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(54) **HIGH-STRENGTH COMPOSITE MODIFIED ALUMINUM ALLOY PART AND PREPARATION
METHOD THEREFOR**

(57) The present invention provides a high-strength composite modified aluminum alloy part and a preparation method therefor. Wherein, the preparation method includes the following steps: step S1, providing an aluminum alloy melt; step S2, providing a modifier; step S3, adding the modifier to the aluminum alloy melt under an inert gas atmosphere and melting, to obtain a modified aluminum alloy melt; step S4, performing casting by using the modified aluminum alloy melt, to obtain the cast aluminum alloy blank; and step S5, performing a heat treatment on the modified aluminum alloy blank, wherein, the heat treatment includes: a solution treatment, heating

the aluminum alloy blank to 530°C-550°C, and maintaining the temperature for 100-300 min; a water quenching treatment, adding the aluminum alloy blank after the solution treatment into a water bath with the temperature of 60°C-70°C, and carrying out water quenching for 2-4 min; an aging treatment, maintaining the aluminum alloy blank after the water quenching treatment at 150°C-165°C for 120-280 min, then cooling to 110°C-130°C and maintaining the temperature for 30-120 min, and then naturally cooling to room temperature, to obtain the high-strength composite modified aluminum alloy part.

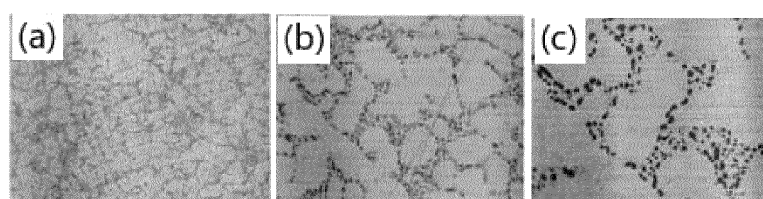


FIG. 2

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Description**Technical field**

5 **[0001]** The present invention relates to the technical field of alloy materials and preparation technologies, and in particular, to a high-strength composite modified aluminum alloy part and a preparation method therefor.

Background

10 **[0002]** Aluminum alloy is the most widely used non-ferrous metal structural material in industry, and has been widely used in aviation, aerospace, automobile, machinery manufacturing, shipbuilding and chemical industry. Cast aluminum alloy has characteristics such as casting fluidity, good air tightness, small shrinkage rate, and small thermal cracking tendency, and has become the preferred material for lightweight automotive wheel hubs.

15 **[0003]** However, as people's requirements for the aluminum alloy are getting higher, the aluminum alloy not only needs to maintain the original lightweight characteristic, but also needs to have certain strength, especially in the production of auto parts and industries. For large-size cast aluminum alloy parts, high strength and medium toughness are required to solve mechanical property problems.

20 **[0004]** For this reason, a process of modifying the aluminum alloy with a modifier such as aluminum-strontium alloy and refining the aluminum alloy with a refining agent is proposed. However, the conventional modification still cannot obtain ideal strength and plasticity. On this basis, the research on heat treatment of the cast aluminum alloy is carried out. However, due to the difference in the composition of aluminum alloy parts, the steps of heat treatment are also different. The current heat treatment requires a high temperature, consumes a lot of energy, takes a long time, and increases the processing cost. Moreover, because the treatment is directly performed at a higher temperature, it is not conducive to mutual transformation of phases and uniform precipitation, and consequently mechanical properties of the alloy are caused to be uneven.

25 **[0005]** Therefore, there is an urgent need to provide a preparation process that can further improve mechanical strength of aluminum alloy parts.

Summary

30 **[0006]** In view of this, the present invention provides a high-strength composite modified aluminum alloy part and a preparation method therefor, which can further improve mechanical strength of the aluminum alloy.

[0007] In order to solve the technical problems described above, the present invention adopts the following technical solution:

35 According to an embodiment of a first aspect of the present invention, a method for preparing a high-strength composite modified aluminum alloy part is provided, including the following steps:

step S1, providing an aluminum alloy melt;

step S2, providing a modifier; where

40 the modifier is a combination of a rare earth aluminum alloy, an aluminum-strontium master alloy, and an aluminum-titanium or aluminum-titanium-boron master alloy, or

the modifier is a combination of a composite rare earth aluminum alloy and an aluminum-titanium or aluminum-titanium-boron master alloy, and the composite rare earth aluminum alloy contains strontium, titanium or titanium boron, and a rare earth metal, and

45 the rare earth metal in the rare earth aluminum alloy and the composite rare earth aluminum alloy is any one or more of lanthanum, cerium, and yttrium;

step S3, adding the modifier to the aluminum alloy melt under an inert gas atmosphere and melting, to obtain a modified aluminum alloy melt;

step S4, performing casting by using the modified aluminum alloy melt, to obtain a modified aluminum alloy blank; and

50 step S5, performing a heat treatment on the modified aluminum alloy blank, where the heat treatment includes:

a solution treatment, heating the modified aluminum alloy blank to 530-550°C, and holding for 100-300 min;

a water quenching treatment, adding the modified aluminum alloy blank after the solution treatment into a water bath at a temperature of 60-70°C, and quenching with water for 2-4 min; and

55 an aging treatment, holding the aluminum alloy blank after the water quenching treatment at 150-165°C for 120-280 min, then cooling to 110-130°C and holding for 30-120 min, and then naturally cooling to room temperature, to obtain the high-strength composite modification alloy part.

[0008] Further, the step S1 includes:

providing an aluminum alloy ingot;
 removing an oxide scale layer on a surface of the aluminum alloy ingot, cleaning, and drying; and
 melting the dried aluminum alloy ingot, refining, and removing slag, to obtain the aluminum alloy melt, where
 the composition of the aluminum alloy ingot is a hypoeutectic aluminum alloy or a eutectic aluminum alloy.

[0009] According to some embodiments of the present invention, the modifier is a combination of a rare earth aluminum alloy, an aluminum-strontium master alloy, and an aluminum-titanium or aluminum-titanium-boron master alloy, where the aluminum-strontium master alloy and the aluminum-titanium or aluminum-titanium-boron master alloy are added at intervals, and

the rare earth aluminum alloy is added first, or added together with the first added component, or added at an interval between adding the aluminum-strontium master alloy and adding the aluminum-titanium or aluminum-titanium-boron master alloy.

[0010] Further, the step S3 includes:

step S301, adding the rare earth aluminum alloy into the aluminum alloy melt and melting, to obtain a first homogeneously mixed melt;

step S302, adding the aluminum-strontium master alloy into the first homogeneously mixed melt and continuing melting, to obtain a second homogeneously mixed melt; and

step S303, adding the aluminum-titanium or aluminum-titanium-boron master alloy into the second homogeneously mixed melt and continuing melting, to obtain the modified aluminum alloy.

[0011] According to some other embodiments of the present invention, the modifier is a combination of a composite rare earth aluminum alloy and an aluminum-titanium or aluminum-titanium-boron master alloy, and the step S3 includes:

step S310, adding the composite rare earth aluminum alloy into the aluminum alloy melt and melting, to obtain a fourth homogeneously mixed melt; and

step S320, adding the aluminum-titanium or aluminum-titanium-boron master alloy into the fourth homogeneously mixed melt and continuing melting, to obtain the modified aluminum alloy.

[0012] Further, the preparation of the composite rare earth aluminum alloy includes:

step S211, providing the aluminum melt;

step S212, providing an aluminum-strontium master alloy, an aluminum-titanium or aluminum-titanium-boron master alloy, and a rare earth aluminum master alloy, where the rare earth metal in the rare earth aluminum master alloy is one or more selected from lanthanum, cerium, and yttrium; and

step S213, under an inert gas atmosphere, sequentially adding the rare earth aluminum alloy, the aluminum-strontium master alloy, and the aluminum-titanium or aluminum-titanium-boron master alloy into the aluminum melt and melting, to obtain the composite rare earth aluminum alloy.

[0013] Further, the modifier accounts for 0.4-0.6wt% of the total amount of the modified aluminum alloy melt, and the mass ratio of the total amount of the rare earth metal: strontium: titanium or titanium boron is 1:(0.1-1.2):(0.1-1.2).

[0014] Further, in the step S5, the heating rate in the solution treatment is controlled at 1.5-3°C/min, and the holding time is controlled within 120-180 min.

[0015] Further, the solution treatment, the water quenching treatment, and the aging treatment are continuous treatments, and the water bath is a circulating water bath, and after the water quenching treatment, before the aging treatment is performed, the temperature of the cast aluminum alloy blank is kept above 55°C.

[0016] Further, in the aging treatment stage, the temperature is cooled from 150-165°C to 110-130°C at a cooling rate of 2-5°C/min.

[0017] According to an embodiment of a second aspect of the present invention, a high-strength composite modified aluminum alloy part is provided, and the high-strength composite modified aluminum alloy part is obtained by the preparation method according to any one embodiment described above, a tensile strength of the high-strength composite modified aluminum alloy part is 300MPa or more, a yield strength is 230MPa or more, and an elongation is 6% or more.

[0018] The technical solution of the present invention has at least one of the following beneficial effects:

According to the method for preparing a high-strength composite modified aluminum alloy part of the embodiments of the present invention, the aluminum alloy is modified by introducing the rare earth metal, and the casting is treated in combination with a specific heat treatment process, so that the mechanical strength of the composite modified aluminum alloy part can be greatly improved to meet the needs of aviation, aerospace, and automotive fields, and the toughness of the composite modified aluminum alloy part is improved at the same time, and the occurrence of brittle cracks is reduced.

Brief description of drawings**[0019]**

FIG. 1 is a photo of the high-strength composite modified aluminum alloy part, that is, the wheel hub, prepared in Embodiment 1; and

FIG. 2 is a metallographic structure image of a rib part of the wheel hub shown in FIG. 1, in which (a) is a low-magnification image, (b) is a medium-magnification image, and (c) is a high-magnification image.

Detailed description of embodiments

[0020] In order to make an objective, a technical solution, and advantages of the embodiments of the present invention clearer, the technical solutions of the present invention are clearly and completely described below with reference to the embodiments of the present invention. Obviously, the described embodiments are some, not all, embodiments of the present invention. All other embodiments obtained by the person of the ordinary skill in the art based on the described embodiments of the present invention fall within the scope of protection of the present invention.

[0021] Unless otherwise defined, the technical terms or scientific terms used in the present invention shall have the usual meanings understood by the person skilled in the art to which the present invention belongs. "First", "second" and similar words used in the present invention do not indicate any order, quantity or importance, but are only used to distinguish different components. Likewise, words like "a" or "one" do not denote a limitation in quantity, but indicate that there is at least one.

[0022] A method for preparing a high-strength composite modified aluminum alloy part according to an embodiment of the present invention is first described below in detail.

[0023] The method for preparing a high-strength composite modified aluminum alloy part according to an embodiment of the present invention includes the following steps:

Step S1: Provide an aluminum alloy melt.

[0024] That is, first, an aluminum alloy melt is prepared.

[0025] Herein, it should be noted that a commercially available high-purity aluminum alloy ingot can be directly heated and melted to prepare an aluminum alloy melt, or the aluminum alloy ingot can be further purified. Purification treatment, for example, may include the following steps:

Step S11: Provide an aluminum alloy ingot.

Step S12: Remove an oxide scale layer on a surface of the aluminum alloy ingot.

Step S13: Clean and dry the aluminum alloy ingot from which the oxide scale layer has been removed.

Step S14: Melt the dried aluminum alloy ingot to obtain an initial melt.

Step S15: Refine the initial melt to obtain the aluminum alloy melt.

[0026] That is, for the aluminum alloy ingot, the oxide scale layer on the surface of the aluminum alloy ingot is first removed, then the aluminum alloy ingot is cleaned to remove surface slag, and is melted after drying, and the melt is refined. The specific refining process is described in detail later.

[0027] After the above purification treatment, undesired impurities such as Fe and oxides can be removed from the aluminum alloy ingot. It is beneficial to further improving the modification and refinement of the rare earth alloy.

[0028] It should be additionally noted here that Fe and its oxides, for example, can be removed by adding manganese or aluminum-manganese alloy to form surface slag.

[0029] As the matrix to be modified, that is, the aluminum alloy melt, for example, may be an aluminum-magnesium alloy, an aluminum-silicon alloy, and an aluminum-silicon-magnesium alloy. This is not specifically limited in the present invention.

Step S2: Provide a modifier.

[0030] The modifier is a combination of a rare earth aluminum alloy, an aluminum-strontium master alloy, and an aluminum-titanium or aluminum-titanium-boron master alloy, or the modifier is a combination of a composite rare earth aluminum alloy, and an aluminum-titanium or aluminum-titanium-boron master alloy.

[0031] The composite rare earth aluminum alloy contains strontium, titanium or titanium boron, and a rare earth metal.

[0032] The rare earth metal in the rare earth aluminum alloy and the composite rare earth aluminum alloy is any one or more of lanthanum, cerium, and yttrium.

[0033] That is, there are two implementations as follows:

Implementation 1:

[0034] The modifier is a combination of a rare earth aluminum alloy, an aluminum-strontium master alloy, and an aluminum-titanium or aluminum-titanium-boron master alloy.

[0035] The aluminum-strontium master alloy is a modifier, and the aluminum-titanium master alloy or the aluminum-titanium-boron master alloy is a refining agent. That is, the conventional modifier and refining agent can be used.

[0036] Further, for the modifier and/or the refining agent, commercially available materials can be used, or the modifier and/or the refining agent can be prepared in a way that the corresponding metal strontium, titanium, titanium & boron are obtained by weighing, and are melted in an aluminum melt to form a homogeneous alloy.

[0037] In addition, in addition to the conventional modifier and refining agent, the rare earth aluminum alloy is further introduced to overcome the limitation of mechanical properties due to the "poisoning" reaction that is the adverse effect or restriction caused by the reaction between the modifier and the refining agent. As the rare earth metal in the rare earth aluminum alloy, considering the strontium in the modifier and the titanium and boron in the refining agent, the group IIIB elements whose electronic structure is between strontium and titanium and boron can be selected. In comprehensive consideration of stability and resources of the rare earth metal, preferably, one or more of lanthanum and cerium in yttrium and lanthanide metals is used. For example, one or more of commercially available Al-10Ce, Al-20Ce, Al-20La, Al-10La, Al-20Y, and Al-10Y can be used as the rare earth aluminum alloy.

[0038] In addition, the rare earth aluminum alloy can also be prepared, and for example, can be prepared by the following method:

adding the rare earth metal or the master alloy containing the rare earth metal into the aluminum melt under an inert atmosphere, and stirring while heating until completely melted;

after complete melting, holding the melt at the temperature for 10-20 minutes to make the melt homogenized;

refining the homogenized melt; and

after refining, standing for a predetermined time and performing casting, to obtain the rare earth aluminum alloy.

[0039] For the aluminum melt, the commercially available high-purity aluminum ingot can be used, and corresponding processing may be performed on the high-purity aluminum ingot with reference to the purification treatment on the aluminum alloy ingot. Details are not described herein.

[0040] In addition, for commercially available aluminum-strontium master alloys, aluminum-titanium master alloys or aluminum-titanium-boron master alloys, and rare-earth aluminum alloys, descaling, ultrasonic cleaning, and refining treatment can be performed sequentially, respectively. In this way, unwanted impurities and oxides can be further removed, so that it is beneficial to improving the refinement and modification of the composite rare earth alloy as a product.

Implementation 2:

[0041] The modifier is a combination of a composite rare earth aluminum alloy and an aluminum-titanium or aluminum-titanium-boron master alloy.

[0042] The composite rare earth aluminum alloy can be prepared by melting and refining the above rare earth aluminum alloy, the aluminum-strontium master alloy, the aluminum-titanium or aluminum-titanium-boron master alloy, and the aluminum melt.

[0043] For example, the preparation of the composite rare earth aluminum alloy may include the following steps:

Step S211, Provide an aluminum melt.

Step S212, Provide an aluminum-strontium master alloy, an aluminum-titanium or aluminum-titanium-boron master alloy, and a rare earth aluminum alloy, where the rare earth metal in the rare earth aluminum alloy is one or more selected from lanthanum, cerium, and yttrium.

Step S213, Add the rare earth aluminum alloy, the aluminum-strontium master alloy, and the aluminum-titanium or aluminum-titanium-boron master alloy into the aluminum melt under an inert gas atmosphere and melt, to obtain the composite rare earth aluminum alloy.

[0044] The aluminum-strontium master alloy and the aluminum-titanium or aluminum-titanium-boron master alloy are added at intervals, and the rare earth aluminum alloy is added before the aluminum-strontium master alloy and the aluminum-titanium or aluminum-titanium-boron master alloy, or is added together with the first added component, or added at an interval between adding the aluminum-strontium master alloy and adding the aluminum-titanium or aluminum-titanium-boron master alloy.

[0045] Preferably, the rare earth aluminum alloy, the aluminum-strontium master alloy, and the aluminum-titanium or aluminum-titanium-boron master alloy are sequentially added to the aluminum melt at intervals.

Step S3, Under an inert gas atmosphere, add the modifier to the aluminum alloy melt and melt, to obtain the modified aluminum alloy melt.

[0046] That is, after the aluminum melt and the modifier are prepared, the modifier is added to the aluminum melt for further melting under an inert gas atmosphere, to obtain a modified aluminum alloy melt.

[0047] According to the preparation method of the embodiment of the present invention, the rare earth metal is introduced into the modifier, so that the mutual poisoning effect between the modifier and the refining agent is greatly overcome, the addition amount of the modifier and the refining agent can be increased, and the effect of modification and refinement can be improved at the same time.

[0048] For the modifiers of the above two combinations, the following melting is carried out respectively.

[0049] Regarding that the modifier is a combination of a rare earth aluminum alloy, an aluminum-strontium master alloy, and an aluminum-titanium or aluminum-titanium-boron master alloy:

Specifically, for each rare earth aluminum alloy, aluminum-strontium master alloy, aluminum-titanium or aluminum-titanium-boron master alloy and pretreatment thereof, reference may be made to the above step S2.

[0050] In the case of this combination, the aluminum-strontium master alloy and the aluminum-titanium or aluminum-titanium-boron master alloy are added at intervals, the rare earth aluminum alloy is added first, or is added together with the first added component, or is added at an interval between adding the aluminum-strontium master alloy and adding the aluminum-titanium or aluminum-titanium-boron master alloy.

[0051] Further preferably, the step S3 may specifically include the following steps:

Step S301, Add the rare earth aluminum alloy into the aluminum melt and melt, to obtain a first homogeneously mixed melt.

Step S302, Add the aluminum-strontium master alloy into the first homogeneously mixed melt and continue melting, to obtain a second homogeneously mixed melt.

Step S303, Add the aluminum-titanium or aluminum-titanium-boron master alloy into the second homogeneously mixed melt and continue melting, to obtain the modified aluminum alloy.

[0052] That is, the rare earth aluminum alloy is first added and melting is performed, and on this basis, the aluminum-strontium master alloy as a modifier, and the aluminum-titanium master alloy or the aluminum-titanium-boron master alloy as a refining agent are sequentially added at intervals, so that the poisoning effect of strontium and boron can be solved well, and a modified aluminum alloy that is more refined, more uniform, and has better mechanical properties is obtained.

[0053] In addition, regarding that the modifier is a combination of a composite rare earth aluminum alloy and an aluminum-titanium or aluminum-titanium-boron master alloy, the step S3 includes:

Step S310, Add the composite rare earth aluminum alloy into the aluminum melt and melt, to obtain a fourth homogeneously mixed melt.

Step S320, Add the aluminum-titanium or aluminum-titanium-boron master alloy into the fourth homogeneously mixed melt and continue melting, to obtain the modified aluminum alloy.

[0054] That is, if the rare earth aluminum alloy, the modifier, the refining agent, and the aluminum are melted in advance to obtain a composite rare earth aluminum alloy, the composite rare earth aluminum alloy can be prepared by adding the rare earth aluminum alloy, the modifier, the refining agent, and the aluminum to the above aluminum melt at one time. Certainly, considering that abnormal growth of crystal grains tends to occur during high-temperature melting, which is not conducive to improving mechanical properties of the composite rare earth aluminum alloy. Preferably, when the composite rare earth aluminum alloy is completely melted and mixed with the aluminum alloy, a refining agent, that is, the aluminum-titanium master alloy or aluminum-titanium-boron master alloy is further added to control grain growth.

[0055] As a modifier, an addition amount of the modifier is correspondingly designed according to the requirements of use and the different contents of active ingredients in the master alloy. As an example, when a composite rare earth alloy (the mass ratio of the total amount of rare earth elements contained therein: strontium: titanium or titanium and boron = 1: (0.1-1.2): (0.1-1.2)) is introduced, the modifier preferably accounts for 0.4-0.6 wt% of the total amount of the modified aluminum alloy.

[0056] Further, the refining in any of the above steps, that is, the refining in the process of purifying the aluminum melt, the refining in the process of preparing the rare earth aluminum alloy, and the refining of each melt in the composite rare earth aluminum alloy can be carried out in the following manner:

The refining agent is blown into by using an inert gas and is held for 3-10 minutes, then the deslagging agent is added and stirred for 5-10 minutes, and the surface slag is removed.

[0057] Further, the added amount of the refining agent accounts for 0.1-0.3% of the mass of the added melt, and the added amount of the deslagging agent accounts for 0.1-0.3% of the mass of the added melt.

[0058] The components of the refining agent, expressed in terms of mass, include:

10-15 parts of potassium chloride, 15-25 parts of sodium chloride, 8-15 parts of calcium fluoride, 15-25 parts of sodium carbonate, 8-12 parts of sodium sulfate, 10-20 parts of sodium fluoroaluminate, and 8-12 parts of hexachloroethane;

[0059] The components of the deslagging agent, expressed in terms of mass, include:

25-30 parts of sodium chloride, 25-30 parts of potassium chloride, 5-10 parts of sodium carbonate, 5-10 parts of sodium sulfate, 1-5 parts of sodium fluoroaluminate, 5-10 parts of sodium fluorosilicate, 5-10 parts of calcium fluoride, 1-5 parts of potassium nitrate, and 5-10 parts of potassium fluorosilicate.

[0060] Further, it is possible to determine whether refining continues by monitoring the hydrogen content of the melt. In the present invention, the hydrogen content is estimated by testing the density of the melt, that is, if the density of the melt is closer to a theoretical density of the melt (the density is slightly different according to the difference in the components contained in the alloy, and the density is roughly around 2.7 g/cm³), it indicates that the hydrogen contained in the melt is lower. For example, it can be set that when the density of the melt is less than 2.65 g/cm³, the refining treatment is performed; when the density of the melt is greater than or equal to 2.65g/cm³, the refining treatment is not performed or the refining treatment is terminated.

[0061] Step S4, Perform casting on the modified aluminum alloy melt, to obtain a cast aluminum alloy blank.

[0062] That is, after melting, the obtained modified aluminum alloy melt is cast into a mold, to obtain the cast aluminum alloy blank.

[0063] For the specific casting process, a conventional casting process may be used. Detailed descriptions thereof are omitted herein.

[0064] Step S5, Perform a heat treatment on the aluminum alloy blank.

[0065] That is, after the aluminum alloy blank is obtained by casting, in order to further improve mechanical strength of the aluminum alloy blank, the inventor has developed a corresponding heat treatment process on the basis of repeated research.

[0066] Specifically, the heat treatment includes:

a solution treatment, heating the aluminum alloy blank to 530-550°C and holding for 100-300min;

a water quenching treatment, adding the aluminum alloy blank after the solution treatment into a water bath at a temperature of 60-70°C, and quenching with water for 2-4 min; and

an aging treatment, holding the aluminum alloy blank after the water quenching treatment at 150-160°C for 120-280 min, then cooling to 110-130°C and holding for 30-120 min, and then naturally cooling to room temperature, to obtain the high-strength composite modified aluminum alloy part.

[0067] That is, the aluminum alloy blank is successively subjected to the solution treatment, the water quenching treatment, and the aging treatment.

[0068] The above solution treatment is designed, so that it is possible to eliminate the stress caused by the cooling rate of the casting due to reasons such as the structure of the casting (such as uneven wall thickness and thick transition) when the crystal solidifies; the mechanical strength and hardness of the alloy can be improved, and the metallographic structure of the alloy can be improved; intergranular and component segregation can be eliminated, so that the structure can be homogeneous.

[0069] In addition, the casting is rapidly cooled by designing the above water quenching treatment, so that the strengthening components are dissolved in the alloy to the maximum extent and then fixed and stored at room temperature.

[0070] Further, by designing the above aging treatment, by means of raising the temperature and extending the time, atoms in the supersaturated solid solution lattice are recombined, a solute atom-enriched region (called a G-PI region) is generated, and then the G-PI region is disappeared. The atoms of the second phase segregate according to a certain rule, a G-PII region is generated, and a metastable second phase (transition phase) is generated. A large number of G-PII regions and a small amount of metastable phase are combined, and the metastable phase is transformed into a stable phase, and the second phase particles aggregate.

[0071] In addition, according to the preparation method of the present invention, high-temperature aging is first adopted, so that more phase transitions are in the β' region and the β'' region, thereby ensuring high strength.

[0072] Preferably, the heating rate in the solution treatment is controlled at 1.5-3°C/min, and the holding time is controlled within 120-180 min. The heating rate and the holding time of the solution treatment are controlled, so that the rose-like α -Al phase and the rounder spherical α -Al phase can be further increased, the primary α -Al phase can be refined, and the number of dendrites can be reduced.

[0073] Further, the solution treatment, the water quenching treatment, and the aging treatment are continuous treat-

ments, and the water bath is a circulating water bath. After the water quenching treatment, before the aging treatment is performed, the temperature of the cast aluminum alloy blank is kept above 55°C. Through the continuous treatments, not only production efficiency can be increased, but also unnecessary defects introduced by process interruption can be avoided. In addition, the lowest temperature is controlled during the period, so that the introduction of defects due to rapid cooling is avoided.

[0074] Further, in the aging treatment stage, the temperature is cooled from 150-165°C to 110-130°C at a cooling rate of 2-5°C/min. The cooling rate in the aging treatment stage is controlled, so that the introduction of defects can be greatly reduced, which helps to improve mechanical strength of the aluminum alloy and maintain a high level of the mechanical strength. The preparation method according to the present invention is further described below in detail by using specific embodiments.

Embodiment 1

[0075] Aluminum alloy: an aluminum-silicon-magnesium alloy (A356) (purchased from: Shandong Weiqiao Aluminum Industry) is used.

[0076] High-purity aluminum ingot (purchased from Aluminum Corporation of China, composition: Al (99.99%), Fe<0.1%, impurity <0.05%)

Refining agent:

[0077] Ingredients: 15 parts of potassium chloride, 20 parts of sodium chloride, 10 parts of CaF₂, 20 parts of Na₂CO₃, 10 parts of Na₂SO₄, 15 parts of Na₃AlF₆, 10 parts of C₂Cl₆.

Deslagging agent:

[0078] Ingredients: 25 parts of sodium chloride, 25 parts of potassium chloride, 5 parts of sodium carbonate, 5 parts of sodium sulfate, 5 parts of sodium fluoroaluminate, 10 parts of sodium fluorosilicate, 10 parts of calcium fluoride, 5 parts of potassium nitrate, and 10 parts of potassium fluorosilicate.

1) Preparation of aluminum alloy melt

[0079] Melting: The preheated aluminum-silicon-magnesium alloy A356 is added into the preheated melting furnace, and heated within the range of 760 degrees to melt into aluminum water.

[0080] Degassing and deslagging: After melting into aluminum water, nitrogen (or argon) is introduced into the aluminum water and then the refining agent (0.3wt% refining agent) is blown into the aluminum water, and the ventilation time is controlled at 15 minutes.

[0081] Standing still: Let the aluminum water in S3 stand for 10 minutes, the temperature is controlled at 760 degrees, and the slag impurities on the surface of the aluminum water are cleaned up.

[0082] During this period, sampling is performed on the aluminum water after standing to determine the chemical composition and estimate the amount of hydrogen:

The hydrogen content in the aluminum water after standing is estimated by using a density method, and the density is required to be greater than or equal to 2.65 g/cm³. When the density (closer to 2.7 g/cm³) is higher, it is considered that the hydrogen content is lower.

2) Purification treatment of master alloy

[0083] 2.1) An aluminum-strontium master alloy: purchased from Nantong Angshen Metal Materials Co., Ltd., composition: Al-10Sr, Fe<0.05.

[0084] Pretreatment: A grinder is used to clean the oxide scale and surface layer of the aluminum-strontium master alloy.

[0085] Ultrasonic cleaning: The pretreated aluminum-strontium master alloy is put into an ultrasonic cleaning tank for ultrasonic treatment.

[0086] Drying: The cleaned aluminum-strontium master alloy is put into an oven and baked at 60-100°C for 30-60 minutes.

[0087] Melting: The aluminum-strontium master alloy is put into a preheated crucible and is melted at 760-780°C.

[0088] Refining treatment: After the aluminum-strontium master alloy is melted, refining treatment is performed. Refining treatment is performed on the molten high-purity aluminum by introducing the Ar+graphite automatic degassing stirring rod. At 5-10 minutes and at 730-750°C, the refining agent is blown in by introducing Ar, the amount of the refining agent blown in is 0.1-0.3% of the melt, and this process is kept for 3-5 minutes. During the refining process, there should

be no boiling bubbles on the upper surface of the aluminum liquid.

[0089] Surface slag removal: At 15-20 minutes, the deslagging agent whose amount is 0.1-0.3% of the melt is added and is evenly spread to remove surface slag.

[0090] Standing still: Let the aluminum melt stand for 8-15 minutes at 740-760°C after removing slag.

2.2) Refining agent: refining treatment of an aluminum-titanium-boron master alloy

[0091] The aluminum-titanium-boron master alloy: purchased from Nantong Angshen Metal Materials Co., Ltd. (composition and content: Ti: 5%, B: 1%, the rest: Al)

[0092] For the aluminum-titanium-boron master alloy used as a refining agent, the same treatment is performed with reference to the above description.

3) Preparation of composite rare earth aluminum alloy

3.1) Melting of high-purity rare earth aluminum master alloy

a) Preparation of high-purity aluminum melt

[0093] Pretreatment: A grinder is used to clean the scale and surface layer on the surface of the high-purity aluminum ingot.

[0094] Ultrasonic cleaning: The pretreated high-purity aluminum ingot is put into the cleaning agent for ultrasonic treatment.

[0095] Drying: The high-purity aluminum ingot after ultrasonic cleaning is put into an oven and is baked at 60-100°C for 30-60 minutes.

[0096] Melting: The dried high-purity aluminum is put into a preheated crucible, and is heated at 760-800°C to melt.

[0097] Refining treatment: Refining treatment is performed after the high-purity aluminum is melted. Specifically: Refining treatment is performed on the melted high-purity aluminum by using the Ar+graphite automatic degassing stirring rod. At 5-10 minutes and at 740-760°C, the refining agent is blown in by introducing Ar, and the amount of the refining agent blown in is 0.1-0.3% of the melt, and this process is kept for 3-5 minutes. After that, let the aluminum melt stand for 10-20 minutes, and the deslagging agent whose amount is 0.1-0.3% of the melt is added in the aluminum melt to make it evenly spread to remove surface slag.

[0098] Standing still: Let the aluminum melt stand for 8-15 minutes at 740-760°C after removing slag.

b) Melting of rare earth aluminum alloy:

[0099] The temperature of the high-purity aluminum obtained in the above a) is adjusted to 780-820°C, and after being heated and melted completely, a rare earth aluminum-lanthanum alloy (purchased from Baotou Rare Earth Research Institute, composition: Al-10La, Fe<0.05) is added according to the set mass percentage, that is, the content of lanthanum in the rare earth aluminum alloy is $0.2 \pm 0.02\text{wt}\%$. Under the protection of argon atmosphere, the rare earth aluminum-lanthanum alloy is heated at 780-820°C to make it melt completely.

[0100] Stirring and heat preservation: The melted melt is stirred for 3-5 minutes to make it homogeneous, and the melt is held at 760-780°C for 10-20 minutes.

[0101] Refining treatment: The whole process is under the protection of argon atmosphere, and the refining treatment is performed after the rare earth aluminum-lanthanum alloy is melted. The Ar+graphite automatic degassing stirring rod is introduced to refine the melted rare earth aluminum-lanthanum alloy. At 5-10 minutes and at 760-780°C, the refining agent is blown in by using Ar, and the amount of the refining agent blown in is 0.1-0.3% of the melt, and this process is kept for 3-5 minutes. During the refining process, there should be no boiling bubbles on the upper surface of the aluminum liquid. Removal of slag on the surface of the melt: At 15-20 minutes, the deslagging agent whose amount is 0.1-0.3% of the melt is added and is evenly spread, to remove the slag on the surface.

[0102] Standing still: Let the melt stand at 720-730°C for 10-15 minutes after removing slag.

3.2) Preparation of composite rare earth alloy

[0103] The aluminum melt, the rare earth aluminum alloy, the aluminum-strontium master alloy, and the aluminum-titanium-boron master alloy are respectively prepared in the above description, and then are mixed and melted to obtain a composite rare earth alloy.

[0104] In this embodiment, as an addition sequence, the rare earth aluminum alloy is firstly added to the aluminum melt, then the aluminum strontium alloy is added, and finally the aluminum titanium boron alloy is added. Details as follows:

Step 1. Ingredients: The high-purity aluminum, the aluminum-titanium-boron master alloy, the aluminum-strontium master alloy, and the rare earth aluminum alloy after weighing according to the required mass percentage are preheated.

[0105] Based on 100 parts by total weight, the high-purity aluminum: 4.8 parts, the aluminum-titanium-boron master alloy: 0.2 parts, the aluminum-strontium master alloy: 60 parts, and the rare earth aluminum alloy: 35 parts.

[0106] Step 2. Adding and melting the rare earth aluminum alloy: For the above aluminum melt, the above purified rare earth aluminum alloy is first heated to 780~820°C to make it soften before melting, and then the overall temperature of the aluminum melt is controlled at 760~780°C, and the rare earth aluminum alloy is added into the aluminum melt for heat preservation.

[0107] The whole process is protected by argon atmosphere, and the rare earth aluminum alloy is melted.

[0108] Step 3. After the rare earth aluminum alloy is completely melted, the temperature is controlled at 750-770°C and is stirred for 5-10 minutes.

[0109] The whole process is under the protection of an argon atmosphere, and the stirring rod is made of graphite material and preheated to 400-500°C before stirring.

[0110] That is, after the rare earth aluminum alloy is completely melted, the temperature is slightly lowered, so that subsequent grain coarsening caused by overheating can be prevented.

[0111] Step 4. The melted melt is kept at 740-760°C, and the holding time is controlled within 5-20 minutes for heat preservation treatment. In this stage, an alloying reaction occurs.

[0112] Step 5. Refining: After the heat preservation is completed, refining, degassing and deslagging are carried out. The 0.3wt% refining agent is blown into the melt by using argon, and the ventilation time is controlled within 3~8 minutes; after that, the 0.2wt% deslagging agent is further added to the melt, and is stirred for 5 minutes, and let the melt stand to remove the slag and impurities on the surface of the melt. The whole process is protected by argon atmosphere.

[0113] Sampling is performed on the aluminum melt before refining and during refining, and the density of the aluminum melt is determined to estimate the hydrogen content. The measurement method adopts the density method (compared with the theoretical value of aluminum of 2.70 g/cm³), and if the density of the measured sample is closer to 2.7 g/cm³, it indicates that the internal hydrogen content of aluminum is lower. Generally, the density of the sample cannot reach 2.7 g/cm³ normally. The hydrogen content can be estimated provided that the density of the tested sample is approximately equal to 2.65g/cm³. During the process of estimating the hydrogen content, vacuum treatment is necessarily performed. If the hydrogen content is unqualified, further refining is carried out, that is, the refining agent and the deslagging agent are added repeatedly for further refining.

[0114] Step 6. Standing still: Let the melt that is added with the rare earth aluminum alloy and refined stand for 3-5 minutes, and the temperature is controlled at 740-760°C.

[0115] Step 7. Adding and melting the aluminum-strontium master alloy: The refined aluminum-strontium master alloy is added to the melt in step 6, and the temperature is controlled at 780-820°C, so that the aluminum-strontium master alloy is completely melted. The whole process is protected by argon atmosphere, and the aluminum-strontium master alloy is melted.

[0116] Step 8. After the aluminum-strontium master alloy is melted, the temperature is controlled at 740-760°C and stirred for 3-8 minutes to achieve homogenization. The whole process is protected by argon atmosphere, and the stirring rod is made of graphite material, and is preheated to 400-500°C before stirring.

[0117] Step 9. Next, heat preservation is carried out at 725-750°C. The heat preservation time is controlled within 15-30 minutes.

[0118] Step 10. Refining, degassing and deslagging: After the heat preservation of the melt is completed, after the argon is introduced, the 0.3wt% refining agent is blown into the aluminum-rare-earth composite melt, and the ventilation time is controlled at 5~10 minutes; the 0.2wt% deslagging agent is put into the aluminum melt, and is stirred for 5 minutes, to remove the slag and impurities on the surface of the aluminum-rare-earth composite melt. The whole process is protected by argon atmosphere.

[0119] Sampling is performed on the aluminum melt before refining and during refining to determine the hydrogen content. (The hydrogen content is required to be greater than or equal to 2.65 g/cm³;) Vacuum treatment is necessarily performed during the hydrogen measurement process. If the hydrogen content is unqualified, further refining is carried out, that is, the refining agent and the deslagging agent are added repeatedly for further refining.

[0120] Step 11. Adding aluminum-titanium-boron master alloy: The aluminum-titanium-boron master alloy is added to the melt treated in Step 10 above, and is heated to completely melt, and is stirred evenly for 3-5 minutes to make the melt homogenize.

[0121] Step 12. Heat preservation: After stirring, the melt is held at a temperature for 8-12 minutes, and the temperature is controlled at 715-725°C.

[0122] Step 13. Refining, degassing and deslagging: After the heat preservation of the melt is completed, after the argon is introduced, the 0.3wt% refining agent is blown into the aluminum-rare-earth composite melt, and the ventilation time is controlled within 5~10 minutes; the 0.2wt% deslagging agent is put into the aluminum melt, and is stirred for 5 minutes, to remove the slag and impurities on the surface of the aluminum rare earth composite melt. The whole process

is protected by argon atmosphere.

[0123] Sampling is performed on the aluminum melt before refining and during refining to determine the hydrogen content. (The hydrogen content is required to be greater than or equal to 2.65g/cm^3 ;) Vacuum treatment is necessarily performed during the hydrogen measurement process. If the hydrogen content is unqualified, further refining is carried out, that is, the refining agent and the deslagging agent are repeatedly added for further refining until the hydrogen content is qualified.

[0124] Step 14. Casting: The mold is preheated at $300\text{--}400^\circ\text{C}$. The temperature of the composite rare earth alloy melt obtained in the above step 13 is controlled at $715\text{--}725^\circ\text{C}$, and then casting is performed.

[0125] Preferably, during casting, the oxides on the surface of the aluminum-rare-earth composite melt are filtered through a glass fiber filter; before each casting, filtering is performed on the surface of the aluminum-rare-earth composite melt, and then casting is performed.

[0126] Preferably, for the cooling control of the casting mold, a water cooling method is adopted to cool the aluminum-rare-earth composite melt that is cast into the mold. During the cooling process, the solidification speed of the aluminum melt is controlled at $50\text{--}100^\circ\text{C/s}$, and the solidification method is sequential solidification.

[0127] The specific amount of rare earth metal: strontium: titanium or titanium boron in the composite rare earth aluminum alloy is not limited by the above embodiments. For example, the mass ratio of the total amount of the rare earth metal: strontium: titanium or titanium boron can be 1: (0.1-1.2): (0.1-1.2).

4) Preparation of the modified aluminum alloy blank

[0128] The aluminum-silicon-magnesium alloy, the composite rare-earth aluminum alloy, and the aluminum-titanium-boron master alloy are prepared according to a ratio that a mass ratio of the aluminum-silicon-magnesium alloy: the composite rare earth aluminum alloy: the aluminum-titanium-boron master alloy is 99.4:0.4:0.2.

[0129] Thereafter, melting is carried out as follows.

[0130] Mixing: According to the above ratio, in the aluminum-silicon-magnesium alloy melt treated in the above 1), when the temperature is controlled at 740 ± 5 degrees, the composite rare earth aluminum alloy obtained in 3) is added first.

[0131] Stirring: The graphite stirrer is used to stir the melt which is added with composite rare earth aluminum alloy and melted. During the stirring process, uniform stirring is required and continuous stirring is required for 8 minutes;

[0132] Heat preservation: After stirring, the temperature is controlled at 735 degrees for heat preservation, and the heat preservation time is controlled at 20 minutes;

[0133] Refining: After the heat preservation is over, after the argon is introduced, the deslagging agent is blown into the aluminum water, and the ventilation time is controlled at 15 minutes;

[0134] Adding the refining agent: 0.2% aluminum-titanium-boron master alloy is added to the refined aluminum water, and is stirred when it melts, and refining is continuously performed;

[0135] Heat preservation and standing: After refining, the aluminum water flows into the heat preservation pool, and when the temperature is controlled at 710 ± 3 degrees, after standing for 10 ± 2 minutes, the slag and impurities on the surface of the aluminum water are removed;

[0136] Casting: When the mold is preheated at $250\text{--}400$ degrees, the refined modified aluminum alloy with the above temperature controlled at 700 ± 5 degrees is cast into the mold, and the modified aluminum alloy blank is obtained after cooling. The thickness of the modified aluminum alloy blank is 30mm.

5) Heat treatment

[0137] Solution treatment: The modified aluminum alloy blank is put in a heating furnace, and is heated to 540°C at a heating rate of 2°C/min , and is held for 120min.

[0138] Water quenching treatment: The modified aluminum alloy blank after the above solution treatment is added into a circulating water bath at a temperature of 65°C , and water quenching is performed for 3 min.

[0139] Aging treatment: The modified aluminum alloy blank after water quenching is kept at 150°C for 120 minutes, then is cooled to 110°C at a cooling rate of 2°C/min and held for 30 minutes, and then is naturally cooled to room temperature to obtain the high-strength composite modified aluminum alloy part.

[0140] FIG. 1 is a photo of the high-strength composite modified aluminum alloy component, namely the wheel hub, prepared in Embodiment 1. FIG. 2 is a metallographic structure image of a rib part of the wheel hub shown in FIG. 1, where (a) is a low magnification image, (b) is a medium magnification image, and (c) is a high magnification image. It can be learned from FIG. 2 that, for the metallographic structure of the modified and heat-treated aluminum alloy in this embodiment, the rounder spherical $\alpha\text{-Al}$ phase is further increased, and the primary $\alpha\text{-Al}$ phase and dendrites are basically invisible. That is, the grains are further homogenized, and the microstructure is more uniform. In addition, the spherical $\alpha\text{-Al}$ phase is uniformly distributed at the grain boundaries.

[0141] In addition, the mechanical properties of the A356 aluminum alloy (denoted as: before modification), the blank

after modification (denoted as: modified alloy 1), and the product after heat treatment (denoted as: Embodiment 1) are evaluated. The evaluation results are shown in Table 1 below.

Table 1 Evaluation results of mechanical properties of the high-strength composite modified aluminum alloy part in Embodiment 1

Mechanical properties	Before modification	Modified alloy 1	Embodiment 1
Tensile strength (MPa)	130 ± 3.5	220 ± 5	320 ± 5
Yield strength (MPa)	65 ± 5.5	108 ± 6	220 ± 5
Elongation (%)	3 ± 0.25	20 ± 0.6	13 ± 0.35

[0142] It can be learned from Table 1 that through the heat treatment in Embodiment 1, even the heat treatment is not performed, the strength can be greatly improved. On the basis of combining the heat treatment, the yield strength and tensile strength are greatly improved (compared with the unmodified and unheated aluminum alloy ingot, the yield strength and tensile strength are increased by nearly 4 times respectively, nearly 3 times), and a high level of elongation (compared to the untreated aluminum alloy ingot, it has increased by more than 4 times) is maintained at the same time, so that the comprehensive mechanical properties are greatly improved.

Embodiment 2

[0143] In this embodiment, compared with Embodiment 1, except that the modifier uses a combination of a rare earth aluminum alloy, an aluminum-strontium master alloy, and an aluminum-titanium or aluminum-titanium-boron master alloy, the rest content is the same as Embodiment 1.

[0144] Below, only the different parts involved in the treatment of the modified aluminum alloy melt are described as follows:

4) Preparation of the modified aluminum alloy blank

[0145] The aluminum-silicon-magnesium alloy, the rare earth aluminum alloy, the aluminum-strontium alloy, and the aluminum-titanium-boron master alloy are prepared according to a ratio that a mass ratio of the aluminum-silicon-magnesium alloy: the rare earth aluminum alloy (the purification treatment of the rare earth aluminum alloy is the same as that in Embodiment 1): the aluminum-strontium alloy: the aluminum-titanium-boron master alloy is 99.4:0.2:0.2:0.2.

[0146] Thereafter, melting is carried out as follows.

[0147] Mixing: According to the above ratio, in the aluminum-silicon-magnesium alloy melt after the treatment in the above 1), when the temperature is controlled at 740 ± 5 degrees, the rare earth aluminum alloy is firstly added.

[0148] Stirring: The graphite stirrer is used to stir the melted melt to which the rare earth aluminum alloy is added, uniform stirring is required during the stirring process, and continuous stirring is required for 8 minutes;

[0149] Heat preservation: After stirring, the temperature is controlled at 735 degrees for heat preservation, and the heat preservation time is controlled at 20 minutes;

[0150] Refining: After the heat preservation is over, after the argon is introduced, the deslagging agent is blown into the aluminum water, and the ventilation time is controlled at 15 minutes;

[0151] Adding the aluminum-strontium master alloy: 0.2% aluminum-strontium master alloy is added to the refined aluminum water, and is stirred when it melts, and refining is continuously performed;

[0152] Homogenization: After the aluminum-strontium master alloy is completely melted, the temperature is controlled at $740 \sim 760^\circ\text{C}$, and is stirred for 3-8 minutes to achieve homogenization;

[0153] Heat preservation: Next, the heat preservation treatment is performed at $725 \sim 750^\circ\text{C}$, and the heat preservation time is controlled at 15-30 minutes;

[0154] Adding the refining agent: 0.2% aluminum-titanium-boron master alloy is added to the refined aluminum water, and is stirred when it melts, and refining is continuously performed;

[0155] Heat preservation and standing: After refining, the aluminum water flows into a heat preservation pool, and when the temperature is controlled at 710 ± 3 degrees, the slag and impurities on the surface of the aluminum water are removed after the aluminum water stands for 10 ± 2 minutes;

[0156] Casting: When the mold is preheated at 250-400 degrees, the refined modified aluminum alloy with the above temperature controlled at 700 ± 5 degrees is cast into the mold, and the modified aluminum alloy blank is obtained after cooling.

[0157] The metallographic structure image of the product obtained in this embodiment is similar to that of Embodiment

1. Details are not described herein.

Table 2 Evaluation results of mechanical properties of the high-strength composite modified aluminum alloy part in Embodiment 2

Mechanical properties	Before modification	Modified alloy 2	Embodiment 2
Tensile strength (MPa)	130 ± 3.5	200 ± 5.5	300 ± 5
Yield strength (MPa)	65 ± 5.5	95 ± 4.2	235 ± 5
Elongation (%)	3 ± 0.25	16.6 ± 0.35	8.4 ± 0.35

[0158] The modified alloy 2 represents the blank after modification without heat treatment.

[0159] It can be learned from Table 2 that similar results to those in Embodiment 1 can also be obtained by using the heat treatment in Embodiment 2.

[0160] At the same time, it can be learned that, compared with Embodiment 2, the rare earth aluminum alloy and the aluminum-strontium master alloy are first melted to prepare a composite rare earth aluminum alloy, and the composite modified aluminum alloy part obtained by modifying the composite rare earth aluminum alloy has higher comprehensive mechanical properties.

Embodiment 3

[0161] In this embodiment, compared with Embodiment 1, except that ZL111 is used instead of A356, the rest contents are the same.

[0162] For specific preparation, reference may be made to Embodiment 1. Details are omitted herein.

[0163] In addition, the mechanical properties of the ZL111 aluminum alloy (denoted as: before modification), the blank after modification (denoted as: modified alloy 3), and the part after heat treatment (denoted as: Embodiment 3) are evaluated. The evaluation results are shown in Table 3 below.

Table 3 Evaluation results of mechanical properties of the high-strength composite modified aluminum alloy part in Embodiment 3

Mechanical properties	Before modification	Modified alloy 3	Embodiment 3
Tensile strength (MPa)	160 ± 4.5	240 ± 5	350 ± 5
Yield strength (MPa)	75 ± 4.5	120 ± 5	240 ± 5
Elongation (%)	3 ± 0.25	15 ± 0.5	10 ± 0.35

[0164] It can be learned from Table 3 that similar results to those in Embodiments 1 and 2 can also be obtained by using the heat treatment in Embodiment 3. That is, the preparation process of the present invention is also applicable to the eutectic aluminum alloy, and better strength and higher toughness can be obtained.

[0165] The above description is the preferred embodiment of the present invention. It should be noted that for the person skilled in the art, various improvements and modifications can be made without departing from the principles disclosed in the present invention, and these improvements and modifications should also be considered within the scope of protection of the present invention.

Claims

1. A method for preparing a high-strength composite modified aluminum alloy part, comprising the following steps:

step S1, providing an aluminum alloy melt;

step S2, providing a modifier; wherein

the modifier is a combination of a rare earth aluminum alloy, an aluminum-strontium master alloy, and an aluminum-titanium or aluminum-titanium-boron master alloy, or

the modifier is a combination of a composite rare earth aluminum alloy and an aluminum-titanium or aluminum-titanium-boron master alloy, and the composite rare earth aluminum alloy contains strontium, titanium or titanium boron, and a rare earth metal, and

the rare earth metal in the rare earth aluminum alloy and the composite rare earth aluminum alloy is any one or more of lanthanum, cerium, and yttrium;

step S3, adding the modifier to the aluminum alloy melt under an inert gas atmosphere and melting, to obtain a modified aluminum alloy melt;

step S4, performing casting by using the modified aluminum alloy melt, to obtain a modified aluminum alloy blank; and

step S5, performing a heat treatment on the modified aluminum alloy blank, wherein the heat treatment comprises:

a solution treatment, heating the modified aluminum alloy blank to 530-550°C, and holding for 100-300 min;

a water quenching treatment, adding the modified aluminum alloy blank after the solution treatment into a water bath at a temperature of 60-70°C, and quenching with water for 2-4 min; and

an aging treatment, holding the modified aluminum alloy blank after the water quenching treatment at 150-165°C for 120-280 min, then further cooling to 110-130°C and holding for 30-120 min, and then naturally cooling to room temperature, to obtain the high-strength composite modification alloy part.

2. The preparation method according to claim 1, wherein the step S1 comprises:

providing an aluminum alloy ingot;

removing an oxide scale layer on a surface of the aluminum alloy ingot, cleaning, and drying; and

melting the dried aluminum alloy ingot, refining, and removing slag, to obtain the aluminum alloy melt, wherein the composition of the aluminum alloy ingot is a hypoeutectic aluminum alloy or a eutectic aluminum alloy.

3. The preparation method according to claim 1, wherein the modifier is a combination of a rare earth aluminum alloy, an aluminum-strontium master alloy, and an aluminum-titanium or aluminum-titanium-boron master alloy, wherein the aluminum-strontium master alloy and the aluminum-titanium or aluminum-titanium-boron master alloy are added at intervals, and

the rare earth aluminum alloy is added first, or added together with the first added component, or added at an interval between adding the aluminum-strontium master alloy and adding the aluminum-titanium or aluminum-titanium-boron master alloy.

4. The preparation method according to claim 3, wherein the step S3 comprises:

step S301, adding the rare earth aluminum alloy into the aluminum alloy melt and melting, to obtain a first homogeneously mixed melt;

step S302, adding the aluminum-strontium master alloy into the first homogeneously mixed melt and continuing melting, to obtain a second homogeneously mixed melt; and

step S303, adding the aluminum-titanium or aluminum-titanium-boron master alloy into the second homogeneously mixed melt and continuing melting, to obtain the modified aluminum alloy.

5. The preparation method according to claim 1, wherein the modifier is a combination of a composite rare earth aluminum alloy and an aluminum-titanium or aluminum-titanium-boron master alloy, and the step S3 comprises:

step S310, adding the composite rare earth aluminum alloy into the aluminum alloy melt and melting, to obtain a fourth homogeneously mixed melt; and

step S320, adding the aluminum-titanium or aluminum-titanium-boron master alloy into the fourth homogeneously mixed melt and continuing melting, to obtain the modified aluminum alloy.

6. The preparation method according to claim 5, wherein the preparation of the composite rare earth aluminum alloy comprises:

step S211, providing the aluminum melt;

step S212, providing an aluminum-strontium master alloy, an aluminum-titanium or aluminum-titanium-boron master alloy, and a rare earth aluminum master alloy, wherein the rare earth metal in the rare earth aluminum master alloy is one or more selected from lanthanum, cerium, and yttrium; and

step S213, under an inert gas atmosphere, sequentially adding the rare earth aluminum alloy, the aluminum-strontium master alloy, and the aluminum-titanium or aluminum-titanium-boron master alloy into the aluminum melt and melting, to obtain the composite rare earth aluminum alloy.

7. The preparation method according to claim 1, wherein the modifier accounts for 0.4-0.6wt% of the total amount of the modified aluminum alloy melt, and the mass ratio of the total amount of the rare earth metal: strontium: titanium or titanium boron is 1:(0.1-1.2):(0.1-1.2).
8. The preparation method according to claim 1, wherein in the step S5, a heating rate in the solution treatment is controlled at 1.5-3°C/min, and the holding time is controlled within 120-180 min.
9. The preparation method according to claim 1, wherein the solution treatment, the water quenching treatment, and the aging treatment are continuous treatments, and the water bath is a circulating water bath, and after the water quenching treatment, before the aging treatment is performed, the temperature of the cast aluminum alloy blank is kept above 55°C.
10. The preparation method according to claim 1, wherein in the aging treatment stage, the temperature is cooled from 150-165°C to 110-130°C at a cooling rate of 2-5°C/min.
11. A high-strength composite modified aluminum alloy part, wherein the high-strength composite modified aluminum alloy part is obtained by the preparation method according to any one of claims 1 to 10, a tensile strength of the high-strength composite modified aluminum alloy part is 300MPa or more, a yield strength is 230MPa or more, and an elongation rate is 6% or more.

Amended claims under Art. 19.1 PCT

1. A method for preparing a high-strength composite modified aluminum alloy part, comprising the following steps:
step S1, providing an aluminum alloy melt;
step S2, providing a modifier, wherein the modifier accounts for 0.4-0.6wt% of the total amount of the modified aluminum alloy melt, wherein the modifier is a combination of a composite rare earth aluminum alloy and an aluminum-titanium master alloy or a composite rare earth aluminum alloy and an aluminum-titanium-boron master alloy, the composite rare earth aluminum alloy contains strontium, titanium or titanium and boron, and a rare earth metal, and the mass ratio of the total amount of the rare earth metal: strontium: titanium or titanium and boron in the composite rare earth aluminum alloy is 1: (0.1-1.2): (0.1-1.2),
the rare earth metal in the composite rare earth aluminum alloy is any one or more of lanthanum, cerium, and yttrium, and
the preparation of the composite rare earth aluminum alloy comprises:

step S211, providing an aluminum melt;
step S212, providing an aluminum-strontium master alloy, an aluminum-titanium or aluminum-titanium-boron master alloy, and a rare earth aluminum master alloy, wherein the rare earth metal in the rare earth aluminum master alloy is one or more selected from lanthanum, cerium, and yttrium; and
step S213, under an inert gas atmosphere, sequentially adding the rare earth aluminum alloy, the aluminum strontium master alloy, and the aluminum-titanium or aluminum-titanium-boron master alloy into the aluminum melt and melting, to obtain the composite rare earth aluminum alloy;
step S3, adding the modifier to the aluminum alloy melt under an inert gas atmosphere and melting, to obtain a modified aluminum alloy melt;
step S4, performing casting by using the modified aluminum alloy melt, to obtain a modified aluminum alloy blank; and
step S5, performing a heat treatment on the modified aluminum alloy blank, wherein the heat treatment comprises:

a solution treatment, heating the modified aluminum alloy blank to 530-550°C, and holding for 100-300 min;
a water quenching treatment, adding the modified aluminum alloy blank after the solution treatment into a water bath at a temperature of 60-70°C, and quenching with water for 2-4 min; and
an aging treatment, holding the modified aluminum alloy blank after the water quenching treatment at 150-165°C for 120-280 min, then further cooling to 110-130°C and holding for 30-120 min, and then naturally cooling to room temperature, to obtain the high-strength composite modification alloy part.

2. The preparation method according to claim 1, wherein the step S1 comprises:

providing an aluminum alloy ingot;
removing an oxide scale layer on a surface of the aluminum alloy ingot, cleaning, and drying; and
melting the dried aluminum alloy ingot, refining, and removing slag, to obtain the aluminum alloy melt, wherein
the composition of the aluminum alloy ingot is a hypoeutectic aluminum alloy or a eutectic aluminum alloy.

3. The preparation method according to claim 1, wherein the step S3 comprises:

step S310, adding the composite rare earth aluminum alloy into the aluminum alloy melt and melting, to obtain
a fourth homogeneously mixed melt; and
step S320, adding the aluminum-titanium or aluminum-titanium-boron master alloy into the fourth homogene-
ously mixed melt and continuing melting, to obtain the modified aluminum alloy.

4. The preparation method according to claim 1, wherein in the step S5, a heating rate in the solution treatment is
controlled at 1.5-3°C/min, and the holding time is controlled within 120-180min.

5. The preparation method according to claim 1, wherein the solution treatment, the water quenching treatment, and
the aging treatment are continuous treatments, and
the water bath is a circulating water bath, and after the water quenching treatment, before the aging treatment is
performed, the temperature of the cast aluminum alloy blank is kept above 55°C.

6. The preparation method according to claim 1, wherein in the aging treatment stage, the temperature is cooled from
150-165°C to 110-130°C at a cooling rate of 2-5°C/min.

7. A high-strength composite modified aluminum alloy part, wherein the high-strength composite modified aluminum
alloy part is obtained by the preparation method according to any one of claims 1-6, a tensile strength of the high-
strength composite modified aluminum alloy part is 300MPa or more, a yield strength is 230MPa or more, and an
elongation rate is 6% or more

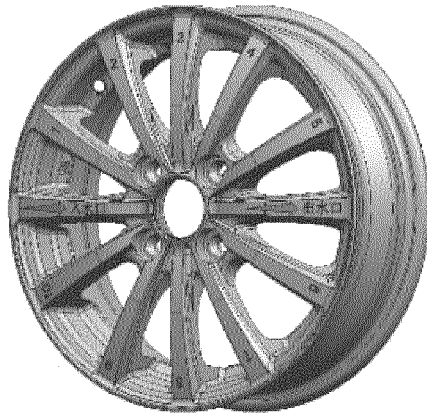


FIG. 1

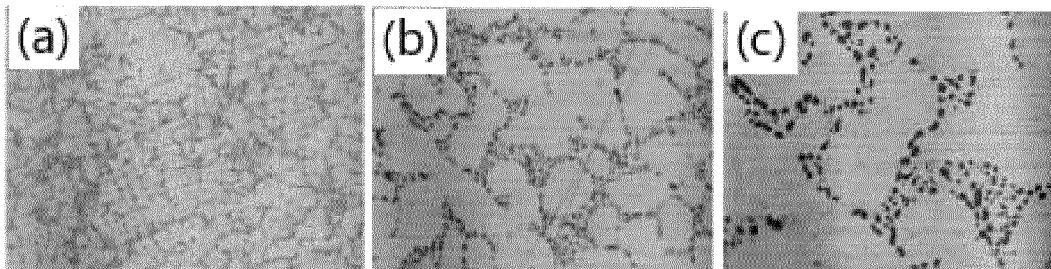


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2022/141288

A. CLASSIFICATION OF SUBJECT MATTER

C22C1/03(2006.01)i;C22C1/06(2006.01)i;C22C21/00(2006.01)i;C22F1/04(2006.01)i

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)

IPC: C22C1/, C22C21/, C22F1/04

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

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

DWPI; CNABS; CNTXT; CNKI: 稀土, 铝, 铝锆, 铝钛, 铝钛硼, 固溶, 时效, rare w earth, RE, aluminum, Al, AlSr, AlTi, AlTiB, Al-Sr, Al-Ti, Al-Ti-B, solution, aging

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 114277271 A (LIYUNGANG STAR-BLAZED MATERIAL SCIENCE AND TECHNOLOGY LIMITED COMPANY) 05 April 2022 (2022-04-05) claims 1-11	1-11
Y	CN 112522554 A (BAODING LIZHONG WHEEL MANUFACTURING CO., LTD.) 19 March 2021 (2021-03-19) description, paragraphs 64 and 125	1-11
Y	CN 1036229 A (HUADONG POLYTECHNIC INSTITUTE) 11 October 1989 (1989-10-11) description, page 5, last paragraph	1-11
Y	CN 108467979 A (SHANGHAI JIAO TONG UNIVERSITY) 31 August 2018 (2018-08-31) description, paragraphs 16-34	1-11
Y	US 5076859 A (ALUMINUM COMPANY OF AMERICA) 31 December 1991 (1991-12-31) description, column 3, line 45 to column 4, line 18	1-11
Y	CN 103938004 A (SOUTHEAST UNIVERSITY) 23 July 2014 (2014-07-23) description, paragraphs 5-7	3-4

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

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“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

22 February 2023

Date of mailing of the international search report

10 March 2023

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2022/141288

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN	114277271	A	05 April 2022	None	
CN	112522554	A	19 March 2021	None	
CN	1036229	A	11 October 1989	None	
CN	108467979	A	31 August 2018	None	
US	5076859	A	31 December 1991	None	
CN	103938004	A	23 July 2014	None	

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