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(54) **ALUMINUM ALLOY, BAR-SHAPED MATERIAL, FORGED MOLDING AND MACHINED MOLDING, AND, PRODUCED THEREFROM, WEAR-RESISTANT ALUMINUM ALLOY AND SLIDING PART EXCELLING IN ANODIC OXIDE COATING HARDNESS, AND PROCESS FOR PRODUCING THEM**

(57) An aluminum alloy containing 5 to12% (mass%; similarly applicable hereinafter) of Si, 0.1 to 1% of Fe, less than 1% of Cu and 0.3 to 1.5% of Mg and having the valance formed of Al and impurities is cast by a continuous casting process. When the cast mass consequently obtained is homogenized, then extruded and/or forged and/or machined and subjected to an anodizing treatment, the resultant formed article is endowed with excellent wear resistance because the anodized coat formed thereon in a thickness of 30 μm or more with hardness Hv of 400 or more allows the presence therein of eutectic Si particles having particle diameters in the range of 0.4 to 5.5 μm.

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Description

Technical Field:

[0001] This invention relates to aluminum alloys, bar materials, forged parts and machined parts which are capable of providing sleeve parts for use in automobiles, require the hardness and thickness of an anodized coat, shun sustaining a crack and demand wear resistance; wear-resistant aluminum alloys using the aluminum alloys mentioned above and excelling in anodized coat hardness; sleeve parts; and methods for the production thereof.

Background Art:

[0002] Among other automobile parts, the casts of the ADC12, AC4C, A390 and Al-Si types and the alloys for the Al-Si type expanded materials of A4032 alloy have been hitherto formed by subjecting extruded materials and forged materials to the T6 treatment, the machining treatment and the anodizing treatment, and the parts consequently obtained have been put to use.

[0003] The casts of the Al-Si type and the alloys for the Al-Si type expanded materials have their Cu and Mg contents adjusted with the object of exalting the wear resistance and strength thereof

[0004] Though the alloy materials mentioned above contain Cu in large amounts with a view to exalting their wear resistance and strength, they are supposed to encounter difficulty in acquiring the thickness and the hardness of an anodized coat.

[0005] The concept of limiting the Ni content as an impurity to less than 0.05% has been proposed (Patent Document 1 (JP-A HEI 10-204566), for example).

[0006] The material of Patent Document 1 is characterized by containing 6 to 12% (weight %, that is applied hereinafter) of Si, 0.1 to 1.0% of Fe, 1.0 to 5.0% of Cu, 0.1 ro 1.0% of Mn, 0.4 to 2.0% of Mg, 0.01 to 0.3% of Ti and 0.005 to 0.2% of Sr, limiting the content of Ni as an impurity to less than 0.05% and having the balance formed of A1 and impurities, having dispersed in the matrix thereof eutectic Si particles of an average particle diameter of 1.5 to 5.0 μm and allowing the presence therein of 5000 or more and less than 10000 eutectic Si particles of this average particle diameter per mm^2.

[0007] However, the material disclosed in Patent Document 1, on being anodized, has formed a film having an unduly low hardness, specifically hardness Hv only in the approximate range of 310 to 370.

[0008] The conventional Al-Si type alloys, therefore, have been mostly such parts as are put to use without undergoing an anodizing treatment. The parts, that need an anodized coat and have an ability to form the coat, have been applied to products (portions) that have no need for the hardness of the coat. Thus, they have proved useful in markedly limited applications and have incurred difficulty in satisfying the demand of the market.

[0009] In the case of the 6000 type alloys and the 5000 type alloys that have a proper ability to succumb to an anodizing treatment, when the coat is applied in a thickness 30 μm or more, the coat sustains a crack and the coated alloy product becomes no longer suitable for the intended use.

[0010] This invention, therefore, aims to provide aluminum alloys, bar materials, forged parts and machined parts which are capable of providing sleeve parts for use in automobiles, require the hardness and thickness of an anodized coat, shun generation of a crack and demand wear resistance; wear-resistant aluminum alloys using the aluminum alloys mentioned above and excelling in anodized coat hardness; sleeve parts; and methods for the production thereof

[0011] With a view to accomplishing the object mentioned above, the present inventors have made a diligent study regarding the characteristic properties of the Al-Si type aluminum alloys and the anodized coats formed on the surfaces thereof. They have perfected this invention based on the knowledge acquired consequently.

Disclosure of the Invention:

[0012] The aluminum alloy according to this invention forms in consequence of an anodizing treatment an anodized coat having a thickness of 30 μm or more and hardness Hv of 400 or more and allows the presence, in the coat, of eutectic Si particles having particle diameters in the range of 0.4 to 5.5 μm.

[0013] Further, the aluminum alloy according to this invention forms in consequence of an anodizing treatment an anodized coat having a thickness of 40 μm or more and hardness Hv of 400 or more and allows the presence, in the coat, of eutectic Si particles having particle diameters in the range of 0.8 to 5.5 μm.

[0014] The aluminum alloy mentioned above contains 5 to 12% (mass %; similarly applicable hereinafter) of Si, 0.1 to 1% of Fe, less than 1% of Cu and 0.3 to 1.5% of Mg, and has the balance formed of Al and impurities, has dispersed in the matrix thereof eutectic Si particles having particle diameters in the range of 0.4 to 5.5 μm, inclusive of 60% or more of the eutectic Si particles having particle diameters of 0.8 to 2.4 μm, and allows the presence therein of 4000 or more and less than 40000 eutectic Si particles per mm^2.

[0015] The aluminum alloy mentioned above, when containing 9 to 12% of Si, has 80% or more of the eutectic Si particles with particle diameters of 0.8 to 2.4 μm.

[0016] The aluminum alloy mentioned above consists in substantially no Cu.

[0017] The aluminum alloy mentioned above consists in containing at least one component selected from among 0.1 to 1% of Mn, 0.04 to 0.3% of Cr, 0.04 to 0.3% ofZr, and 0.01 to 0.1% of V.

[0018] The aluminum alloy mentioned above consists in containing at least one component selected from among 0.01 to 0.3% of Ti, 0.0001 to 0.05% of B and 0.001 to 0.1% of Sr.

[0019] The aluminum alloy mentioned above consists in being a bar material cast by a continuous casting technique.

[0020] The aluminum alloy mentioned above in 9) the ninth aspect of the present invention consists in being a bar material obtained by subjecting a bar material cast by the continuous casting technique further to an extruding process or an extruding and drawing process.

[0021] The bar material according to this invention consists in being formed of an aluminum alloy.

[0022] The bar material of this invention consists in being used as a sleeve part.

[0023] The bar material of this invention consists in being a forged part formed by subjecting a bar material to a forging process.

[0024] The bar material of this invention consists in being a machined part formed by subjecting a bar material or a forced part to a machining process.

[0025] This invention further consists in being a wear-resistant aluminum alloy allowing the presence, in an anodized coat, of eutectic Si particles of particle diameters in the range of 0.4 to 5.5 μm, forming the coat in a thickness of 30 μm or more and with hardness Hv of 400 or more and consequently excelling in hardness of the anodized coat.

[0026] This invention also consists in being a wear-resistant aluminum alloy allowing the presence, in an anodized coat, of eutectic Si particles of particle diameters in the range of 0.8 to 5.5 μm, forming the coat in a thickness of 40 μm or more and with hardness Hv of 400 or more and consequently excelling in hardness of the anodized coat.

[0027] This invention consists in being a sleeve part resulting from subjecting a machined part to a treatment for forming an anodized coat and consequently excelling in hardness of the anodized coat.

[0028] Further, this invention consists in a method for the production of a wear-resistant aluminum alloy excellent in hardness of an anodized coat, comprising casting the aluminum alloy of the composition mentioned above to a continuous casting process, subjecting the resultant cast mass to a homogenizing treatment, extruding and/or forging and/or machining the homogenized cast mass and anodizing the resultant formed cast, thereby allowing the presence, in the anodized coat, of eutectic Si particles of particle diameters in the range of 0.4 to 5.5 μm and forming the coat in a thickness of 30 μm or more and with hardness Hv of 400 or more.

[0029] This invention also consists in a method for the production of a sleeve part excellent in hardness of an anodized coat and formed of an aluminum alloy, comprising casting an aluminum alloy of the composition mentioned above by a continuous casting process, subjecting the resultant cast mass to a homogenizing treatment, extruding and/or forging and/or machining the homogenized cast mass and anodizing the resultant formed cast, thereby allowing the presence, in the anodized coat, of eutectic Si particles of particle diameters in the range of 0.4 to 5.5 μm and forming the coat in a thickness of 30 μm or more and with hardness Hv of 400 or more.

[0030] The anodized coat produced as described above cannot form a crack. The thickness and hardness of the coat mentioned above do not represent mere target qualities, but indicate the qualities which can be attained by heeding and controlling the limits on the particle diameter distribution of eutectic Si particles in the anodized coat and the content of Cu therein.

[0031] This invention, as described above, concerns an aluminum alloy which allows the presence of eutectic Si particles having particle diameters in the range of 0.4 to 5.5 μm in an anodized coat formed by an anodizing treatment and permits manufacture of sleeve parts furnished with an anodized coat excelling in hardness and possessing resistance to wear and other wear-resistant aluminum alloy products which can be properly utilized for automobile parts and other parts requiring the hardness and thickness of an anodized coat, shunning generation of a crack and demanding wear resistance.

[0032] This aluminum alloy acquires sufficient hardness without requiring any special anodizing treatment and, therefore, can be applied to parts that are put to use without being anodized in advance.

[0033] This invention concerns an aluminum alloy which allows the presence of eutectic Si particles having particle diameters in the range of 0.8 to 5.5 μm in an anodized coat formed by an anodizing treatment and permits manufacture of sleeve parts furnished with an anodized coat excelling further in hardness and possessing wear resistance and other wear-resistant aluminum alloy products.

[0034] The aluminum alloy of this invention is characterized by containing 5 to 12% (mass %; similarly applicable hereinafter) of Si, 0.1 to 1% of Fe, less than 1% of Cu and 0.3 to 1.5% of Mg and having the balance formed of A1 and impurities, having dispersed in the matrix thereof eutectic Si particles of particle diameters in the range of 0.4 to 5.5 μm, inclusive of 60% or more of the eutectic Si particles existing with particle diameters of 0.8 to 2.4 μm, and allowing the presence therein of 4000 or more and less than 40000 eutectic Si particles per mm^2, thereby permitting manufacture of sleeve parts furnished with an anodized coat excelling further in hardness and possessing a wear resistance and other wear-resistant aluminum alloy products.

[0035] Further, the aluminum alloy of this invention, when containing 9 to 12% of Si, has 80% or more of the eutectic Si particles with particle diameters of 0.8 to 2.4 μm and therefore permits manufacture of sleeve parts furnished with an anodized coat excelling further in hardness and possessing wear resistance and other wear-resistant aluminum alloy products.

[0036] The aluminum alloy of this invention contains substantially no Cu and therefore acquires a further exalted ability to undergo an anodizing treatment and permits provision of sleeve parts furnished with an anodized coat excelling further in hardness and possessing wear resistance and other wear-resistant aluminum alloy products.

[0037] The aluminum alloy of this invention contains one or two or more components selected from among 0.1 to 1% of Mn, 0.04 to 0.3% of Cr, 0.04 to 0.3% ofZr and 0.01 to 0.1 % of V and, owing to the inclusion of Mn, Cr, Zr and V, induces precipitation of the Al-Mn type, Al-Mn-Fe-Si type, Al-Cr type, Al-Cr-Fe-Si type, Al-Zr type or Al-V type particles and thereby effects refinement of recrystallized particles, acquires exalted workability and permits formation of sleeve parts of complicated shapes and other wear-resistant aluminum alloy products. Further, the inclusion of Mn, Cr, Zr and V results in inducing precipitation of the particles of the Al-Mn type, Al-Mn-Fe-Si type, Al-Cr type, Al-Cr-Fe-Si type, Al-Zr type and Al-V type, suppressing recrystallization of the sleeve parts by a heat treatment given after the formation thereof and exalting the ductility and toughness of the sleeve parts.

[0038] The aluminum alloy of this invention contains at least one component selected from among 0.01 to 0.3% of Ti, 0.0001 to 0.05% of B and 0.001 to 0.1% of Sr and, when containing Ti and B, induces refinement of the texture of the cast mass, prevents the alloy mass from sustaining a crack during the course of forging, allows the aluminum alloy of this invention to be cast stably, further imparts exalted workability to the cast mass and permits manufacture of sleeve parts of complicated shapes. The inclusion of Sr results in allowing the eutectic Si particles to be refined and consequently enabling the aluminum alloy of this invention to acquire improvement in ductility and toughness.

[0039] The aluminum alloy of this invention is a bar material cast by a continuous casting process. This aluminum alloy, therefore, permits manufacture of sleeve parts excelling in hardness and possessing wear resistance and other wear-resistant aluminum alloy products.

[0040] The aluminum alloy of this invention is a bar material resulting from subjecting a bar material cast by a continuous casting process to an extruding process or an extruding and drawing process. Even when the subsequent process omits a forging step or comprises a forging step of a small processing ratio, it enjoys a sufficient processing ratio and acquires exalted ductility and toughness. It also permits easy manufacture of a bar material having a diameter of 20 mm or less which is not easily obtained by the continuous casting technique.

[0041] The formed article which uses the bar material of the aluminum alloy of this invention mentioned above constitutes a product excellent in hardness and possessing wear resistance.

[0042] The bar material of the aluminum alloy of this invention mentioned above permits manufacture of a sleeve part possessing an anodized coat of excellent hardness and excelling in wear resistance.

[0043] The bar material of the aluminum alloy of this invention mentioned above undergoes a forging treatment. The forged part consequently obtained permits manufacture of sleeve parts furnished with an anodized coat excelling in hardness and possessing wear resistance and other wear-resistant aluminum alloy products.

[0044] The bar material or forged part of the aluminum alloy of this invention mentioned above undergoes a machining treatment. The machined part consequently obtained permits manufacture of sleeve parts furnished with an anodized coat excelling in hardness and possessing wear resistance and other wear-resistant aluminum alloy products.

[0045] The aluminum alloy of this invention allows the presence, in an anodized coat, of eutectic Si particles of particle diameters in the range of 0.4 to 5.5 μm and forms the coat in a thickness of 30 μm or more and with hardness Hv of 400 or more. The aluminum alloy product consequently obtained, therefore, excels in hardness of the anodized coat and possesses wear resistance.

[0046] The aluminum alloy of this invention allows the presence, in an anodized coat, of eutectic Si particles of particle diameters in the range of 0.8 to 5.5 μm and forms the coat in a thickness of 40 μm or more and with hardness Hv of 400 or more. The aluminum alloy product consequently obtained, therefore, excels in hardness of the anodized coat and possesses wear resistance.

[0047] The machined part of the aluminum alloy of this invention has undergone a treatment for the formation of an anodized coat. It, therefore, constitutes a sleeve part that is furnished with an anodized coat excelling in hardness and possessing wear resistance.

[0048] Then, the method for the production of an aluminum alloy according to this invention comprises casting an aluminum alloy of the composition mentioned above in accordance with a continuous casting process, subjecting the resultant cast mass to a homogenizing treatment, extruding and/or forging and/or machining the homogenized cast mass and anodizing the resultant formed cast, thereby allowing the presence, in an anodized coat, of eutectic Si particles of particle diameters in the range of 0.4 to 5.5 μm and forming the coat in a thickness of 30 μm or more and with hardness Hv of 400 or more. The method, therefore, permits easy manufacture of wear-resistant aluminum alloy products excelling in hardness of an anodized coat.

[0049] Then, the method for the production of an aluminum alloy according to this invention comprises casting an aluminum alloy of the composition mentioned above in accordance with a continuous casting process, subjecting the resultant cast mass to a homogenizing treatment, extruding and/or forging and/or machining the homogenized cast mass and anodizing the resultant formed cast, thereby allowing the presence, in an anodized coat, of eutectic Si particles of particle diameters in the range of 0.4 to 5.5 μm and forming the coat in a thickness of 30 μm or more and with hardness Hv of 400 or more. The method, therefore, permits easy manufacture of sleeve parts excelling in hardness of an anodized coat.

Best Mode for carrying out the Invention:

[0050] The aluminum alloy according to this invention is characterized by inducing in consequence of an anodizing treatment the formation of an anodized coat having a thickness of 30 μm or more, preferably 40 μm or more, and hardness Hv of 400 or more and the presence of eutectic Si particles of particle diameters in the range of 0.4 to 5.5 μm, preferably 0.8 to 5.5 μm, in the coat.

[0051] The aluminum alloy mentioned above, in one preferred example of the composition thereof, contains 5 to 12% (mass %; similarly applicable hereinafter, preferably 5 to 11%) of Si, 0.1 to 1% of Fe, less than 1% (preferably less than 0.5% and more preferably substantially no content) of Cu and 0.3 to 1.5% (preferably 0.4 to 1%) of Mg, and has the balance formed of A1 and impurities.

[0052] The aluminum alloy mentioned above preferably contains at least one component selected from among 0.1 to 1% of Mn, 0.04 to 0.3% of Cr; 0.04 to 0.3% of Zr and 0.01 to 0.1% ofV.

[0053] Preferably it further contains one or two or more components selected from among 0.01 to 0.3% ofTi, 0.0001 to 0.05% ofB and 0.001 to 0.1% of Sr.

[0054] The aluminum alloy of this composition excels in workability and ability to yield to an anodizing treatment and acquires an ability to retain the hardness (Hv: 400 or more) of the anodized coat mentioned above.

[0055] It proves advantageous in respect that this aluminum alloy acquires sufficient hardness without undergoing any special anodizing treatment and therefore fits application to parts that are put to use without requiring an anodizing treatment.

[0056] Particularly, Si while coexisting with Mg induces precipitation of Mg_2Si particles and exalts the strength of the aluminum alloy and, owing to the distribution of eutectic Si, adds to strength and wear-resistance. The Si content is in the range of 5 to 12%, preferably 5 to 11%. If the Si content falls short of 5%, the shortage will prevent this effect of Si from being manifested fully satisfactorily. If it exceeds 12%, the excess will result in inducing precipitation of a primary crystal of Si and exerting an adverse effect to bear on the ability to undergo an anodizing treatment.

[0057] The Fe content is preferred to fall in the range of 0.1 to 1% (preferably 0.1 to 0.5% and more preferably 0.21 to 0.3%). The reason for this range is that the Fe content is capable of inducing precipitation of the particles of the Al-Fe type or Al-Fe-Si type and, during the heat treatment after the formation of a sleeve part, repressing recrystallization and exalting the ductility and the toughness of the sleeve part. Then, in the extruded material, the Fe content is capable of refining recrystallized particles during the course of extrusion, exalting the forgeability of the material in the subsequent step and consequently permitting manufacture of sleeve parts of complicated shapes. If the Fe content falls short of 0.1%, the shortage will prevent the effect of Fe from being manifested satisfactorily. If it exceeds 1%, the excess will result in increasing the precipitation of coarse crystals of the Al-Fe type or Al-Fe-Si type, exerting an adverse effect to bear on the ability of the aluminum ally to succumb to an anodizing treatment and impairing the ductility and the toughness of the aluminum alloy.

[0058] The Cu content is less than 1% (preferably 0.9% or less and more preferably less than 0.5%) or substantially absent.

[0059] The inclusion of Cu results in inducing precipitation of $CuAl_2$ particles and consequently contributing to the strength and hardness of the aluminum alloy. If the Cu content is 1% or more, the excess will result in decreasing the hardness of the anodized coat. For the purpose of further increasing the hardness of the coat, the Cu content is preferred to be less than 0.5% and more preferably to be substantially nil.

[0060] Cu is dissolved during the course of an anodizing treatment. Since the Cu ions formed by this dissolution are precious metal ions, Cu is precipitated again on the surface of the aluminum alloy matrix and is suffered to render the formation of an anodized coat difficult and degrade the denseness of the coat. By controlling the Cu content, it is made possible to exalt the formability and the denseness of the anodized coat and increase the hardness of the coat.

[0061] The coexistence of Mg and Si is effective in inducing precipitation of Mg_2Si particles and contributing to the strength of the aluminum alloy. The Mg content falls preferably in the range of 0.3 to 1.5% and more preferably in the range of 0.4 to 1%. If the Mg content falls short of 0.3%, the shortage will result in decreasing the effect. If it exceeds 1.5%, the excess will results in lowering the workability of the aluminum alloy.

[0062] The inclusion of at least one component selected from among 0.1 to 1% (preferably 0.2 to 0.4%) of Mn, 0.04 to 0.3% (preferably 0.15 to 0.25%) of Cr, 0.04 to 0.3% (preferably 0.1 to 0.2%) of Zr and 0.01 to 0.1% (preferably 0.05

to 0.1%) of V in the composition of the aluminum alloy mentioned above is effective in inducing precipitation of the particles of the Al-Mn type, Al-Mn-Fe-Si type, Al-Cr type, Al-Cr-Fe-Si type, Al-Zr type or Al-V type, suppressing recrystallization during the heat treatment after the formation of a sleeve part and exalting the ductility and toughness of the sleeve part. Then, in the case of the extruded material, the inclusion is effective in refining the recrystallized particles during the course of the extrusion, exalting the forgeability of the extruded material in the subsequent step and consequently enabling the sleeve part to be formed in a complicated shape. If the Mn content falls short of 0.1 %, the Cr content falls short of 0.04%, the Zr content falls short of 0.04% and the V content falls short of 0.01%, these shortages will result in preventing the effects of these elements from being manifested satisfactorily. If the Mn content exceeds 1%, the Cr content exceeds 0.3%, the Zr content exceeds 0.3% and the V content exceeds 0.1%, their excesses will result in adding to the precipitation of coarse crystals, exerting an adverse effect to bear on the ability of the aluminum alloy to succumb to an anodizing treatment and impairing the ductility and toughness of the aluminum alloy.

[0063] The inclusion of at least one component selected from among 0.01 to 0.3% (preferably 0.01 to 0.2% and more preferably 0.002 to 0.1%) of Ti, 0.0001 to 0.05% (preferably 0.005 to 0.1%) of B and 0.001 to 0.2% (preferably 0.005 to 0.1% and more preferably 0.005 to 0.05%) of Sr is favorable for the following reason. To be specific, the inclusion of Ti and B is effective in refining the texture of a cast mass, preventing the cast mass from being fractured during the course of casting and exalting the workability of the cast mass and consequently permitting sleeve parts to be formed in complicated shapes. If the Ti content falls short of 0.01%, the shortage will result in preventing the effects of its inclusion from being manifested sufficiently. If its content exceeds 0.3%, the excess will result in inducing crystallization of giant intermetallic compound particles and exerting an adverse effect to bear on the aluminum alloy's workability and ability to succumb to an anodizing treatment. Then, the inclusion of Sr is effective in refining the eutectic Si and exalting the aluminum alloy's workability and ability to succumb to an anodizing treatment. If the Sr content falls short of 0.001%, the shortage will prevent the effect of the inclusion from being manifested satisfactorily. If it exceeds 0.2%, the excess will result in degrading the effect.

[0064] The Ni content is preferred to be 0.1% or less.

[0065] In this invention, it has been found that the state of distribution of eutectic Si particles in an anodized coat is extremely important and further that the control thereof enables the coat to acquire a thickness of 30 μm or more and hardness Hv of 400 or more and prevents the coat from generating a crack.

[0066] For this purpose, it is important to uniformly specify the state of dispersion of eutectic Si in an alloy matrix. The aluminum alloy can be precluded from sustaining a crack by allowing the presence of eutectic Si particles in the anodized coat and enabling the aluminum alloy to excel in hardness of the coat and acquire an increased thickness.

[0067] To be specific, the eutectic Si particles dispersed in the alloy matrix have particle diameters of 0.4 to 5.5 μm (preferably 0.8 to 5.5 μm). It is proper and necessary that 60% or more (preferably 80% or more) of the eutectic Si particles have particle diameters of 0.8 to 2.4 μm and that the matrix allow the presence therein of 4000 or more and less than 40000 (preferably 10000 or more and less than 38000) eutectic Si particles per mm^2.

[0068] Incidentally, the expression "the eutectic Si particles have particle diameters of 0.4 to 5.5 μm" means that the substantial particle diameter distribution is in the range of 0.4 to 5.5 μm. For example, it means that 95% or more, preferably 98% or more, of the eutectic Si particles have particle diameters falling in the range of 0.4 to 5.5 μm.

[0069] The eutectic Si particles in the anodized coat have particle diameters of 0.4 to 5.5 μm as described above. If the particle diameters fall short of 0.4 μm, particularly 0.3 μm, the shortage will result in heightening the voltage of the bath used for the anodizing treatment, increasing the resistance to the anodization, rendering the flow of electric current difficult and permitting no easy formation of the coat. If the particle diameters exceed 5.6 μm, particularly 6.0 μm, the excess will result in forming a cause for degrading the ability of the aluminum alloy to succumb to an anodizing treatment and aggravating the surface coarseness of the formed coat.

[0070] Of the eutectic Si particles, those that have particle diameters of 0.8 to 2.4 μm account for a proportion of 60% or more as described above. If this proportion falls short of 60%, particularly within 50% inclusive, the shortage will result in increasing the difference between the portion allowing easy flow of electric current and the portion not allowing easy flow of electric current during the course of the anodizing treatment, disrupting the uniformity of flow of the electric current and consequently preventing the formed coat from acquiring a uniform thickness.

[0071] Particularly in the case of the Si content of 9 to 12% (especially 10.5 ± 0.5%) that finds a wide application for uses on the commercial scale, the proportion mentioned above is preferred to be 80% or more.

[0072] When the alloy matrix contains 4000 or more and less than 40000 eutectic Si particles of particle diameters of 0.8 to 2.4 μm per mm^2, the flow of the electric current during the course of the anodizing treatment is fixed and the produced coat is allowed to have a uniform thickness. Though the eutectic Si particles dispersed in the aluminum alloy matrix allow more difficult flow of electric current than the matrix, since the difficulty can be suppressed, the anodized coat can be formed in a uniform thickness. The degradation of the hardness of the coat can be suppressed further because the possibility of the eutectic Si surviving dissolution during the course of the anodizing treatment and persisting in the coat can be diminished and the possibility of the residual eutectic Si particles in the coat degrading the denseness of the coat surrounding the eutectic Si particles can be suppressed.

[0073] To be more specific, the aluminum alloy of the composition mentioned above is cast by the continuous casting process, such as the gas pressure hot top continuous casting process, the resultant cast mass is subjected to the homogenizing treatment, and the homogenized alloy mass is either directly machined or subjected to a proper processing selected from among extruding, forging and machining operations. By further subjecting the resultant formed aluminum alloy to the anodizing treatment, it is made possible to obtain an aluminum alloy product which excels in hardness of the anodized coat and allows the coat to acquire an increased thickness without sustaining a crack.

[0074] The state of the generation of the eutectic Si in the alloy is affected by the temperature of the melt of the alloy and the speed of casting while the melt of the alloy of the given composition is solidified by the continuous casting process.

[0075] The aluminum alloy contemplated by this invention, therefore, can be obtained by controlling the temperature of the melt and the speed of casting, thereby enabling the eutectic Si particles to acquire particle diameters in the range of 0.4 to 5.5 μm. Further, by controlling the temperature of the melt and the speed of casting, thereby enabling 60% or more of the eutectic Si particles to possess particle diameters of 0.8 to 2.4 μm, it is made possible to obtain the aluminum alloy aimed at by this invention.

[0076] It is provided, however, that the speed of solidification must be controlled to a rather higher level than ever because the aluminum alloy of this invention has a small Cu content, forms a small region of solid-liquid coexistence during solidification, and becomes liable to solidify. In the case of a forging diameter of 72 mm, for example, the speed of solidification is preferred to be in the range of 200 to 350 mm/min.

[0077] The gas pressure hot top continuous casting process presses the gap between the melt and the mold with a gas and therefore permits the speed of casting to be increased. It is, therefore, at an advantage in permitting easy production of the aluminum alloy of this invention having the particle diameters of the eutectic Si controlled in a given state.

[0078] The state of generation of the eutectic Si in the alloy succumbs to the influences of the temperature of homogenization and the time of homogenization during the course of the homogenizing treatment and controls the particle diameter of the eutectic Si and controls the shape of the eutectic Si particles as well.

[0079] By controlling the temperature of homogenization and the time of homogenization, thereby enabling the eutectic Si particles to assume particle diameters in the range of 0.4 to 5.5 μm, therefore, it is made possible to obtain the aluminum alloy of this invention. Further, by controlling the temperature of homogenization and the time of homogenization, thereby enabling 60% or more of the eutectic Si particles to assume particle diameters of 0.8 to 2.4 μm, it is made possible to obtain the aluminum alloy of this invention.

[0080] Owing to the assumption of a granular form by the eutectic Si particles, the cast mass is enabled to have the workability thereof exalted as compared with the acerate form prior to the anodizing treatment. Further, the ability of the aluminum alloy to succumb to an anodizing treatment is exalted.

[0081] The homogenizing treatment does not need to be particularly restricted but is only required to satisfy the conditions mentioned above. It may be properly carried out at a temperature of 450°C or more and lower than 500°C (preferably 480°C or more) for a period of four hours or more.

[0082] The primary crystal Si is preferred to be in the following state (position of distribution of particles, average particle diameter, and ratio of occupation of area) or to be substantially absent from the outer peripheral part of the cast mass which is destined to form a sleeve part in consequence of an anodizing treatment. If the primary crystal Si is present in the part subjected to the anodizing treatment, it will prevent the flow of electric current from being fixed during the course of the anodizing treatment, render the thickness of the coat uneven, decrease the denseness of the coat and lower the hardness of the coat.

[0083] Position of distribution of particles of primary crystal Si: Absent of the primary crystal Si from the outer periphery of the cast mass through the position of 20% or less of the radius of the cast mass (0.2% or less of the ratio of occupation of area).

[0084] Average particle diameter of primary crystal Si: 30 μm or less.

[0085] Ratio of occupation of area by primary crystal Si: 0.8% or less.

[0086] For example, the procedure of setting the Si content at 12% or less and controlling the conditions of the amount of gas pressure, the speed of casting and the temperature of the melt during the course of a gas pressure hot top continuous casting operation is at an advantage in enabling the primary crystal Si to assume the state mentioned above.

[0087] The aluminum alloy mentioned above may be cast through the continuous casting process to form cast billets and the cast billets may be subjected to a homogenizing treatment and then machined directly without being modified. Otherwise, the cast billets may be subjected to properly selected processes, such as extruding, forging and machining operations. Alternatively, the aluminum alloy may be cast to manufacture bar materials and the bar materials may be manufactured into formed articles having given shapes.

[0088] The manufacture of bar materials into formed articles may be accomplished by properly combining various processes, such as machining and forging operations. The bar materials are preferred to undergo an extruding or drawing process prior to the forging or machining process. The bar materials which have undergone the extruding or drawing process are at an advantage in enjoying exalted ductility and excelling in workability and imparting ductility to end products. While round bars measuring 20 mm or less in diameter are not easily obtained by the continuous casting method, they can be easily obtained through the extruding or drawing process.

[0089] The extruding process does not need to be particularly restricted but may be properly attained by using an extruding device of 2500 tons, for example, and extruding a given bar material at the highest extruding rate of 8 m/min.

[0090] The anodizing treatment that is performed on a formed article does not need to be particularly restricted but may be properly accomplished by using an aqueous 15-wt% sulfuric acid solution as the electrolytic bath.

[0091] The coat may be obtained in a given thickness by adjusting the temperature of the bath, the electric voltage and the time of the treatment.

[0092] The aluminum alloy of this invention and the sleeve parts manufactured therefrom can be effectively used in sleeve portions of more exacting requirements because their matrix parts excel in hardness and their coats enjoy an exalted ability to resist wear. They are suitable for the following uses, for example.

(a) Compressor parts, such as scrolls and pistons, for use in air conditioning devices.
(b) Compressor pistons for use in automobile air suspensions.
(c) Automobile engines, transmissions and ABS grade hydraulic parts, such as spools and sleeves.
(d) Brake master cylinder pistons/caliper pistons for automobiles
(e) Clutch cylinder pistons for automobiles
(f) Brake caliper bodies for automobiles

[0093] The wear-resistant aluminum alloy that is consequently obtained does not restrict the uses to be found therefor. Among other automobile parts, it is particularly suitable for brake caliper pistons, air suspension quality compressor pistons and other parts that require a coat excelling in hardness and defying infliction of a crack.

[0094] Examples of this invention will be explained below in contrast with Comparative Examples.

<Test 1>

[Example 1]

[0095] The aluminum alloys having the compositions shown in Table1 were manufactured by the gas pressure hot top continuous casting method into cast billets (8 inches in diameter). These cast billets were subjected to a homogenizing treatment at 490°C for 12 hours and extruded by an indirect extruding device to form extruded bars 44 mm in diameter. The extruded bars were subjected to a T6 treatment performed by an ordinary method. The extruded bars resulting from this treatment were used as test materials and were tested for ability to succumb an anodizing treatment, hardness of coat, presence or absence of the occurrence of a crack in the coat, wear resistance and mechanical properties based on the standards shown below. The results of the test were rated. The test materials were further tested for determining the cross section, eutectic Si particles in an anodized coat and state of distribution of particle diameters by the use of an image analysis system under the following conditions.

[0096] The determination was performed by cutting a given sample in an arbitrary size, embedding the cut sample in an abrading resin, micro-abrading the resin till eutectic Si particles became detectable and visually examining the abraded surface.

[0097] Conditions of determination: LUZEX joined to an optical microscope, magnifications on a picture plane: 1240, and calculated from the results of a continuous determination of 20 fields of view.

[0098] Thickness of coat: 44 to 47 μm

[0099] In the data shown in Table 1, those that deviated from the conditions conforming to this invention are indicated with an underline.

<Rating of Test 1>

"Ability to succumb to an anodizing treatment"

[0100] A cross section of a given extruded bar perpendicular to the direction of extrusion was cut till it formed a smooth surface having a fixed surface roughness. The cross section was used as a sample for rating the ability.

[0101] For the anodizing treatment, an aqueous 15-wt% sulfuric acid solution was used as the electrolytic bath and the anodizing treatment was performed, with the bath temperature, voltage and time so set as to form an anodized coat of a target thickness of 40 μm on the sample surface.

[0102] The cross section of the sample consequently obtained was visually observed and measured for coat thickness with arbitrary 10 mm lengths. The ability of the sample to succumb to the anodizing treatment was rated by the average thickness of the actually formed coat. The thickness of the coat formed under the same conditions served as the index for the ability to succumb to the anodizing treatment. The results are shown in Table 3.

○: Average coat thickness of 40 μm or more
x: Average coat thickness of 33 μm or less
Δ: Intermediate between o and x.

"Coat hardness"

[0103] The determination was performed by cutting a given sample which had undergone an anodizing treatment in an arbitrary size, embedding the cut sample in a resin, micro-abrading the resin till the coat thickness became detectable, and determining and rating the hardness of the coat. The results are shown in Table 3.

○: Average coat hardness Hv of 400 or more
x: Average coat hardness Hv of 330 or less
Δ: Intermediate between o and x.

"Wear resistance"

[0104] A given sample was tested for wear resistance by the use of an Ogoshi abrasion tester under the conditions of 1 m/s in speed of abrasion, 200 m in distance of abrasion, 3.2 kg in load and S50C (Hv 750) in opposite material. The results were compared in terms of the relative amount of wear. The results are shown in Table 2.

○: Less than 6.0×10^{-7} mm^2/kg
x: More than 9.0×10^{-7} mm^2/kg
△: 6.0 to $9.0 \times 10^{-7} mm^2/kg$

"Crack in coat"

[0105] A given sample that had undergone an anodizing treatment had the surface condition thereof observed under an optical microscope to determine and rate the presence or absence of a crack in the coat. The results are shown in Table 3.

o: Absence of a crack in the coat.
x: Presence of a crack in the coat.

"Mechanical properties"

[0106] A JIS No. 4 test piece was taken from the central part of an extruded material in parallel to the direction of extrusion and tested for tensile strength. The passage of the commendable tensile strength: 310 (N/mm^2) and proof strength: 230 (N/mm^2) was taken as the standard. The results are shown in Table 2.

[Examples 2 to 13 and Comparative Examples 1 to 10]

[0107] The same procedure as in Example 1 was repeated, with the compositions changed as shown in Table 1. The conditions of forming an anodized coat were the same as in

Example 1.

[0108] It is clear from Table 2 and Table 3 that Examples 1 to 13 of this invention invariably excelled in ability to succumb to an anodizing treatment, hardness of coat, freedom from infliction of a crack in the coat and wear resistance, and were possessed of tensile strengths exceeding 310 N/mm^2 and proof strengths exceeding 230 N/mm^2 as respect mechanical properties.

[0109] Comparative Example 1 was deficient in the ability to succumb to an anodizing treatment because it had a small Si content. Further, Comparative Examples 1, 2, 4, 5 and 8 were deficient in the ability to succumb to an anodizing treatment and in hardness of the coat because they had large Cu contents.

[Table 1]

Test material	Composition (mass %)								
	Si	Fe	Cu	Mn	Mg	Cr	Ti	Sr	Al
Ex. 1	5.0	0.2	0.3	0.2	0.4	0.1	0.01	0.01	Balance
Ex.2	5.0	0.2	0.4	0.2	0.4	0.1	0.01	0.01	Balance
Ex.3	5.0	0.2	0.9	0.2	0.4	0.1	0.01	0.01	Balance
Ex.4	5.0	0.2	0.9	0.2	0.8	0.1	0.01	0.01	Balance
Ex.5	7.5	0.2	0.4	0.2	0.4	0.1	0.01	0.01	Balance
Ex.6	7.5	0.2	0.9	0.2	0.4	0.1	0.01	0.01	Balance
Ex.7	7.5	0.2	0.95	0.2	0.8	0.1	0.01	0.01	Balance
Ex. 8	8.1	0.2	0.6	0.2	0.4	0.1	0.01	0.01	Balance
Ex. 9	10.1	0.2	0.3	0.2	0.4	0.1	0.01	0.01	Balance
Ex.10	10.1	0.2	0.4	0.2	0.4	0.1	0.01	0.01	Balance
Ex. 11	10.1	0.2	0.4	0.2	0.8	0.1	0.01	0.01	Balance
Ex. 12	10.5	0.2	0.9	0.2	0.4	0.1	0.01	0.01	Balance
Ex. 13	10.5	0.2	0.9	0.2	0.8	0.1	0.01	0.01	Balance
Comp. Ex. 1	4.5	0.2	2.5	0.2	1.1	0.1	-	-	Balance
Comp. Ex. 2	7.0	0.2	3.0	0.2	1.1	0.1	-	-	Balance
Comp. Ex. 3	7.5	0.2	1.4	0.2	0.3	0.1	-	-	Balance
Comp. Ex. 4	7.5	0.2	2.5	0.2	0.4	0.1	-	-	Balance
Comp. Ex. 5	8.2	0.2	2.5	0.2	0.6	0.1	-	-	Balance
Comp. Ex 6	10.2	0.2	1.6	0.2	0.1	0.1	-	0.01	Balance
Comp. Ex. 7	10.7	0.2	1.5	0.2	0.4	0.1	-	0.01	Balance
Comp. Ex. 8	10.5	0.2	2.7	0.2	0.4	0.1	-	0.01	Balance
Comp. Ex. 9*	0.7	0.2	0.3	-	1.0	0.1	-	-	Balance
Comp. Ex. 10*	0.8	0.2	0.4	0.2	1.0	0.2	-	-	Balance

[Table 2]

Test material	Wear resistance	Tensile strength σ'B (N/mm^2)	Proof strength σ0.2 (N/mm^2)
Ex.1	○	312.0	234.0
Ex. 2	○	337.3	252.3
Ex. 3	○	343.3	240.6
Ex. 4	○	389.4	272.1
Ex. 5	○	343.5	241.5
Ex. 6	○	350.0	258.7
Ex. 7	○	359.3	271.3
Ex. 8	○	357.1	272.7
Ex. 9	○	342.6	249.2
Ex. 10	○	345.2	251.1
Ex. 11	○	346.2	255.3

(continued)

Test material	Wear resistance	Tensile strength σ'B (N/mm^2)	Proof strength σ0.2 (N/mm^2)
Ex. 12	○	368.2	263.3
Ex. 13	○	369.2	273.4
Comp. Ex. 1	x	410.0	340.0
Comp. Ex. 2	○	435.0	330.0
Comp. Ex. 3	○	389.3	271.3
Comp. Ex. 4	○	387.1	272.7
Comp. Ex. 5	○	415.0	307.0
Comp. Ex. 6	○	398.3	302.8
Comp. Ex. 7	○	406.8	304.0
Comp. Ex. 8	○	405.0	307.0
Comp. Ex. 9	x	312.0	284.0
Comp. Ex. 10	x	289.9	252.3

[Table 3]

Test material	Diameter of eutectic Si particles (μm)			Number (pieces/mm^2)	Distribution of diameters of eutectic Si particles (%)								Proportion of 0.8 to 2.4 μm (%)	Hardness of coat		Ability to yield anodization treatment	Thickness of coat (μm)	Crack
	Max.	Min.	Ave.		≥0.8 (μm)	≥1.6 (μm)	≥2.4 (μm)	≥3.2 (μm)	≥4.0 (μm)	≥4.8 (μm)	≥5.5 (μm)	5.6≤ (μm)			(Hv)			
Ex. 1	4.32	0.80	2.20	9643	-	16.7	46.6	28.2	7.5	1.0	-	-	63.3	○	422	○	47.1	○
Ex. 2	3.52	0.96	2.17	9740	-	14.9	46.6	31.6	6.9	-	-	-	61.5	○	412	○	46.5	○
Ex. 3	4.96	0.80	2.18	9690	-	16.3	44.2	27.9	7.0	2.3	2.3	-	60.5	○	405	○	46.2	○
Ex. 4	4.32	0.96	2.05	9830	-	16.3	44.9	27.9	8.6	2.3	-	-	612	○	403	○	41.3	○
Ex.5	4.80	0.96	2.12	18737	-	21.4	45.8	24.2	6.7	1.6	0.3	-	672	○	415	○	47.3	○
Ex.6	4.16	0.80	2.08	19245	-	22.0	44.0	27.1	6.6	0.3	-	-	66.0	○	403	○	46.7	○
Ex.7	4.16	0.80	2.06	22312	-	19.6	46.1	23.5	9.8	1.0	-	-	65.7	○	409	○	43.3	○
Ex.8	3.84	0.80	1.98	24415	-	21.6	46.8	22.7	8.9	-	-	-	68.4	○	401	○	41.1	○
Ex.9	4.16	0.80	1.93	31450	-	31.7	46.8	18.9	2.5	0.1	-	-	78.5	○	410	○	45.1	○
Ex. 10	3.52	0.80	1.81	35543	-	33.1	46.2	18.8	1.9	-	-	-	79.3	○	413	○	44.9	○
Ex. 11	3.36	0.80	1.85	33471	-	34.7	46.4	17.7	1.2	-	-	-	81.1	○	409	○	44.1	○
Ex. 12	3.52	0.80	1.83	34768	-	34.5	47.6	16.1	1.8	-	-	-	82.1	○	402	○	44.4	○
Ex. 13	3.35	0.80	1.87	32275	-	34.7	47.7	15.7	1.9	-	-	-	82.4	○	402	○	44.2	○
Comp. Ex. 1	4.78	0.96	2.30	8698	-	16.7	45.3	27.3	6.5	2.6	1.6	-	62.0	x	325	Δ	38.5	○
Comp. Ex. 2	4.75	0.92	2.17	18698	-	19.4	44.6	25.6	7.5	2.9	-	-	64.0	x	298	x	32.2	○
Comp. Ex. 3	4.58	0.90	2.18	21987	-	21.4	44.2	25.3	8.3	0.8	-	-	65.6	△	381	△	39.5	○

(continued)

Test material	Diameter of eutectic Si particles (μm)			Number (pieces/ mm^2)	Distribution of diameters of eutectic Si particles (%)								Proportion of 0.8 to 2.4 μm (%)	Hardness of coat		Ability to yield anodization treatment	Thickness of coat (μm)	Crack
	Max.	Min.	Ave.		≥0.8 (μm)	≥1.6 (μm)	≥2.4 (μm)	≥3.2 (μm)	≥4.0 (μm)	≥4.8 (μm)	≥5.5 (μm)	5.6≤ (μm)			(Hv)			
Comp. Ex. 4	4.51	0.96	2.05	22098	-	21.6	45.6	24.5	7.6	0.7	-	-	672	x	324	△	39.1	○
Comp. Ex. 5	4.33	0.80	2.08	25349	-	21.8	46.4	23.6	7.4	0.8	-	-	682	x	322	△	37.8	○
Comp. Ex. 6	3.63	0.80	1.93	32115	-	33.2	46.6	18.7	1.5	-	-	-	79.8	△	365	△	38.3	○
Comp. Ex. 7	3.56	0.80	1.81	35543	-	32.8	46.8	18.8	1.6	-	-	-	79.6	△	374	△	38.6	○
Comp. Ex. 8	3.45	0.80	1.85	33471		32.6	46.4	18.6	2.0	0.4	-	-	79.0	x	313	△	37.8	○
Comp. Ex. 9	-	-	-	-	-	-	-	-	-	-	-	-	-	○	475	○	44.1	x
Comp. Ex. 10	-	-	-	-	-	-	-	-	-	-	-	-	-	○	477	○	44.3	x

Comparative Examples 9 and 10 showed no discernible sign of eutectic Si particle.
The diameter and the distribution of eutectic Si particles are the results of measuring in a cross section.

[Table 4]

Distribution of diameters of eutectic Si particles in anodized coat													
Test material	Diameter of eutectic Si particles (μm)			Number (pieces/ mm^2)	Distribution of diameters of eutectic Si particles (%)								Proportion of 0.8 to 2.4 μm (%)
	Max.	Min.	Ave.		≥0.8 (μm)	≥1.6 (μm)	≥2.4 (μm)	≥3.2 (μm)	≥4.0 (μm)	≥4.8 (μm)	≥5.5 (μm)	5.6≤ (μm)	
Ex.3	4.86	0.80	2.11	9530	-	16.7	44.4	27.9	6.9	2.0	2.1	-	61.1
Ex.6	4.06	0.80	2.02	19143	-	22.4	43.6	28.1	5.8	0.1	-	-	66.0
Ex. 12	3.32	0.80	1.80	34595	-	35.2	48.1	15.7	1.0	-	-	-	83.3

<Test 2> (Bar material formed by hot top continuous casting, bar material formed by hot top continuous casting + forging)

[0110] An aluminum alloy having the composition shown in Table 5 was manufactured by the gas pressure hot top continuous casting method disclosed in JP-B SHO 54-42827 into bar materials of a diameter of 72 mm. The bar materials were then subjected to a homogenizing treatment at 490˚C for four hours and subjected to a T6 treatment according to an ordinary method under the conditions shown in Table 6 (a solution treatment at 500 to 510˚C for two to three hours, followed by water cooling and further by an aging treatment at 180 to 190˚C for five to six hours) to obtain test materials. Otherwise, the continuous casting (continuously cast) bar materials were similarly subjected to a homogenizing treatment, then to a shaving treatment to remove the cast skin, cut to given lengths, and the cut lengths were subjected to an annealing treatment and a bonde treatment, and forged into double wall cups measuring 68 mm in outside diameter of the outer cup, 52 mm in inside diameter of the outer cup, 32 mm in outside diameter of the inner cup, 15 mm in inside diameter of the inner cup, 40 mm in height and 10 mm in bottom thickness. These double wall cups were subjected to a T6 treatment according to the ordinary method under the conditions shown in Table 8 (a solution treatment at 500 to 510˚C for two to three hours, following by water cooling and further by an aging treatment at 180 to 190˚C for five to six hours) to obtain forged parts as test materials. The test materials were further machined and thereafter tested for ability to succumb to an anodizing treatment, hardness of coat, the presence or absence of a crack in the coat, wear resistance and mechanical properties under the following standards. They were also tested for the cross section of test material, eutectic Si particles in the anodized coat and distribution of particle diameters by the use of an image analysis system under the conditions shown below.
[0111] The determination was performed through cutting a given sample in an arbitrary size, embedding the cut sample in a resin and micro-abrading the resin till eutectic Si particles became detectable.
[0112] Conditions of determination: Magnifications on a picture plane: 1240, and calculated from the results of a continuous determination of 20 fields of view.

Thickness of coat: 25 to 47 μm

[0113] In the data shown in Table 5, those that deviated from the conditions conforming to this invention are indicated with an underline.

<Test 3> (Bar material obtained by horizontal continuous casting, bar material obtained by horizontal continuous casting + forging)

[0114] An aluminum alloy having the composition shown in Table 5 was manufactured by the horizontal continuous casting method disclosed in JP-A SHO 61-33735 into bar materials of a diameter of 30 mm. The bar materials were then subjected to a homogenizing treatment at 490˚C for four hours and to a T6 treatment according to an ordinary method under the conditions shown in Table 20 (a solution treatment at 500 to 510˚C for two to three hours, followed by water cooling and further by an aging treatment at 180 to 190˚C for five to six hours) to obtain test materials. Otherwise, the continuously cast bar materials were similarly subjected to a homogenizing treatment and then to a shaving treatment to remove the cast skin, and cut to given lengths, and the cut lengths were subjected to an annealing treatment and a bonde treatment, and forged into cups measuring 32 mm in outside diameter, 15 mm in inside diameter, 27 mm in height and 8 mm in bottom thickness. These cups were subjected to a T6 treatment according to the ordinary method under the conditions shown in Table 8 (a solution treatment at 500 to 510˚C for two to three hours, following by water cooling and further by an aging treatment at 180 to 190˚C for five to six hours) to obtain forged parts as test materials. The test materials were further machined and thereafter tested for ability to succumb to an anodizing treatment, hardness of coat, presence or absence of a crack in the coat, wear resistance and mechanical properties under the following standards. They were also tested for the cross section of test material, eutectic Si particles in the anodized coat and distribution of particle diameters by the use of an image analysis system under the conditions shown below.
[0115] The determination was performed by cutting a given sample in an arbitrary size, embedding the cut sample in a resin, micro-abrading the resin till eutectic Si particles became detectable.
[0116] Conditions of determination: magnifications on a picture plane of the image analysis system: 1240, and calculated from the results of a continuous determination of 20 fields of view.

Thickness of coat: 25 to 47 μm

[0117] In the data shown in Table 5, those (Comparative Examples) that deviated from the conditions conforming to this invention are indicated with an underline.

<Test 4> (Extruded material/drawn material, extruded material/drawn material + forging)

[0118] An aluminum alloy having the composition shown in Table 5 was manufactured using the gas-pressure hot top continuous casting method disclosed in JP-B SHO 54-42827 into billets (8 inches in diameter). Then, the cast billets were subjected to a homogenizing treatment at 490˚C for four hours. Subsequently, the cast mass was heated to 350˚C and then extruded by the use of an indirect extruding device to manufacture extruded bars 32 mm in diameter and subjected to a T6 treatment according to an ordinary method under the conditions shown in Table 20 (a solution treatment at 500 to 510˚C for two to three hours, followed by water cooling, and further by an aging treatment at 180 to 190˚C for five to six hours) to obtain extruded bars as test materials. Otherwise, the indirectly extruded bars were drawn into bars 39.2 mm in diameter, subjected to a T6 treatment by an ordinary method under the conditions shown in Table 6 (a solution treatment at 500 to 510˚C for two to three hours, followed by water cooling and further by an aging treatment at 180 to 190˚C for five to six hours) to obtain drawn bars as test materials. Alternatively, the drawn bars 39.2 mm in diameter manufactured from the extruded bars were cut into given lengths, subjected to an annealing treatment and a bonde treatment, and forged into cups measuring 32 mm in outside diameter, 15 mm in inside diameter, 27 mm in height and 8 mm in bottom thickness. These cups were subjected to a T6 treatment by the ordinary method under the conditions shown in Table 8 (a solution treatment at 500 to 510˚C for two to three hours, followed by water cooling and further by an aging treatment at 180 to 190˚C for five to six hours) to obtain forged parts as test materials, machined and subsequently tested for ability to succumb to an anodizing treatment, hardness of a coat, presence or absence of a crack in the coat, wear resistance and mechanical properties by the standard shown below. They were also tested for the cross section of test material, eutectic Si particles in the anodized coat and distribution of particle diameters by the use of an image analysis system under the conditions shown below.
[0119] The determination was performed by cutting a given sample in an arbitrary size, embedding the cut sample in a resin, micro-abrading the resin till eutectic Si particles became detectable.
[0120] Conditions of determination: Magnifications on a picture plane of the image analysis system: 1240, and calculated from the results of a continuous determination of 20 fields of view.

Thickness of coat: 25 to 47 μm

[0121] In the data shown in Table 5, those that deviated from the conditions conforming to this invention are indicated with an underline.

<Evaluation of Tests 2 to 4>

"Ability to succumb to anodizing treatment"

[0122] A cross section of a given extruded bar perpendicular to the direction of extrusion was cut till it formed a smooth surface having a fixed surface roughness. The cross section was used as a sample for rating the ability.
[0123] For the anodizing treatment, an aqueous 15-wt% sulfuric acid solution was used as the electrolytic bath and the anodizing treatment was performed with the bath temperature, electric voltage and time so set as to form an anodized coat of a target thickness of 30 μm on the sample surface.
[0124] The cross section of the sample consequently obtained was visually observed and measured for coat thickness with arbitrary 10 mm lengths. The ability of the sample to succumb to the anodizing treatment was rated by the average thickness of the actually formed coat. The thickness of the coat formed under the same conditions served as the index for the ability to succumb to the anodizing treatment. The larger the thickness, the better the ability is. The results obtained of samples having undergone no forging treatment are shown in Table 7 and those obtained of samples having undergone a forging treatment are shown in Table 9.

o: Average coat thickness of 30 μm or more
x: Average coat thickness of less than 30 μm

[0125] While the preceding test 1 used a target thickness of 40 μm, the present tests 2 to 4 used a target thickness of 30 μm on account of the large total number of samples. Therefore, the standard for the rating was as shown above.

"Hardness of coat"

[0126] The determination was performed through cutting a given sample in an arbitrary size, embedding the cut sample in a resin and micro-abrading the resin till eutectic Si particles became detectable. The hardness of the coat was measured and rated. The results of the samples that had not undergone a forging treatment are shown in Table 6 and those of the samples that had undergone the forging treatment are shown in Table 8.

"Wear resistance"

[0127] A given sample was tested for relative wear resistance by the use of an Ogoshi abrasion tester under the conditions of 1 m/s in speed of abrasion, 200 m in distance of abrasion, 3.2 kg in load and S50C (Hv: 750) in opposite material. The results obtained of the sample that had not undergone any forging treatment are shown in Table 6 and those of the samples that had undergone the forging treatment are shown in Table 8.

o: Less than 6.0 x 10^{-7} mm^2/kg
x: More than 9.0 x 10^{-7} mm^2/kg
Δ: 6.0 to 9.0 x 10^{-7} mm^2/kg

"Crack in coat"

[0128] A given sample that had undergone an anodizing treatment was visually observed through a magnifying mirror having 10 or more magnifications to confirm and rate the presence or absence of a crack. The results of the samples that had not undergone a forging treatment are shown in Table 7 and those of the samples that had undergone the forging treatment are shown in Table 9.
[0129] The results are shown in Table 3.

o: No crack in the coat
x: A crack found in the coat

"Mechanical properties"

[0130] A JIS No. 4 test piece was taken from the central part of an extruded material in parallel to the direction of extrusion and tested for tensile strength. The passage of the commendable tensile strength of 310 N/mm^2 and proof strength of 230 N/mm^2 was taken as the standard. The results are shown in Table 6.

"Product test, brake caliper piston"

[0131] The continuously cast materials, extruded materials and drawn materials of Examples 101 to 104, 121 to 125, 141 to 144 and 150 to 153 having the compositions shown in Table 1 and the forced products thereof (Example 201 to 204, 221 to 225, 241 to 244 and 250 to 253) were manufactured by machining into brake caliper pistons. These brake caliper pistons were subjected to a T6 treatment by following the ordinary method to form anodized coats of 38 μm or more on their surfaces. These brake caliper pistons were incorporated into brake master cylinders of four wheelers and were made to repeat braking operations to determine the conditions of seizure and locking. For the purpose of comparison, the aluminum alloys of Comparative Examples 101, 104, 108, 109, 111, 114, 115, 118 to 120 and 124 to 126 having the compositions shown in Table 1 were similarly manufactured to form brake caliper pistons and tested.
[0132] With 500,000 braking motions as the common standard, the brake caliper pistons of Example 101 to 153 and Examples 201 to 253 and those of the Comparative Examples produced no sign of problem. When the test was further continued, with the braking motions increased up to 1,000,000 times, the brake caliber pistons of Examples 11 to 153 and Examples 201 to 253 sustained absolutely no scar, whereas those of the Comparative Examples sustained streaky scratches. The brake caliper pistons using the aluminum alloys of Comparative Examples 125 and 126 and having the compositions shown in Table 1 could not be put to the test because they sustained cracks on their surfaces.

[Table 5]

Material									
	Method of production	Composition (wt%)							
		Si	Fe	Cu	Mn	Mg	Cr	Ti	Sr
Ex.101	Hot top continuous forging	5.0	0.25	-	-	0.4	-	-	-
Ex. 102	Horizontal continuous forging	do.	do.	do.	do.	do.	do.	do.	do.
Ex.103	Extruding	do.	do.	do.	do.	do.	do.	do.	do.

(continued)

Material									
	Method of production	Composition (wt%)							
		Si	Fe	Cu	Mn	Mg	Cr	Ti	Sr
Ex.104	Extruding/drawing	do.	do.	do.	do.	do.	do.	do.	do.
Ex.105	Hot top continuous forging	5.0	0.25	-	-	0.8	-	-	-
Ex. 106	Hot top continuous forging	5.0	0.25	0.4	-	0.4	-	-	-
Ex. 107	Hot top continuous forging	5.0	0.25	0.9	-	0.4	-	-	-
Ex. 108	Horizontal continuous forging	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 109	Extruding	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 110	Extruding/drawing	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 111	Hot top continuous forging	5.0	0.25	0.9	-	0.8	-	-	-
Ex. 112	Hot top continuous forging	5.0	0.25	0.9	0.2	0.4	-	-	-
Ex. 113	Hot top continuous forging	5.0	0.25	0.9	0.2	0.8	0.1	-	-
Ex. 114	Hot top continuous forging	5.0	0.25	0.9	0.2	0.5	0.1	-	0.015
Ex. 115	Hot top continuous forging	5.0	0.25	0.9	0.2	0.5	0.1	0.015	-
Ex. 116	Hot top continuous forging	7.0	0.25	-	-	0.4	-	-	-
Ex. 117	Horizontal continuous forging	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 118	Extruding	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 119	Extruding/drawing	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 120	Hot top continuous forging	7.0	0.25	-	-	0.8	-	-	-
Ex. 121	Hot top continuous forging	7.0	0.25	0.4	-	0.4	-	-	-
Ex. 122	Hot top continuous forging	7.0	0.25	0.9	-	0.8	-	-	-
Ex. 123	Horizontal continuous forging	do.	do.	do.	do.	do.	do.	do.	do.
Ex.124	Extruding	do.	do.	do.	do.	do.	do.	do.	do.
Ex.125	Extruding/drawing	do.	do.	do.	do.	do.	do.	do.	do.
Ex.126	Hot top continuous forging	7.0	0.25	0.9	0.2	0.4	-	-	-
Ex. 127	Hot top continuous forging	7.0	0.25	0.9	0.2	0.8	0.1	-	-
Ex. 128	Hot top continuous forging	7.0	0.25	0.4	0.2	0.5	0.1	-	0.015
Ex. 129	Hot top continuous forging	7.0	0.25	0.4	0.2	0.5	0.1	0.015	
Ex. 130	Hot top continuous forging	8.2	0.25	0.6	-	0.4	-	-	-
Ex. 131	Hot top continuous forging	10.0	0.25	-	-	0.4	-	-	-
Ex. 132	Horizontal continuous forging	do.	do.	do.	do.	do.	do.	do.	do.
Ex.133	Extruding	do.	do.	do.	do.	do.	do.	do.	do.
Ex.134	Extruding/drawing	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 135	Hot top continuous forging	10.0	0.25	-	-	0.8	-	-	-
Ex. 136	Hot top continuous forging	10.0	0.25	-	-	0.4	-	-	0.015
Ex. 137	Hot top continuous forging	10.0	0.25	0.4	-	0.4	-	-	-
Ex. 138	Horizontal continuous forging	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 139	Extruding	do.	do.	do.	do.	do.	do.	do.	do.

(continued)

Material									
	Method of production	Composition (wt%)							
		Si	Fe	Cu	Mn	Mg	Cr	Ti	Sr
Ex. 140	Extruding/drawing	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 141	Hot top continuous forging	10.0	0.25	0.9	-	0.4	-	-	-
Ex. 142	Horizontal continuous forging	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 143	Extruding	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 144	Extruding/drawing	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 145	Hot top continuous forging	10.0	0.25	0.9	-	0.8	-	-	-
Ex. 146	Hot top continuous forging	10.0	0.25	0.9	0.2	0.4	-	-	-
Ex. 147	Hot top continuous forging	10.0	0.25	0.9	0.2	0.8	0.1	-	-
Ex. 148	Hot top continuous forging	10.5	0.25	0.95	-	0.8	-	-	-
Ex. 149	Hot top continuous forging	10.5	0.25	0.4	0.2	0.4	0.1	-	0.015
Ex. 150	Hot top continuous forging	10.5	0.25	0.9	-	0.4	-	-	0.015
Ex. 151	Extruding	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 152	Extruding/drawing	do.	do.	do.	do.	do.	do.	do.	do.
Ex. 153	Hot top continuous forging	10.5	0.25	0.9	0.2	0.8	0.1	0.015	-
Comp. Ex. 101	Hot top continuous forging	4.5	0.25	2.5	-	1.1	-	-	-
Comp. Ex. 102	Horizontal continuous forging	do.	do.	do.	do.	do.	do.	do.	do.
Comp. Ex. 103	Extruding	do.	do.	do.	do.	do.	do.	do.	do.
Comp. Ex. 104	Extruding/drawing	do.	do.	do.	do.	do.	do.	do.	do.
Comp. Ex. 105	Hot top continuous forging	7.0	0.25	3.0	-	1.1	-	-	-
Comp. Ex. 106	Hot top continuous forging	7.0	0.25	3.0	0.2	1.1	0.1	-	-
Comp. Ex. 107	Hot top continuous forging	7.5	0.25	1.4	-	0.3	-	-	-
Comp. Ex. 108	Hot top continuous forging	7.5	0.25	2.5	0.2	0.4	-	-	-
Comp. Ex. 109	Horizontal continuous forging	do.	do.	do.	do.	do.	do.	do.	do.
Comp. Ex. 110	Extruding	do.	do.	do.	do.	do.	do.	do	do.
Comp. Ex. 111	Extruding/drawing	do.	do.	do.	do.	do.	do.	do.	do.
Comp. Ex. 112	Hot top continuous forging	8.5	0.25	2.5	0.2	0.6	0.1	-	-
Comp. Ex. 113	Hot top continuous forging	10.3	0.25	1.6	-	0.1	-	-	-
Comp. Ex. 114	Hot top continuous forging	10.6	0.25	1.5	-	0.4	-	-	-
Comp. Ex. 115	Horizontal continuous forging	do.	do.	do.	do.	do.	do.	do.	do.
Comp. Ex. 117	Extruding	do.	do.	do.	do.	do.	do.	do.	do.
Comp. Ex. 118	Extruding/drawing	do.	do.	do.	do.	do.	do.	do.	do.
Comp. Ex. 119	Hot top continuous forging	10.5	0.25	1.6	-	0.5	-	0.015	-
Comp. Ex. 120	Hot top continuous forging	10.7	0.25	1.5	-	0.5	-	-	0.015
Comp. Ex. 121	Hot top continuous forging	10.5	0.25	2.7	0.2	0.4	-	-	0.015
Comp. Ex. 122	Extruding	do.	do.	do.	do.	do.	do.	do.	do.
Comp. Ex. 123	Extruding/drawing	do.	do.	do.	do.	do.	do.	do.	do.

(continued)

Material									
	Method of production	Composition (wt%)							
		Si	Fe	Cu	Mn	Mg	Cr	Ti	Sr
Comp. Ex. 124	Hot top continuous forging	10.6	0.25	2.5	0.2	0.4	0.1	-	0.015
Comp. Ex. 125	Extruding/drawing	0.7	0.25	0.3	-	1.0	0.2	0.015	-
Comp. Ex. 126	Extruding/drawing	1.0	0.25	-	0.8	0.8	-	0.015	-

[Table 6]

Heat-treating conditions/mechanical properties of cast bars and extruded material						
	T6 condition	Mechanical property				Wear resistance
		Tensile strength (N/mm^2)	0.2% proof stremgth (N/mm^2)	Elongation (%)	Hardness (HRB)	
Ex. 101	510˚C x 2.5 hrs → Water cooling → 180˚C x 6 hrs	322	244	17.9	59.7	○
Ex. 102	do.	325	246	18.3	59.8	○
Ex. 103	do.	318	239	18.5	59.2	○
Ex. 104	do.	316	238	18.9	58.9	○
Ex. 105	do.	333	263	17.5	61.6	○
Ex.106	do.	338	275	17.4	63.1	○
Ex.107	500˚C x 2.5 hrs → Water cooling → 190˚C x 6 hrs	358	302	16.5	67.6	○
Ex.108	do.	360	305	16.9	67.8	○
Ex. 109	do.	356	299	17.0	67.2	○
Ex. 110	do.	354	297	17.4	67.0	○
Ex.111	do.	366	310	15.5	68.7	○
Ex.112	do.	355	298	16.6	67.7	○
Ex.113	do.	363	307	16.1	68.8	○
Ex.114	do.	356	300	16.4	67.8	○
Ex.115	do.	352	297	16.7	67.7	○
Ex. 116	510˚C x 2.5 hrs → Water cooling → 180˚C x 6 hrs	320	249	16.6	59.9	○
Ex. 117	do.	322	250	17.0	60.1	○
Ex. 118	do.	315	244	17.3	59.5	○
Ex. 119	do.	313	241	17.6	59.1	○
Ex. 120	do.	330	266	15.8	61.9	○

(continued)

Heat-treating conditions/mechanical properties of cast bars and extruded material						
	T6 condition	Mechanical property				Wear resistance
		Tensile strength (N/mm^2)	0.2% proof stremgth (N/mm^2)	Elongation (%)	Hardness (HRB)	
Ex. 121	do.	336	276	15.6	63.4	○
Ex. 122	500˚C x 2.5 hrs → Water cooling → 190˚C x 6 hrs	363	311	14.0	69.0	○
Ex. 123	do.	365	315	14.2	69.2	○
Ex. 124	do.	360	309	14.5	68.6	○
Ex. 125	do.	358	306	14.9	68.3	○
Ex. 126	do.	353	299	15.0	68.1	○
Ex. 127	do.	361	309	14.4	69.1	○
Ex. 128	510˚C x 2.5 hrs → Water cooling → 180˚C x 6 hrs	337	275	15.7	63.6	○
Ex. 129	do.	335	274	15.6	63.9	○
Ex. 130	500˚C x 2.5 hrs → Water cooling → 190˚C x 6 hrs	340	278	13.9	65.1	o o
Ex. 131	510˚C x 2.5 hrs → Water cooling → 180˚C x 6 hrs	317	242	13.4	60.4	o o
Ex.132	do.	318	244	13.6	60.5	o
Ex.133	do.	314	237	13.9	60.1	o
Ex.134	do.	311	235	14.1	59.9	o
Ex.135	do.	327	268	13.0	62.3	○
Ex.136	do.	318	240	13.6	60.3	○
Ex. 137	do.	333	279	12.6	63.8	o
Ex. 138	do.	334	280	12.9	63.8	o
Ex.139	do.	329	274	13.1	63.4	o
Ex. 140	do.	327	273	13.4	63.2	o
Ex. 141	500˚C x 2.5 hrs → Water cooling → 190˚C x 6 hrs	349	297	11.6	68.4	○
Ex. 142	do.	351	299	11.8	68.5	○
Ex. 143	do.	347	294	12.0	68.1	○
Ex.144	do.	345	292	12.2	67.9	○

(continued)

Heat-treating conditions/mechanical properties of cast bars and extruded material						
	T6 condition	Mechanical property				Wear resistance
		Tensile strength (N/mm^2)	0.2% proof stremgth (N/mm^2)	Elongation (%)	Hardness (HRB)	
Ex. 145	do.	360	312	10.5	69.3	○
Ex.146	do.	350	300	11.0	68.6	○
Ex.147	do.	358	314	10.4	69.5	○
Ex.148	do.	360	313	10.2	70.1	○
Ex. 149	510°C x 2.5 hrs → Water cooling → 180°C x 6 hrs	336	281	12.8	64.3	○
Ex. 150	500°C x 2.5 hrs → Water cooling → 190°C x 6 hrs	350	301	11.6	68.7	○
Ex.151	do.	347	294	12.1	68.3	○
Ex.152	do.	346	293	12.3	68.1	○
Ex.153	do.	356	312	10.4	70.5	○
Comp. Ex. 101	495°C x 2.5 hrs → Water cooling → 190°C x 6 hrs	415	373	13.9	73.1	△
Comp. Ex. 102	do.	416	372	14.3	73.0	Δ
Comp. Ex. 103	do.	411	368	14.6	72.6	△
Comp. Ex. 104	do.	409	367	14.7	72.4	Δ
Comp. Ex. 105	do.	417	378	12.1	73.9	○
Comp. Ex. 106	do.	410	365	12.0	74.1	○
Comp. Ex. 107	do.	376	321	13.6	71.4	○
Comp. Ex. 108	do.	410	363	13.1	74.3	○
Comp. Ex. 109	do.	412	365	13.2	74.4	○
Comp. Ex. 110	do.	407	359	13.6	74.0	○
Comp. Ex. 111	do.	406	357	13.7	73.9	○
Comp. Ex. 112	do.	411	366	12.7	74.5	○

(continued)

Heat-treating conditions/mechanical properties of cast bars and extruded material						
	T6 condition	Mechanical property				Wear resistance
		Tensile strength (N/mm^2)	0.2% proof stremgth (N/mm^2)	Elongation (%)	Hardness (HRB)	
Comp. Ex. 113	do.	319	244	11.5	60.7	○
Comp. Ex. 114	do.	383	328	10.2	72.0	○
Comp. Ex. 115	do.	386	330	10.4	72.3	○
Comp. Ex. 117	do.	380	324	10.9	71.7	○
Comp. Ex. 118	do.	378	321	11.2	71.5	○
Comp. Ex. 119	do.	387	331	9.7	72.2	○
Comp. Ex. 120	do.	384	329	10.3	72.1	○
Comp. Ex. 121	do.	405	358	9.3	74.9	○
Comp. Ex. 122	do.	401	354	9.7	74.4	○
Comp. Ex. 123	do.	399	351	10.0	74.2	○
Comp. Ex. 124	do.	403	357	9.4	74.6	○
Comp. Ex. 125	530˚C x 2.5 hrs → Water cooling → 180˚C x 6 hrs	334	290	22.9	64.1	x
Comp. Ex. 126	do.	333	294	20.8	64.7	x

[Table 7]

Particle diameters of cast bars and extruded material/anodized coat properties										
	Eutectic Si					Ability yield to anodization treatment	Anodized coat			
	Ave. particle diameter (μm)	Max. particle diameter (μm)	Min. particle diameter (μm)	Number pieces/ mm^2	Proportion of 0.8 to 2.4 μm (%)		Hardness of coat (Hv)		Thickness of coat (μm)	Crack
Ex.101	2.02	4.81	0.4	10,012	64.1	○	432	○	46.8	○
Ex. 102	1.91	4.43	0.4	10,889	66.3	○	433	○	46.9	○
Ex. 103	2.24	5.26	0.8	9,222	61.5	○	431	○	46.7	○
Ex.104	2.25	5.21	0.8	9,334	60.8	○	430	○	46.6	○
Ex.105	2.01	4.81	0.4	10,043	64.3	○	431	○	46.2	○
Ex.106	2.00	4.79	0.4	10,057	64.5	○	422	○	43.2	○
Ex. 107	1.99	4.78	0.4	10,065	64.4	○	410	○	41.1	○
Ex.108	1.90	4.46	0.4	10,907	66.5	○	411	○	41.0	○
Ex. 109	2.23	5.23	0.8	9,235	61.8	○	409	○	41.1	○
Ex. 110	2.24	5.28	0.8	9,332	61.6	○	408	○	41.0	○
Ex. 111	2.00	4.79	0.4	9,992	64.3	○	407	○	40.8	○
Ex.112	1.99	4.78	0.4	9,983	64.7	○	408	○	41.0	○
Ex.113	1.98	4.77	0.4	10,004	64.2	○	406	○	40.7	○
Ex.114	1.91	4.48	0.4	10,616	67.6	○	409	○	41.0	○
Ex.115	2.01	4.80	0.4	10,032	64.1	○	408	○	40.7	○
Ex.116	1.96	4.70	0.4	20,115	68.7	○	430	○	45.8	○
Ex.117	1.88	4.30	0.4	21,633	70.8	○	429	○	45.7	○
Ex.118	2.20	5.12	0.8	18,573	66.0	○	427	○	45.8	○
Ex.119	2.19	5.15	0.8	18,495	65.7	○	428	○	45.7	○
Ex. 120	1.97	4.72	0.4	20,104	69.0	○	427	○	45.4	○
Ex. 121	1.96	4.70	0.4	20,135	68.8	○	416	○	42.4	○

(continued)

Particle diameters of cast bars and extruded material/anodized coat properties										
	Eutectic Si					Ability yield to anodization treatment	Anodized coat			
	Ave. particle diameter (µm)	Max. particle diameter (µm)	Min. particle diameter (µm)	Number pieces/ mm^2	Proportion of 0.8 to 2.4 µm (%)		Hardness of coat (Hv)		Thickness of coat (µm)	Crack
Ex. 122	1.98	4.67	0.4	20,121	69.1	○	406	○	40.6	○
Ex. 123	1.89	4.32	0.4	21,602	71.3	○	405	○	40.4	○
Ex. 124	2.21	5.14	0.8	18,532	66.7	○	406	○	40.5	○
Ex. 125	2.22	5.16	0.8	18,486	66.5	○	405	○	40.4	○
Ex. 126	1.97	4.70	0.4	20,114	68.9	○	407	○	40.3	○
Ex.127	1.98	4.72	0.4	20,103	69.3	○	405	○	40.1	○
Ex. 128	1.90	4.34	0.4	21,731	71.7	○	414	○	40.5	○
Ex.129	1.97	4.72	0.4	20,170	68.5	○	411	○	40.3	○
Ex.130	1.95	4.68	0.4	25,334	72.3	○	407	○	40.2	○
Ex.131	1.93	4.64	0.4	34,007	80.6	○	427	○	44.9	○
Ex.132	1.79	4.00	0.4	35,863	83.7	○	428	○	44.8	○
Ex.133	2.16	5.20	0.8	32,142	78.5	○	428	○	44.7	○
Ex.134	2.14	5.23	0.8	32,263	78.1	○	427	○	44.7	○
Ex.135	1.95	4.60	0.8	33,989	80.9	○	426	○	44.4	○
Ex. 136	1.79	3.94	0.8	34,060	83.1	○	428	○	44.9	○
Ex. 137	1.93	4.54	0.8	34,071	81.1	○	416	○	42.0	○
Ex.138	1.78	3.98	0.4	35,891	84.1	○	417	○	41.9	○
Ex. 139	2.07	5.06	0.4	32,154	79.2	○	416	○	41.9	○
Ex. 140	2.09	5.08	0.8	32,276	79.0	○	416	○	41.8	○
Ex. 141	1.91	4.48	0.4	34,084	82.6	○	405	○	39.9	○
Ex. 142	1.83	4.14	0.4	35,908	84.7	○	405	○	39.8	○
Ex. 143	2.10	5.00	0.8	32,182	80.3	○	404	○	39.8	○

(continued)

Particle diameters of cast bars and extruded material/anodized coat properties										
	Eutectic Si					Ability yield to anodization treatment	Anodized coat			
	Ave. particle diameter (μm)	Max. particle diameter (μm)	Min. particle diameter (μm)	Number pieces/ mm^2	Proportion of 0.8 to 2.4 μm (%)		Hardness of coat (Hv)		Thickness of coat (μm)	Crack
Ex.144	2.09	5.02	0.8	32,297	80.1	○	404	○	39.8	○
Ex. 145	1.91	4.57	0.4	34,170	83.3	○	403	○	39.3	○
Ex. 146	1.89	4.52	0.4	34,139	82.9	○	406	○	39.6	○
Ex. 147	1.91	4.56	0.4	34,269	83.4	○	404	○	39.2	○
Ex. 148	19.2	4.60	0.4	34,286	83.5	○	404	○	39.0	○
Ex.149	1.77	3.92	0.4	35,188	84.9	○	417	○	40.1	○
Ex. 150	1.76	3.92	0.4	35,201	85.3	○	407	○	39.7	○
Ex.151	1.98	4.37	0.8	34,163	82.2	○	406	○	39.8	○
Ex. 152	1.99	4.39	0.8	34,194	82.1	○	406	○	39.6	○
Ex. 153	1.91	4.56	0.4	33,948	83.4	○	404	○	39.0	○
Comp. Ex. 101	2.02	4.88	0.4	9,224	63.2	x	324	x	31.7	○
Comp. Ex. 102	1.92	4.52	0.4	9,976	65.6	x	325	x	31.5	○
Comp. Ex. 103	2.26	5.30	0.8	8,766	61.2	x	324	x	31.6	○
Comp. Ex. 104	2.28	5.34	0.8	8,704	61.1	x	324	x	31.6	○
Comp. Ex. 105	1.98	4.76	0.4	20,346	70.2	x	297	x	29.6	○
Comp. Ex. 106	1.97	4.74	0.4	20,359	70.3	x	296	x	29.4	○
Comp. Ex. 107	1.96	4.81	0.4	21,052	69.5	Δ	384	Δ	35.8	○

(continued)

Particle diameters of cast bars and extruded material/anodized coat properties										
	Eutectic Si					Ability yield to anodization treatment	Anodized coat			
	Ave. particle diameter (μm)	Max. particle diameter (μm)	Min. particle diameter (μm)	Number pieces/ mm^2	Proportion of 0.8 to 2.4 μm (%)		Hardness of coat (Hv)		Thickness of coat (μm)	Crack
Comp. Ex. 108	1.95	4.78	0.4	21,084	69.9	x	325	x	30.7	○
Comp. Ex. 109	1.89	4.76	0.4	22,251	72.2	x	324	x	30.5	○
Comp. Ex. 110	2.22	5.20	0.8	18,724	67.9	x	325	x	30.6	○
Comp. Ex. 111	2.21	5.18	0.8	18,745	67.8	x	326	x	30.5	○
Comp. Ex. 112	1.94	4.67	0.4	26,118	72.8	x	322	x	29.9	○
Comp. Ex. 113	1.92	4.63	0.4	34,225	82.1	△	389	△	34.6	○
Comp. Ex. 114	1.91	4.58	0.4	34,286	82.4	△	381	△	34.1	○
Comp. Ex. 115	1.81	4.40	0.4	35,946	85.3	△	382	△	34.0	○
Comp. Ex. 117	2.14	5.06	0.8	32,945	79.8	△	380	△	34.0	○
Comp. Ex. 118	2.16	5.08	0.8	33,017	79.6	△	380	△	33.9	○
Comp. Ex. 119	1.92	4.54	0.4	34,346	82.3	△	379	△	33.7	○
Comp. Ex. 120	1.81	4.10	0.4	35,347	85.4	△	381	△	34.1	○
Comp. Ex. 121	1.82	4.08	0.4	35,459	85.8	x	323	x	29.7	○

(continued)

Particle diameters of cast bars and extruded material/anodized coat properties										
	Eutectic Si					Ability yield to anodization treatment	Anodized coat			
	Ave. particle diameter (μm)	Max. particle diameter (μm)	Min. particle diameter (μm)	Number pieces/ mm^2	Proportion of 0.8 to 2.4 μm (%)		Hardness of coat (Hv)		Thickness of coat (μm)	Crack
Comp. Ex. 122	2.07	5.02	0.8	34,428	81.9	x	322	x	29.6	○
Comp. Ex. 123	2.08	5.00	0.8	34,481	81.8	x	320	x	29.5	○
Comp. Ex. 124	1.80	4.06	0.4	35,878	85.3	x	323	x	29.7	○
Comp. Ex. 125	-	-	-	-	-	○	462	○	47.1	x
Comp. Ex. 126	-	-	-	-	-	○	469	○	47.3	x

[Table 8]

Heat treatment conditions for forged parts						
	Production method of material for forging		Forging treatment	T6 conditions	Hardness (HRB)	Wear resistance
Ex. 201	Ex.101	Hot top continuous forging	Presence	510˚C x 2.5 hr → Water cooling→ 180˚C x 6 hrs	59.2	○
Ex. 207	Ex. 107	Hot top continuous forging	Presence	500˚C x 2.5 hr → Water cooling → 190˚C x 6 hrs	67.0	○
Ex. 208	Ex. 108	Horizontal continuous forging	Presence	do.	67.3	○
Ex.210	Ex.110	Extruding/ drawing	Presence	do.	66.4	○
Ex. 216	Ex. 116	Hot top continuous forging	Presence	510˚C x 2.5 hr → Water cooling → 180˚C x 6 hrs	59.3	○
Ex.217	Ex.117	Horizontal continuous forging	Presence	do.	59.4	○
Ex.219	Ex.119	Extruding/ drawing	Presence	do.	58.4	○
Ex. 221	Ex. 121	Hot top continuous forging	Presence	do.	62.8	○
Ex. 222	Ex. 122	Hot top continuous forging	Presence	500˚C x 2.5 hr → Water cooling → 190˚C x 6 hrs	68.3	○
Ex. 223	Ex. 123	Horizontal continuous forging	Presence	do.	68.6	○
Ex. 225	Ex. 125	Extruding/ drawing	Presence	do.	67.5	○
Ex. 228	Ex. 128	Hot top continuous forging	Presence	510˚C x 2.5 hr → Water cooling → 180˚C x 6 hrs	62.8	○
Ex. 231	Ex. 131	Hot top continuous forging	Presence	510˚C x 2.5 hr → Water cooling → 180˚C x 6 hrs	59.7	○
Ex. 232	Ex. 132	Horizontal continuous forging	Presence	do.	59.7	o

(continued)

Heat treatment conditions for forged parts						
	Production method of material for forging		Forging treatment	T6 conditions	Hardness (HRB)	Wear resistance
Ex. 234	Ex. 134	Extruding/ drawing	Presence	do.	59.1	○
Ex. 237	Ex. 137	Hot top continuous forging	Presence	do.	63.2	○
Ex. 238	Ex.138	Horizontal continuous forging	Presence	do.	63.1	○
Ex. 240	Ex.140	Extruding/ drawing	Presence	do.	62.4	○
Ex. 241	Ex. 141	Hot top continuous forging	Presence	500˚C x 2.5 hr → Water cooling → 190˚C x 6 hrs	67.5	○
Ex. 242	Ex. 142	Horizontal continuous forging	Presence	do.	67.7	○
Ex. 243	Ex.143	Extruding	Presence	do.	67.4	○
Ex. 244	Ex. 144	Extruding/ drawing	Presence	do.	67.3	o
Ex. 245	Ex. 145	Hot top continuous forging	Presence	do.	68.5	○
Ex. 250	Ex. 150	Hot top continuous forging	Presence	500˚C x 2.5 hr → Water cooling → 190˚C x 6 hrs	67.9	○
Ex.252	Ex.152	Extruding/ drawing	Presence	do.	67.4	○
Ex. 253	Ex.153	Hot top continuous forging	Presence	do.	69.9	○
Comp. Ex. 201	Comp. Ex. 101	Hot top continuous forging	Presence	495˚Cx2.5hr→ Water cooling → 190˚C x 6 hrs	72.6	△
Comp. Ex. 205	Comp. Ex. 105	Hot top continuous forging	Presence	do.	73.3	○
Comp. Ex. 206	Comp. Ex. 106	Hot top continuous forging	Presence	do.	73.4	○
Comp. Ex. 208	Comp. Ex. 108	Hot top continuous forging	Presence	do.	73.7	○

(continued)

Heat treatment conditions for forged parts						
	Production method of material for forging		Forging treatment	T6 conditions	Hardness (HRB)	Wear resistance
Comp. Ex. 209	Comp. Ex. 109	Horizontal continuous forging	Presence	do.	73.8	○
Comp. Ex. 211	Comp. Ex. 111	Extruding/ drawing	Presence	do.	73.4	○
Comp. Ex. 214	Comp. Ex. 114	Hot top continuous forging	Presence	do.	71.4	○
Comp. Ex. 215	Comp. Ex. 115	Horizontal continuous forging	Presence	do.	71.8	○
Comp. Ex. 218	Comp. Ex. 118	Extruding/ drawing	Presence	do.	70.9	○
Comp. Ex. 219	Comp. Ex. 119	Hot top continuous forging	Presence	do.	71.5	○
Comp. Ex. 220	Comp. Ex. 120	Hot top continuous forging	Presence	do.	71.5	○
Comp. Ex. 221	Comp. Ex. 121	Hot top continuous forging	Presence	do.	74.1	○
Comp. Ex. 222	Comp. Ex. 122	Extruding	Presence,	do.	73.5	○
Comp. Ex. 223	Comp. Ex. 123	Extruding/ drawing	Presence	do.	73.5	○
Comp. Ex. 225	Comp. Ex. 125	Extruding/ drawing	Presence	530˚C x 2.5 hr → Water cooling → 180˚C x 6 hrs	63.5	x
Comp. Ex. 226	Comp. Ex. 126	Extruding/ drawing	Presence	do.	64.2	x

[Table 9]

Particle diameters of cast bars and extruded material/anodized coat properties										
	Eutectic Si					Ability to yield to anodization treatment	Anodized coat			
	Ave. particle diameter (μm)	Max. particle diameter (μm)	Min. particle diameter (μm)	Number pieces/ mm²	Proportion of 0.8 to 2.4 μm (%)		Hardness of coat (Hv)		Thickness of coat (μm)	Crack
Ex. 201	2.03	4.82	0.4	10,003	63.9	○	433	○	46.7	○
Ex. 207	2.01	4.79	0.4	10,055	64.3	○	411	○	40.9	○
Ex. 208	1.91	4.48	0.4	10,896	66.3	○	413	○	41.1	○
Ex.210	2.25	5.31	0.8	9,323	61.3	○	410	○	40.8	○
Ex.216	1.98	4.71	0.4	20,106	68.5	○	431	○	45.6	○
Ex. 217	1.89	4.32	0.4	21,623	70.5	○	431	○	45.6	○
Ex.219	2.21	5.18	0.8	18,485	65.5	○	430	○	45.8	○
Ex. 221	1.97	4.72	0.4	20,123	68.5	○	417	○	42.5	○
Ex. 222	2.00	4.68	0.4	20,108	68.7	○	408	○	40.8	○
Ex. 223	1.90	4.34	0.4	21,593	71.0	○	406	○	40.5	○
Ex. 225	2.24	5.17	0.8	18,472	66.1	○	407	○	40.2	○
Ex. 228	1.91	4.36	0.4	21,716	71.5	○	415	○	40.4	○
Ex. 231	1.95	4.65	0.4	33,994	80.2	○	429	○	45.1	○
Ex. 232	1.80	4.01	0.4	35,852	83.4	○	429	○	44.9	○
Ex. 234	2.15	5.24	0.8	32,248	77.9	○	429	○	44.9	○
Ex. 237	1.95	4.56	0.8	34,055	80.8	○	417	○	42.1	○
Ex. 238	1.79	3.99	0.4	35,878	83.8	○	419	○	42.0	○
Ex. 240	2.11	5.11	0.8	32,264	78.8	○	417	○	42.0	○
Ex. 241	1.92	4.50	0.4	34,072	82.2	○	406	○	39.8	○
Ex. 242	1.85	4.15	0.4	35,895	84.5	○	407	○	39.9	○
Ex. 243	2.13	5.01	0.8	32,169	80.0	○	405	○	39.9	○

(continued)

Particle diameters of cast bars and extruded material/anodized coat properties										
	Eutectic Si					Ability to yield to anodization treatment	Anodized coat			
	Ave. particle diameter (μm)	Max. particle diameter (μm)	Min. particle diameter (μm)	Number pieces/ mm²	Proportion of 0.8 to 2.4 μm (%)		Hardness of coat (Hv)		Thickness of coat (μm)	Crack
Ex. 244	2.10	5.04	0.8	32,280	79.7	○	404	○	40.0	○
Ex. 245	1.92	4.59	0.4	34,152	83.0	○	404	○	39.2	○
Ex. 250	1.78	3.96	0.4	35,180	85.1	○	407	○	39.6	○
Ex. 252	2.01	4.42	0.8	34,171	81.8	○	407	○	39.4	○
Ex. 253	1.93	4.59	0.4	33,924	83.0	○	406	○	38.9	○
Comp. Ex. 201	2.04	4.90	0.4	9,199	63.0	x	326	x	31.9	○
Comp. Ex. 205	2.00	4.78	0.4	20,321	69.7	x	298	x	29.7	○
Comp. Ex. 206	1.99	4.76	0.4	20,331	70.1	x	296	x	29.5	○
Comp. Ex. 208	1.97	4.79	0.4	21,072	69.6	x	327	x	30.9	○
Comp. Ex. 209	1.91	4.78	0.4	22,238	71.8	x	324	x	30.6	○
Comp. Ex. 211	2.22	5.21	0.8	18,731	67.6	x	328	x	30.6	○
Comp. Ex. 214	1.94	4.60	0.4	34,261	82.1	Δ	382	△	34.2	○
Comp. Ex. 215	1.84	4.42	0.4	35,923	84.9	Δ	384	Δ	33.9	○
Comp. Ex. 218	2.18	5.11	0.8	32,991	79.3	Δ	381	Δ	33.8	○
Comp. Ex. 219	1.93	4.55	0.4	34,317	82.0	△	381	△	33.5	○

(continued)

Particle diameters of cast bars and extruded material/anodized coat properties										
	Eutectic Si					Ability to yield to anodization treatment	Anodized coat			
	Ave. particle diameter (μm)	Max. particle diameter (μm)	Min. particle diameter (μm)	Number pieces/ mm²	Proportion of 0.8 to 2.4 μm (%)		Hardness of coat (Hv)		Thickness of coat (μm)	Crack
Comp. Ex. 220	1.82	4.12	0.4	35,318	85.0	△	382	△	33.9	○
Comp. Ex. 221	1.84	4.11	0.4	35,433	85.5	x	324	x	29.6	○
Comp. Ex. 222	2.08	5.03	0.8	34,402	81.7	x	324	x	29.5	○
Comp. Ex. 223	2.11	5.03	0.8	34,457	81.5	x	322	x	29.3	○
Comp. Ex. 225	-	-	-	-	-	○	463	○	47	x
Comp. Ex. 226	-	-	-	-	-	○	471	○	47.2	x

[Table 10]

Material				
Eutectic Si in anodized coat				
Ave. particle diameter (μm)	Max. particle diameter (μm)	Min. particle diameter (μm)	Number (pieses/mm²)	Proportion of 0.8 to 2.4 μm (%)
1.98	4.79	0.4	9,689	63.8
2.20	5.17	0.8	8,961	60.6
1.96	4.65	0.4	19,711	68.4
2.04	5.04	0.8	31,681	78.5
1.87	4.43	0.4	33,463	82
1.78	4.08	0.4	35,282	84
2.03	4.95	0.8	31,455	80.1
2.05	4.99	0.8	31,663	79.8

[Table 11]

Forged parts				
Eutectic Si in anodized coat				
Ave. particle diameter (μm)	Max. particle diameter (μm)	Min. particle diameter (μm)	Number (pieses/mm²)	Proportion of 0.8 to 2.4 μm (%)
1.98	4.78	0.4	9,503	63.6
1.91	4.67	0.4	19,582	68.0
1.88	4.44	0.4	33,329	81.6
1.80	4.10	0.4	35,110	83.8
2.06	4.97	0.8	31,400	79.3
2.05	4.99	0.8	31,495	79.1

Industrial Applicability:

[0133] The aluminum alloy according to this invention derives from an anodizing treatment that results in the presence of eutectic Si particles in the anodized coat, is endowed with excellent wear resistance and can be used for:

(a) Air-conditioner grade compressor parts, such as scrolls and pistons
(b) Compressor pistons for use in air suspensions of automobiles
(c) Spools and sleeves for automobile engines, and transmission and ABS hydraulic parts
(d) Brake master cylinder pistons/caliper pistons for automobiles
(e) Clutch cylinder pistons for automobiles
(f) Brake caliper bodies for automobiles

[0134] It is particularly suitable for brake caliper pistons and air suspension grade compressor pistons and other parts that require a coat excelling in hardness and defying infliction of a crack.

Claims

1. An aluminum alloy that forms in consequence of an anodizing treatment an anodized coat having a thickness of 30 μm or more and hardness Hv of 4000 or more and allows a presence, in the coat, of eutectic Si particles having

particle diameters in the range of 0.4 to 5.5 μm.

2. An aluminum alloy that forms in consequence of an anodizing treatment an anodized coat having a thickness of 40 μm or more and hardness Hv of 4000 or more and allows a presence, in the coat, of eutectic Si particles having particle diameters in a range of 0.8 to 5.5 μm.

3. An aluminum alloy according to claim 1 or claim 2, which contains 5 to 12% (mass%; similarly applicable hereinafter) of Si, 0.1 to 1% of Fe, less than 1% of Cu and 0.3 to 1.5% of Mg, and has the balance formed of Al and impurities, has dispersed in a matrix thereof eutectic Si particles having particle diameters in a range of 0.4 to 5.5 μm, inclusive of 60% or more of the eutectic Si particles having particle diameters of 0.8 to 2.4 μm, and allows a presence of 4000 or more and less than 40000 eutectic Si particles per mm^2.

4. An aluminum alloy according to any one of claims 1 to 3, which when containing 9 to 12% of Si, has 80% or more of the eutectic Si particles with particle diameters of 0.8 to 2.4 μm.

5. An aluminum alloy according to any one of claims 1 to 4, which contains substantially no Cu.

6. An aluminum alloy according to any one of claims 1 to 5, further containing at least one component selected from among 0.1 to 1% of Mn, 0.04 to 0.3% of Cr, 0.04 to 0.3% of Zr and 0.01 to 0.1% of V.

7. An aluminum alloy according to any one of claims 1 to 6, further comprising at least one component selected from among 0.01 to 0.3% of Ti, 0.0001 to 0.05% of B and 0.001 to 0.1% of Sr.

8. An aluminum alloy according to any one of claims 1 to 7, wherein the aluminum alloy is a bar material cast by a continuous casting method.

9. An aluminum alloy according to any one of claims 1 to 7, wherein the aluminum alloy is a bar material manufactured by a continuous casting method and then extruded or extruded and drawn.

10. A bar material comprising the aluminum alloy according to any one of claims 1 to 9.

11. A bar material according to claim 10, wherein the bar material is used as a sleeve part.

12. A forged article resulting from subjecting the bar material according to claim 10 or claim 11 to a forging process.

13. A machined article resulting from subjecting the bar material according to claim 10 or claim 11 or the forged article according to claim 12 to a machining process.

14. A wear-resistant aluminum alloy having an anodized coat having a thickness of 30 μm or more and hardness Hv of 400, which allows a presence, in the anodized coat, of eutectic Si particles of particle diameters in a range of 0.4 to 5.5 μm.

15. A wear-resistant aluminum alloy excelling in hardness of an anodized coat, which allows a presence, in an anodized coat, of eutectic Si particles of particle diameters in a range of 0.8 to 5.5 μm and forms the coat in a thickness of 40 μm or more and with hardness Hv of 400 or more.

16. A sleeve part excelling in hardness of an anodized coat, resulting from subjecting the machined article according to claim 13 to an anodizing treatment.

17. A method for the production of a wear-resistant aluminum alloy excelling in hardness of an anodized coat, comprising casting the aluminum alloy according to any one of claims 3 to 7 by a continuous casting process to form a cast mass, homogenizing the cast mass to form a homogenized cast mass, then extruding and/or forging and/or machining the homogenized cast mass to form a formed cast mass and subjecting the formed cast mass to an anodizing treatment, thereby allowing a presence, in the anodized coat, of eutectic Si particles of particle diameters in a range of 0.4 to 5.5 μm and forming the coat in a thickness of 30 μm or more and with hardness Hv of 400 or more.

18. A method for the production of a sleeve part excelling in hardness of an anodized coat and formed of an aluminum alloy, comprising casting the aluminum alloy according to any one of claims 3 to 7 by a continuous casting process

to form a cast mass, homogenizing the cast mass to form a homogenized cast mass, then extruding and/or forging and/or machining the homogenized cast mass to form a formed cast mass and subjecting the formed cast mass to an anodizing treatment, thereby allowing a presence, in the anodized coat, of eutectic Si particles of particle diameters in a range of 0.8 to 5.5 μm and forming the coat in a thickness of 40 μm or more and with hardness Hv of 400 or more.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2004/005677

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] C25D11/04, C22C21/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] C25D11/04

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

Jitsuyo Shinan Koho	1922-1996	Toroku Jitsuyo Shinan Koho	1994-2004
Kokai Jitsuyo Shinan Koho	1971-2004	Jitsuyo Shinan Toroku Koho	1996-2004

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 10-204566 A (Sumitomo Light Metal Industries, Ltd.), 04 August, 1998 (04.08.98), Claims; Par. Nos. [0001], [0022], [0023], [0025] (Family: none)	1-18
X	JP 2000-026996 A (Yamaha Motor Co., Ltd.), 25 January, 2000 (25.01.00), Par. No. [0001]; tables 1, 2, 4, 10; Par. No. [0075] (Family: none)	1,2,5-18
X	JP 2003-086979 A (Sky Aluminium Co., Ltd.), 20 March, 2003 (20.03.03), Claim 6; Par. Nos. [0010], [0025] (Family: none)	1,2,5-10, 12-15,17,18

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search 23 August, 2004 (23.08.04)	Date of mailing of the international search report 07 September, 2004 (07.09.04)
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