manufactured under the casting conditions c and d shown in the following Table 10.

Table 10

	Casting condition c	Casting condition d
Molten metal temperature in tundish	730 °C	730 °C
Amount of cooling water	8 litter/min.	2 litter/min.
Casting diameter	Diameter of 25 mm	Diameter of 10 mm
Casting rate	800 mm/min.	3,000 mm/min.
Lubricating oil	castor oil	castor oil
Amount of Lubricating oil	0.2 cc/min.	0.2 cc/min.
Diameter of molten metal input	5 mm	5 mm

[Metal mold casting]

[0208] The cast molds Nos. IIB-9 and IIB-10, which are comparative examples, are ingots obtained by the sand-mold type test mold (ISO mold) under the casting conditions shown in the following Table 11.

[0209] To the cast members Nos. IIB-1 to IIB-4 and IIB-9, aging of 170 °C x 11 hours was performed, and then scalping processing was performed to eliminate the surface of 1.5 mm depth, to thereby obtain test members. To the cast members Nos. IIB-5 to IIB-8 and IIB-10, scalping processing was performed to eliminate the surface of 1.5 mm depth, and then aging of 170 °C x 11 hours was performed, to thereby obtain test members.

[0210] The metal texture of each of these test pieces was observed, and the average DAS, the distribution state of the particle in the eutectic lamella texture, (the mean particle diameter of the eutectic Si particle, the number of particles and the area share of the eutectic Si particles and the second phase particles), the eutectic lamella texture size (the mean skeleton line length Lm, the mean width Wm, these ratio L/Wm) were examined. The main points of the manufacture conditions of each casting example are again shown in Table 11, the observation results of the metal texture are shown in Table 11.

Table 11

Casting No. (IIB-n)	Alloy No.	Casting conditions				Aging		Metal texture						
		Casting method, Casting conditions	Casting rate Mm/min.	Cast diameter mm	Cooling rate °C/min.	Temp. °C	Hours h	Distribution state of particle			Eutectic lamella texture			
								Mean DAS μm	Mean diameter μm	Area share %	Particle number Pieces/mm <sup>2</sup>	Mean skeleton line length μm	Mean width μm	L/Wm
Invention	IIA-30	1	150	120	20	170	11	15.9	0.78	3.1	2.7x10 <sup>3</sup>	42.4	4.6	9.2
		2	300	53	40			20.4	0.91	2.9	5.9x10 <sup>3</sup>	50.6	4.9	10.3
		3	3,000	10	400			4.9	0.45	3.6	2.9x10 <sup>4</sup>	49.5	3.2	15.5
		4	800	25	100			7.6	0.50	3.0	1.8x10 <sup>4</sup>	44.6	3.9	11.4
		5	150	120	20			8.7	1.02	7.5	2.7x10 <sup>4</sup>	108.6	4.1	26.5
		6	300	53	40			12.4	1.55	7.7	2.7x10 <sup>4</sup>	112.4	5.3	21.2
		7	3,000	10	400			4.5	0.65	6.9	2.7x10 <sup>4</sup>	70.2	4.1	17.1
		8	800	25	100			7.2	1.01	7.6	2.7x10 <sup>4</sup>	88.6	3.7	23.9
Comparative	IIA-30	Mold	10	200	0.5	170	11	22.7	6.20	4.2	3.5x10 <sup>3</sup>	10.3	2.1	4.9
		Mold	10	200	0.5			16.2	7.22	9.5	2.5x10 <sup>3</sup>	15.5	4.6	3.4

The underlined means the data falls out of the scope of the invention.

[0211] About each test piece, the mechanical properties of 0.2% proof strength, tensile strength, fracture elongation

were measured, and the casting nature, cutting ability, abrasion of a tool, quality of the finished surface, cutting crack nature and corrosion resistance were examined by the same method as in the aforementioned alloy composition test. Furthermore, the existence and the number of internal defects were also evaluated relatively. Furthermore, the comprehensive quality as an alloy material was evaluated. The evaluation was made as the following four grade relative evaluations.

- ⊙: Excellent
- : Slightly excellent
- △: Slightly poor
- ×: Very poor

Table 12

Casting No. (II B-n)	Mechanical property	Productivity Castability	Cutting ability	Tool abrasion	Quality of finished surface	Cutting crack nature	Corrosion resistance	Internal defect	Overall evaluation
	Invention	1	⊙	⊙	⊙	⊙	⊙	⊙	⊙
2		⊙	○	○	⊙	⊙	○	⊙	○
3		○	○	⊙	⊙	⊙	○	⊙	○
4		⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
5		⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
6		○	⊙	○	⊙	⊙	○	⊙	○
7		⊙	○	⊙	⊙	⊙	⊙	⊙	○
8		⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
Comparative	9	△	△	×	△	×	△	×	×
	10	×	△	×	△	×	△	×	×

[0212] From the results of Table 12, it was confirmed that the aluminum alloy material manufactured by the method of this invention has an eutectic lamella texture where Si particles are dispersed finely in the metal texture, and therefore

has outstanding cutting ability (including quality of finished surface and cutting crack nature) and corrosion resistance.

C. Aging treatment and secondary forming processing

5 **[0213]** Using the alloys Nos. IIA-30 and IIA-127 as casting materials, a non-hollow of a round cross-section with a diameter of 53 mm was made under the casting conditions b shown in Table 7 by the same gas pressurization type hot top casting as the aforementioned example of "A. chemical composition of an aluminum alloy." The surface portion of the cast non-hollow member of 1.5 mm depth was eliminated by peeling processing, and then aging is performed under the conditions shown in Table 13. Furthermore, to the processing Nos. IIC-5 to IIC-8 and IIC13 to IIC-16, drawing processing was given thereto at the temperature shown in Table 13 and the cross-sectional area reduction ratio. Drawing was performed well in all processing Numbers.

10 **[0214]** About each test piece manufactured, the mechanical properties of 0.2% proof strength, tensile strength, fracture elongation were measured, and the cutting ability, abrasion of a tool, quality of the finished surface, cutting crack nature and impact property were evaluated. The impact property was examined by the following method and the examination method of the other items was performed by the same method as in the aforementioned alloy compositions examination. The evaluation was made as the following four grade relative evaluations. In this examination, the mechanical property was evaluated as relative evaluation.

- 15 ◎ : Excellent
- : Slightly excellent
- 20 Δ : Slightly poor
- × : Very poor

[Impact property]

25 **[0215]** The metallic material impact test based on JIS Z2202 and JIS Z2242 was performed, and the impact property was evaluated by the charpy impact.

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Table 13

Treatment No. (IIC-n)	Alloy No.	Aging		Drawing processing		Various characteristics						
		Temp. °C	Time H	Temp. °C	Cross-section area reduction ratio %	Mechanical property	Cutting ability	Tool abrasion	Quality of finished surface	Cutting crack nature	Corrosion resistance	Impact property
Invention	1	170	11	-	-	⊙	⊙	○	⊙	⊙	○	○
	2	160	6	-	-	○	○	○	○	○	○	○
	3	160	15	-	-	⊙	⊙	○	⊙	⊙	○	○
	4	200	7	-	-	⊙	⊙	○	⊙	⊙	○	○
	5	160	9	Room temp.	5	⊙	⊙	○	⊙	⊙	○	○
	6	160	8	Room temp.	10	⊙	⊙	○	⊙	⊙	○	○
	7	170	7	Room temp.	10	⊙	⊙	○	⊙	⊙	○	○
	8	200	4	Room temp.	10	⊙	⊙	○	⊙	⊙	○	○
	9	170	11	-	-	⊙	⊙	○	⊙	⊙	○	○
	10	160	6	-	-	⊙	⊙	○	⊙	⊙	○	○
	11	160	15	-	-	○	○	○	○	○	○	○
	12	200	7	-	-	⊙	⊙	○	⊙	⊙	○	○
	13	160	9	Room temp.	5	⊙	⊙	○	⊙	⊙	○	○
	14	160	8	Room temp.	10	⊙	⊙	○	⊙	⊙	○	○
	15	170	7	Room temp.	10	⊙	⊙	○	⊙	⊙	○	○
	16	200	4	Room temp.	10	⊙	⊙	○	⊙	⊙	○	○
Comparative	17	310	1	-	-	X	△	○	△	○	△	△
	18	160	105	-	-	X	△	○	△	○	△	△
	19	310	1	-	-	X	△	○	△	○	△	△
	20	160	105	-	-	X	△	○	△	○	△	△

In this Table, the underlined numeral is out of the scope of the invention.

[0216] From the result shown in Table 13, it was confirmed that, by giving the aging treatment to a cast member under

the conditions of the invention, outstanding mechanical property, cutting ability (including quality of finished surface and cutting crack nature), corrosion resistance and impact property can be obtained, and abrasion of a tool can be suppressed. Furthermore, it was also confirmed that the secondary forming processing under the conditions of the invention enables forming processing without deteriorating various characteristics, especially cutting ability.

**[0217]** It should be appreciated that the terms and descriptions herein are not used for limiting the scope of the invention, but used only for explanatory purposes, and the invention does not eliminate any feature equivalent to the feature disclosed and explained herein, and permits any modifications and substitutions within the scope of the present invention defined by the appended claims.

### Industrial Applicability

**[0218]** As mentioned above, since the aluminum alloy material of the invention is excellent in cutting ability, the member can be applied to materials of various kinds of member accompanied by cutting processing. Furthermore, since no toxic Pb is contained, not bad influence is given to the environment and recycle nature is also preferable. Therefore, the material is excellent from the viewpoint of earth environment protection.

### Claims

1. An aluminum alloy, consisting of:

Mg: 0.3 - 6 mass%;

Si: 0.3 - 10 mass%;

Zn: 0.05 - 1 mass%

Sr: 0.001 - 0.3 mass%; and optionally

one or more of selective additional elements selected from the group consisting of Cu: 0.01 mass% or more but less than 1 mass%, Fe: 0.01 - 1 mass%, Mn: 0.01 - 1 mass%, Cr: 0.01 - 1 mass%, Zr: 0.01 - 1 mass%, Ti: 0.01 - 1 mass%, Na: 0.001 - 0.5 mass% and Ca: 0.001 - 0.5 mass% ; and the balance being aluminum and impurities.

2. The aluminum alloy as recited in claim 1, wherein the content of Mg is 0.5 - 1.1 mass%.

3. The aluminum alloy as recited in claim 1 or 2, wherein the content of Si is 1.5 - 5 mass%.

4. The aluminum alloy as recited in any one of claims 1 - 3, wherein the content of Zn is 0.1 - 0.3 mass%.

5. The aluminum alloy as recited in any one of claims 1 - 4, wherein the content of Sr is 0.005 - 0.05 mass%.

6. The aluminum alloy as recited in any one of claims 1 to 5, wherein the selective additional element is Cu.

7. The aluminum alloy as recited in any one of claims 1 to 5, wherein the selective additional element is Fe.

8. The aluminum alloy as recited in any one of claims 1 to 5, wherein the selective additional element is one or more elements selected from the group consisting of Cr and Mn.

9. The aluminum alloy as recited in any one of claims 1 to 5, wherein the selective additional element is Zr.

10. The aluminum alloy as recited in any one of claims 1 to 5, wherein the selective additional element is Ti.

11. The aluminum alloy as recited in any one of claims 1 to 5, wherein the selective additional element is one or more elements selected from the group consisting of Na and Ca.

12. The aluminum alloy as recited in any one of claims 1 to 6, wherein the content of Cu is 0.1 - 0.3 mass%.

13. The aluminum alloy as recited in any one of claims 1 to 5, 7, 12, wherein the content of Fe is 0.1 - 0.3 mass%.

14. The aluminum alloy as recited in any one of claims 1 to 5, 8, 12, 13, wherein the content of Mn is 0.1 - 0.3 mass%.

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15. The aluminum alloy as recited in any one of claims 1 to 5, 8, 12 or 12-14, wherein the content of Cr is 0.1 - 0.3 mass%.
16. The aluminum alloy as recited in any one of claims 1 to 5, 9 or 12-15, wherein the content of Zr is 0.1 - 0.3 mass%.
- 5 17. The aluminum alloy as recited in any one of claims 1 to 5, 10 or 12-16, wherein the content of Ti is 0.1 - 0.3 mass%.
18. The aluminum alloy as recited in any one of claims 1 to 5 or 11-17, wherein the content of Na is 0.005 - 0.3 mass%.
19. The aluminum alloy as recited in any one of claims 1 to 5 or 11-18, wherein the content of Ca is 0.005 - 0.3 mass%.
- 10 20. The aluminum alloy as recited in any one of claims 1 -19,  
wherein a mean particle diameter of Si particle is 1 - 5  $\mu\text{m}$  and a mean aspect ratio of Si particle is 1 - 3, as an alloy  
texture of the aluminum alloy.
- 15 21. The aluminum alloy as recited in claim 20, wherein the mean particle diameter of the Si particle is 3  $\mu\text{m}$  or less.
22. The aluminum alloy as recited in claim 20 or 21, wherein the mean aspect ratio of the Si particle is 2 or less.
23. A method for manufacturing an aluminum alloy material, the method comprising:
- 20 making a billet at a casting rate of 10 - 180 mm/min., the billet composed of aluminum alloy as recited in any  
one of claims 1 to 19;  
homogenizing the billet at 400 - 570°C for 6 hours or more to obtain a homogenized billet;  
extruding the homogenized billet at a billet temperature of 300 - 550 °C, an extrusion rate of 0.5 - 100 m/min.  
25 and an extrusion ratio of 10 - 200 into an extruded article having a predetermined configuration;  
executing a solution treatment to the extruded article at 400- 570°C for 1 hour or more; and  
aging the solution treated extruded article at 90 - 300°C for 1 - 30 hours.
24. The method for manufacturing an aluminum alloy material as recited in claim 23, wherein the casting rate is 30 -  
30 130 mm/min.
25. The method for manufacturing an aluminum alloy material as recited in claim 23 or 24, wherein the homogenization  
is performed at 500 - 545 °C for 10 hours or more.
- 35 26. The method for manufacturing an aluminum alloy material as recited in any one of claims 23-25, wherein the extrusion  
is performed at the billet temperature of 350 - 500°C the extrusion rate of 2 - 30 m/min. and the extrusion ratio of 20 - 85.
27. The method for manufacturing an aluminum alloy material as recited in any one of claims 23-26, wherein the solution  
treatment is performed at 500 - 545 °C for 3 hours or more.
- 40 28. The method for manufacturing an aluminum alloy material as recited in any one of claims 23-27, wherein the aging  
is performed at 140 - 200°C for 3 - 20 hours.
29. The method for manufacturing an aluminum alloy material as recited in any one of claims 23-28, wherein the solution  
45 treated extruded article is drawn at a reduction rate of 5 - 30% into a predetermined configuration, and thereafter  
the aging is performed.
30. The method for manufacturing an aluminum alloy material as recited in claim 29, wherein the reduction rate of the  
drawing is 10 - 20%.
- 50 31. An aluminum alloy, consisting of:
- Mg: 0.1 - 6 mass%;  
Si: 1.2-8.5 mass%;  
55 Cu: 0.01 mass% or more but less than 1 mass%;  
Zn: 0.01 - 3 mass% ;  
Sr: 0.001 - 0.5 mass%; optionally  
one or more of selective additional elements selected from the group consisting of Ti: 0.001 - 1 mass%, B:

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0.0001 - 0.03 mass%, C: 0.0001 - 0.5 mass%, Fe: 0.01 - 1 mass%, Cr: 0.01 - 1 mass%, Mn: 0.01 - 1 mass%;  
Zr: 0.01 - 1 mass%, V: 0.01 - 1 mass%, Sc: 0.0001 - 0.5 mass%, Ni: 0.005 - 1 mass%, Na: 0.001 - 0.5 mass%,  
Sb: 0.001 - 0.5 mass%, Ca: 0.001 - 0.5 mass%, Sn: 0.01 - 1 mass%, Bi: 0.01 - 1 mass%, and In: 0.001 - 0.5  
mass%; and

the balance being Aluminum and impurities.

- 5
32. The aluminum alloy as recited in claim 31, wherein the content of Mg is 0.3 - 5 mass%.
- 10
33. The aluminum alloy as recited in claim 31 or 32, wherein the content of Cu is 0.1 - 0.8 mass%.
34. The aluminum alloy as recited in any one of claims 31 - 33, wherein the content of Zn is 0.05 - 1.5 mass%.
35. The aluminum alloy as recited in any one of claims 31 - 34, wherein the content of Sr is 0.005 - 0.3 mass%.
- 15
36. The aluminum alloy as recited in any one of claims 31 - 35, wherein the selective additional element is one or more elements selected from the group consisting of Ti, B, C and Sc.
37. The aluminum alloy as recited in any one of claims 31 - 35, wherein the selective additional element is Fe.
- 20
38. The aluminum alloy as recited in any one of claims 31 - 35 wherein the selective additional element is one or more elements selected from the group consisting of Cr and Mn.
39. The aluminum alloy as recited in any one of claims 31 - 35, wherein the selective additional element is one or more elements selected from the group consisting of Zr and V.
- 25
40. The aluminum alloy as recited in any one of claims 31 - 35, wherein the selective additional element is Ni.
41. The aluminum alloy as recited in any one of claims 31 - 35, wherein the selective additional element is one or more elements selected from the group consisting of Na, Sb and Ca.
- 30
42. The aluminum alloy as recited in any one of claims 31 - 35, wherein the selective additional element is one or more elements selected from the group consisting of Sn, Bi and In.
43. The aluminum alloy as recited in any one of claims 31 - 36, wherein the content of Ti is 0.003 - 0.5 mass%.
- 35
44. The aluminum alloy as recited in any one of claims 31 - 36 or 43, wherein the content of B is 0.0005 - 0.01 mass%.
45. The aluminum alloy as recited in any one of claims 31 - 36, 43, or 44 wherein the content of C is 0.001 - 0.3 mass%.
- 40
46. The aluminum alloy as recited in any one of claims 31 - 35, 37, or 43 - 45, wherein the content of Fe is 0.05 - 0.7 mass%.
47. The aluminum alloy as recited in any one of claims 31 - 35, 38 or 43 - 46, wherein the content of Cr is 0.03 - 0.7 mass%.
48. The aluminum alloy as recited in any one of claims 31 - 35, 38 or 43 - 47, wherein the content of Mn is 0.03 - 0.7 mass%.
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49. The aluminum alloy as recited in any one of claims 31 - 35, 39, or 43 - 48, wherein the content of Zr is 0.03 - 0.7 mass%.
50. The aluminum alloy as recited in any one of claims 31 - 35, 39 or 43 - 49, wherein the content of V is 0.03 - 0.7 mass%.
- 50
51. The aluminum alloy as recited in any one of claims 31 - 36 or 43 - 50, wherein the content of Sc is 0.01 - 0.3 mass%.
52. The aluminum alloy as recited in any one of claims 31 - 35, 40 or 43 - 51, wherein the content of Ni is 0.03 - 0.7 mass%
53. The aluminum alloy as recited in any one of claims 31 - 35, 41 or 43 - 52, wherein the content of Na is 0.005 - 0.3 mass%.
- 55
54. The aluminum alloy as recited in any one of claims 31 - 35, 41 or 43 - 53, wherein the content of Sb is 0.005 - 0.3 mass%.

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55. The aluminum alloy as recited in any one of claims 31 - 35, 41 or 43 - 54, wherein the content of Ca is 0.005 - 0.3 mass%.
56. The aluminum alloy as recited in any one of claims 31 - 35 or 42 - 55, wherein the content of Sn is 0.05 - 0.5 mass%.
57. The aluminum alloy as recited in any one of claims 31 - 35 or 42 - 56, wherein the content of Bi is 0.05 - 0.5 mass%.
58. The aluminum alloy as recited in any one of claims 31 - 35 or 42 - 57, wherein the content of In is 0.01 - 0.3 mass%.
59. The aluminum alloy as recited in any one of claims 31 - 58, wherein, in a metal texture, a mean dendrite arm spacing is 1 - 200  $\mu\text{m}$ , a dendrite boundary zone includes eutectic Si particles of 0.01 - 5  $\mu\text{m}$  of a mean particle diameter and other second phase particles, and an eutectic lamella texture in which a mean skeleton line length ( $L_m$ ) in a longitudinal direction is 0.5  $\mu\text{m}$  or more and a mean width ( $W_m$ ) is 0.5  $\mu\text{m}$  or more is formed in a shape of a network.
60. The aluminum alloy as recited in claim 59, wherein, in the eutectic lamella texture, the eutectic Si particles and other second phase particles exist 500 pieces/ $\text{mm}^2$  or more in total, and the area share of these particles is 0.1 - 50%.
61. The aluminum alloy as recited in claim 59 or 60, wherein the mean dendrite arm spacing is 3 - 100  $\mu\text{m}$ .
62. The aluminum alloy as recited in any one of claims 59 - 61, wherein the mean particle diameter of the eutectic Si particle is 0.1 - 3  $\mu\text{m}$ .
63. The aluminum alloy as recited in any one of claims 59 - 62 wherein the eutectic lamella texture has a mean skeleton line length ( $L_m$ ) of 3  $\mu\text{m}$  or more and a mean width ( $W_m$ ) of 1  $\mu\text{m}$  or more.
64. The aluminum alloy as recited in any one of claims 59 - 63 wherein a mean ratio ( $L/W_m$ ) of the skeleton line length to the skeleton width in the eutectic lamella texture is 3 or more.
65. The aluminum alloy as recited in any one of claims 59 - 64, wherein the eutectic Si particles and other second phase particles exist 1,000 pieces/ $\text{mm}^2$  or more in total.
66. The aluminum alloy as recited in any one of claims 59 - 65, wherein the area share of the eutectic Si particles and other second phase particles is 0.3 - 40%.
67. A method for manufacturing an aluminum alloy material, the method comprising:  
continuously casting molten aluminum alloy to obtain a shape member having a prescribed cross section at a casting rate of 30 - 5000 mm/min. and a cooling rate of 10 - 600  $^{\circ}\text{C}/\text{sec.}$ , the molten aluminum alloy as recited in any one of claims 31-58 and held at the solidus temperature or more; thereafter aging the shape member at 100 - 300  $^{\circ}\text{C}$  for 0.5 - 100 hours.
68. The method for manufacturing an aluminum alloy material as recited in claim 67, wherein the casting rate is 100 - 2000 mm/min.
69. The method for manufacturing an aluminum alloy material as recited in claim 67 or 68 wherein the cooling rate is 30 - 300  $^{\circ}\text{C}/\text{sec.}$
70. The method for manufacturing an aluminum alloy material as recited in any one of claims 67 - 69, wherein the aging is performed at 120 - 220 $^{\circ}\text{C}$  for 1 - 30 hours.
71. The method for manufacturing an aluminum alloy material as recited in any one of claims 67 - 70 wherein the shape member is a non-hollow member.
72. The method for manufacturing an aluminum alloy material as recited in any one of claims 67 - 71, wherein the shape member circumscribes to a circle with a diameter of 10 - 150 mm in cross section.
73. The method for manufacturing an aluminum alloy material as recited in any one of claims 67 - 72 further comprising

a step of eliminating a surface layer portion of 0.1 - 10 mm depth from the continuously cast shape member.

74. The method for manufacturing an aluminum alloy material as recited in claim 73, wherein the eliminated surface layer portion is 0.2 - 5 mm in depth.

75. The method for manufacturing an aluminum alloy material as recited in any one of claims 67 - 74, further comprising the step of performing a secondary forming processing of a cross-sectional area decreasing ratio of 30% or less to the shape member after the continuous casting at a temperature of 400 °C or below.

76. The method for manufacturing an aluminum alloy material as recited in claim 75, wherein the processing temperature is 250°C or below.

77. The method for manufacturing an aluminum alloy material as recited in claim 75 or 76, wherein the cross-sectional area decreasing ratio is 20% or less.

### Patentansprüche

1. Eine Aluminiumlegierung, die aus

- 0.3 - 6 Massen-% Mg;
- 0.3 - 10 Massen-% Si;
- 0.05 - 1 Massen-% Zn;
- 0.001 - 0.3 Massen-% Sr; und

optional einem oder mehreren selektiven zusätzlichen Elementen besteht, die aus der Gruppe, die aus 0.01 Massen-% oder mehr aber weniger als 1 Massen-% Cu, 0.01 - 1 Massen-% Fe, 0.01 - 1 Massen-% Mn, 0.01 - 1 Massen-% Cr, 0.01 - 1 Massen-% Zr, 0.01 - 1 Massen-% Ti, 0.001 - 0.5 Massen-% Na und 0.001 - 0.5 Massen-% Ca besteht, ausgewählt werden, wobei der Rest Aluminium und Verunreinigungen ist.

2. Die Aluminiumlegierung wie in Anspruch 1 wiedergegeben, wobei der Gehalt an Mg 0.5 - 1.1 Massen-% ist.

3. Die Aluminiumlegierung wie in Anspruch 1 oder 2 wiedergegeben, wobei der Gehalt an Si 1.5 - 5 Massen-% ist.

4. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 3 wiedergegeben, wobei der Gehalt an Zn 0.1 - 0.3 Massen-% ist.

5. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 4 wiedergegeben, wobei der Gehalt an Sr 0.005 - 0.05 Massen-% ist.

6. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5 wiedergegeben, wobei das selektive zusätzliche Element Cu ist.

7. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5 wiedergegeben, wobei das selektive zusätzliche Element Fe ist.

8. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5 wiedergegeben, wobei das selektive zusätzliche Element ein oder mehrere Elemente ist, die aus der Gruppe, die aus Cr und Mn besteht, ausgewählt werden.

9. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5 wiedergegeben, wobei das selektive zusätzliche Element Zr ist.

10. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5 wiedergegeben, wobei das selektive zusätzliche Element Ti ist.

11. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5 wiedergegeben, wobei das selektive zusätzliche Element ein oder mehrere Elemente ist, die aus der Gruppe, die aus Na und Ca besteht, ausgewählt werden.

12. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 6 wiedergegeben, wobei der Gehalt an Cu 0.1 - 0.3 Massen-

% ist.

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13. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5, 7 oder 12 wiedergegeben, wobei der Gehalt an Fe 0.1 - 0.3 Massen-% ist.
14. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5, 8, 12 oder 13 wiedergegeben, wobei der Gehalt an Mn 0.1 - 0.3 Massen-% ist.
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15. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5, 8, 12 oder 12 - 14 wiedergegeben, wobei der Gehalt an Cr 0.1 - 0.3 Massen-% ist.
16. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5, 9 oder 12 - 15 wiedergegeben, wobei der Gehalt an Zr 0.1 - 0.3 Massen-% ist.
- 15
17. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5, 10 oder 12-16 wiedergegeben, wobei der Gehalt an Ti 0.1 - 0.3 Massen-% ist.
18. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5 oder 11 - 17 wiedergegeben, wobei der Gehalt an Na 0.005 - 0.3 Massen-% ist.
- 20
19. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 5 oder 11 - 18 wiedergegeben, wobei der Gehalt an Ca 0.005 - 0.3 Massen-%.
- 25
20. Die Aluminiumlegierung wie in einem der Ansprüche 1 - 19 wiedergegeben, wobei ein durchschnittlicher Teilchendurchmesser eines Si-Teilchens 1 - 5  $\mu\text{m}$  ist und ein durchschnittliches Längenverhältnis eines Si-Teilchens 1 - 3 ist, als eine Legierungstextur der Aluminiumlegierung.
- 30
21. Die Aluminiumlegierung wie in Anspruch 20 wiedergegeben, wobei der durchschnittliche Teilchendurchmesser des Si-Teilchens 3  $\mu\text{m}$  oder weniger ist.
22. Die Aluminiumlegierung wie in Anspruch 20 wiedergegeben, wobei das durchschnittliche Längenverhältnis des Si-Teilchens 2 oder weniger ist.
- 35
23. Ein Verfahren zur Herstellung eines Aluminiumlegierungsmaterials, wobei das Verfahren umfasst:
- Herstellen eines Stranges bei einer Gießgeschwindigkeit von 10 - 180 mm/min, wobei der Strang aus einer Aluminiumlegierung wie in einem der Ansprüche 1 bis 19 wiedergegeben besteht;
  - Homogenisieren des Stranges bei 400 - 570 °C für 6 Stunden oder mehr, um einen homogenisierten Strang zu erhalten;
  - Extrudieren des homogenisierten Strangs bei einer Strangtemperatur von 300 - 550 °C, einer Extrusionsgeschwindigkeit von 0.5 - 100 m/min und einem Extrusionsverhältnis von 10 - 200 in einen extrudierten Gegenstand mit einer vorherbestimmten Konfiguration;
  - Ausführen einer Lösungsglühung des extrudierten Gegenstands bei 400 - 570 °C für 1 Stunde oder mehr; und
  - Härten des lösungsgeglühten extrudierten Gegenstands bei 90 - 300 °C für 1 - 30 Stunden.
- 40
- 45
24. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in Anspruch 23 wiedergegeben, wobei die Gießgeschwindigkeit 30 - 130 mm/min ist.
- 50
25. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in Anspruch 23 oder 24 wiedergegeben, wobei die Homogenisierung bei 500 - 545 °C für 10 Stunden oder mehr durchgeführt wird.
- 55
26. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in einem der Ansprüche 23 - 25 wiedergegeben, wobei die Extrusion bei der Strangtemperatur von 350 - 500 °C, der Extrusionsgeschwindigkeit von 2 - 30 m/min und dem Extrusionsverhältnis von 20 - 85 durchgeführt wird.
27. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in einem der Ansprüche 23 - 26 wiedergegeben, wobei die Lösungsglühung bei 500 - 545 °C für 3 Stunden oder mehr durchgeführt wird.

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28. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in einem der Ansprüche 23 - 27 wiedergegeben, wobei das Härten bei 140 - 200 °C für 3 - 20 Stunden durchgeführt wird.
- 5 29. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in einem der Ansprüche 23 - 28 wiedergegeben, wobei der lösungsgeglühte extrudierte Gegenstand bei einem Reduktionsgrad von 5 - 30% in eine vorherbestimmte Konfiguration gezogen wird und danach das Härten durchgeführt wird.
- 10 30. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in Anspruch 29 wiedergegeben, wobei der Reduktionsgrad des Ziehens 10 - 20% ist.
- 15 31. Eine Aluminiumlegierung, die aus
- 0.1 - 6 Massen-% Mg;
  - 1.2 - 8.5 Massen-% Si;
  - 0.01 Massen-% oder mehr, aber weniger als 1 Massen-% Cu;
  - 0.01 - 3 Massen-% Zn;
  - 0.001 - 0.5 Massen-% Sr; und
- optional einem oder mehreren selektiven zusätzlichen Elementen besteht, die aus der Gruppe, die aus 0.001 - 1 Massen-% Ti, 0.0001 - 0.03 Massen-% B, 0.0001 - 0.5 Massen-% C, 0.01 - 1 Massen-% Fe, 0.01 - 1 Massen-% Cr, 0.01 - 1 Massen-% Mn, 0.01 - 1 Massen-% Zr, 0.01 - 1 Massen-% V, 0.0001 - 0.5 Massen-% Sc, 0.005 - 1 Massen-% Ni, 0.001 - 0.5 Massen-% Na, 0.001 - 0.5 Massen-% Sb, 0.001 - 0.5 Massen-% Ca, 0.01 - 1 Massen-% Sn, 0.01 - 1 Massen-% Bi, und 0.001 - 0.5 Massen-% In besteht, ausgewählt werden, wobei der Rest Aluminium und Verunreinigungen ist.
- 20 32. Die Aluminiumlegierung wie in Anspruch 31 wiedergegeben, wobei der Gehalt an Mg 0.3 - 5 Massen-% ist.
- 25 33. Die Aluminiumlegierung wie in Anspruch 31 oder 32 wiedergegeben, wobei der Gehalt an Cu 0.1 - 0.8 Massen-% ist.
- 30 34. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 33 wiedergegeben, wobei der Gehalt an Zn 0.05 - 1.5 Massen-% ist.
- 35 35. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 34 wiedergegeben, wobei der Gehalt an Sr 0.005 - 0.3 Massen-% ist.
- 40 36. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35 wiedergegeben, wobei das selektive zusätzliche Element eines oder mehrere Elemente ist, die aus der Gruppe, die aus Ti, B, C und Sc besteht, ausgewählt werden.
- 45 37. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35 wiedergegeben, wobei das selektive zusätzliche Element Fe ist.
- 50 38. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35 wiedergegeben, wobei das selektive zusätzliche Element eines oder mehrere Elemente ist, die aus der Gruppe, die aus Cr und Mn besteht, ausgewählt werden.
- 55 39. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35 wiedergegeben, wobei das selektive zusätzliche Element eines oder mehrere Elemente ist, die aus der Gruppe, die aus Zr und V besteht, ausgewählt werden.
40. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35 wiedergegeben, wobei das selektive zusätzliche Element Ni ist.
41. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35 wiedergegeben, wobei das selektive zusätzliche Element eines oder mehrere Elemente ist, die aus der Gruppe, die aus Na, Sb und Ca besteht, ausgewählt werden.
42. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35 wiedergegeben, wobei das selektive zusätzliche Element eines oder mehrere Elemente ist, die aus der Gruppe, die aus Sn, Bi und In besteht, ausgewählt werden.
43. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 36 wiedergegeben, wobei der Gehalt an Ti 0.003 - 0.5 Massen-% ist.

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44. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 36 oder 43 wiedergegeben, wobei der Gehalt an B 0.0005 - 0.01 Massen-% ist.
- 5 45. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 36, 43 oder 44 wiedergegeben, wobei der Gehalt an C 0.001 - 0.3 Massen-% ist.
46. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35, 37 oder 43 - 45 wiedergegeben, wobei der Gehalt an Fe 0.05 - 0.7 Massen-% ist.
- 10 47. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35, 38 oder 43 - 46 wiedergegeben, wobei der Gehalt an Cr 0.03 - 0.7 Massen-% ist.
48. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35, 38 oder 43 - 47 wiedergegeben, wobei der Gehalt an Mn 0.03 - 0.7 Massen-% ist.
- 15 49. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35, 39 oder 43 - 48 wiedergegeben, wobei der Gehalt an Zr 0.03 - 0.7 Massen-% ist.
- 20 50. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35, 39 oder 43 - 49 wiedergegeben, wobei der Gehalt an V 0.03 - 0.7 Massen-% ist.
51. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 36 oder 43 - 50 wiedergegeben, wobei der Gehalt an Sc 0.01 - 0.3 Massen-% ist.
- 25 52. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35, 40 oder 43 - 51 wiedergegeben, wobei der Gehalt an Ni 0.03 - 0.7 Massen-% ist.
53. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35, 41 oder 43 - 52 wiedergegeben, wobei der Gehalt an Na 0.005 - 0.3 Massen-% ist.
- 30 54. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35, 41 oder 43 - 53 wiedergegeben, wobei der Gehalt an Sb 0.005 - 0.3 Massen-% ist.
- 55 55. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35, 41 oder 43 - 54 wiedergegeben, wobei der Gehalt an Ca 0.005 - 0.3 Massen-% ist.
56. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35 oder 42 - 55 wiedergegeben, wobei der Gehalt an Sn 0.05 - 0.5 Massen-% ist.
- 40 57. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35 oder 42 - 56 wiedergegeben, wobei der Gehalt an Bi 0.05 - 0.5 Massen-% ist.
58. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 35 oder 42 - 57 wiedergegeben, wobei der Gehalt an In 0.01 - 0.3 Massen-% ist.
- 45 59. Die Aluminiumlegierung wie in einem der Ansprüche 31 - 58 wiedergegeben, wobei in einer Metalltextur ein durchschnittlicher Dendritenarmabstand 1 - 200  $\mu\text{m}$  ist, eine Dendritengrenzzone eutektische Si-Teilchen mit 0.01 - 5  $\mu\text{m}$  eines durchschnittlichen Teilchendurchmessers und andere Zweitphasen-Teilchen beinhaltet und eine eutektische Lamellenstruktur, bei der eine durchschnittliche Skelettlinienlänge (Lm) in einer longitudinalen Richtung 0.5  $\mu\text{m}$  oder mehr ist und eine durchschnittliche Breite (Wm) 0.5  $\mu\text{m}$  oder mehr ist, in Form eines Netzwerks gebildet ist.
- 50 60. Die Aluminiumlegierung wie in Anspruch 59 wiedergegeben, wobei in der eutektischen Lamellenstruktur die eutektischen Si-Teilchen und andere Zweitphasen-Teilchen insgesamt in 500 Teilen/ $\text{mm}^2$  oder mehr existieren, und der Oberflächenanteil dieser Teilchen 0.1 - 50% ist.
- 55 61. Die Aluminiumlegierung wie in Anspruch 59 oder 60 wiedergegeben, wobei der durchschnittliche Dendritenarmabstand 3 - 100  $\mu\text{m}$  ist.

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- 5
62. Die Aluminiumlegierung wie in einem der Ansprüche 59 - 61 wiedergegeben, wobei der durchschnittliche Teilchendurchmesser des eutektischen Si-Teilchens 0.1 - 3  $\mu\text{m}$  ist.
63. Die Aluminiumlegierung wie in einem der Ansprüche 59 - 62 wiedergegeben, wobei die eutektische Lamellentextur eine durchschnittliche Skelettlinienlänge ( $L_m$ ) von 3  $\mu\text{m}$  oder mehr und eine durchschnittliche Breite ( $W_m$ ) von 1  $\mu\text{m}$  oder mehr hat.
- 10
64. Die Aluminiumlegierung wie in einem der Ansprüche 59 - 63 wiedergegeben, wobei ein durchschnittliches Verhältnis ( $L/W_m$ ) der Skelettlinienlänge zu der Skelettbreite in der eutektischen Lamellentextur 3 oder mehr ist.
65. Die Aluminiumlegierung wie in einem der Ansprüche 59 - 64 wiedergegeben, wobei die eutektischen Si-Teilchen und anderen Zweitphasen-Teilchen insgesamt in 1000 Teile/ $\text{mm}^2$  oder mehr existieren.
- 15
66. Die Aluminiumlegierung wie in einem der Ansprüche 59 - 65 wiedergegeben, wobei der Oberflächenanteil der eutektischen Si-Teilchen und anderer Zweitphasen-Teilchen 0.3 - 40% ist.
67. Ein Verfahren zur Herstellung eines Aluminiumlegierungsmaterials, wobei das Verfahren umfasst:
- 20
- kontinuierliches Gießen einer geschmolzenen Aluminiumlegierung, um ein Formelement mit einem vorgeschriebenen Querschnitt bei einer Gießgeschwindigkeit von 30 - 5000 mm/min und einer Abkühlgeschwindigkeit von 10 - 600  $^{\circ}\text{C}/\text{Sek}$  zu erhalten, wobei die geschmolzene Aluminiumlegierung wie in einem der Ansprüche 31 - 58 wiedergegeben ist und bei der Solidustemperatur oder mehr gehalten wird; danach
  - Härten des Formelements bei 100 - 300  $^{\circ}\text{C}$  für 0.5 - 100 Stunden.
- 25
68. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in Anspruch 67 wiedergegeben, wobei die Gießgeschwindigkeit 100 - 2000 mm/min ist.
69. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in Anspruch 67 oder 68 wiedergegeben, wobei die Abkühlgeschwindigkeit 30 - 300  $^{\circ}\text{C}/\text{Sek}$  ist.
- 30
70. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in einem der Ansprüche 67 - 69 wiedergegeben, wobei das Härten bei 120 - 220  $^{\circ}\text{C}$  für 1 - 30 Stunden durchgeführt wird.
- 35
71. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in einem der Ansprüche 67 - 70 wiedergegeben, wobei das Formelement ein nichthohles Element ist.
72. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in einem der Ansprüche 67 - 71 wiedergegeben, wobei das Formelement einen Kreis mit einem Durchmesser von 10 - 150 mm im Querschnitt umschreibt.
- 40
73. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in einem der Ansprüche 67 - 72 wiedergegeben, das weiter einen Schritt des Eliminierens eines Teils einer Oberflächenschicht von 0.1 - 10 mm Tiefe von dem kontinuierlichen Gussformelement umfasst.
- 45
74. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in Anspruch 73 wiedergegeben, wobei der eliminierte Teil der Oberflächenschicht eine Tiefe von 0.2 - 5 mm hat.
- 50
75. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in einem der Ansprüche 67 - 74 wiedergegeben, das weiter den Schritt des Durchführens einer zweiten Formverarbeitung eines Querschnittsflächen-Verringerungsverhältnisses von 30% oder weniger zu dem Formelement nach dem kontinuierlichen Gießen bei einer Temperatur von 400  $^{\circ}\text{C}$  oder niedriger.
- 55
76. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in Anspruch 75 wiedergegeben, wobei die Verarbeitungstemperatur 250  $^{\circ}\text{C}$  oder weniger ist.
77. Das Verfahren zur Herstellung eines Aluminiumlegierungsmaterials wie in Anspruch 75 oder 76 wiedergegeben, wobei das Querschnittsflächen-Verringerungsverhältnis 20% oder weniger ist.

**Revendications**

1. Alliage d'aluminium, constitué de :
  - Mg : 0,3 à 6% en masse ;
  - Si : 0,3 à 10% en masse ;
  - Zn : 0,05 à 1 % en masse ;
  - Sr : 0,001 à 0,3% en masse ; et éventuellement
  - un ou plusieurs éléments sélectifs supplémentaires choisis dans le groupe consistant en Cu : 0,01 % en masse
  - ou plus mais moins de 1% en masse, Fe : 0,01 à 1% en masse, Mn : 0,01 à 1 % en masse, Cr : 0,01 à 1 % en
  - masse, Zr : 0,01 à 1 % en masse, Ti : 0,01 à 1 % en masse, Na : 0,001 à 0,5% en masse et Ca : 0,001 à 0,5%
  - en masse ; et
  - le reste étant constitué d'aluminium et d'impuretés.
2. Alliage d'aluminium selon la revendication 1, dans lequel la teneur en Mg est comprise entre 0,5 et 1,1 % en masse.
3. Alliage d'aluminium selon la revendication 1 ou 2, dans lequel la teneur en Si est comprise entre 1,5 et 5% en masse.
4. Alliage d'aluminium selon l'une quelconque des revendications 1 à 3, dans lequel la teneur en Zn est comprise
- entre 0,1 et 0,3% en masse.
5. Alliage d'aluminium selon l'une quelconque des revendications 1 à 4, dans lequel la teneur en Sr est comprise entre
- 0,005 et 0,05% en masse.
6. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5, dans lequel l'élément sélectif supplémentaire
- est Cu.
7. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5, dans lequel l'élément sélectif supplémentaire
- est Fe.
8. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5, dans lequel l'élément sélectif supplémentaire
- est un ou plusieurs éléments choisis dans le groupe consistant en Cr et Mn.
9. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5, dans lequel l'élément sélectif supplémentaire
- est Zr.
10. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5, dans lequel l'élément sélectif supplémentaire
- est Ti.
11. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5, dans lequel l'élément sélectif supplémentaire
- est un ou plusieurs éléments choisis dans le groupe consistant en Na et Ca.
12. Alliage d'aluminium selon l'une quelconque des revendications 1 à 6, dans lequel la teneur en Cu est comprise
- entre 0,1 et 0,3% en masse.
13. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5, 7 ou 12,
- dans lequel la teneur en Fe est comprise entre 0,1 et 0,3% en masse.
14. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5, 8, 12 ou 13,
- dans lequel la teneur en Mn est comprise entre 0,1 et 0,3% en masse.
15. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5, 8 ou 12 à 14, dans lequel la teneur en Cr est
- comprise entre 0,1 et 0,3% en masse.
16. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5, 9 ou 12 à 15, dans lequel la teneur en Zr est
- comprise entre 0,1 et 0,3% en masse.
17. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5, 10 ou 12 à 16, dans lequel la teneur en Ti est

comprise entre 0,1 et 0,3% en masse.

- 5
18. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5 ou 11 à 17, dans lequel la teneur en Na est comprise entre 0,005 à 0,3% en masse.
- 10
19. Alliage d'aluminium selon l'une quelconque des revendications 1 à 5 ou 11 à 18, dans lequel la teneur en Ca est comprise entre 0,005 et 0,3% en masse.
- 15
20. Alliage d'aluminium selon l'une quelconque des revendications 1 à 19, dans lequel la texture d'alliage de l'alliage d'aluminium est **caractérisée par** un diamètre moyen des particules de Si compris entre 1 et 5  $\mu\text{m}$  et un rapport de forme moyen des particules de Si compris entre 1 et 3.
- 20
21. Alliage d'aluminium selon la revendication 20, dans lequel le diamètre moyen des particules de Si est inférieur ou égal à 3  $\mu\text{m}$ .
- 25
22. Alliage d'aluminium selon la revendication 20 ou 21, dans lequel le rapport de forme moyen des particules de Si est inférieur ou égal à 2.
- 30
23. Procédé de fabrication d'un matériau d'alliage d'aluminium, lequel procédé consistant à :
- former une billette à une vitesse de coulée comprise entre 10 et 180 mm/min, la billette étant constituée d'un alliage d'aluminium selon l'une quelconque des revendications 1 à 19 ;
  - homogénéiser la billette à une température comprise entre 400 et 570°C pendant 6 heures ou plus afin d'obtenir une billette homogénéisée ;
  - extruder la billette homogénéisée à une température de billette comprise entre 300 et 550°C, une vitesse d'extrusion comprise entre 0,5 et 100 m/min et un rapport d'extrusion compris entre 10 et 200 en un article extrudé ayant une configuration prédéterminée ;
  - effectuer un traitement en solution de l'article extrudé à une température comprise entre 400 et 570°C pendant 1 heure ou plus ; et
  - effectuer un vieillissement de l'article extrudé traité en solution à une température comprise entre 90 et 300°C pendant 1 à 30 heures.
- 35
24. Procédé de fabrication d'un matériau d'alliage d'aluminium selon la revendication 23, dans lequel la vitesse de coulée est comprise entre 30 et 130 mm/min
- 40
25. Procédé de fabrication d'un matériau d'alliage d'aluminium selon la revendication 23 ou 24, dans lequel l'homogénéisation est effectuée à une température comprise entre 500 et 545°C pendant 10 heures ou plus.
- 45
26. Procédé de fabrication d'un matériau d'alliage d'aluminium selon l'une quelconque des revendications 23 à 25, dans lequel l'extrusion est effectuée à une température de billette comprise entre 350 et 500°C, une vitesse d'extrusion comprise entre 2 et 30 m/min et un rapport d'extrusion compris entre 20 et 85.
- 50
27. Procédé de fabrication d'un matériau d'alliage d'aluminium selon l'une quelconque des revendications 23 à 26, dans lequel le traitement en solution est effectué à une température comprise entre 500 et 545°C pendant 3 heures ou plus.
- 55
28. Procédé de fabrication d'un matériau d'alliage d'aluminium selon l'une quelconque des revendications 23 à 27, dans lequel le vieillissement est effectué à une température comprise entre 140 et 200°C pendant 3 à 20 heures.
29. Procédé de fabrication d'un matériau d'alliage d'aluminium selon l'une quelconque des revendications 23 à 28, dans lequel l'article extrudé traité en solution est étiré à un taux de réduction compris entre 5 et 30% en une configuration prédéterminée, et par la suite le vieillissement est effectué.
30. Procédé de fabrication d'un matériau d'alliage d'aluminium selon la revendication 29, dans lequel le taux de réduction de l'étirement est compris entre 10 et 20%.
31. Alliage d'aluminium, constitué de :

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Mg : 0,1 à 6% en masse ;  
Si : 1,2 à 8,5% en masse ;  
Cu : 0,01 % en masse ou plus mais moins de 1 % en masse ;  
Zn : 0,01 à 3% en masse ;

5 Sr : 0,001 à 0,5% en masse ; éventuellement  
un ou plusieurs éléments sélectifs supplémentaires choisis dans le groupe consistant en Ti : 0,001 à 1% en  
masse, B : 0,0001 à 0,03% en masse, C : 0,0001 à 0,5% en masse, Fe : 0,01 à 1 % en masse, Cr : 0,01 à 1%  
10 en masse, Mn : 0,01 à 1% en masse ; Zr : 0,01 à 1% en masse, V : 0,01 à 1% en masse, Sc : 0,0001 à 0,5%  
en masse, Ni : 0,005 à 1 % en masse, Na : 0,001 à 0,5% en masse, Sb : 0,001 à 0,5% en masse, Ca : 0,001  
à 0,5% en masse, Sn : 0,01 à 1% en masse, Bi : 0,01 à 1% en masse, et In : 0,001 à 0,5% en masse ; et  
le reste étant constitué d'aluminium et d'impuretés.

32. Alliage d'aluminium selon la revendication 31, dans lequel la teneur en Mg est comprise entre 0,3 et 5% en masse.
- 15 33. Alliage d'aluminium selon les revendications 31 ou 32, dans lequel la teneur en Cu est comprise entre 0,1 et 0,8%  
en masse.
34. Alliage d'aluminium selon l'une quelconque des revendications 31 à 33, dans lequel la teneur en Zn est comprise  
20 entre 0,05 et 1,5% en masse.
35. Alliage d'aluminium selon l'une quelconque des revendications 31 à 34, dans lequel la teneur en Sr est comprise  
entre 0,005 et 0,3% en masse.
36. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, dans lequel l'élément sélectif supplémentaire  
25 est un ou plusieurs éléments choisis dans le groupe consistant en Ti, B, C et Sc.
37. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, dans lequel l'élément sélectif supplémentaire  
est Fe.
38. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, dans lequel l'élément sélectif supplémentaire  
30 est un ou plusieurs éléments choisis dans le groupe consistant en Cr et Mn.
39. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, dans lequel l'élément sélectif supplémentaire  
est un ou plusieurs éléments choisis dans le groupe consistant en Zr et V.
- 35 40. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, dans lequel l'élément sélectif supplémentaire  
est Ni.
41. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, dans lequel l'élément sélectif supplémentaire  
40 est un ou plusieurs éléments choisis dans le groupe consistant en Na, Sb et Ca.
42. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, dans lequel l'élément sélectif supplémentaire  
est un ou plusieurs éléments choisis dans le groupe consistant en Sn, Bi et In.
- 45 43. Alliage d'aluminium selon l'une quelconque des revendications 31 à 36, dans lequel la teneur en Ti est comprise  
entre 0,003 et 0,5% en masse.
44. Alliage d'aluminium selon l'une quelconque des revendications 31 à 36 ou 43, dans lequel la teneur en B est  
50 comprise entre 0,0005 et 0,01 % en masse.
45. Alliage d'aluminium selon l'une quelconque des revendications 31 à 36, 43 ou 44  
dans lequel la teneur en C est comprise entre 0,001 et 0,3% en masse.
46. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, 37 ou 43 à 45, dans lequel la teneur en Fe  
55 est comprise entre 0,05 et 0,7% en masse.
47. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, 38 ou 43 à 46, dans lequel la teneur en Cr  
est comprise entre 0,03 et 0,7% en masse.

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48. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, 38 ou 43 à 47, dans lequel la teneur en Mn est comprise entre 0,03 et 0,7% en masse.
- 5 49. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, 39 ou 43 à 48, dans lequel la teneur en Zr est comprise entre 0,03 et 0,7% en masse.
50. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, 39 ou 43 à 49, dans lequel la teneur en V est comprise entre 0,03 et 0,7% en masse.
- 10 51. Alliage d'aluminium selon l'une quelconque des revendications 31 à 36 ou 43 à 50, dans lequel la teneur en Sc est comprise entre 0,01 et 0,3% en masse.
52. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, 40 ou 43 à 51, dans lequel la teneur en Ni est comprise entre 0,03 et 0,7% en masse.
- 15 53. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, 41 ou 43 à 52, dans lequel la teneur en Na est comprise entre 0,005 et 0,3% en masse.
54. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, 41 ou 43 à 53, dans lequel la teneur en Sb est comprise entre 0,005 et 0,3% en masse.
- 20 55. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35, 41 ou 43 à 54, dans lequel la teneur en Ca est comprise entre 0,005 et 0,3% en masse.
- 25 56. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35 ou 42 à 55, dans lequel la teneur en Sn est comprise entre 0,05 et 0,5% en masse.
57. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35 ou 42 à 56, dans lequel la teneur en Bi est comprise entre 0,05 et 0,5% en masse.
- 30 58. Alliage d'aluminium selon l'une quelconque des revendications 31 à 35 ou 42 à 57, dans lequel la teneur en In est comprise entre 0,01 et 0,3% en masse.
59. Alliage d'aluminium selon l'une quelconque des revendications 31 à 58, dans lequel, dans une texture métallique, l'espacement moyen entre les ramifications des dendrites est compris entre 1 et 200  $\mu\text{m}$ , la zone frontière des dendrites comprend des particules de Si eutectique ayant un diamètre moyen de particules compris entre 0,01 et 5  $\mu\text{m}$  et d'autres particules de seconde phase, et une texture eutectique lamellaire dans laquelle la longueur moyenne de ligne de structure ( $L_m$ ) dans la direction longitudinale est de 0,5  $\mu\text{m}$  ou plus et la largeur moyenne ( $l_m$ ) est de 0,5  $\mu\text{m}$  ou plus est formée sous forme d'un réseau.
- 40 60. Alliage d'aluminium selon la revendication 59, dans lequel, dans la texture eutectique lamellaire, les particules de Si eutectique et les autres particules de seconde phase correspondent à un total de 500 particules/ $\text{mm}^2$  ou plus, et le partage de surface de ces particules est compris entre 0,1 et 50%.
- 45 61. Alliage d'aluminium selon la revendication 59 ou 60, dans lequel l'espacement moyen entre les ramifications des dendrites est compris entre 3 et 100  $\mu\text{m}$ .
62. Alliage d'aluminium selon l'une quelconque des revendications 59 à 61, dans lequel le diamètre moyen des particules de Si eutectique est compris entre 0,1 et 3  $\mu\text{m}$ .
- 50 63. Alliage d'aluminium selon l'une quelconque des revendications 59 à 62, dans lequel la texture eutectique lamellaire a une longueur moyenne de ligne de structure ( $L_m$ ) de 3  $\mu\text{m}$  ou plus et une largeur moyenne ( $l_m$ ) de 1  $\mu\text{m}$  ou plus.
64. Alliage d'aluminium selon l'une quelconque des revendications 59 à 63, dans lequel le rapport moyen ( $L/l_m$ ) entre la longueur de ligne de structure et la largeur de structure dans la texture eutectique lamellaire est de 3 ou plus.
- 55 65. Alliage d'aluminium selon l'une quelconque des revendications 59 à 64, dans lequel les particules de Si eutectique et les autres particules de seconde phase correspondent à un total de 1000 particules/ $\text{mm}^2$  ou plus.

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66. Alliage d'aluminium selon l'une quelconque des revendications 59 à 65, dans lequel le partage de surface des particules de Si eutectique et des autres particules de seconde phase est compris entre 0,3 et 40%.

67. Procédé de fabrication d'un matériau d'alliage d'aluminium, lequel procédé consistant à :

- mouler en continu l'alliage d'aluminium fondu afin d'obtenir un élément façonné ayant une section transversale déterminée à une vitesse de coulée comprise entre 30 et 5000 mm/min et une vitesse de refroidissement comprise entre 10 et 600°C/s, l'alliage d'aluminium fondu selon l'une quelconque des revendications 31 à 58 et maintenu à la température de solidus ou à une température supérieure ; puis
- effectuer un vieillissement de l'élément façonné à une température comprise entre 100 et 300°C pendant 0,5 à 100 heures.

68. Procédé de fabrication d'un matériau d'alliage d'aluminium selon la revendication 67, dans lequel la vitesse de coulée est comprise entre 100 et 2000 mm/min.

69. Procédé de fabrication d'un matériau d'alliage d'aluminium selon la revendication 67 ou 68, dans lequel la vitesse de refroidissement est comprise entre 30 et 300°C/s.

70. Procédé de fabrication d'un matériau d'alliage d'aluminium selon l'une quelconque des revendications 67 à 69, dans lequel le vieillissement est effectué à une température comprise entre 120 et 220°C pendant 1 à 30 heures.

71. Procédé de fabrication d'un matériau d'alliage d'aluminium selon l'une quelconque des revendications 67 à 70, dans lequel l'élément façonné est un élément non creux.

72. Procédé de fabrication d'un matériau d'alliage d'aluminium selon l'une quelconque des revendications 67 à 71, dans lequel l'élément façonné est circonscrit à un cercle ayant un diamètre transversal compris entre 10 et 150 mm.

73. Procédé de fabrication d'un matériau d'alliage d'aluminium selon l'une quelconque des revendications 67 à 72, comprenant en outre une étape consistant à éliminer une portion de couche de surface située à une profondeur de 0,1 à 10 mm de l'élément façonné coulé en continu.

74. Procédé de fabrication d'un matériau d'alliage d'aluminium selon la revendication 73, dans lequel la portion de couche de surface éliminée est à une profondeur de 0,2 à 5 mm.

75. Procédé de fabrication d'un matériau d'alliage d'aluminium selon l'une quelconque des revendications 67 à 74, comprenant en outre l'étape consistant à effectuer un traitement de formation secondaire ayant un rapport décroissant de section transversale de 30% ou moins de l'élément façonné après coulée continue à une température de 400°C ou inférieure.

76. Procédé de fabrication d'un matériau d'alliage d'aluminium selon la revendication 75, dans lequel la température de traitement est de 250°C ou inférieure.

77. Procédé de fabrication d'un matériau d'alliage d'aluminium selon la revendication 75 ou 76, dans lequel le rapport décroissant de section transversale est de 20% ou moins.

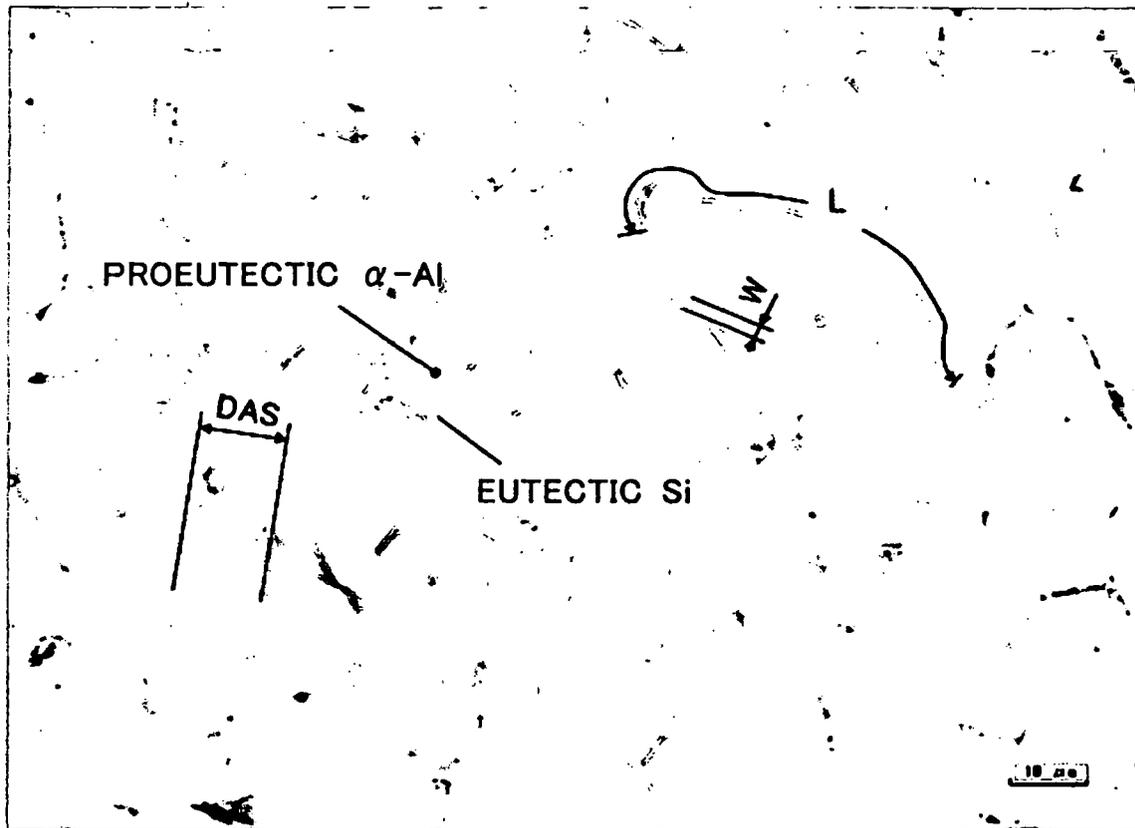


FIG. 1

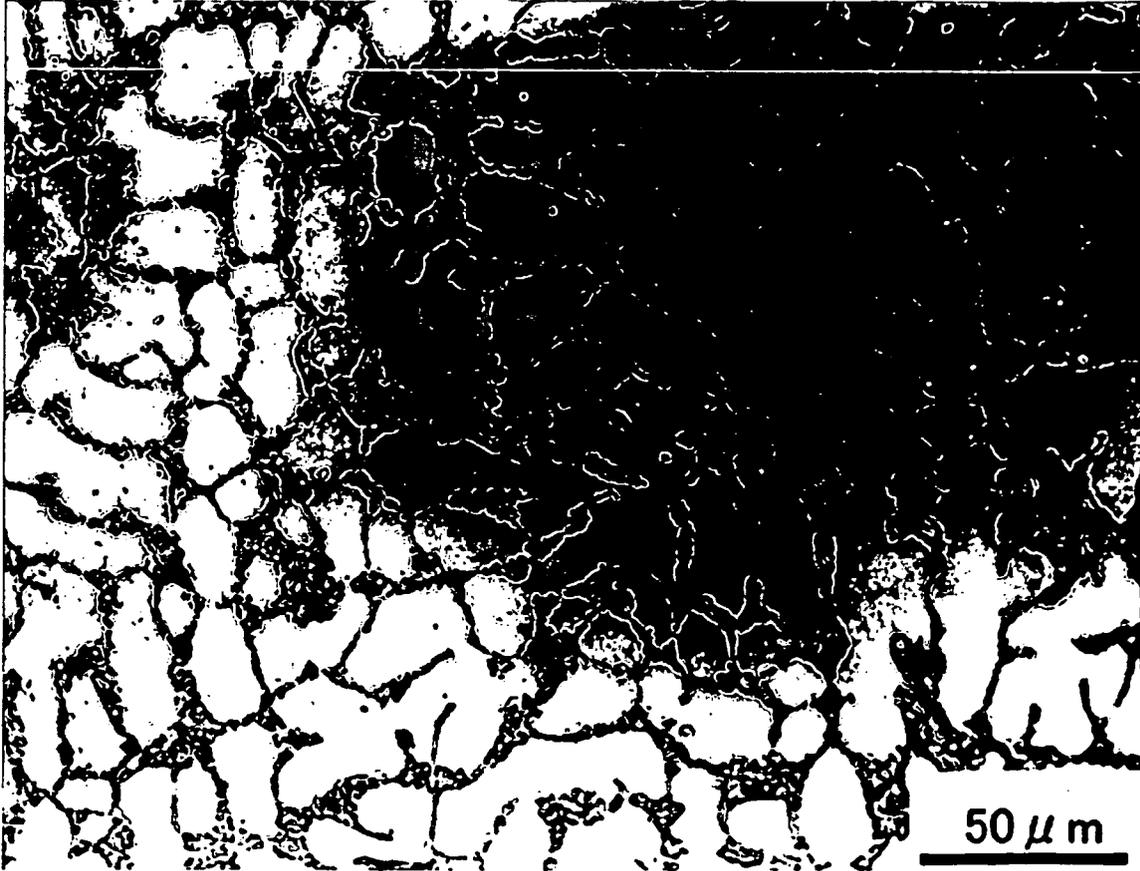


FIG. 2

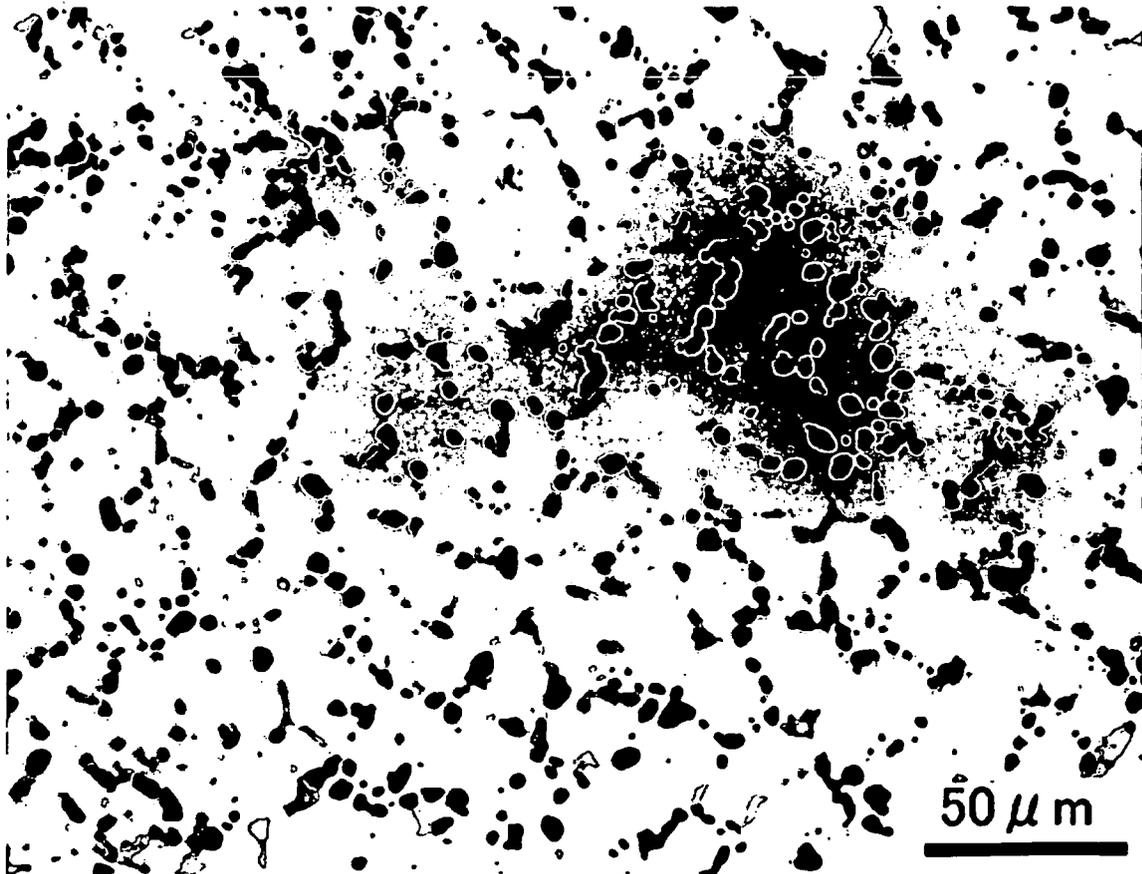


FIG. 3

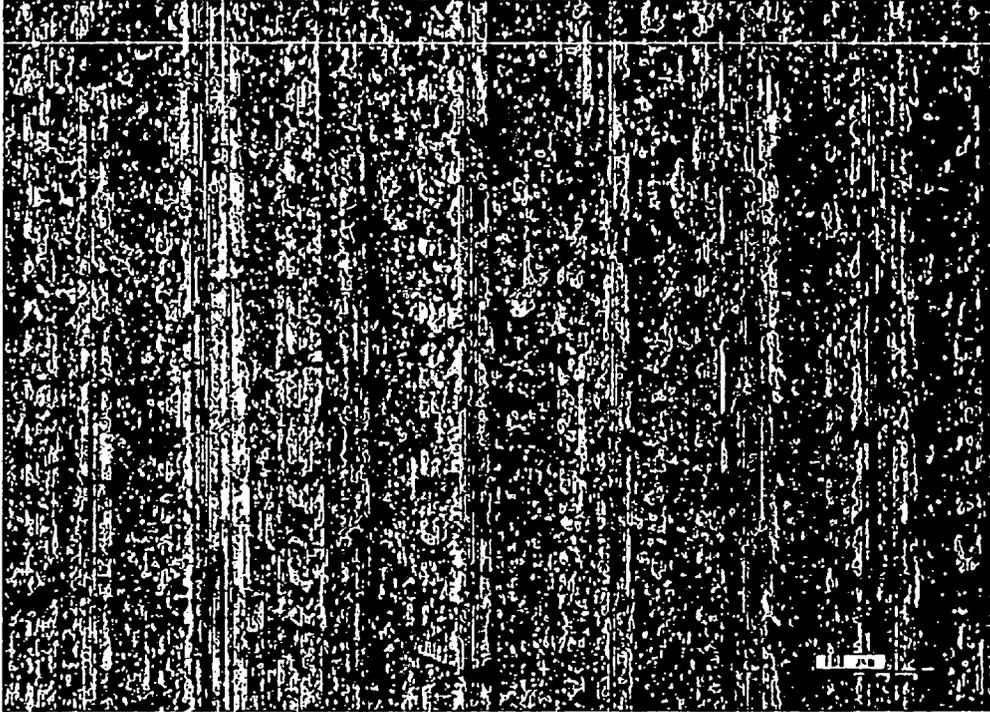


FIG. 4

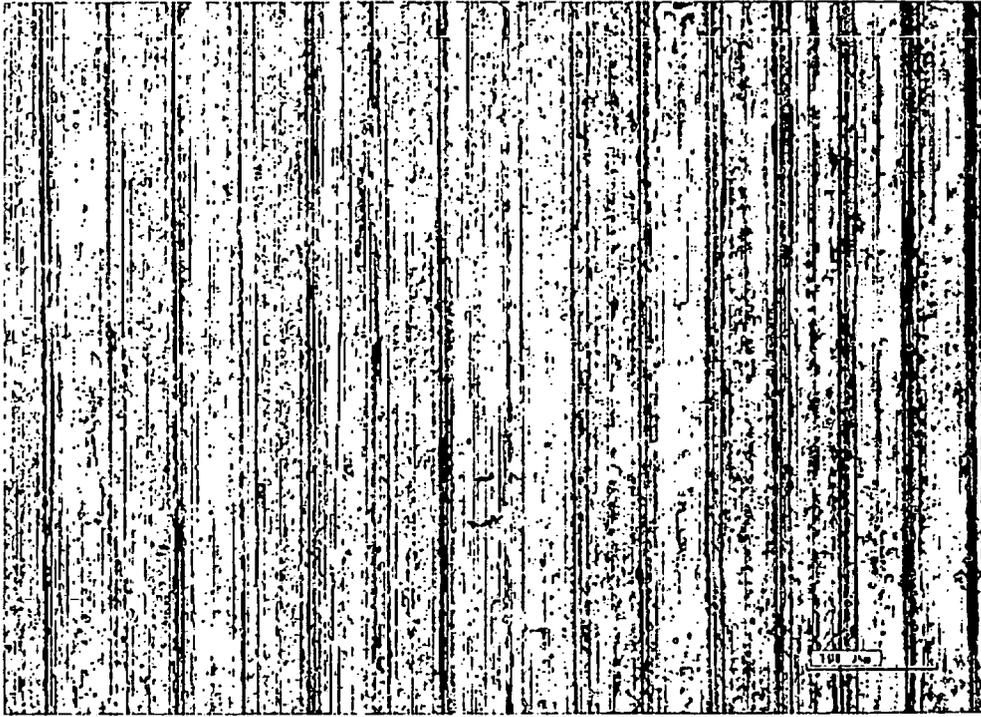


FIG. 5

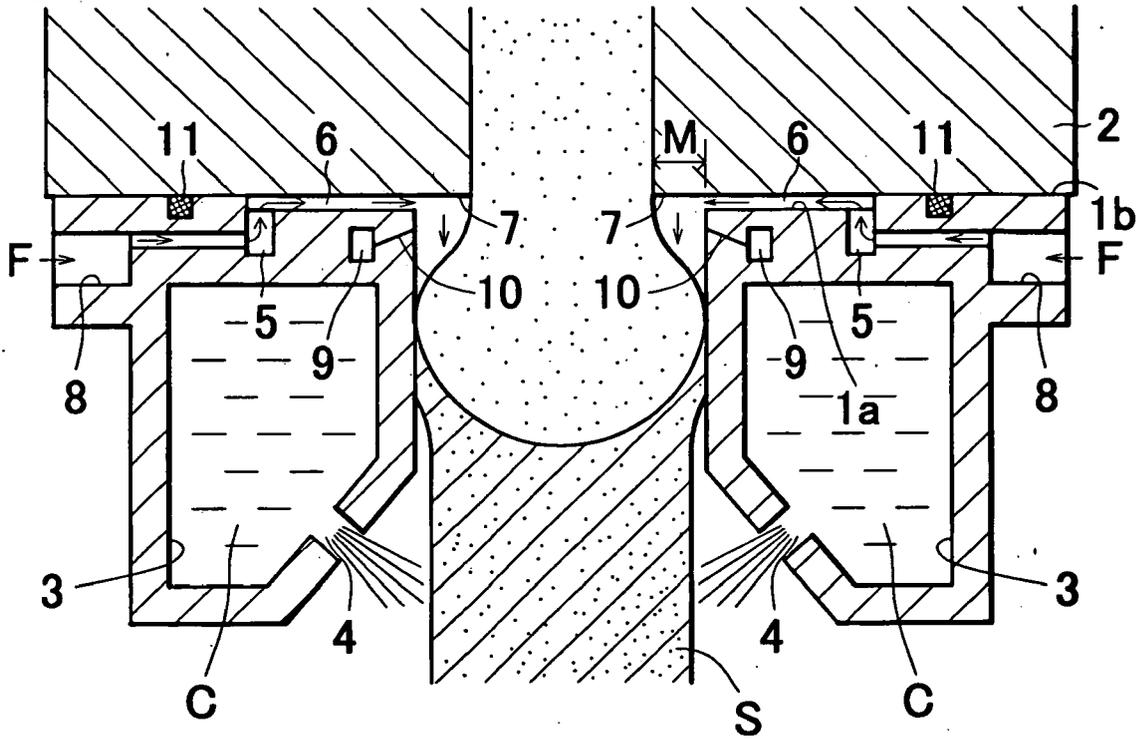


FIG. 6

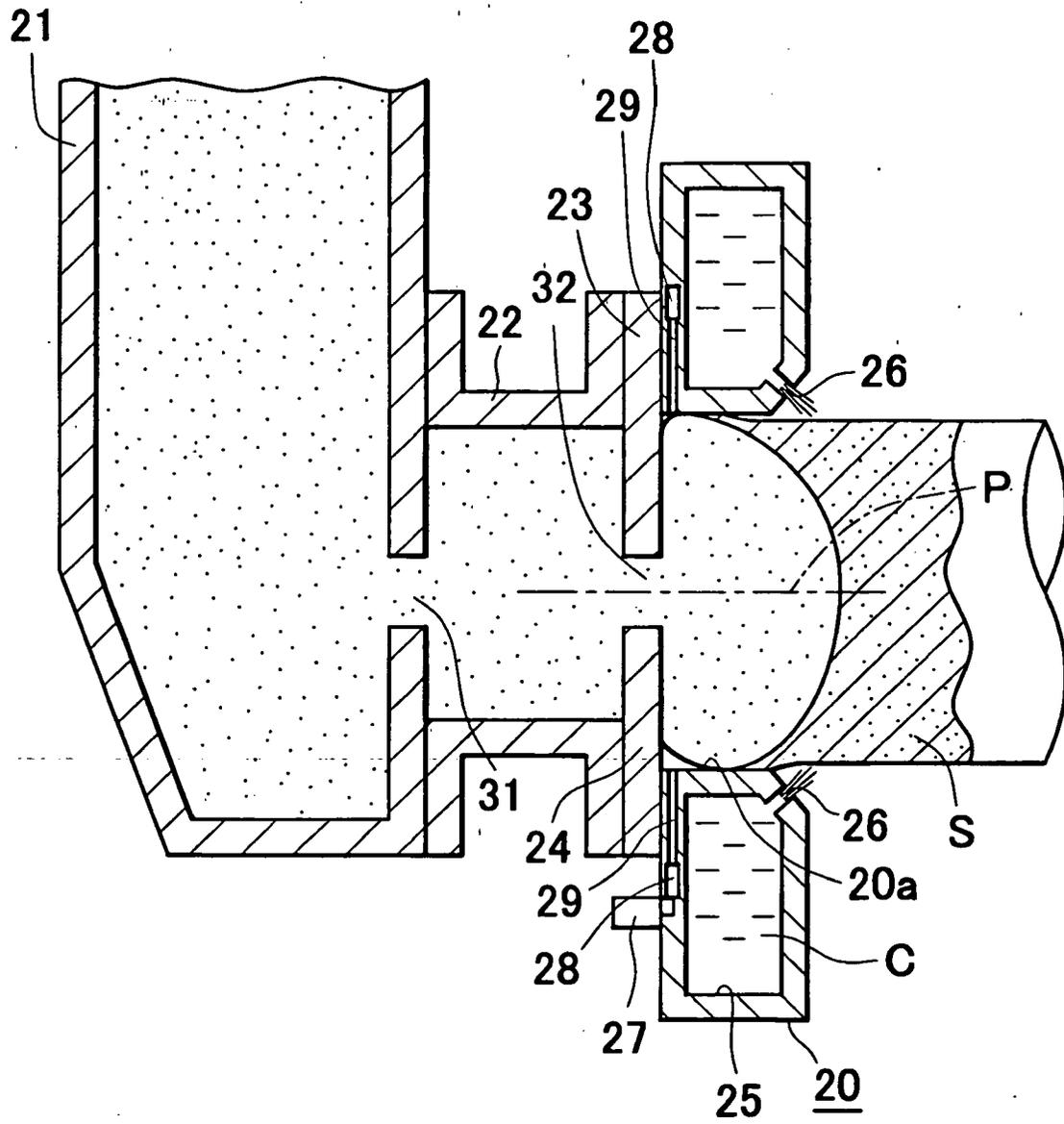


FIG.7

**REFERENCES CITED IN THE DESCRIPTION**

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