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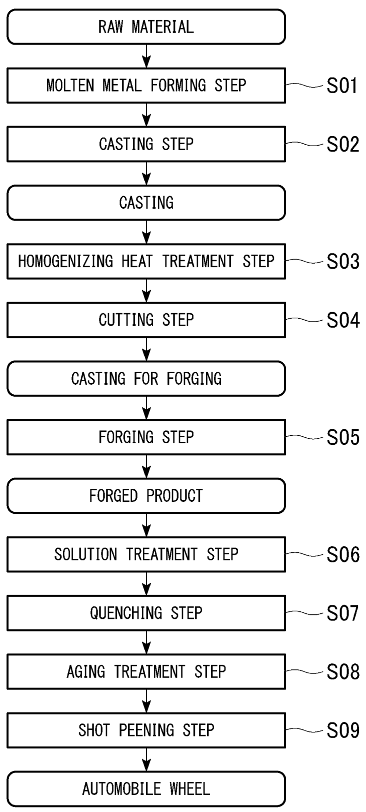
(54) ALUMINUM ALLOY FOR AUTOMOBILE WHEELS, AND AUTOMOBILE WHEEL

(57) There is provided an aluminum alloy for automobile wheels which contains Si in a range of 8.0% by mass or more and 11.5% by mass or less, Cu in a range of 0.7% by mass or more and 1.2% by mass or less, Mg in a range of 0.2% by mass or more and 0.6% by mass or less, Mn in a range of 0.30% by mass or more and 0.60% by mass or less, Fe in a range of 0.10% by mass or more and 0.30% by mass or less, Cr in a range of 0.01% by mass or more and 0.03% by mass or less, and balance Al with inevitable impurities, in which the aluminum alloy does not contain, per 1182 μm^2, two or more crystallized products containing 1% by mass or more of Cu and having a circle equivalent diameter exceeding 5 μm, the aluminum alloy does not contain, per 1182 μm^2, two or more Cr-containing intermetallic compounds having a length of 8 μm or more, and the aluminum alloy does not contain, per 4726 μm^2, two or more primary crystal Si particles having a circle equivalent diameter exceeding 10 μm.

FIG. 1



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Description

[Technical Field]

[0001] The present invention relates to an aluminum alloy for automobile wheels, and an automobile wheel.
[0002] Priority is claimed on Japanese Patent Application No. 2020-182091, filed October 30, 2020, the content of which is incorporated herein by reference.

[Background Art]

[0003] Due to the recent demand for improved fuel efficiency in the automobile industry, various parts used in automobiles, such as wheels, are required to be lighter and to have higher functionality. In order to reduce the weight of automobile wheels, it is preferable that the material of the wheel have a high specific strength, which is the ratio of strength to weight. Aluminum alloys are used as materials for automobile wheels that have a large non-strength ratio. Al-Mg-based aluminum alloys and Al-Si-based aluminum alloys are used as aluminum alloys. In addition, a die casting method and a forging method are used as methods for manufacturing automobile wheels using aluminum alloys. In order to improve the properties of automobile wheels, various metallic elements have been added to aluminum alloys, and manufacturing methods such as a die casting method and a forging method have been selected (Patent Documents 1 and 2).

[Citation List]

[Patent Document]

[0004]

Patent Document 1: Japanese Unexamined Patent Application, First Publication No. 2017-39986
Patent Document 2: Japanese Unexamined Patent Application, First Publication No. 2019-173111

[Summary of Invention]

[Technical Problem]

[0005] It is preferable that automobile wheels be resistant to breaking when impact is applied, that is, have high tensile strength and elongation. In order to exert the clipping force of the tire, it is preferable that the automobile wheels not be easily deformed, that is, have a large modulus of longitudinal elasticity (Young's modulus). Furthermore, it is preferable that the automobile wheels be resistant to corrosion by water such as rainwater, that is, be excellent in corrosion resistance. However, it is difficult to improve tensile properties such as tensile strength and elongation, modulus of longitudinal elasticity, and corrosion resistance in a well-balanced manner. For example, when certain metallic elements are added to improve tensile properties such as tensile strength and elongation of the wheel, properties such as modulus of longitudinal elasticity and corrosion resistance will deteriorate.
[0006] The present invention has been made in view of the above-mentioned technical background, and an object of the present invention is to provide an aluminum alloy for automobile wheels and an automobile wheel having improved tensile properties, modulus of longitudinal elasticity, and corrosion resistance.

[Solution to Problem]

[0007] In order to achieve the above object, the present inventors have conducted intensive research, found that tensile properties, modulus of longitudinal elasticity, and corrosion resistance are improved by adding Cu, Mg, Mn, Fe, and Cr in specific amounts to an Al-Si-based aluminum alloy, and by suppressing the contamination of coarse Cu-containing crystallized products, coarse Cr-containing intermetallic compounds formed of two or more types of metals, and coarse primary crystal Si particles, and completed the present invention.
[0008] A first aspect of the present invention provides an aluminum alloy described in [1] below.

[1] An aluminum alloy for automobile wheels containing Si in a range of 8.0% by mass or more and 11.5% by mass or less, Cu in a range of 0.7% by mass or more and 1.2% by mass or less, Mg in a range of 0.2% by mass or more and 0.6% by mass or less, Mn in a range of 0.30% by mass or more and 0.60% by mass or less, Fe in a range of 0.10% by mass or more and 0.30% by mass or less, Cr in a range of 0.01% by mass or more and 0.03% by mass

or less, and balance Al with inevitable impurities, in which the aluminum alloy does not contain, per 1182 μm^2, two or more crystallized products containing 1% by mass or more of Cu and having a circle equivalent diameter exceeding 5 μm, and the aluminum alloy does not contain, per 1182 μm^2, two or more Cr-containing intermetallic compounds having a length of 8 μm or more, and does not contain, per 4726 μm^2, two or more primary crystal Si particles having a circle equivalent diameter exceeding 10 μm.

It is also preferable that the aluminum alloy for wheels contain Si in a range of 8.5% by mass or more and 10.5% by mass or less, Cu in a range of 0.8% by mass or more and 1.1% by mass or less, and Mg in a range of 0.4% by mass or more and 0.6% by mass or less.

The first aspect of the present invention preferably has the following feature [2].

[2] The aluminum alloy for automobile wheels according to [1], in which an average particle size of eutectic Si particles is in a range of 0.5 μm or more and 4 μm or less, and an area ratio of the eutectic Si particles is 8% or more.

A second aspect of the present invention provides an automobile wheel described in [3] below.

[3] An automobile wheel formed of the aluminum alloy for automobile wheels according to [1] or [2] above.

The second aspect of the present invention preferably has the feature of the following feature [4].

[4] The automobile wheel according to [3] above, wherein the automobile wheel is a forged product.

[Advantageous Effects of Invention]

[0009] According to the present invention, it is possible to provide an aluminum alloy for automobile wheels and an automobile wheel having improved tensile properties, modulus of longitudinal elasticity, and corrosion resistance.

[Brief Description of Drawings]

[0010]

FIG. 1 is a flowchart showing an example of a method for manufacturing an automobile wheel according to one embodiment of the present invention.

FIG. 2 is a schematic perspective view showing an example of an aluminum alloy (casting) obtained in a casting step of the method for manufacturing an automobile wheel according to the embodiment of the present invention.

[Description of Embodiments]

[0011] Hereinafter, preferable examples of an aluminum alloy for automobile wheels and an automobile wheel according to one embodiment of the present invention will be described in detail.

[0012] The present embodiment is specifically described for better understanding of the gist of the invention, and does not limit the present invention unless otherwise specified. Numbers, materials, amounts, shapes, numerical values, ratios, positions, configurations, and the like may be changed, added, omitted, or replaced without departing from the scope of the present invention.

<Aluminum alloy for automobile wheels>

[0013] The aluminum alloy for automobile wheels of the present embodiment contains Si in a range of 8.5% by mass or more and 10.5% by mass or less, Cu in a range of 0.8% by mass or more and 1.1% by mass or less, Mg in a range of 0.4% by mass or more and 0.6% by mass or less, Mn in a range of 0.30% by mass or more and 0.60% by mass or less, Fe in a range of 0.10% by mass or more and 0.30% by mass or less, Cr in a range of 0.01% by mass or more and 0.03% by mass or less, and balance Al with inevitable impurities. In addition, the aluminum alloy for wheels of the present embodiment does not contain, per 1182 μm^2, two or more crystallized products containing 1% by mass or more of Cu and having a circle equivalent diameter exceeding 5 μm, and the aluminum alloy does not contain, per 1182 μm^2, two or more Cr-containing intermetallic compounds having a length of 8 μm or more, and does not contain, per 4726 μm^2, two or more primary crystal Si particles having a circle equivalent diameter exceeding 10 μm. In addition, in the aluminum alloy for wheels of the present embodiment, an average particle size of eutectic Si particles may be in a range of 0.5 μm or more and 4 μm or less, and an area ratio of the eutectic Si particles may be 8% or more. Further, the aluminum alloy for wheels of the present embodiment may have a tensile strength within a range of 330 MPa or more and 380 MPa or less, and an elongation within a range of 8% or more and 12% or less. Further, the aluminum alloy for wheels of the present embodiment may have a modulus of longitudinal elasticity of 77 GPa or more. Further, the corrosion resistance of the aluminum alloy for wheels of the present embodiment may be less than 1 mm as a corrosion progress depth when immersed in a test solution at a liquid temperature of 90°C for 10 hours under a stress of 70% of 0.2% proof stress.

(Si: 8.0% by mass or more and 11.5% by mass or less)

[0014] Si (component) has the effect of improving the tensile strength and modulus of longitudinal elasticity of the aluminum alloy. However, when Si is excessively added to the aluminum alloy, there is a concern of decrease in the elongation of the aluminum alloy due to the crystallization of coarse primary crystal Si particles.

[0015] When the Si content is less than 8.0% by mass, there is a concern of difficulty obtaining the effect of improving tensile strength and modulus of longitudinal elasticity by Si. On the other hand, when the Si content exceeds 11.5% by mass, there is a concern of coarse primary crystal Si particles being easily crystallized. For the above reasons, in the present embodiment, the Si content is in a range of 8.0% by mass or more and 11.5% by mass or less. The Si content is preferably in a range of 8.3% by mass or more and 11.3% by mass or less, more preferably in a range of 8.5% by mass or more and 11.0% by mass or less, and even more preferably in a range of 9.0% by mass or more and 10.0% by mass or less. Any Si content can be selected as long as the content is within the above range. For example, the content may be 8.00% by mass to 11.50% by mass, 8.10% by mass to 11.30% by mass, 8.30% by mass to 11.00% by mass, 8.50% by mass to 10.50% by mass, 8.70% by mass to 10.30% by mass, 8.90% by mass to 10.00% by mass, 9.20% by mass to 9.80% by mass, or 9.40% by mass to 9.60% by mass.

(Cu: 0.7% by mass or more and 1.2% by mass or less)

[0016] Cu (component) has the effect of improving the tensile strength of the aluminum alloy. Cu forms a G. P. zone in aluminum alloys. This Guinier-Preston zone (G. P. zone) is an intermediate phase, which contributes to the improvement of the tensile strength of the aluminum alloy. A G. P. zone is an aggregate of solute atoms that appears in a matrix phase during aging of an age hardening alloy.

[0017] When the Cu content is less than 0.7% by mass, there is a concern of difficulty obtaining the effect of improving tensile strength by Cu. On the other hand, when the Cu content exceeds 1.2% by mass, there is a concern of deterioration of the corrosion resistance. For the above reasons, in the present embodiment, the Cu content is in a range of 0.7% by mass or more and 1.2% by mass or less. The Cu content is preferably in a range of 0.8% by mass or more and 1.1% by mass or less, and more preferably in a range of 0.9% by mass or more and 1.0% by mass or less. Any Cu content can be selected as long as the content is within the above range. For example, the content may be 0.80% by mass to 1.10% by mass, 0.85% by mass to 1.05% by mass, 0.90% by mass to 1.00% by mass, or 0.93% by mass to 0.98% by mass.

(Mg: 0.2% by mass or more and 0.6% by mass or less)

[0018] Mg (component) has the effect of improving the tensile strength of the aluminum alloy similarly to Cu. Mg forms compounds containing Si and/or Cu in aluminum alloys. This compound precipitates as a Q phase, thereby contributing to the improvement of the tensile strength of the aluminum alloy.

[0019] When the Mg content is less than 0.2% by mass, there is a concern of difficulty obtaining the effect of improving tensile strength by Mg. On the other hand, when the Mg content exceeds 0.6% by mass, there is a concern of deterioration of the effect of improving tensile strength by Mg. Therefore, in the present embodiment, the Mg content is set to be in a range of 0.2% by mass or more and 0.6% by mass or less. The Mg content is preferably in a range of 0.4% by mass or more and 0.6% by mass or less, and more preferably in a range of 0.45% by mass or more and 0.55% by mass or less. Any Mg content can be selected as long as the content is within the above range. For example, the content may be 0.40% by mass to 0.60% by mass, 0.43% by mass to 0.58% by mass, or 0.47% by mass to 0.53% by mass.

(Mn: 0.30% by mass or more and 0.60% by mass or less)

[0020] Mn (component) has the effect of improving the tensile strength of the aluminum alloy. Mn forms fine granular crystallized products containing Al-Mn-Si intermetallic compounds and the like in aluminum alloys, thereby contributing to the improvement of the tensile strength of aluminum alloy.

[0021] When the Mn content is less than 0.30% by mass, there is a concern of difficulty obtaining the effect of improving tensile strength by Mn. On the other hand, when the Mn content exceeds 0.60% by mass, there is a concern of the intermetallic compound forming coarse crystallized products, which will deteriorate the tensile strength and elongation of the aluminum alloy. For the above reasons, in the present embodiment, the Mn content is in the range of 0.30% by mass or more and 0.60% by mass or less. The Mn content is preferably in a range of 0.35% by mass or more and 0.55% by mass or less. Any Mn content can be selected as long as the content is within the above range. For example, the content may be 0.38% by mass to 0.53% by mass, 0.40% by mass to 0.50% by mass, or 0.43% by mass to 0.47% by mass.

(Fe: 0.10% by mass or more and 0.30% by mass or less)

[0022] Fe (component) has the effect of improving the tensile strength of the aluminum alloy. Fe crystallizes in the aluminum alloy as fine crystallized products including Al-Fe-Si intermetallic compounds, Al-Cu-Fe intermetallic compounds, Al-Mn-Fe intermetallic compounds, and the like, thereby contributing to the improvement of the mechanical properties of the aluminum alloys.

[0023] When the Fe content is less than 0.10% by mass, there is a concern of difficulty obtaining the effect of improving tensile strength by Fe. On the other hand, when the Fe content exceeds 0.30% by mass, there is a concern of the intermetallic compound forming coarse crystallized products, which will deteriorate the tensile strength and elongation of the aluminum alloy. For the above reasons, in the present embodiment, the Fe content is in the range of 0.10% by mass or more and 0.30% by mass or less. The Fe content is preferably in a range of 0.15% by mass or more and 0.25% by mass or less. Any Fe content can be selected as long as the content is within the above range. For example, the content may be 0.13% by mass to 0.27% by mass, or 0.17% by mass to 0.20% by mass.

(Cr: 0.01% by mass or more and 0.03% by mass or less)

[0024] Cr (component) has the effect of improving the mechanical properties of the aluminum alloy. Cr crystallizes in the aluminum alloy as fine Cr-containing intermetallic compounds including Al-Fe-Cr intermetallic compounds and the like, thereby contributing to the improvement of the mechanical properties of the aluminum alloy.

[0025] When the Cr content is less than 0.01 % by mass, there is a concern of difficulty obtaining the effect of improving tensile strength by Cr. On the other hand, when the Cr content exceeds 0.03% by mass, there is a concern of the Cr-containing intermetallic compound forming coarse crystallized products, which will deteriorate the tensile strength and elongation of the aluminum alloy. For the above reasons, in the present embodiment, the Cr content is in the range of 0.01% by mass or more and 0.03% by mass or less. The Cr content is preferably in a range of 0.015% by mass or more and 0.02% by mass or less. Any Cr content can be selected as long as the content is within the above range. For example, the content may be 0.013% by mass to 0.028% by mass, 0.018% by mass to 0.026% by mass, or 0.020% by mass to 0.024% by mass.

(Inevitable impurities)

[0026] The inevitable impurities are impurities that are inevitably mixed into the aluminum alloy from the raw material of the aluminum alloy or from the manufacturing process. In the aluminum alloy for wheels of the present embodiment, the mixed amount of each of the elements Zn, Ni, Zr, and Ti preferably does not exceed 0.5% by mass in terms of the total content of each of these elements. When the total content of each of the above elements exceeds 0.5% by mass, there is a concern of each element crystallizing before the an Al matrix phase and forming coarse crystallized products, thereby reducing the ductility of the aluminum alloy and deteriorating tensile strength and elongation. Any amount of inevitable impurities can be selected as long as the content is within the above range. For example, the amount may be less than 0.50% by mass, 0.40% by mass or less, 0.30% by mass or less, 0.20% by mass or less, 0.10% by mass or less, 0.05% by mass or less, 0.01% by mass or less, or 0.001% by mass or less.

(Number of crystallized products containing 1 % by mass or more of Cu and having circle equivalent diameter exceeding 5 μm: not more than two per 1182 μm^2)

[0027] When the circle equivalent diameter of the Cu-based crystallized products containing 1 % by mass or more of Cu exceeds 5 μm, there is a concern of deterioration of the tensile strength and elongation of the aluminum alloy. Therefore, in the present embodiment, two or more coarse Cu-based crystallized products having a circle equivalent diameter exceeding 5 μm are not contained per 1182 μm^2. The number of coarse Cu-based crystallized products per 1182 μm^2 is preferably one or less, and more preferably, no coarse Cu-based crystallized products are contained. When the aluminum alloy does not contain coarse Cu-based crystallized products, the maximum circle equivalent diameter of the Cu-based crystallized products contained in the aluminum alloy is preferably 3 μm or less, and more preferably 1 μm or less.

[0028] The circle equivalent diameter and the number of Cu-based crystallized products are measured, for example, by cutting an aluminum alloy and observing a range of 30.47 μm $\times$ 38.79 μm (= 1182 μm^2) of a cross section thereof using a field emission scanning electron microscope (FE-SEM)/energy dispersive X-ray spectrometer (EDS). That is, the measurement can be performed by performing elemental analysis using EDS, detecting Cu-based crystallized products containing 1% by mass or more of Cu, and by measuring the circle equivalent diameter and the number of the detected Cu-based crystallized products using SEM images. Examples of the crystallized products include, but are not limited to, Al-Cu-Mg-Si.

(Number of Cr-containing intermetallic compounds having length of 8 μm or more: not more than 2 per 1182 μm^2)

[0029] In a Cr-containing intermetallic compound having a length of 8 μm or more, there is a concern of deterioration of the tensile strength and elongation of the aluminum alloy. Therefore, in the present embodiment, two or more coarse Cr-containing intermetallic compounds having a length of 8 μm or more are not contained per 1182 μm^2. The number of coarse Cr-containing intermetallic compounds per 1182 μm^2 is preferably one or less, and more preferably, no coarse Cr-containing intermetallic compounds are contained. When no coarse Cr-containing intermetallic compounds are contained, the maximum length of the Cr-containing intermetallic compound contained in the aluminum alloy is preferably 6 μm or less, and more preferably 4 μm or less.

[0030] Similar to the case of the above-described Cu-based crystallized product, the length and the number of the Cr-containing intermetallic compounds can be measured by detecting the Cr-containing intermetallic compounds by using FE-SEM/EDS for a range of 1182 μm^2 of the cross section of the aluminum alloy, and by measuring the length and the number of the detected Cr-containing intermetallic compounds using SEM images. Examples of the intermetallic compounds include, but are not limited to, Al-Cr-Si. The difference between the Cr-containing intermetallic compound and the Cu-based crystallized product is the shape of the intermetallic compound, or the like.

(Number of primary crystal Si particles having circle equivalent diameter exceeding 10 μm: not more than two per 4726 μm^2)

[0031] In coarse primary crystal Si particles having a circle equivalent diameter exceeding 10 μm, there is a concern of deterioration of the elongation of the aluminum alloy. Therefore, in the present embodiment, it is set that two or more coarse primary crystal Si particles having a circle equivalent diameter exceeding 10 μm are not contained per 4726 μm^2. The number of coarse primary crystal Si particles is preferably one or less, and more preferably, no coarse primary crystal Si particles are contained. When the aluminum alloy does not contain coarse primary crystal Si particles, the maximum circle equivalent diameter of the primary crystal Si particles contained in the aluminum alloy is preferably 8 μm or less, and more preferably 4 μm or less.

[0032] Regarding the circle equivalent diameter and the number of primary crystal Si particles, by observing a range of 60.9 μm × 77.6 μm (= 4726 μm^2) of the cross section of the aluminum alloy using FE-SEM/EDS, the circle equivalent diameter of primary crystal Si particles can be measured. Further, the primary crystal Si particles are made only of Si.

(Average particle size of eutectic Si particles: 0.5 μm or more and 4 μm or less)

[0033] When the average particle size of the eutectic Si particles is less than 0.5 μm, there is a concern of insufficient wear resistance. On the other hand, when the average particle size of the eutectic Si particles exceeds 4 μm, the wear resistance is excessive, and there is a concern of increase in the aggression against the mating member (for example, tire and shaft). Therefore, in the present embodiment, the average particle size of the eutectic Si particles is in the range of 0.5 μm or more and 4 μm or less. Further, the average particle size is the average value of the circle equivalent diameters of the observed eutectic Si particles.

(Area ratio of eutectic Si particles: 8% or more)

[0034] When the area ratio of the eutectic Si particles is less than 8%, there is a concern of insufficient wear resistance. Therefore, in the present embodiment, the area ratio of the eutectic Si particles is set to 8% or more. The area ratio of the eutectic Si particles may be 15% or less. For example, the area ratio of the eutectic Si particles may be 8.0 to 15.0%, 9.0 to 14.0%, 10.0 to 13.0%, or 11.0 to 12.0%.

[0035] The average particle size and the area ratio of the eutectic Si particles can be measured by observation using FE-SEM/EDS for a range of 4726 μm^2 of the cross section of the aluminum alloy in the same manner as in the case of obtaining the circle equivalent diameter of the primary crystal Si particles. The area ratio of the eutectic Si particles is the ratio of the total area of the observed eutectic Si particles to the area of the observed cross section.

(Tensile strength: 330 MPa or more and 380 MPa or less, elongation: 8% or more and 12% or less)

[0036] The aluminum alloy for wheels of the present embodiment may have a tensile strength in the range of 330 MPa or more and 380 MPa or less at 25°C. Further, the elongation at 25°C may be in the range of 8% or more and 12% or less. Tensile strength and elongation are values measured in accordance with the provisions of JIS Z2241:2011 (metal material tensile test method) using a JIS No. 4 tensile test piece. The tensile strength may be 340 MPa or more and 370 MPa or less, or 350 MPa or more and 360 MPa or less. The elongation may be 8.5% or more and 11.5% or less, or 9.0% or more and 11.0% or less.

(Modulus of longitudinal elasticity: 77 GPa or more)

[0037] The aluminum alloy for wheels of the present embodiment may have a modulus of longitudinal elasticity (Young's modulus) of 77 GPa or more at 25°C. The modulus of longitudinal elasticity may be 85 GPa or less. The modulus of longitudinal elasticity is a value obtained by a method of measuring the resonance frequency (eigenfrequency) by applying mechanical or electrical forced vibration to the test piece for modulus of longitudinal elasticity measurement, and calculating the modulus of longitudinal elasticity from this resonance frequency (resonance method). The modulus of longitudinal elasticity may be, for example, 77.0 GPa or more and 85.0 GPa or less, 78.0 GPa or more and 84.0 GPa or less, 79.0 GPa or more and 83.0 GPa or less, or 80.0 GPa or more and 82.0 GPa or less.

(Corrosion resistance: corrosion progress depth less than 1 mm when immersed in test solution under prescribed conditions)

[0038] The corrosion progress depth of the aluminum alloy for wheels of the present embodiment may be less than 1 mm when immersed in a test solution at a liquid temperature of 90°C for 10 hours under a stress of 70% of 0.2% proof stress. The test solution is an aqueous solution having a potassium dichromate concentration of 3% by mass, a chromic anhydride concentration of 3.6% by mass, and a sodium chloride concentration of 0.3% by mass.

<Automobile wheel>

[0039] The automobile wheel of the present embodiment is made of the above-described aluminum alloy for wheels of the present embodiment. That is, in the wheel of the present embodiment, the content of each additive element such as Si, Cu, Mg, Mn, Fe, and Cr is equivalent to that of the aluminum alloy for wheels of the above-described present embodiment. In addition, in the wheel of the present embodiment, the content of precipitates such as crystallized products containing 1% by mass or more of Cu, Cr-containing intermetallic compounds, primary crystal Si particles, and eutectic Si particles is equivalent to that of the aluminum alloy for wheels of the above-described embodiment. The automobile wheel of the present embodiment may be a forged product.

[0040] Next, a method for manufacturing an automobile wheel according to the present embodiment will be described.

[0041] FIG. 1 is a flowchart showing a method for manufacturing an automobile wheel according to one embodiment of the present invention. As shown in FIG. 1, the method for manufacturing a wheel of the present embodiment includes a molten metal forming step S01 for obtaining a molten aluminum alloy, a casting step S02 for obtaining a casting by casting the molten metal, and a forging step S05 for obtaining a forged product by forging the casting. A homogenizing heat treatment step S03 and a cutting step S04 may be performed between the casting step S02 and the forging step S05. Moreover, after the forging step S05, a solution treatment step S06, a quenching step S07, an aging treatment step S08, and a shot peening step S09 may be performed.

(Molten metal forming step S01)

[0042] In the molten metal forming step S01, a molten aluminum alloy is obtained by mixing the raw materials of Al source, Si source, Cu source, Mg source, Mn source, Fe source, and Cr source to have a composition that forms the above alloy, and heating and dissolving the obtained mixture at optionally selected temperature. Each of Al source, Si source, Cu source, Mg source, Mn source, Fe source, and Cr source may be a single metal material, or may be an alloy material containing two or more metals. Any temperature can be chosen as a temperature used to form the molten metal.

(Casting step S02)

[0043] In the casting step S02, a casting (first casting) is obtained by casting the molten aluminum alloy obtained in the molten metal forming step S01. FIG. 2 is a perspective view showing an example of the aluminum alloy (casting) obtained in the casting step S02. As shown in FIG. 2, it is preferable to obtain a cylindrical casting 10 in the casting step S02. The casting method is not particularly limited. As the casting method, for example, known methods that have been conventionally used as aluminum alloy casting methods such as a continuous casting and rolling method, a hot top casting method, a float casting method, and a semi-continuous casting method (DC casting method) can be used. Due to this casting step, Mn forms fine granular crystallized products containing Al-Mn-Si intermetallic compounds. Further, Fe forms fine crystallized products such as Al-Fe-Si intermetallic compounds, Al-Cu-Fe intermetallic compounds, and Al-Mn-Fe intermetallic compounds. Further, Cr forms crystallized products as fine Cr-containing intermetallic compounds such as Al-Fe-Cr intermetallic compounds.

(Homogenizing heat treatment step S03)

[0044] In the homogenizing heat treatment step S03, the cylindrical casting 10 obtained in the casting step S02 is subjected to homogenizing heat treatment. This homogenizing heat treatment eliminates the segregation of the additive elements that occurs during casting, homogenizes the composition, precipitates the supersaturated solid solution generated by solidification during casting, and further, changes a metastable phase formed by solidification during casting to an equilibrium phase. Any temperature can be selected as the heating temperature in the homogenizing heat treatment, but is, for example, within a range of 420°C or higher and 500°C or lower. If necessary, the temperature may be 430°C or higher and 480°C or lower, or 440°C or higher and 460°C or lower.

(Cutting step S04)

[0045] In the cutting step S04, the cylindrical casting 10 subjected to the homogenizing heat treatment in the homogenizing heat treatment step S03 is cut into a predetermined size to obtain a casting which is used for forging. That is, in the cutting step S04, a casting which is used for forging is obtained by cutting the casting 10 along a plane.

(Forging step S05)

[0046] In the forging step S05, forging is performed on the casting which is used for forging obtained in the cutting step S04 to obtain a forged product (second casting; automobile wheel) of a desired shape. The forging method may be hot forging or cold forging. The heating temperature in hot forging is, for example, within a range of 350°C or higher and 450°C or lower. If necessary, the temperature may be 370°C or higher and 430°C or lower, or 390°C or higher and 420°C or lower.

(Solution treatment step S06)

[0047] In the solution treatment step S06, the forged product obtained in the forging step S05 is subjected to solution treatment. By this solution treatment, elements such as Si, Cu, and Mg in the forged product are redissolved in the aluminum alloy to form a solid solution state. Any temperature can be selected as the heating temperature in the solution treatment, but is, for example, within a range of 450°C or higher and 540°C or lower. If necessary, the temperature may be 470°C or higher and 530°C or lower, or 490°C or higher and 510°C or lower.

(Quenching step S07)

[0048] In the quenching step S07, the forged product that has been put into a solid solution state in the solution treatment step S06 is quenched. This quenching treatment rapidly cools the forged product to form a supersaturated solid solution in which the solid solution state is maintained.

[0049] Further, in the forging step S05, when the forging is performed by hot forging, forging and quenching, in which quenching is performed as it is after forging, may be performed by utilizing the heating during hot forging without performing the solution treatment step S06. Examples of the quenching treatment include water quenching.

(Aging treatment step S08)

[0050] In the aging treatment step S08, the forged product made into a supersaturated solid solution in the quenching treatment step S07 is subjected to aging treatment. By this aging treatment, the forged product is tempered at a low temperature. Due to this aging treatment, clusters are generated in the aluminum alloy that forms the forged product, and Cu is precipitated from these clusters as nuclei to form a G. P. zone. Moreover, Mg forms a compound with Si or Cu and precipitates as a Q phase. Any temperature can be selected as the heating temperature in the aging treatment, but is, for example, within a range of 150°C or higher and 220°C or lower. If necessary, the temperature may be 170°C or higher and 200°C or lower, or 180°C or higher and 190°C or lower. Any time can be selected as the heating time, but examples thereof include 0.5 hours to 20 hours and 1 hour to 16 hours.

(Shot peening step S09)

[0051] In the shot peening step S09, the forged product subjected to the aging treatment in the aging treatment step S08 is cut by machining and then shot peened to apply plastic working in the vicinity of the surface to improve the fatigue strength. The size of the abrasive grains used in shot peening, in which the abrasive grains collide with the alloy surface at high speed, is preferably 1 mm or less. As a material for the abrasive grains, for example, stainless steel (for example, SUS304), alumina, or the like can be used. Further, the peening pressure is preferably 1 MPa or less.

[0052] An automobile wheel (forged product) can be manufactured by the manufacturing method described above.

[0053] The aluminum alloy for automobile wheels of the present embodiment having the above configuration contains each additive element of Si, Cu, Mg, Mn, Fe, and Cr within the above range, and balance Al with inevitable impurities, the aluminum alloy does not contain, per 1182 μm^2, two or more crystallized products containing 1% by mass or more of Cu and having a circle equivalent diameter exceeding 5 μm, the aluminum alloy does not contain, per 1182 μm^2, two or more Cr-containing intermetallic compounds having a length of 8 μm or more, and the aluminum alloy does not contain, per 4726 μm^2, two or more primary crystal Si particles having a circle equivalent diameter exceeding 10 μm. Therefore, properties such as tensile properties, modulus of longitudinal elasticity, and corrosion resistance are improved.

[0054] In addition, in the aluminum alloy for wheels of the present embodiment, when an average particle size of eutectic Si particles is in the range of 0.5 μm or more and 4 μm or less, and an area ratio of the eutectic Si particles is 8% or more, the tensile properties and the modulus of longitudinal elasticity are more reliably improved.

[0055] In addition, since an automobile wheel of the present embodiment is formed of the aluminum alloy for wheels described above, properties such as tensile properties, modulus of longitudinal elasticity, and corrosion resistance are improved.

[0056] In addition, the present invention is not necessarily limited to the above-described embodiments, and various modifications can be made without departing from the gist of the present invention.

[Examples]

[0057] Next, specific examples of the present invention will be described, but the present invention is not particularly limited to these examples.

<Example 1>

[0058] By heating a mixture containing Si source, Cu source, Mg source, Mn source, Cr source, Fe source, and Al source, a molten aluminum alloy containing 10.0% by mass Si, 0.9% by mass Cu, 0.3% by mass Mg, 0.5% by mass Mn, 0.02% by mass Cr, 0.20% by mass Fe, and the balance Al was formed. Subsequently, the obtained molten metal was subjected to continuous casting to obtain a cylindrical casting (first casting) having a diameter of 76 mm and a height of 1000 mm. The obtained casting was subjected to homogenizing heat treatment, and then the casting was air-cooled. The casting was then cut to a height of 75 mm to obtain a casting which is used for forging. The obtained casting was subjected to hot forging to obtain a wheel-shaped forged product (second casting). The obtained forged product was subjected to solution treatment and then to water quenching. Next, the casting after the water quenching treatment was subjected to the aging treatment to obtain a forged product for wheels.

<Examples 2 and 3 and Comparative Examples 1 to 12>

[0059] A forged product for wheels was obtained in the same manner as in Example 1, except that the contents of Si, Cu, Mg, Mn, Cr, and Fe in the aluminum alloy were changed to the proportions shown in Table 1.

[Table 1]

	Composition of aluminum alloy (% by mass)						
	Si	Cu	Mg	Mn	Cr	Fe	Al
Example 1	10.0	0.9	0.3	0.5	0.02	0.20	balance
Example 2	11.5	1.2	0.6	0.6	0.03	0.28	balance
Example 3	8.2	0.7	0.2	0.3	0.01	0.12	balance
Comparative Example 1	13.0	0.9	0.3	0.5	0.02	0.20	balance
Comparative Example 2	7.3	0.9	0.3	0.5	0.02	0.20	balance
Comparative Example 3	10.0	0.5	0.3	0.5	0.02	0.20	balance
Comparative Example 4	10.0	1.4	0.3	0.5	0.02	0.20	balance
Comparative Example 5	9.9	1.0	0.1	0.5	0.02	0.20	balance
Comparative Example 6	9.9	1.0	1.0	0.5	0.02	0.20	balance

(continued)

	Composition of aluminum alloy (% by mass)						
	Si	Cu	Mg	Mn	Cr	Fe	Al
Comparative Example 7	10.0	0.9	0.3	0.01	0.02	0.20	balance
Comparative Example 8	10.0	0.9	0.3	0.9	0.02	0.20	balance
Comparative Example 9	10.0	0.9	0.3	0.5	0.05	0.20	balance
Comparative Example 10	10.0	0.9	0.3	0.5	0.003	0.20	balance
Comparative Example 11	10.0	0.9	0.3	0.5	0.02	0.38	balance
Comparative Example 12	10.0	0.9	0.3	0.5	0.02	0.07	balance

[Evaluation]

[0060] The forged products for wheels obtained in Examples 1 to 3 and Comparative Examples 1 to 12 were evaluated as follows.

<Composition>

[0061] The contents of the elements Si, Cu, Mg, Mn, Cr, and Fe in the forged product for wheels were measured as follows. The forged product for wheels are dissolved using hydrochloric acid and hydrogen peroxide. The content of each element in the resulting solution is measured using an ICP emission spectrometer, and the measured value is converted to the content of each element in the forged product.

[0062] As a result of this measurement, the contents of each element in the forged products obtained in each of the examples and the comparative examples were the same as the contents shown in Table 1.

<Structure observation>

[0063] The structure of the forged product for wheels was observed as follows.

[0064] A forged product for wheels was cut into a size of 2 × 5 × 10 mm to prepare an observation sample. In order to obtain an observation surface, a surface parallel to a forging direction of the observation sample was machined as an observation surface. The observation surface of the observation sample was observed using FE-SEM/EDS at a magnification of 3000 times. An observation field (30.47 μm × 38.79 μm = 1182 μm^2) was subjected to element analysis using EDS to specify Cr-containing intermetallic compounds and Cu-based crystallized products containing 1% by mass or more of Cu. In addition, the magnification of the FE-SEM was set to 1500 times, and the shape and size of the crystal grains containing Si were observed with respect to the observation field of the FE-SEM (60.9 μm × 77.6 μm = 4726 μm^2) , and primary crystal Si particles and eutectic Si particles were specified. The circle equivalent diameter of the Cu-based crystallized products was calculated, and "the number of Cu-based crystallized products having a circle equivalent diameter exceeding 5 μm" and "the maximum circle equivalent diameter" were obtained. The length of the Cr-containing intermetallic compound was calculated, and "the number of Cr-containing intermetallic compounds having a length of 8 μm or more" and "maximum length" were obtained. The circle equivalent diameters of the primary crystal Si particles were calculated, and "the number of primary crystal Si particles having a circle equivalent diameter exceeding 10 μm" and "the maximum circle equivalent diameter" were obtained. For the eutectic Si particles, 150 particle sizes were measured, the "average particle size" was calculated, and the "area ratio", which is the occupancy rate of the eutectic Si particles in the observation field, was obtained.

[0065] Table 2 shows the measurement results.

<Corrosion resistance>

[0066] Corrosion resistance of the forged products for wheels was evaluated by stress corrosion cracking (SCC) testing.

[0067] A forged product for wheels is cut into a size of 4 × 2 × 45 mm to prepare a corrosion resistance evaluation sample. The corrosion resistance evaluation sample is bent at three points using a strain gauge such that a stress equivalent to 70% of the 0.2% proof stress measured in advance is applied. A corrosion resistance evaluation sample that has been bent at three points is immersed in a test solution (an aqueous solution with potassium dichromate concentration of 3% by mass, chromic anhydride concentration of 3.6% by mass, and sodium chloride concentration of

0.3% by mass) at a liquid temperature of 90°C for 10 hours. After immersion, the corrosion resistance evaluation sample is taken out from the test solution, washed with water, and then dried. The corrosion resistance evaluation sample after drying is observed using an optical microscope to determine the presence or absence of cracks, and if no cracks are present, the corrosion progress depth is measured.

[0068] Table 2 shows the measurement results. In Table 2, the corrosion resistance was evaluated as "○ (acceptable)" when the maximum corrosion progress depth was less than 1 mm, and "× (not acceptable)" when the maximum corrosion progress depth was 1 mm or more.

<Tensile properties (tensile strength/breaking elongation)>

[0069] The tensile strength and elongation of the forged products for wheels were measured as follows.

[0070] A forged product for wheels was cut into a size of 10 × 10 × 70 mm to prepare a JIS No. 14A tensile test piece. A tensile test was performed on the obtained JIS No. 14A tensile test piece in accordance with the provisions of JIS Z2241:2011 (metal material tensile test method), and the tensile strength (MPa) and breaking elongation (%) at 25°C were measured.

[0071] Table 2 shows the measurement results. In Table 2, in the evaluation of tensile properties, the case where a tensile strength was 330 MPa or more and a breaking elongation was 8% or more was indicated as "○ (acceptable)", and the case where a tensile strength was less than 330 MPa or an elongation was less than 8% was indicated as "× (not acceptable)."

<Longitudinal elasticity (modulus of longitudinal elasticity)>

[0072] The modulus of longitudinal elasticity of the forged products for wheels was measured as follows.

[0073] A forget product for wheels is cut into a predetermined size to prepare a longitudinal elasticity evaluation sample. A modulus of longitudinal elasticity (GPa) at 25°C is measured using a resonance method on the longitudinal elasticity evaluation sample.

[0074] Table 2 shows the measurement results. In Table 2, in the evaluation of the longitudinal elasticity, the modulus of longitudinal elasticity was evaluated as "○ (acceptable)" when the modulus of longitudinal elasticity was 77 GPa or more, and "× (not acceptable)" when the modulus of longitudinal elasticity was lower than 77 GPa.

<Overall evaluation>

[0075] When all of corrosion resistance, tensile properties, and longitudinal elasticity are "○ (acceptable)", the overall evaluation will be indicated as pass ("○"), and when any one of corrosion resistance, tensile properties, and longitudinal elasticity is "×" (not acceptable)", the overall evaluation will be indicated as failure ("×"). The results are shown in Table 2.

[Table 2]

Longitudinal elasticity: Modulus of longitudinal elasticity (GPa)	Longitudinal elasticity: Evaluation	Overall evaluation
79.4	○	○
80.5	○	○
77.3	○	○
83.0	○	×
75.9	×	×
78.1	○	×
79.0	○	×
77.0	○	×
77.9	○	×
76.3	○	×
79.2	○	×
78.7	○	×
77.9	○	×
80.1	○	×
79.0	○	×

Cr-containing intermetallic compound		Primary Crystal Si particles		Eutectic Si particles		Corrosion resistance	Tensile properties		
Number of Cr-containing intermetallic compounds having length of 8 μm or more (number/1182 μm²)	Maximum length (μm)	Number of primary crystal Si particles having circle equivalent diameter exceeding 10 μm (number/4726 μm²)	Maximum circle equivalent diameter (μm)	Average particle size (μm)	Area ratio (%)		Tensile strength (MPa)	Elongation (%)	Evaluation
0	5.3	Not detected		2.9	9.2	○	351	9.1	○
0	4.7	Not detected		2.7	9.4	○	362	8.6	○
0	1.8	Not detected		2.8	8.9	○	331	10.9	○
0	3.3	2	18	2.8	9.3	○	350	6.6	×
0	4.5	Not detected		2.6	7.5	○	325	10.2	×
0	3.9	Not detected		2.7	9.1	○	319	10.3	×
0	6.6	Not detected		2.6	9.2	×	365	9.3	○
0	5.0	Not detected		2.8	9.0	○	314	9.7	×
0	5.2	Not detected		3.0	9.3	○	323	9.8	×
0	3.6	Not detected		2.5	9.2	○	302	10.1	×
0	3.9	Not detected		3.1	8.8	○	322	7.2	×
2	8.8	Not detected		2.9	9.1	○	305	8.1	×
0	0.9	Not detected		2.8	9.3	○	324	9.8	×
0	9.3	Not detected		3.0	8.9	○	323	6.4	×
0	4.2	Not detected		2.7	9.3	○	329	9.5	×

	Cu-based crystallized product	
	Number of Cu-based crystallized products having circle equivalent diameter exceeding 5 μm (number/1182 μm²)	Maximum circle equivalent diameter (μm)
Example 1	0	0.2
Example 2	0	0.4
Example 3	0	0.2
Comparative Example 1	0	0.2
Comparative Example 2	0	0.2
Comparative Example 3	0	0.1
Comparative Example 4	2	5.4
Comparative Example 5	0	0.3
Comparative Example 6	0	0.2
Comparative Example 7	0	0.3
Comparative Example 8	0	0.2
Comparative Example 9	0	0.2
Comparative Example 10	0	0.2
Comparative Example 11	0	0.4
Comparative Example 12	0	0.2

[0076] From the results in Table 2, it was confirmed that the forged products of Examples 1 to 3, in which the contents of each additive element of Si, Cu, Mg, Mn, Fe, and Cr and the contents of the precipitates such as the crystallized products containing 1% by mass or more of Cu, the Cr-containing intermetallic compounds, the primary crystal Si particles, and the eutectic Si particles were within the range of the present invention, were excellent in all items of corrosion resistance, tensile properties, and longitudinal elasticity. On the other hand, in Comparative Examples 1 to 12 in which the contents of each additive element and the amount of mixed precipitates are out of the scope of the present invention, at least one characteristic of the corrosion resistance, tensile properties, and longitudinal elasticity was insufficient.

[Industrial Applicability}

[0077] According to the present invention, provided are an aluminum alloy for automobile wheels and an automobile wheel having improved tensile properties, modulus of longitudinal elasticity, and corrosion resistance.

[0078] The automobile wheel according to the present invention has high tensile strength and elongation, and thus, it is less likely to break when impact is applied. In addition, the automobile wheel according to the present invention has a large modulus of longitudinal elasticity and is not easily deformed, and thus, the clipping force of the tire can be exerted. Furthermore, the automobile wheel according to the present invention is excellent in rain corrosion resistance, and thus, it can be used for a long period of time.

[Reference Signs List]

[0079]

10 Casting

Claims

1. An aluminum alloy for automobile wheels containing Si in a range of 8.0% by mass or more and 11.5% by mass or less, Cu in a range of 0.7% by mass or more and 1.2% by mass or less, Mg in a range of 0.2% by mass or more and 0.6% by mass or less, Mn in a range of 0.30% by mass or more and 0.60% by mass or less, Fe in a range of 0.10% by mass or more and 0.30% by mass or less, Cr in a range of 0.01 % by mass or more and 0.03% by mass or less, and balance Al with inevitable impurities, wherein

the aluminum alloy does not contain, per 1182 μm^2, two or more crystallized products containing 1% by mass or more of Cu and having a circle equivalent diameter exceeding 5 μm,
the aluminum alloy does not contain, per 1182 μm^2, two or more Cr-containing intermetallic compounds having a length of 8 μm or more, and
the aluminum alloy does not contain, per 4726 μm^2, two or more primary crystal Si particles having a circle equivalent diameter exceeding 10 μm.

2. The aluminum alloy for automobile wheels according to claim 1, wherein
an average particle size of eutectic Si particles is in a range of 0.5 μm or more and 4 μm or less, and an area ratio of the eutectic Si particles is 8% or more.

3. An automobile wheel formed of the aluminum alloy for automobile wheels according to claim 1 or 2.

4. The automobile wheel according to claim 3, wherein the automobile wheel is a forged product.

5. The aluminum alloy for automobile wheels according to claim 1, wherein the aluminum alloy contains Si in a range of 8.5% by mass or more and 10.5% by mass or less, Cu in a range of 0.8% by mass or more and 1.1% by mass or less, and Mg in a range of 0.4% by mass or more and 0.6% by mass or less.

FIG. 1

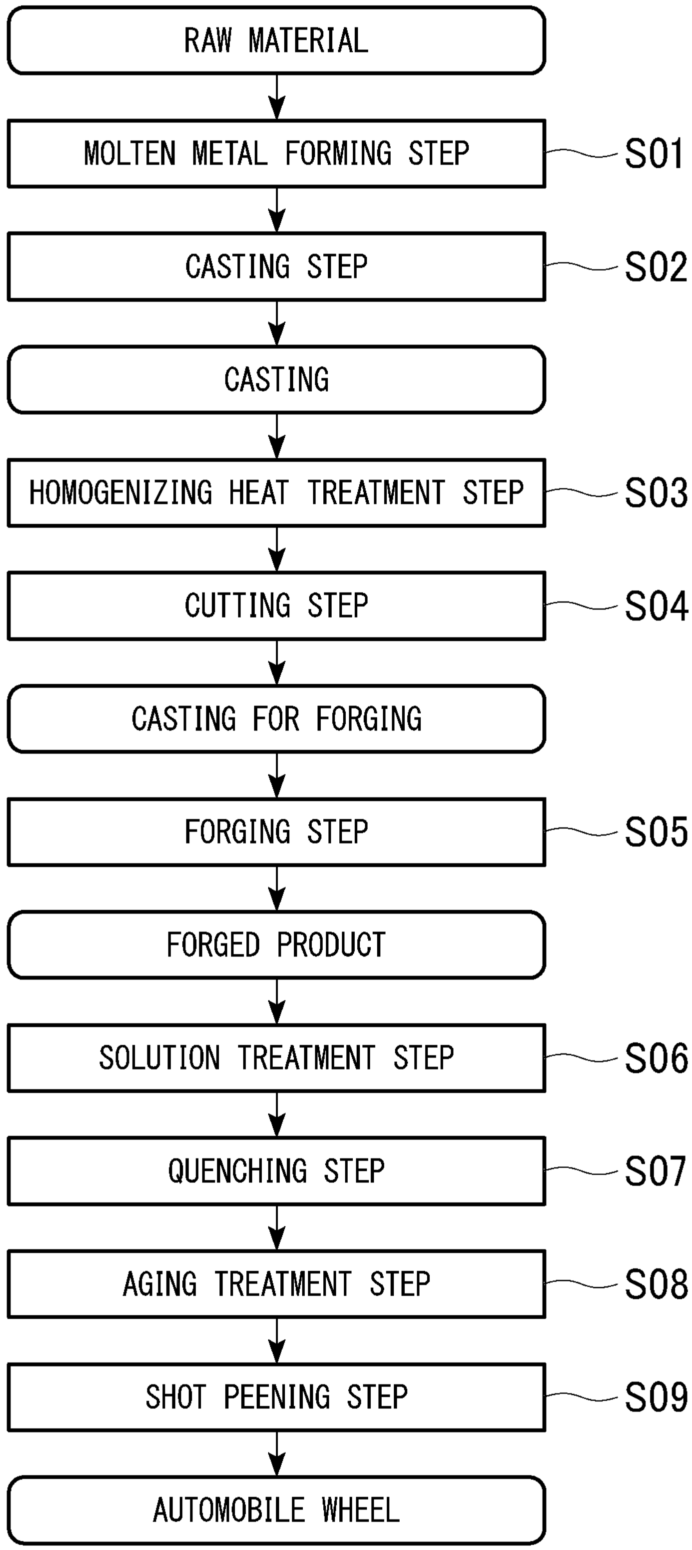
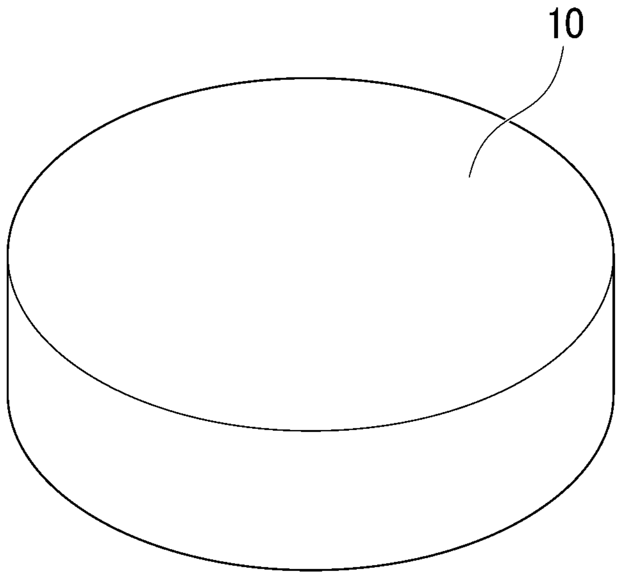

RAW MATERIAL
MOLTEN METAL FORMING STEP
S01
CASTING STEP
S02
CASTING
HOMOGENIZING HEAT TREATMENT STEP
S03
CUTTING STEP
S04
CASTING FOR FORGING
FORGING STEP
S05
FORGED PRODUCT
SOLUTION TREATMENT STEP
S06
QUENCHING STEP
S07
AGING TREATMENT STEP
S08
SHOT PEENING STEP
S09
AUTOMOBILE WHEEL

FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/038965

A. CLASSIFICATION OF SUBJECT MATTER

C22C 21/02(2006.01)i; ***C22F 1/00***(2006.01)i; ***C22F 1/043***(2006.01)i
FI: C22C21/02; C22F1/043; C22F1/00 602; C22F1/00 624; C22F1/00 630A; C22F1/00 630K; C22F1/00 631A; C22F1/00 640A; C22F1/00 640C; C22F1/00 682; C22F1/00 683; C22F1/00 685Z; C22F1/00 691B; C22F1/00 692A

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)

C22C21/02; C22F1/00; C22F1/043

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2021
Registered utility model specifications of Japan 1996-2021
Published registered utility model applications of Japan 1994-2021

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.
A	JP 2020-125525 A (BBS JAPAN CO LTD) 20 August 2020 (2020-08-20)	1-5
A	WO 2016/166779 A1 (DAIKI ALUMINIUM IND CO LTD) 20 October 2016 (2016-10-20)	1-5
A	JP 10-298689 A (HITACHI METALS LTD) 10 November 1998 (1998-11-10)	1-5
A	JP 2006-336044 A (HITACHI METALS LTD) 14 December 2006 (2006-12-14)	1-5
A	JP 9-125181 A (SUMITOMO LIGHT METAL IND LTD) 13 May 1997 (1997-05-13)	1-5
A	JP 2008-127579 A (TOYAMA GOKIN KK) 05 June 2008 (2008-06-05)	1-5

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
15 December 2021	**28 December 2021**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/038965

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2020-125525 A	20 August 2020	DE 102020102625 A1 CN 111532080 A TW 202031909 A	
WO 2016/166779 A1	20 October 2016	US 2017/0121793 A1 EP 3121302 A1 CN 106255770 A KR 10-2017-0138916 A MX 2016010352 A PL 3121302 T3 PH 12017500237 A1	
JP 10-298689 A	10 November 1998	(Family: none)	
JP 2006-336044 A	14 December 2006	(Family: none)	
JP 9-125181 A	13 May 1997	(Family: none)	
JP 2008-127579 A	05 June 2008	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2020182091 A **[0002]**
- JP 2017039986 A **[0004]**
- JP 2019173111 A **[0004]**