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(71) Applicant: **SHENYUANCHUANG (SHANGHAI) ADVANCED MATERIAL TECHNOLOGY CO., LTD.**
Shanghai 201611 (CN)

(72) Inventor: **WANG, Xin**
Shanghai 201611 (CN)

(74) Representative: **Gulde & Partner**
Patent- und Rechtsanwaltskanzlei mbB
Wallstraße 58/59
10179 Berlin (DE)

(54) NON-HEAT-TREATED HIGH-TOUGHNESS DIE-CASTING ALUMINUM-SILICON ALLOY AND PREPARATION METHOD THEREFOR

(57) This invention discloses a non-heat treatable die-cast aluminum-silicon (Al-Si) alloy with high toughness and its preparation method. By controlling the Mn/Fe ratio to a specific value, the adverse effects of Fe in the alloy can be effectively suppressed. In addition, a certain proportion of rare earth elements are introduced into the alloy to effectively refine the Si and form high-temperature phases with elements such as Al and Cu, therefore improving the deformation resistance of the alloy when applied to one-piece die-cast large-scale structural parts. When taking specimens from the casting after die casting for testing, the specimens have the following properties: tensile strength 290Mpa, yield strength 140Mpa, and elongation 13%. The alloy also has excellent die-cast molding performance, and the energy used is clean, which meets low-carbon emission standards.

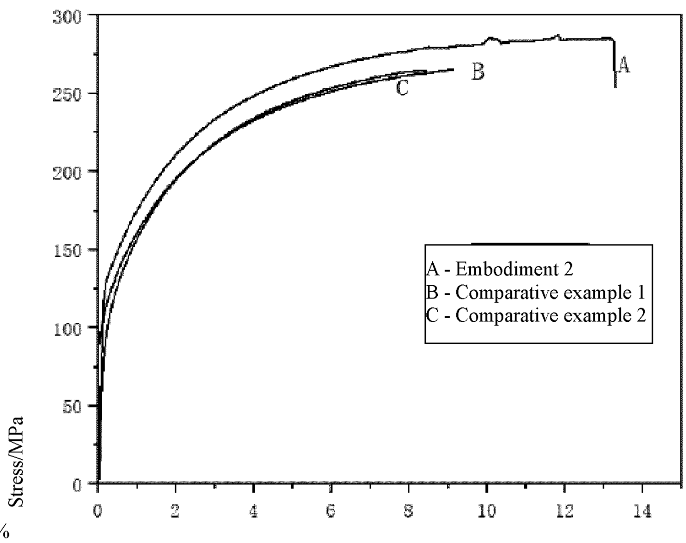

Figure 3

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Description

CROSS-REFERENCE OF RELATED APPLICATIONS

[0001] This application claims priority to Chinese Patent Application No. 202111507879.5 entitled " A non-heat treatable die-cast Al-Si alloy with high toughness and its preparation method " and filed December 10th, 2021, which is hereby incorporated by reference in its entirety.

Technical Field

[0002] This invention relates to the technical field of metal materials, particularly relating to a non-heat treatable die-cast Al-Si alloy with high toughness and its preparation method.

Background

[0003] As the policies about peak carbon dioxide emissions and carbon neutrality become tighter and the carbon emission index values continue to be lowered, recycled aluminum shows its obvious advantage of low energy consumption, and helps the aluminum industry move away from the dependency on electricity price. Taking recycled aluminum as the leading product is more conducive to the healthy, stable and long-term development of the aluminum industry. The carbon emission of recycled aluminum is significantly lower than that of virgin aluminum extracted by electrolysis, which consumes a significant amount of thermal power. Extracting 1 ton of aluminum from aluminum oxide emits about 12 tons of carbon dioxide, while producing 1 ton recycled aluminum only emits about 300Kg of carbon dioxide, saving about 3.4 tons of standard coal and 14 cubic meters of water, and reducing the solid waste emission by 20 tons. If 1 ton of standard coal emits 3 tons of carbon dioxide, plus the carbon emissions from other auxiliary materials, 1 ton of recycled aluminum can reduce a total of about 11.5 tons of carbon dioxide emissions. In addition, the economic benefits of recycled aluminum are significant. The production of virgin aluminum involves the mining and long-distance transportation of bauxite. The production of aluminum oxide and the extraction of aluminum by electrolysis consumes a huge amount of energy, and compared with the virgin aluminum, the production cost of recycled aluminum is lower. With the rapid growth of the amount of aluminum scrap in China and the continuous improvement of the recycling system of waste resources, the price of aluminum scrap is expected to further decline, and the cost advantage of recycled aluminum production over virgin aluminum extraction by electrolysis will be more distinct. Or clean energy (such as hydropower, wind power or photovoltaic energy) can be used to extract virgin aluminum by electrolysis to avoid CO_2 emissions.

[0004] In recent years, in consideration of the continuous emergence and development of new energy vehicles, the battery-driven new energy vehicles being constrained by the weight and the distance per charge of the power battery, and the high pressure from energy-saving and automotive emission reduction policies, there is a more urgent need for body weight reduction than conventional vehicles in vehicle design and material selection. As one of the lightweight materials, aluminum alloy has comparative advantages in both application technologies and operational safety and recycling performance, so aluminum alloy has gradually replaced steel in the automotive industry, and the die-casting process has been widely used to produce automotive parts and components from aluminum alloy.

[0005] The automotive and aerospace industries have stringent demands on components, and the materials are required to have excellent impact toughness and high elongation even when deformed. In view of this, large-scale one-piece body structural parts have been proposed in the automotive industry, requiring the tensile strength of its aluminum alloy die castings greater than 180MPa, the yield strength greater than 120MPa, and the elongation greater than 10%. Although the conventional Al-Si alloy has good strength and good casting properties, its plasticity is poor, and the elongation is low. Therefore this material does not meet the molding requirements of large-scale one-piece die castings in automotive industry. In recent years, more attentions have been paid to the development of high toughness aluminum alloys to meet the needs of the automotive market, such as the Silafont-36 alloy developed by Rheinland (patent number US6364970B1), which has an elongation of no more than 6% at room temperature. After a long time of T7 heat treatment, the tensile strength of Silafont-36 is about 210Mpa, the yield strength reaches 140Mpa, and the elongation becomes 15%, which then meet the requirements of structural parts. However, this process has the disadvantages of low production efficiency, complex heat treatment which is not easy to control and the cost is very high. Another example is the non-heat treatable die-cast Al-Mg-Si alloys with high strength and high toughness developed by Shanghai Jiaotong University (patent number CN108754256A). Such Al-Mg-Si alloys have excellent mechanical properties, but the casting properties are poor. High Mg content is prone to be oxidized and causes burning loss; the viscosity of the molten aluminum alloy is high; and the shrinkage is high, which cause a great erosion to the die-casting molds, reduce the life of molds, and make such alloys unsuitable for producing large-scale structural body parts. In addition, Fengyang Aiersi and Shanghai Jiaotong University have developed a non-heat treatable self-strengthened Al-Si alloy, which requires high control on impurity elements and cannot be produced from aluminum scrap. So this alloy cannot meet the future demands in the context of carbon emissions control. Moreover, the elongation of precision die-castings is about 7.5%, which cannot meet the high toughness requirement for large-scale body structural parts at the present stage. For example, Shanghai Wantai Aluminum Co.,Ltd. and Shanghai Jiaotong University have developed a high strength and high toughness die-casting aluminum alloy (patent number CN109881056A). Although the alloy has good casting properties, the elongation of its non-heat treatable die castings is only 7%, which cannot meet the high toughness requirement for automotive structural parts. Another example is a high toughness die-cast aluminum alloy developed by Suzhou Hyspeed Light Alloy Processing Technology Co., Ltd. (patent number CN106636787A), which has good casting properties and strength, but the content of impurity elements shall be controlled at 0.005% or less. Considering the extremely high requirement on impurities control, it is also impossible to produce with aluminum scrap. Meanwhile, the elongation of its non-heat treatable die castings is only up to 9.7%, which does not meet the high toughness requirement of large-scale one-piece structural parts.

Summary of the invention

[0006] The summary of the invention is provided in order to present the ideas in a brief form, which will be described in detail later in the section Embodiments. The summary of the invention is not intended to identify the key or essential features of the technical solution claimed for protection, nor is it intended to be used to limit the scope of the technical solution claimed for protection.

[0007] This invention provides a non-heat treatable die-cast Al-Si alloy with high toughness and its preparation method, which reduces the carbon emissions from production and achieves an elongation of 11%-16% with no need for heat treatment.

[0008] In the first aspect, the embodiments of the invention disclose a non-heat treatable die-cast Al-Si alloy with high toughness, which is characterized in that it consists of the following components (in percent by weight):
Si: 6.3-8.3%; Fe: 0.07-0.45%; Cu: 0.05-0.5%; Mn: 0.5-0.8%; Mg: 0.15-0.35%; Ti: 0.01-0.2%; Sr: 0.015-0.035%; rare earth elements: 0.04%-0.2% (the rare earth elements include at least one of La/Ce/Sc); Ni: 0.001-0.1%; Zn: 0.005-0.1%; Ga: 0.01-0.03%; the total amount of other impurities shall be less than or equal to 0.2%, and the balance is Al.

[0009] Optionally, the die-cast Al-Si alloy consists of the following components (in percent by weight):
Si: 6.3-7.0%; Fe: 0.2-0.4%; Cu: 0.35-0.45%; Mn: 0.5-0.8%; Mg: 0.25-0.35%; Ti: 0.1-0.2%; Sr: 0.015-0.035%; rare earth elements: 0.04%-0.2% (the rare earth elements include at least one of La/Ce/Sc); Ni: 0.001-0.1%; Zn: 0.005-0.1%; Ga: 0.01-0.03%; the total amount of other impurities shall be less than or equal to 0.2%, and the balance is Al.

[0010] Optionally, the die-cast Al-Si alloy consists of the following components (in percent by weight):
Si: 6.4-7.1%; Fe: 0.10-0.25%; Cu: 0.05-0.28%; Mn: 0.5-0.8%; Mg: 0.25-0.35%; Ti: 0.03-0.16%; Sr: 0.025-0.035%; rare earth elements: 0.04%-0.15% (the rare earth elements include at least one of La/Ce/Sc); Ni: 0.001-0.1%; Zn: 0.005-0.1%; Ga: 0.01-0.03%; the total amount of other impurities shall be less than or equal to 0.2%, and the balance is Al.

[0011] Optionally, the die-cast Al-Si alloy consists of the following components (in percent by weight):
Si: 7.0-7.7%; Fe: 0.15-0.3%; Cu: 0.2-0.35%; Mn: 0.6-0.8%; Mg: 0.2-0.3%; Ti: 0.05-0.2%; Sr: 0.015-0.035%; rare earth elements: 0.04%-0.2% (the rare earth elements include at least one of La/Ce/Sc); Ni: 0.001-0.1%; Zn: 0.005-0.1%; Ga: 0.01-0.03%; the total amount of other impurities shall be less than or equal to 0.2%, and the balance is Al.

[0012] Optionally, the die-cast Al-Si alloy consists of the following components (in percent by weight):
Si: 7.7-8.3%; Fe: 0.07-0.2%; Cu: 0.05-0.2%; Mn: 0.6-0.8%; Mg: 0.15-0.3%; Ti: 0.01-0.15%; Sr: 0.015-0.035%; rare earth elements: 0.04%-0.2% (the rare earth elements include at least one of La/Ce/Sc); Ni: 0.001-0.1%; Zn: 0.005-0.1%; Ga: 0.01-0.03%; the total amount of other impurities shall be less than or equal to 0.2%, and the balance is Al.

[0013] Optionally, the die-cast Al-Si alloy has a tensile strength greater than or equal to 270Mpa, a yield strength greater than or equal to 130Mpa, and an elongation greater than or equal to 11%.

[0014] In the second aspect, the embodiments of the invention disclose a process method for preparing the die-cast Al-Si alloy, which is characterized in that it comprises the following steps:
In terms of the preparation of the die-cast Al-Si alloy, first, the raw materials not easy to cause burning loss are heated and melted to obtain molten aluminum alloy. Next the molten aluminum alloy is de-slagged and refined before adding the raw materials that are easy to cause burning loss. Then after the composition reaches the specified value, pour the molten alloy into molds to obtain the die-cast Al-Si alloy.

[0015] Optionally, it also comprises the die-casting of the Al-Si alloy. For the Al-Si alloy, the die-casting temperature is 680-720°C, the die-casting speed is 2.5-5m/s, and the holding time is 2-10s, and then the non-heat treatable die casting is obtained.

[0016] Optionally, it also comprises the following operations: after all raw materials are completely melted, the molten aluminum alloy is stirred well, left to stand and then sampled and analyzed to adjust the contents of required elements to the required composition range.

[0017] Optionally, the refining agent used does not contain Na ions.

[0018] This invention provides a non-heat treatable die-cast Al-Si alloy with high toughness and its preparation method.

[0019] The aluminum alloy disclosed by the present invention breaks the limitation that the traditional die-cast aluminum alloy needs T7 heat treatment before it can meet the requirements of structural body parts. Meanwhile, this alloy can be produced from aluminum scrap, which reduces the carbon emissions from production and achieves an elongation of 11%-16% with no need for heat treatment.

[0020] It is important to understand that both the general description above and the detailed description below are merely exemplary in nature and are intended to provide a further description of the invention claimed for protection.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] By referring to the figures, the following embodiments, the above and other features, advantages and aspects of the embodiments of the present disclosure will become more distinct. In these figures, the same or similar marks indicate the same or similar elements. It shall be understood that the figures are only schematic and the originals and elements would not be plotted to scale.

Figure 1 shows the microstructure metallographs of the die-cast aluminum alloy obtained in Embodiment 2, where Figure (a) is a 100X metallograph of microstructure, and Figure (b) is a 500X metallograph of microstructure.

Figure 2 illustrates the fluidity test mold for the die-cast aluminum alloy obtained in Embodiment 2.

Figure 3 shows the tensile stress-strain curves of the die-cast aluminum alloy obtained in Embodiment 2, Comparative example 1 and Comparative example 2.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0022] The embodiments of the present disclosure will be described in detail below by referring to the figures. Although certain embodiments of the disclosure are shown in the figures, it is important to understand that the disclosure may be implemented in various forms and shall not be construed as being limited to the embodiments described herein. Instead, these embodiments are provided for a more thorough and complete understanding of the present disclosure. It is important to understand that the figures and embodiments of the present disclosure are merely exemplary in nature and are not intended to limit the scope of protection of the disclosure.

[0023] It is important to understand that the individual steps described in the method embodiments of the disclosure may be performed in a different order, and/or in parallel. In addition, the method embodiments may include additional steps and/or omit the illustration of some performed steps. The scope of the present disclosure is not limited in this regard.

[0024] The present disclosure provides a non-heat treatable die-cast Al-Si alloy with high toughness and its preparation method. The embodiments of the present disclosure are described in detail as follows through Figures.

Embodiment 1

[0025] In this embodiment, a non-heat treatable die-cast Al-Si alloy with high toughness produced from renewable energy for low carbon emission is provided, which consists of the following components (in percent by weight): Mg: 0.2%; Si: 6.5%; Fe: 0.15%; Cu: 0.1%; Mn: 0.5%; Ti: 0.03%; Sr: 0.025%; total amount of La and Ce: 0.05%; Ni: 0.005%; Zn: 0.006%; Ga: 0.015%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.

[0026] In this embodiment, a method for preparing the non-heat treatable die-cast Al-Si alloy is disclosed, which comprises the following steps:

(1) Furnace preparation: clean the furnace hearth and start heating the furnace up until the furnace wall turns red. Dry and preheat all operating tools after they have been coated with graphite powder.

(2) Dosing: prepare Al ingots, Mg ingots, industrial Si, the intermediate alloy Al-Mn or Mn, Fe, the intermediate alloy Al-Ti, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga, the intermediate alloy Al-Sr, and the aluminum rare earth alloy as raw materials for the preparation of the aluminum alloy. Then add these raw materials in the above proportions, taking into account the burning loss.

(3) Charge to the furnace for melting: first put the Al ingots into the furnace for melting, and the melting temperature is controlled at 760-790°C. After all the Al ingots are melted, the temperature is increased and controlled at 760-780°C. Then the industrial Si, Fe, the intermediate alloy Al-Mn or Mn, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga are added for smelting.

(4) Refining and slagging off: the temperature of the molten aluminum alloy is controlled at 740-760°C for stirring well. Refining agent special for aluminum alloy is then added for primary injection refining and secondary injection refining, and the time interval between two refinements is controlled at 50-60min. Perform slagging off after each refining to remove the flux and dross from the hearth.

(5) Add other metallic elements: when the molten alloy temperature is 740-760°C, the intermediate alloy Al-Ti, the

aluminum rare earth alloy, Mg, the intermediate alloy Al-Sr are added for alloy refinement and modification. After the materials are fully melted, the molten aluminum alloy is sampled for analysis.

(6) Furnace degassing: when the melting temperature is maintained at 740-760°C, degas the furnace for 30-50min, and then leave to stand for 15-30min.

(7) Casting or die-casting: once the composition analysis results of on-the-spot sample are qualified, cast into finished ingots at casting temperature or perform high pressure casting through die casting process to obtain non-heat treatable die castings.

Embodiment 2

[0027] In this embodiment, a non-heat treatable die-cast Al-Si alloy with high toughness produced from renewable energy for low carbon emission is provided, which consists of the following components (in percent by weight): Mg: 0.3%; Si: 6.9%; Fe: 0.2%; Cu: 0.2%; Mn: 0.6%; Ti: 0.07%; Sr: 0.02%; La: 0.1%; Ni: 0.003%; Zn: 0.07%; Ga: 0.02%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.

[0028] In this embodiment, a method for preparing the non-heat treatable die-cast Al-Si alloy is disclosed, which comprises the following steps:

(1) Furnace preparation: clean the furnace hearth and start heating the furnace up until the furnace wall turns red. Dry and preheat all operating tools after they have been coated with graphite powder.

(2) Dosing: prepare Al ingots or aluminum scrap, Mg ingots, industrial Si, the intermediate alloy Al-Mn or Mn, Fe, the intermediate alloy Al-Ti, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga, the intermediate alloy Al-Sr, and the aluminum rare earth alloy as raw materials for the preparation of the aluminum alloy. Then add these raw materials in the above proportions, taking into account the burning loss.

(3) Charge to the furnace for melting: first put the Al ingots or aluminum scrap into the furnace for melting, and the melting temperature is controlled at 760-790°C. After all the Al ingots or aluminum scrap are melted, the temperature is increased and controlled at 760-780°C. Then the industrial Si, Fe, the intermediate alloy Al-Mn or Mn, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga are added for smelting.

(4) Refining and slagging off: the temperature of the molten aluminum alloy is controlled at 740-760°C for stirring well. Refining agent special for aluminum alloy is then added for primary injection refining and secondary injection refining, and the time interval between two refinements is controlled at 50-60min. Perform slagging off after each refining to remove the flux and dross from the hearth.

(5) Add other metallic elements: when the molten alloy temperature is 740-760°C, the intermediate alloy Al-Ti, the aluminum rare earth alloy, Mg, the intermediate alloy Al-Sr are added for alloy refinement and modification. After the materials are fully melted, the molten aluminum alloy is sampled for analysis.

(6) Furnace degassing: when the melting temperature is maintained at 740-760°C, degas the furnace with nitrogen for 30-50min, and then leave to stand for 15-30min.

(7) Casting or die-casting: once the composition analysis results of on-the-spot sample are qualified, cast into finished ingots at casting temperature or perform high pressure casting through die casting process to obtain non-heat treatable die castings.

Embodiment 3

[0029] In this embodiment, a non-heat treatable die-cast Al-Si alloy with high toughness produced from renewable energy for low carbon emission consists of the following components (in percent by weight): Mg: 0.35%; Si: 7.5%; Fe: 0.25%; Cu: 0.3%; Mn: 0.7%; Ti: 0.15%; Sr: 0.03%; Ce: 0.08%; Ni: 0.08%; Zn: 0.09%; Ga: 0.025%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.

[0030] In this embodiment, a method for preparing the non-heat treatable die-cast Al-Si alloy is disclosed, which comprises the following steps:

(1) Furnace preparation: clean the furnace hearth and start heating the furnace up until the furnace wall turns red. Dry and preheat all operating tools after they have been coated with graphite powder.

(2) Dosing: prepare Al ingots or aluminum scrap, Mg ingots, industrial Si, the intermediate alloy Al-Mn or Mn, Fe, the intermediate alloy Al-Ti, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga, the intermediate alloy Al-Sr, and the aluminum rare earth alloy as raw materials for the preparation of the aluminum alloy. Then add these raw materials in the above proportions, taking into account the burning loss.

(3) Charge to the furnace for melting: first put the Al ingots or aluminum scrap into the furnace for melting, and the melting temperature is controlled at 760-790°C. After all the Al ingots or aluminum scrap are melted, the temperature is increased and controlled at 760-780°C. Then the industrial Si, Fe, the intermediate alloy Al-Mn or Mn, Cu or the

intermediate alloy Al-Cu, Ni, Zn and Ga are added for smelting.

(4) Refining and slagging off: the temperature of the molten aluminum alloy is controlled at 740-760°C for stirring well. Refining agent special for aluminum alloy is then added for primary injection refining and secondary injection refining, and the time interval between two refinements is controlled at 50-60min. Perform slagging off after each refining to remove the flux and dross from the hearth.

(5) Add other metallic elements: when the molten alloy temperature is 740-760°C, the intermediate alloy Al-Ti, the aluminum rare earth alloy, Mg, the intermediate alloy Al-Sr are added for alloy refinement and modification. After the materials are fully melted, the molten aluminum alloy is sampled for analysis.

(6) Furnace degassing: when the melting temperature is maintained at 740-760°C, degas the furnace with nitrogen for 30-50min, and then leave to stand for 15-30min.

(7) Casting or die-casting: once the composition analysis results of on-the-spot sample are qualified, cast into finished ingots at casting temperature or perform high pressure casting through die casting process to obtain non-heat treatable die castings.

Embodiment 4

[0031] In this embodiment, a non-heat treatable die-cast Al-Si alloy with high toughness produced from renewable energy for low carbon emission is provided, which consists of the following components (in percent by weight): Mg: 0.25%; Si: 7.8%; Fe: 0.35%; Cu: 0.4%; Mn: 0.8%; Ti: 0.2%; Sr: 0.035%; Sc: 0.15%; Ni: 0.02%; Zn: 0.08%; Ga: 0.012%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.

[0032] In this embodiment, a method for preparing the non-heat treatable die-cast Al-Si alloy is disclosed, which comprises the following steps:

(1) Furnace preparation: clean the furnace hearth and start heating the furnace up until the furnace wall turns red. Dry and preheat all operating tools after they have been coated with graphite powder.

(2) Dosing: prepare Al ingots or aluminum scrap, Mg ingots, industrial Si, the intermediate alloy Al-Mn or Mn, Fe, the intermediate alloy Al-Ti, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga, the intermediate alloy Al-Sr, and the aluminum rare earth alloy as raw materials for the preparation of the aluminum alloy. Then add these raw materials in the above proportions, taking into account the burning loss.

(3) Charge to the furnace for melting: first put the Al ingots or aluminum scrap into the furnace for melting, and the melting temperature is controlled at 760-790°C. After all the Al ingots or aluminum scrap are melted, the temperature is increased and controlled at 760-780°C. Then the industrial Si, Fe, the intermediate alloy Al-Mn or Mn, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga are added for smelting.

(4) Refining and slagging off: the temperature of the molten aluminum alloy is controlled at 740-760°C for stirring well. Refining agent special for aluminum alloy is then added for primary injection refining and secondary injection refining, and the time interval between two refinements is controlled at 50-60min. Perform slagging off after each refining to remove the flux and dross from the hearth.

(5) Add other metallic elements: when the molten alloy temperature is 740-760°C, the intermediate alloy Al-Ti, the aluminum rare earth alloy, Mg, the intermediate alloy Al-Sr are added for alloy refinement and modification. After the materials are fully melted, the molten aluminum alloy is sampled for analysis.

(6) Furnace degassing: when the melting temperature is maintained at 740-760°C, degas the furnace with nitrogen for 30-50min, and then leave to stand for 15-30min.

(7) Casting or die-casting: once the composition analysis results of on-the-spot sample are qualified, cast into finished ingots at casting temperature or perform high pressure casting through die casting process to obtain non-heat treatable die castings.

Embodiment 5

[0033] In this embodiment, a non-heat treatable die-cast Al-Si alloy with high toughness produced from renewable energy for low carbon emission is provided, which consists of the following components (in percent by weight): Mg: 0.15%; Si: 8.3%; Fe: 0.45%; Cu: 0.5%; Mn: 0.65%; Ti: 0.15%; Sr: 0.03%; the total amount of La and Sc: 0.2%; Ni: 0.08%; Zn: 0.01%; Ga: 0.018%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.

[0034] In this embodiment, a method for preparing the non-heat treatable die-cast Al-Si alloy is disclosed, which comprises the following steps:

(1) Furnace preparation: clean the furnace hearth and start heating the furnace up until the furnace wall turns red. Dry and preheat all operating tools after they have been coated with graphite powder.

(2) Dosing: prepare Al ingots or aluminum scrap, Mg ingots, industrial Si, the intermediate alloy Al-Mn or Mn, Fe,

the intermediate alloy Al-Ti, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga, the intermediate alloy Al-Sr, and the aluminum rare earth alloy as raw materials for the preparation of the aluminum alloy. Then add these raw materials in the above proportions, taking into account the burning loss.

(3) Charge to the furnace for melting: first put the Al ingots or aluminum scrap into the furnace for melting, and the melting temperature is controlled at 760-790°C. After all the Al ingots or aluminum scrap are melted, the temperature is increased and controlled at 760-780°C. Then the industrial Si, Fe, the intermediate alloy Al-Mn or Mn, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga are added for smelting.

(4) Refining and slagging off: the temperature of the molten aluminum alloy is controlled at 740-760°C for stirring well. Refining agent special for aluminum alloy is then added for primary injection refining and secondary injection refining, and the time interval between two refinements is controlled at 50-60min. Perform slagging off after each refining to remove the flux and dross from the hearth.

(5) Add other metallic elements: when the molten alloy temperature is 740-760°C, the intermediate alloy Al-Ti, the aluminum rare earth alloy, Mg, the intermediate alloy Al-Sr are added for alloy refinement and modification. After the materials are fully melted, the molten aluminum alloy is sampled for analysis.

(6) Furnace degassing: when the melting temperature is maintained at 740-760°C, degas the furnace with nitrogen for 30-50min, and then leave to stand for 15-30min.

(7) Casting or die-casting: once the composition analysis results of on-the-spot sample are qualified, cast into finished ingots at casting temperature or perform high pressure casting through die casting process to obtain non-heat treatable die castings.

Embodiment 6

[0035] In this embodiment, a method using recycled aluminum scrap to prepare the non-heat treatable die-cast Al-Si alloy is disclosed, which comprises the following steps:

(1) Furnace preparation: clean the furnace hearth and start heating the furnace up until the furnace wall turns red. Dry and preheat all operating tools after they have been coated with graphite powder.

(2) Dosing: the recycled aluminum scrap is sorted and processed. Then prepare Al ingots, Mg ingots, industrial Si, the intermediate alloy Al-Mn or Mn, Fe, the intermediate alloy Al-Ti, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga, the intermediate alloy Al-Sr, and the aluminum rare earth alloy as raw materials for the preparation of the aluminum alloy. Add these raw materials in the above proportions, taking into account the burning loss.

(3) Charge to the furnace for smelting: add Al ingots (40%) and aluminum scrap (60%) to the furnace in turn for smelting, and the melting temperature is controlled at 760-790°C. After all materials are completely melted, sample the molten alloy for analysis in order to adjust the contents of elements to the required composition. After that, the temperature is increased and controlled at 760-780°C. Then the industrial Si, Fe, the intermediate alloy Al-Mn or Mn, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga are added for smelting.

(4) Refining and slagging off: the temperature of the molten aluminum alloy with qualified composition is controlled at 740-760°C for stirring well. Refining agent special for aluminum alloy is then added for primary injection refining and secondary injection refining, and the time interval between two refinements is controlled at 50-60min. Perform slagging off after each refining to remove the flux and dross from the hearth.

(5) Add other metallic elements: when the molten alloy temperature is 740-760°C, the intermediate alloy Al-Ti, the aluminum rare earth alloy, Mg, the intermediate alloy Al-Sr are added for alloy refinement and modification. After the materials are fully melted, the molten aluminum alloy is sampled for analysis.

(6) Furnace degassing: when the melting temperature is maintained at 740-760°C, degas the furnace with nitrogen for 30-50min, and then leave to stand for 15-30min.

(7) Casting or die-casting: the cast alloy consists of the following components at last (in percent by weight): Mg: 0.25%; Si: 7.0%; Fe: 0.35%; Cu: 0.25%; Mn: 0.6%; Ti: 0.12%; Sr: 0.028%; the total amount of La, Ce and Sc: 0.2%; Ni: 0.005%; Zn: 0.06%; Ga: 0.02%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al. Once the composition analysis results of on-the-spot sample are qualified, cast into finished ingots at casting temperature or perform high pressure casting through die casting process to obtain non-heat treatable die castings.

Embodiment 7

[0036] In this embodiment, a method using recycled aluminum scrap to prepare the non-heat treatable die-cast Al-Si alloy is disclosed, which comprises the following steps:

(1) Furnace preparation: clean the furnace hearth and start heating the furnace up until the furnace wall turns red. Dry and preheat all operating tools after they have been coated with graphite powder.

(2) Dosing: the recycled aluminum scrap is sorted and processed. Then prepare Mg ingots, industrial Si, the intermediate alloy Al-Mn or Mn, Fe, the intermediate alloy Al-Ti, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga, the intermediate alloy Al-Sr, and the aluminum rare earth alloy as raw materials for the preparation of the aluminum alloy. Add these materials in the required proportions, taking into account the burning loss.
(3) Charge to the furnace for smelting: add aluminum scrap (100%) to the furnace for smelting, and the melting temperature is controlled at 760-790°C. After all materials are completely melted, sample the molten alloy for analysis in order to adjust the contents of elements to the required composition. After that, the temperature is increased and controlled at 760-780°C. Then the industrial Si, Fe, the intermediate alloy Al-Mn or Mn, Cu or the intermediate alloy Al-Cu, Ni, Zn and Ga are added for smelting.
(4) Refining and slagging off: the temperature of the molten aluminum alloy with qualified composition is controlled at 740-760°C for stirring well. Refining agent special for aluminum alloy is then added for primary injection refining and secondary injection refining, and the time interval between two refinements is controlled at 50-60min. Perform slagging off after each refining to remove the flux and dross from the hearth.
(5) Add other metallic elements: when the molten alloy temperature is 740-760°C, the intermediate alloy Al-Ti, the aluminum rare earth alloy, Mg, the intermediate alloy Al-Sr are added for alloy refinement and modification. After the materials are fully melted, the molten aluminum alloy is sampled for analysis.
(6) Furnace degassing: when the melting temperature is maintained at 740-760°C, degas the furnace with nitrogen for 30-50min, and then leave to stand for 15-30min.
(7) Casting or die-casting: the cast alloy consists of the following components at last (in percent by weight): Mg: 0.3%; Si: 7.7%; Fe: 0.15%; Cu: 0.3%; Mn: 0.7%; Ti: 0.15%; Sr: 0.035%; Ce: 0.08%; Ni: 0.1%; Zn: 0.1%; Ga: 0.03%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al. Once the composition analysis results of on-the-spot sample are qualified, cast into finished ingots at casting temperature or perform high pressure casting through die casting process to obtain non-heat treatable die castings.

Comparative example 1

[0037] This comparative example is an adjustment based on the composition of Embodiment 2, with fewer Sr added than that in Embodiment 2, and no La added. The alloy provided in this comparative example consists of the following components (in percent by weight): Si: 6.9%; Fe: 0.2%; Cu: 0.2%; Mn: 0.6%; Mg: 0.3%; Ti: 0.07%; Sr: 0.008%; Ni: 0.003%; Zn: 0.07%; Ga: 0.02%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.
[0038] A method for preparing the die-cast Al alloy provided in this comparative example comprises the following steps:

(1) Furnace preparation: clean the furnace hearth and start heating the furnace up until the furnace wall turns red. Dry and preheat all operating tools after they have been coated with graphite powder.
(2) Dosing: prepare Al ingots, Mg ingots, industrial Si, Cu, the intermediate alloy Al-Mn or Mn, Fe, the intermediate alloy Al-Ti, and the intermediate alloy Al-Sr as raw materials for the preparation of the aluminum alloy. Then add these materials in the above proportions, taking into account the burning loss.
(3) Charge to the furnace for smelting: first put the Al ingots into the furnace for smelting, and the melting temperature is controlled at 670-690°C. After all the Al ingots are melted, the temperature is increased and controlled at 760-780°C. Then the industrial Si, Fe, Cu, and the intermediate alloy Al-Mn or Mn are added for smelting.
(4) Refining and slagging off: the temperature of the molten aluminum alloy with qualified composition is controlled at 740-760°C for stirring well. Refining agent special for aluminum alloy is then added for primary injection refining and secondary injection refining, and the time interval between two refinements is controlled at 50-60min. Perform slagging off after each refining to remove the flux and dross from the hearth.
(5) Add other metallic elements: when the molten alloy temperature is 740-760°C, the intermediate alloy Al-Ti, Mg, and the intermediate alloy Al-Sr are added for smelting. After the materials are fully melted, the molten aluminum alloy is sampled for analysis.
(6) Furnace degassing: when the melting temperature is maintained at 740-760°C, degas the furnace with nitrogen for 30-50min, and then leave to stand for 15-30min.
(7) Casting or die-casting: once the composition analysis results of on-the-spot sample are qualified, cast into finished ingots at casting temperature or perform high pressure casting through die casting process to obtain non-heat treatable die castings.

Comparative example 2

[0039] This comparative example is an adjustment based on the composition of Embodiment 2, with more Sr added than that in Embodiment 2, and no La added. The alloy provided in this comparative example consists of the following components (in percent by weight): Si: 6.9%; Fe: 0.2%; Cu: 0.2%; Mn: 0.6%; Mg: 0.3%; Ti: 0.07%; Sr: 0.05%; Ni: 0.003%;

Zn: 0.07%; Ga: 0.02%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.

[0040] The preparation method of this comparative example is the same as that of Comparative example 1.

Comparative example 3

[0041] This comparative example is an adjustment based on the composition of Embodiment 6, and in this comparative example, the elements La, Ce, Sc, Zn, Ni and Ga are not added. The alloy provided in this comparative example consists of the following components (in percent by weight): Si: 7.0%; Fe: 0.35%; Cu: 0.25%; Mn: 0.6%; Mg: 0.25%; Ti: 0.12%; Sr: 0.028%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.

[0042] The preparation method of this comparative example is the same as that of Comparative example 1.

Comparative example 4

[0043] This comparative example is an adjustment based on the composition of Embodiment 6, and in this comparative example, the elements La, Ce and Sc are not added. The alloy provided in this comparative example consists of the following components (in percent by weight): Si: 7.0%; Fe: 0.35%; Cu: 0.25%; Mn: 0.6%; Mg: 0.25%; Ti: 0.12%; Sr: 0.028%; Ni: 0.06%; Zn: 0.005%; Ga: 0.02%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.

[0044] The preparation method of this comparative example is the same as that of Comparative example 1.

Comparative example 5

[0045] This comparative example is an adjustment based on the composition of Embodiment 6, and in this comparative example, a high content of La, Ce and Sc are added. The alloy provided in this comparative example consists of the following components (in percent by weight): Si: 7.0%; Fe: 0.35%; Cu: 0.25%; Mn: 0.6%; Mg: 0.25%; Ti: 0.12%; Sr: 0.028%; La: 0.2; Ce: 0.2; Sc: 0.2; Ni: 0.06%; Zn: 0.005%; Ga: 0.02%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.

[0046] The preparation method of this comparative example is the same as that of Comparative example 1.

Comparative example 6

[0047] This comparative example is an adjustment based on the composition of Embodiment 6, and in this comparative example, a high content of La is added. The alloy provided in this comparative example consists of the following components (in percent by weight): Si: 7.0%; Fe: 0.35%; Cu: 0.25%; Mn: 0.6%; Mg: 0.25%; Ti: 0.12%; Sr: 0.028%; La: 1.0; Ni: 0.06%; Zn: 0.005%; Ga: 0.02%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.

[0048] The preparation method of this comparative example is the same as that of Comparative example 1.

Comparative example 7

[0049] This comparative example is an adjustment based on the composition of Embodiment 6, and in this comparative example, a high content of Sc is added. The alloy provided in this comparative example consists of the following components (in percent by weight): Si: 7.0%; Fe: 0.35%; Cu: 0.25%; Mn: 0.6%; Mg: 0.25%; Ti: 0.12%; Sr: 0.028%; Sc: 0.5; Ni: 0.06%; Zn: 0.005%; Ga: 0.02%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.

[0050] The preparation method of this comparative example is the same as that of Comparative example 1.

Comparative example 8

[0051] This comparative example is an adjustment based on the composition of Embodiment 6, and in this comparative example, a high content of Sc is added. The alloy provided in this comparative example consists of the following components (in percent by weight): Si: 7.0%; Fe: 0.35%; Cu: 0.25%; Mn: 0.6%; Mg: 0.25%; Ti: 0.12%; Sr: 0.028%; La: 0.01; Sc: 0.01; Ni: 0.06%; Zn: 0.005%; Ga: 0.02%; the total amount of other impurities is less than or equal to 0.2%, and the balance is Al.

[0052] The preparation method of this comparative example is the same as that of Comparative example 1.

[0053] Table 1 shows the aluminum alloy compositions for embodiments 1 to 7 and comparative example 1 to 8.

Table 1 Alloy composition

Element	Si	Fe	Cu	Mn	Mg	Ti	Sr	La	Ce	Sc	Zn	Ni	Ga
Embodiment 1	6.5	0.15	0.1	0.5	0.2	0.03	0.025	0.02	0.03	/	0.006	0.005	0.015
Embodiment 2	6.9	0.2	0.2	0.6	0.3	0.07	0.02	0.1	/	/	0.07	0.003	0.02
Embodiment 3	7.5	0.25	0.3	0.7	0.35	0.15	0.03	/	0.08	/	0.09	0.08	0.025
Embodiment 4	7.8	0.35	0.4	0.8	0.25	0.2	0.035	/	/	0.15	0.08	0.02	0.012
Embodiment 5	8.3	0.45	0.5	0.65	0.15	0.15	0.03	0.15	/	0.05	0.01	0.08	0.018
Embodiment 6	7.0	0.35	0.25	0.6	0.25	0.12	0.028	0.05	0.1	0.05	0.06	0.005	0.02
Embodiment 7	7.7	0.15	0.3	0.7	0.3	0.15	0.035	/	0.08	/	0.1	0.1	0.03
Comparative example 1	6.9	0.2	0.2	0.6	0.3	0.07	0.008	/	/	/	0.07	0.003	0.02
Comparative example 2	6.9	0.2	0.2	0.6	0.3	0.07	0.05	/	/	/	0.07	0.003	0.02
Comparative example 3	7.0	0.35	0.25	0.6	0.25	0.12	0.028	/	/	/	/	/	/
Comparative example 4	7.0	0.35	0.25	0.6	0.25	0.12	0.028	/	/	/	0.06	0.005	0.02
Comparative example 5	7.0	0.35	0.25	0.6	0.25	0.12	0.028	0.2	0.2	0.2	0.06	0.005	0.02
Comparative example 6	7.0	0.35	0.25	0.6	0.25	0.12	0.028	1.0	/	/	0.06	0.005	0.02
Comparative example 7	7.0	0.35	0.25	0.6	0.25	0.12	0.028	/	/	0.5	0.06	0.005	0.02
Comparative example 8	7.0	0.35	0.25	0.6	0.25	0.12	0.028	0.01	/	0.01	0.06	0.005	0.02

[0054] Table 2 shows the tensile properties at room temperature of the F-state specimens and the specimens which have been held in furnace at 180°C for 30min as well as the fluidity. These specimens are taken from the Al alloy castings provided in Embodiments 1 to 7 and Comparative examples 1 to 8.

Table 2 Mechanical properties

Example	Specimen thickness, mm	Specimen state	Tensile strength, MPa	Yield strength, MPa	Elongation, %	Fluidity
Embodiment 1	3	F-state	290	130	15.1	Excellent
	3	Baked	310	153	12.6	/
Embodiment 2	3	F-state	287	139	13.3	Excellent
	3	Baked	316	167	12.2	/
Embodiment 3	3	F-state	300	145	13.0	Excellent
	3	Baked	320	178	11.5	/
Embodiment 4	3	F-state	300	138	12.3	Excellent
	3	Baked	320	165	10.8	/
Embodiment 5	3	F-state	295	133	12.4	Excellent
	3	Baked	310	159	10.3	/

(continued)

Example	Specimen thickness, mm	Specimen state	Tensile strength, MPa	Yield strength, MPa	Elongation, %	Fluidity
Embodiment 6	3	F-state	285	143	12.6	Excellent
	3	Baked	306	166	11.0	/
Embodiment 7	3	F-state	297	149	13.2	Excellent
	3	Baked	313	180	11.1	/
Comparative example 1	3	F-state	265	113	9.1	Good
	3	Baked	275	125	8.2	/
Comparative example 2	3	F-state	264	122	8.4	Good
	3	Baked	278	155	6.5	/
Comparative example 3	3	F-state	253	118	9.3	Good
	3	Baked	268	136	8.4	/
Comparative example 4	3	F-state	255	120	9.0	Good
	3	Baked	270	138	8.1	/
Comparative example 5	3	F-state	250	125	7.8	Good
	3	Baked	261	133	6.5	/
Comparative example 6	3	F-state	245	127	7.5	Good
	3	Baked	258	136	6.2	/
Comparative example 7	3	F-state	256	123	8.5	Good
	3	Baked	266	131	7.3	/
Comparative example 8	3	F-state	260	128	8.4	Good
	3	Baked	268	126	6.9	/

[0055] According to Tables 1 and 2, the content of Sr in Comparative example 1 is much lower than that in Embodiment 2; and moreover, when no rare earth element is added, the yield strength is reduced by 26Mpa and the elongation is reduced by 4.2%. Compared with Embodiment 2, the content of Sr in Comparative example 2 is much higher than that in Embodiment 2; and moreover, when no rare earth element is added, the yield strength is reduced by 17Mpa and the elongation is reduced by 4.9%. Compared with Embodiment 6, when rare earth elements, Zn, Ni and Ga are not added in Comparative example 3, the yield strength is reduced by 25Mpa and the elongation is reduced by 3.3%. Compared with Embodiment 6, when rare earth elements are not added in Comparative example 4, the yield strength is reduced by 23Mpa and the elongation is reduced by 3.6%. Compared with Embodiment 6, when the rare earth elements La, Ce and Sc are added in Comparative example 5 with a total amount of 0.6%, the yield strength is reduced by 18Mpa and the elongation is reduced by 4.8%. Compared with Embodiment 6, when the rare earth element La is added in Comparative example 6 with a total amount of 1.0%, the yield strength is reduced by 16Mpa and the elongation is reduced by 5.1%. Compared with Embodiment 6, when the rare earth element Sc is added in Comparative example 7 with a total amount of 0.5%, the yield strength is reduced by 20Mpa and the elongation is reduced by 4.1%. Compared with Embodiment 6, when the rare earth elements La and Sc are added in Comparative example 8 with a total amount of 0.02%, the yield strength is reduced by 16Mpa and the elongation is reduced by 4.2%. In summary, only when Sr and the rare earth elements La, Ce and Sc are included in the scope of this invention, the mechanical properties can be excellent. When the content of Sr and the rare earth elements La, Ce and Sc is too low or too high, the mechanical properties are not satisfied.

[0056] The above describes in detail the preferred embodiments of the invention. However, the invention is not limited thereto. Within the scope of the technical concept of the invention, various simple variants can be made for the technical solution of the invention, including the combination of individual technical features in any other suitable manner. Such simple variants and combinations shall also be considered as part of the content disclosed by the invention and are within the scope of protection of the invention.

Claims

1. A non-heat treatable die-cast Al-Si alloy with high toughness, **characterized in that** the die-cast Al-Si alloy consists of the following components ,in percent by weight:
Si: 6.3-8.3%; Fe: 0.07-0.45%; Cu: 0.05-0.5%; Mn: 0.5-0.8%; Mg: 0.15-0.35%; Ti: 0.01-0.2%; Sr: 0.015-0.035%; rare earth elements: 0.04%-0.2% (the rare earth elements include at least one of La/Ce/Sc); Ni: 0.001-0.1%; Zn: 0.005-0.1%; Ga: 0.01-0.03%; the total amount of other impurities shall be less than or equal to 0.2%, and the balance is Al.

2. A non-heat treatable die-cast Al-Si alloy with high toughness according to Claim 1,is **characterized in that** the die-cast Al-Si alloy consists of the following components (in percent by weight):
Si: 6.3-7.0%; Fe: 0.2-0.4%; Cu: 0.35-0.45%; Mn: 0.5-0.8%; Mg: 0.25-0.35%; Ti: 0.1-0.2%; Sr: 0.015-0.035%; rare earth elements: 0.04%-0.2% (the rare earth elements include at least one of La/Ce/Sc); Ni: 0.001-0.1%; Zn: 0.005-0.1%; Ga: 0.01-0.03%; the total amount of other impurities shall be less than or equal to 0.2%, and the balance is Al.

3. The non-heat treatable die-cast Al-Si alloy with high toughness according to Claim 1, is **characterized in that** the die-cast Al-Si alloy consists of the following components (in percent by weight):
Si: 6.4-7.1%; Fe: 0.10-0.25%; Cu: 0.05-0.28%; Mn: 0.5-0.8%; Mg: 0.25-0.35%; Ti: 0.03-0.16%; Sr: 0.025-0.035%; rare earth elements: 0.04%-0.15% (the rare earth elements include at least one of La/Ce/Sc); Ni: 0.001-0.1%; Zn: 0.005-0.1%; Ga: 0.01-0.03%; the total amount of other impurities shall be less than or equal to 0.2%, and the balance is Al.

4. The non-heat treatable die-cast Al-Si alloy with high toughness according to Claim 1, is **characterized in that** the die-cast Al-Si alloy consists of the following components (in percent by weight):
Si: 7.0-7.7%; Fe: 0.15-0.3%; Cu: 0.2-0.35%; Mn: 0.6-0.8%; Mg: 0.2-0.3%; Ti: 0.05-0.2%; Sr: 0.015-0.035%; rare earth elements: 0.04%-0.2% (the rare earth elements include at least one of La/Ce/Sc); Ni: 0.001-0.1%; Zn: 0.005-0.1%; Ga: 0.01-0.03%; the total amount of other impurities shall be less than or equal to 0.2%, and the balance is Al.

5. The non-heat treatable die-cast Al-Si alloy with high toughness according to Claim 1, is **characterized in that** the die-cast Al-Si alloy consists of the following components (in percent by weight):
Si: 7.7-8.3%; Fe: 0.07-0.2%; Cu: 0.05-0.2%; Mn: 0.6-0.8%; Mg: 0.15-0.3%; Ti: 0.01-0.15%; Sr: 0.015-0.035%; rare earth elements: 0.04%-0.2% (the rare earth elements include at least one of La/Ce/Sc); Ni: 0.001-0.1%; Zn: 0.005-0.1%; Ga: 0.01-0.03%; the total amount of other impurities shall be less than or equal to 0.2%, and the balance is Al.

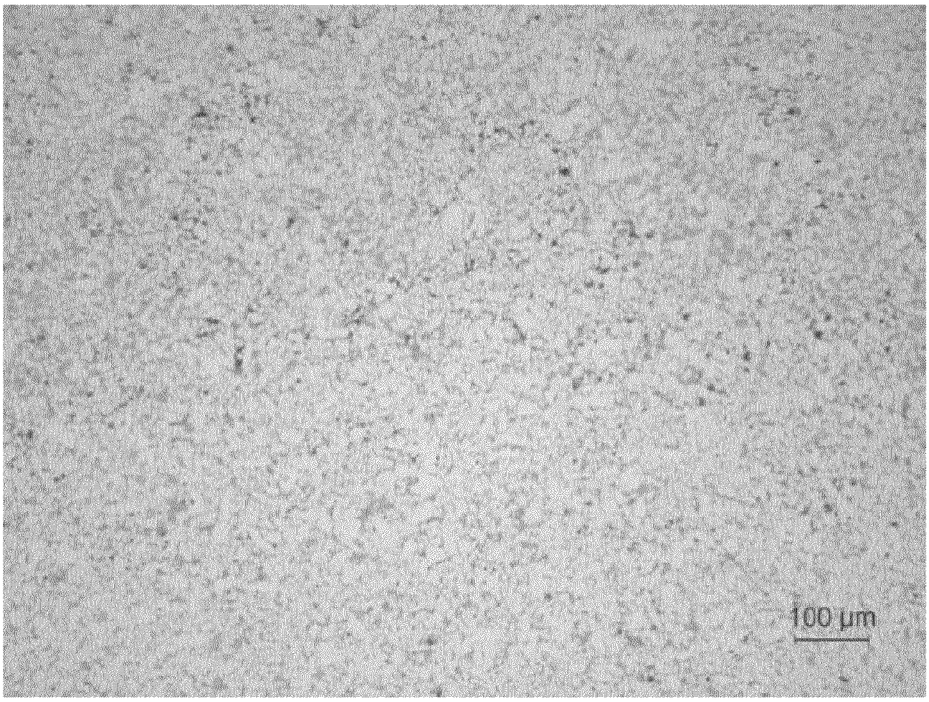
6. The non-heat treatable die-cast Al-Si alloy with high toughness according to any one of Claims 1-5, is **characterized in that** the die-cast Al-Si alloy has a tensile strength greater than or equal to 270Mpa, a yield strength greater than or equal to 130Mpa, and an elongation greater than or equal to 11%.

7. A process method for preparing the non-heat treatable die-cast Al-Si alloy with high toughness according to any one of Claims 1-6, **characterized in that** it comprises the following steps:
In terms of the preparation of the die-cast Al-Si alloy, first, the raw materials not easy to cause burning loss are heated and melted to obtain molten aluminum alloy. Next the molten aluminum alloy is de-slagged and refined before adding the raw materials that are easy to cause burning loss. Then after the composition reaches the specified value, pour the molten alloy into molds to obtain the die-cast Al-Si alloy.

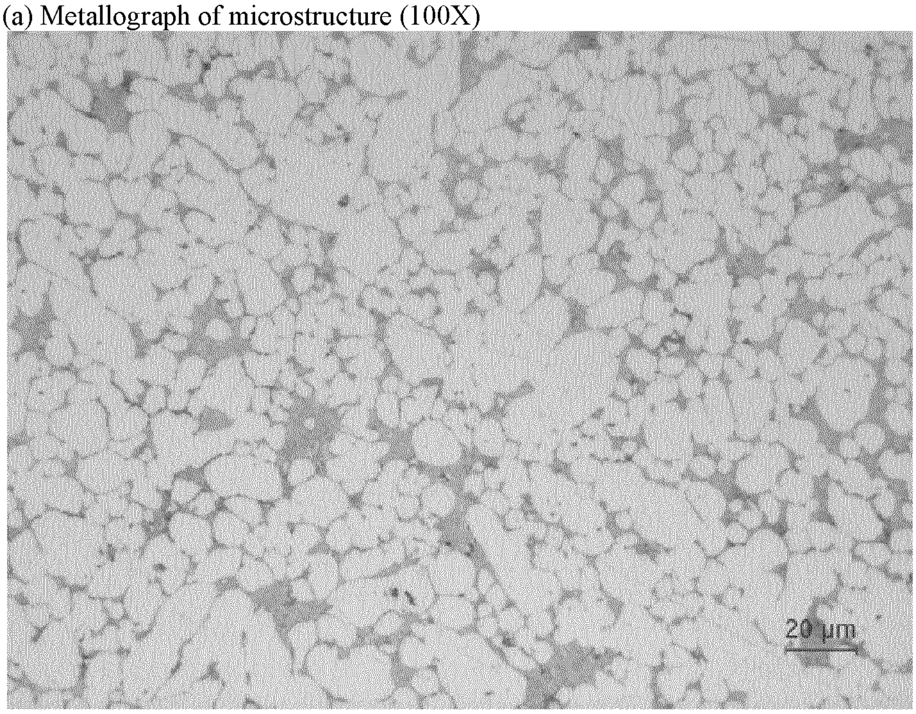
8. The process method according to Claim 7 , is **characterized in that** it also comprises the die-casting of the Al-Si alloy. For the Al-Si alloy, the die-casting temperature is 680-720°C, the die-casting speed is 2.5-5m/s, and the holding time is 2-10s, and then the non-heat treatable die casting is obtained.

9. The process method according to Claim 7, is **characterized in that** it also comprises the following operations: after all raw materials are completely melted, the molten aluminum alloy is stirred well, left to stand and then sampled and analyzed to adjust the contents of required elements to the required composition range.

10. The process method according to Claim 7, is **characterized in that** the refining agent used does not contain Na ions.



(a) Metallograph of microstructure (100X)



(b) Metallograph of microstructure (500X)

Figure 1

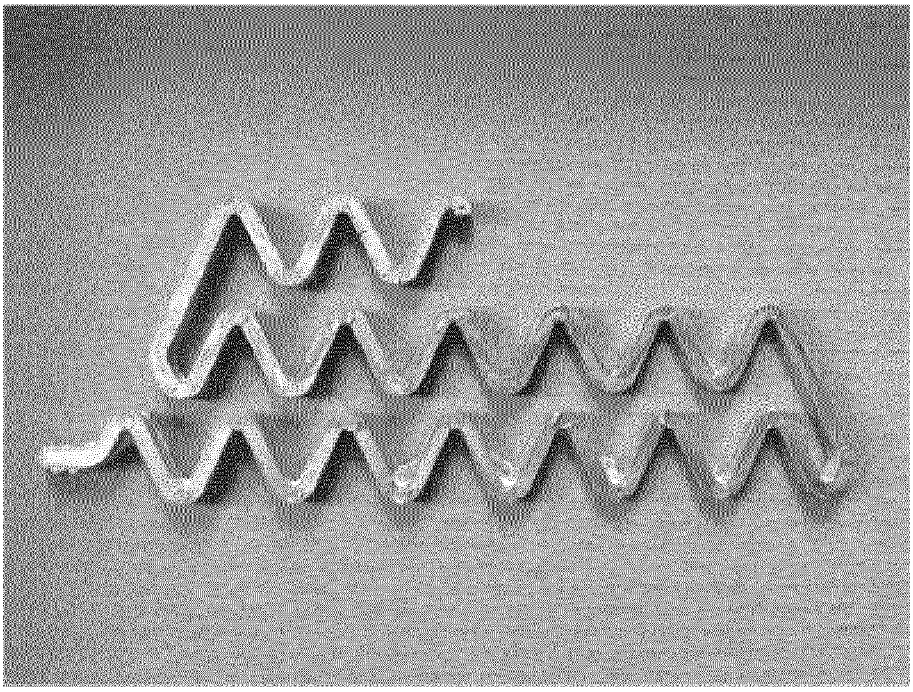
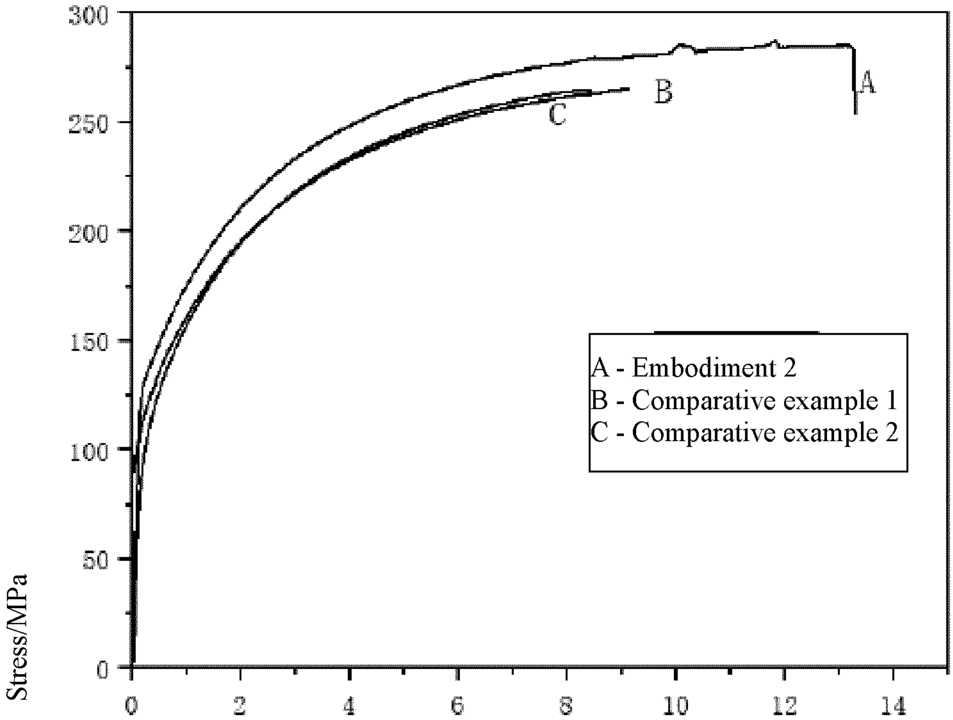


Figure 2



Strain/%

Figure 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2022/080807

A. CLASSIFICATION OF SUBJECT MATTER

C22C 21/04(2006.01)i; C22C 1/03(2006.01)i; B22D 7/00(2006.01)i; B22D 17/00(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)

B22D; C22C

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)

CNKI, DWPI, CNABS: 压铸, 铝硅合金, 热处理, 铁, 铜, 锰, 镁, 钛, 锶, 稀土, 镍, 锌, 镓, 烧损, die casting, aluminum silicon alloy, heat treatment, iron, copper, manganese, magnesium, titanium, strontium, rare earth, nickel, zinc, gallium, burn

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 113755722 A (LONGDA ALUMINIUM (SHUNPING) CO., LTD. et al.) 07 December 2021 (2021-12-07) description, paragraphs 7-14	1-10
Y	CN 101629258 A (TAICANG HUBEI SPECIAL ALUMINUM CO., LTD.) 20 January 2010 (2010-01-20) abstract	1-10
A	WO 2016161908 A1 (SHANGHAI JIAOTONG UNIVERSITY et al.) 13 October 2016 (2016-10-13) entire document	1-10
A	CN 109881056 A (SHANGHAI YONGMAOTAI AUTO PARTS CO., LTD. et al.) 14 June 2019 (2019-06-14) entire document	1-10

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

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Date of the actual completion of the international search	Date of mailing of the international search report
15 June 2022	**01 August 2022**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088, China** Facsimile No. **(86-10)62019451**	Authorized officer Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2022/080807

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 113755722 A	07 December 2021	None	
CN 101629258 A	20 January 2010	None	
WO 2016161908 A1	13 October 2016	CN 104831129 A	12 August 2015
CN 109881056 A	14 June 2019	None	

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

REFERENCES CITED IN THE DESCRIPTION

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- US 6364970 B1 **[0005]**
- CN 108754256 A **[0005]**
- CN 109881056 A **[0005]**
- CN 106636787 A **[0005]**