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(54) **NON-HEAT-TREATED REINFORCED HIGH-STRENGTH AND HIGH-TOUGHNESS DIE-CAST ALUMINUM-SILICON ALLOY AND PREPARATION METHOD THEREFOR**

(57) The present invention discloses a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy and a preparation method therefor. The alloy includes the following components in percentage by weight: 8.0-10.0% of Si, 0.1-0.5% of Mg, 0.5-0.8% of Mn, 0.05-0.5% of Cu, 0.05-0.2% of Ti, 0.01-0.05% of Sr, 0.01-0.1% of V, 0.01-0.15% of RE, less than 0.2% of Fe, less than or equal to 0.4% of other impurities and the balance of Al. Based on modification refinement of eutectic Si by Sr, during preparation, the elements V and RE are imported to further significantly refine eutectic Si structures, so that the alloy obtains features of high strength and high toughness with a high Si content, thereby satisfying the requirements of a large body structural member on flowability, strength and plasticity of a die-casting aluminum alloy material. Under a die-casting condition, the yield strength of the alloy can be 120-160 Mpa, the tensile strength thereof can be 260-320 Mpa and the ductility thereof can be 10-15%. The alloy features high strength and high toughness in a die-casting state, and can have good die-casting performance.

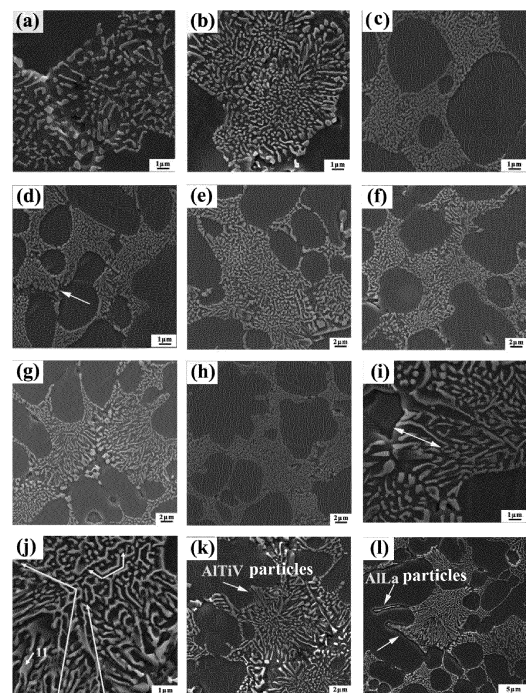


FIG. 1

DescriptionTECHNICAL FIELD

5 **[0001]** The present invention relates to the technical field of metal materials, and particularly relates to a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy and a preparation method therefor.

BACKGROUND

10 **[0002]** Aiming at "carbon peaking and carbon neutrality", China has put an increasingly high requirement for environmental protection. With release of technology roadmap for energy conservation and new energy automobiles, weight reduction of new energy automobiles becomes a development direction of high concern. As a metal structural material frequently used in a vehicle body, an aluminum alloy featuring small density, high specific strength and good damping effect is used in parts such as a shock tower and a rear side member of an automobile with an obvious weight reduction advantage, high strength and rigidity and high fatigue durability. Integrated design and integrated die-cast formation contribute to reducing machining processes, so that the environment can be prevented from being repeatedly polluted. Meanwhile, a casting structure features flexible design and can satisfy different product demands.

15 **[0003]** The body structural member of the new energy automobile often uses a die-casting aluminum alloy, and a heat-treated high-strength and high-toughness die-casting aluminum alloy material represented by a Silafont-36 alloy (the publication number of a patent: US6364970B1) by is mainly used. The material is subjected to "high vacuum die casting+heat treatment", so that the yield strength of a casting reaches 100-120 MPa, the tensile strength thereof reaches 180-220 MPa, and the ductility thereof reaches 10-15%. As far as a thin-walled die casting is concerned, there are defects in two aspects by using the technique: (1) high vacuum die casting greatly increases the process difficulty and the manufacturing cost; and (2) by adopting a heat treatment process, the casting will be subjected to certain deformation and bubbling, so that the percent of pass of the product is affected and the cost is increased. Therefore, research institutions in various countries actively develop the high-strength and high-toughness non-heat-treatable die-casting aluminum alloy material which is suitable for batch production of complicated die-casting structural members. Particularly, new energy automobile manufacturers represented by TESLA use a heat treatment-free alloy to prepare an integrated body structural member, and the main component of the used alloy is an Al7SiMgMn alloy (the publication number of a patent: US20050167012A1). The alloy is cooperated with high vacuum and even ultrahigh vacuum die casting to prepare parts. By adopting the technical route, a problem of part deformation caused by an original heat-treatable alloy can be alleviated. However, there are still two major problems: (1) the Si content in the alloy is low (about 7 wt.%), and the ductility of the material can be increased to 10-15%. The low Si content restricts the flowability of the non-heat-treatable alloy, which causes a risk of short filling for a large casting. (2) An existing Al7SiMgMn alloy features low strength (the typical yield strength is 110-120 MPa and the tensile strength is 180-220 MPa), so that the overall wall thickness of the large casting in structural design is great and there are more wall thickness areas. Therefore, under circumstance of not changing or slightly reducing the ductility of the material (guaranteeing that the ductility is greater than 10% to satisfy a riveting requirement of the body structural member), to improve the flowability of the material by increasing the Si content in the alloy and improving the strength of the material is of great significance to optimize a large body casting structure.

20 30 35 40 **[0004]** Therefore, one of the targets pursued in the die casting field is to develop a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy and study its preparation and die-casting process, so as to satisfy the actual operating requirements improved day by day on a high quality high-performance aluminum alloy die casting.

SUMMARY

45 **[0005]** The objective of the present invention is to, under the background of the prior art, provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy and a preparation method therefor. In the premise of guaranteeing good casting performance of the alloy, a non-heat-treatable casting features excellent comprehensive mechanical properties so as to satisfy the performance requirement on the body structural member, particularly a large thin-walled body structural member.

50 **[0006]** To achieve the objective, it is found in a long-term aluminum die casting alloy study that the Si content in the die-casting aluminum-silicon alloy significantly affects the casting performance, the strength and the plasticity of the alloy. Under normal circumstances, with increase of the Si content, the strength of the alloy is increased, the flowability thereof is increased, and the plasticity thereof is reduced. Although the element Sr can play a role of modification refinement on eutectic Si in the alloy, the plasticity thereof still shows a reducing trend along with increase of the Si content. Therefore, 10% of plasticity is hardly achieved. The present invention mainly aims to solve the problem that the plasticity of the Al-Si alloy is reduced under a die-casting condition in a case where the Si content is increased. With increase of the Si content in the alloy, the content of the eutectic Si in structures is increased, and the size and shape

of the eutectic Si are also changed therewith, which becomes a key factor that affects the plasticity of the alloy. To overcome reduction of the plasticity of the material due to increase of the Si content in the alloy, the present invention creatively introduces the element V to refine an eutectic Si phase, so as to obtain a fine eutectic Si structure. In addition, it is found by a plenty of experimental verifications in early stage that rare earth elements such as La, Er and Ce can be compounded with element V to further refine the eutectic Si structures in the alloy, so that the size and shape of the eutectic Si change. Due to compound addition of V+RE, fine eutectic Si particles are generated in an as-cast structure, thereby guaranteeing that a die-casting aluminum alloy material with great Si content still has high plasticity. On the one hand, by adding the high content of Si, the alloy features excellent strength and flowability. On the other hand, due to compound addition of V+RE, the eutectic Si is retained in a fine and dispersed state, so that the plasticity of the alloy is improved. Furthermore, in the premise of guaranteeing excellent casting performance, the present invention can greatly improve the mechanical performance of the die-casting aluminum-silicon alloy and obtain comprehensive mechanical properties of high strength and high toughness taking strength and shaping into consideration.

[0007] Accordingly, the objective of the present invention is realized by the following technical solution:

The present invention provides a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 8.0-10.0% of Si, 0.1-0.5% of Mg, 0.5-0.8% of Mn, 0.05-0.5% of Cu, 0.05-0.2% of Ti, 0.01-0.05% of Sr, 0.01-0.1% of V, 0.01-0.15% of RE, less than 0.2% of Fe, less than or equal to 0.4% of other impurities and the balance of Al.

[0008] As an embodiment of the present invention, the element RE includes one or more of elements La, Ce and Er.

[0009] The present invention further relates to a method for preparing a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following steps:

S1: drying: pre-heating prepared raw materials: pure Al, pure Si, pure Mg, an Al-Mn intermediate alloy, an Al-Ti intermediate alloy, an Al-Cu intermediate alloy, an Al-RE intermediate alloy and an Al-V intermediate alloy for drying treatment; and

S2: smelting: adding the Al-Ti intermediate alloy, the Al-Cu intermediate alloy, the Al-Mn intermediate alloy, the Al-V intermediate alloy and pure Si after melting the pure Al by means of preliminary heating, and performing cooling after melting the intermediate alloys; pressing the pure Mg into a bottom of a melt for melting, and performing secondary heating on the alloy melt to refine the alloy melt after completely melting the melt; and then pressing the Al-RE intermediate alloy into the bottom of the melt for melting, and leaving the melt still after completely melting the melt to obtain the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy.

[0010] As an embodiment of the present invention, a pre-heating temperature in S1 is 190-210°C.

[0011] As an embodiment of the present invention, a preliminary heating temperature in S2 is 750-760°C.

[0012] As an embodiment of the present invention, a cooling temperature in S2 is 680-700°C.

[0013] As an embodiment of the present invention, in S2, the pure Mg and the Al-RE intermediate alloy are pressed into the melt and are stirred for 3-5 min till the pure Mg and the Al-RE intermediate alloy are completely melted.

[0014] As an embodiment of the present invention, a secondary heating temperature in S2 is 720-730°C. RE is a modified element, which is finally added in the aluminum alloy smelting process.

[0015] As an embodiment of the present invention, the refining in S2 specifically includes: introducing nitrogen with a refining agent powder into the melt by using a rotary blowing device for injection refining, performing deslagging and degassing treatments, then leaving the melt still for 10-15 min, and completing slagging-off treatment to obtain the refined melt.

[0016] As an embodiment of the present invention, process parameters for the rotary blowing device are as follows: a degassing revolution is 300-350 r/min; a degassing time is 5-10 min, a pressure of a gas source during degassing is 0.35 ± 0.05 MPa, and a gas flow is 0.2-0.8 sccm.

[0017] As an embodiment of the present invention, the used refining agent includes one of magnesium chloride and calcium chloride, and an addition of the refining agent is 0.2-0.5% by weight of the melt.

[0018] As an embodiment of the present invention, a standing time in S2 is 10-15 min.

[0019] As an embodiment of the present invention, the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy in S2 is an alloy ingot further subjected to die-cast formation after casting or pouring.

[0020] As an embodiment of the present invention, a casting temperature is 690-710°C.

[0021] As an embodiment of the present invention, specific parameters for the die-cast formation are as follows: an injection speed is 3-6 m/s, a ratio of a release agent to water is 1: 80-1: 120, a die temperature is 200-250°C, and a casting pressure is 30-100 MPa.

[0022] Compared with the prior art, the present invention has the following beneficial effects:

1. The high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy prepared in the present invention has important industrial application value. Under a die-casting condition, the die-casting aluminum-

silicon alloy obtains excellent performance: the yield strength is 120-160 Mpa, the tensile strength is 260-320 Mpa and the ductility is 10-15% (for the AlSi10MnMg alloy, the as-cast tensile strength is 200-220 MPa, and the ductility is 5-8%). The alloy can realize good die-casting performance, which greatly satisfies the application requirement on the large thin-walled body structural member in the automobile industry.

2. Under an as cast condition, the alloy has excellent performance: the yield strength is 120-160 MPa, the tensile strength is 260-320 MPa and the ductility is 10-15%. Compared with existing heat treatable alloys, heat treatment steps for parts can be reduced, so that the percent of pass of the casting is improved and the cost of the casting is lowered.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] By reading and referring to detailed description made by the following drawings to non-restrictive embodiments, other features, purposes and advantages of the present invention will become more obvious.

[0024] FIG. 1 shows observation schematic diagrams of SEM structures of castings in examples and comparative examples, wherein a represents the observation schematic diagram of the SEM structure of the casting A1, b represents the observation schematic diagram of the SEM structure of the casting A2, c represents the observation schematic diagram of the SEM structure of the casting A3, d represents the observation schematic diagram of the SEM structure of the casting A4, e represents the observation schematic diagram of the SEM structure of the casting A5, f represents the observation schematic diagram of the SEM structure of the casting A6, g represents the observation schematic diagram of the SEM structure of the casting A7, h represents the observation schematic diagram of the SEM structure of the casting A8, i represents the observation schematic diagram of the SEM structure of the casting A9, j represents the observation schematic diagram of the SEM structure of the casting A10, k represents the observation schematic diagram of the SEM structure of the casting A11 and l represents the observation schematic diagram of the SEM structure of the casting A12.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0025] A high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy and a preparation method therefor provided by the present invention are further described below in combination with examples, so that those skilled in the art can easily understand advantages and features of the present invention, which is not used to limit the application scope of the present invention.

Example 1

[0026] The embodiment of the present invention provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 8.0% of Si, 0.25% of Mg, 0.6% of Mn, 0.15% of Ti, 0.15% of Cu, 0.02% of V, 0.025% of Sr, 0.12% of Fe, 0.3% of other impurities and the balance of Al.

[0027] Preparation and die-casting processes for the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy of the embodiment include the following steps:

1) drying: prepared raw materials: pure Al, pure Si, pure Mg, an Al-10Mn intermediate alloy, an Al-10Ti intermediate alloy, an Al-50Cu intermediate alloy, and an Al-5V intermediate alloy were pre-heated to 200°C for drying treatment; and

2) smelting: a furnace was heated to 755°C to melt the pure aluminum, then the Al-10Ti, Al-50Cu, Al-10Mn, Al-5V and pure Si alloys were added into the furnace, the furnace was cooled to 690°C after the intermediate alloys were melted, the pure Mg was pressed into a bottom area of a crucible by using a bell jar for melting, and then the pure Mg was stirred for 5 min. Then a melt was heated to 720°C, nitrogen at a pressure of 0.4 MPa was introduced into the melt, a refining agent powder accounting for 0.4% of total weight of the melt was brought in, and nitrogen was introduced with a gas flow of 0.5 at 300r/min for 10 min to deslag and degas. Then the melt was left still for 12 min, slagging-off treatment was completed, and a blast furnace component analytical test was performed. High pressure casting was performed at 690°C after the test passed. An injections peed was 3 m/s, a casting pressure was 80 MPa, a ratio of a release agent was 1: 100, and a die temperature was 230°C. The die used in a production process was a die-casting test bar die, and an obtained casting was labeled as A1.

Example 2

[0028] The embodiment of the present invention provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 8.0% of Si, 0.25% of Mg,

0.6% of Mn, 0.15% of Ti, 0.15% of Cu, 0.05% of Er, 0.025% of Sr, 0.12% of Fe, 0.3% of other impurities and the balance of Al.

[0029] Preparation and die-casting processes for the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy of the embodiment include the following steps:

1) drying: prepared raw materials: pure aluminum, pure Si, pure Mg, an Al-10Mn intermediate alloy, an Al-10Ti intermediate alloy, an Al-50Cu intermediate alloy, and an Al-10Er intermediate alloy were pre-heated to 200°C for drying treatment; and

2) smelting: a furnace was heated to 755°C to melt the pure aluminum, then the Al-10Ti, Al-50Cu, Al-10Mn and pure Si alloys were added into the furnace, the furnace was cooled to 690°C after the intermediate alloys were melted, the pure Mg was pressed into a bottom area of a crucible by using a bell jar for melting, and then the pure Mg was stirred for 5 min. Then a melt was heated to 720°C, nitrogen at a pressure of 0.4 MPa was introduced into the melt, a refining agent powder accounting for 0.4% of total weight of the melt was brought in, and nitrogen was introduced with a gas flow of 0.5 at 300r/min for 10 min to deslag and degas. Then the melt was left still for 12 min, and slagging-off treatment was completed; after refining was completed, the Al-10Er intermediate alloy was pressed into the bottom area of the crucible by using the bell jar for melting, and then the Al-10Er intermediate alloy was stirred for 5 min till the Al-10Er intermediate alloy was completely melted, and then the melt was left still for 12 min, and a blast furnace component analytical test was performed. High pressure casting was performed at 690°C after the test passed. An injections peed was 3 m/s, a casting pressure was 80 MPa, a ratio of a release agent was 1: 100, and a die temperature was 230°C. The die used in a production process was a die-casting test bar die, and an obtained casting was labeled as A2.

Example 3

[0030] The embodiment of the present invention provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 8.0% of Si, 0.25% of Mg, 0.6% of Mn, 0.15% of Ti, 0.15% of Cu, 0.02% of V, 0.05% of Er, 0.025% of Sr, 0.12% of Fe, 0.3% of other impurities and the balance of Al.

[0031] Preparation and die-casting processes for the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy of the embodiment include the following steps:

1) drying: prepared raw materials: pure aluminum, pure Si, pure Mg, an Al-10Mn intermediate alloy, an Al-10Ti intermediate alloy, an Al-50Cu intermediate alloy, an Al-10Er intermediate alloy and an Al-5V intermediate alloy were pre-heated to 200°C for drying treatment; and

2) smelting: a furnace was heated to 755°C to melt the pure aluminum, then the Al-10Ti, Al-50Cu, Al-10Mn, Al-5V and pure Si alloys were added into the furnace, the furnace was cooled to 690°C after the intermediate alloys were melted, the pure Mg was pressed into a bottom area of a crucible by using a bell jar for melting, and then a melt was stirred for 5 min. Then the melt was heated to 720°C, nitrogen at a pressure of 0.4 MPa was introduced into the melt, a refining agent powder accounting for 0.4% of total weight of the melt was brought in, and nitrogen was introduced with a gas flow of 0.5 at 300r/min for 10 min to deslag and degas. Then the melt was left still for 12 min, and slagging-off treatment was completed; after refining was completed, the Al-10Er intermediate alloy was pressed into the bottom area of the crucible by using the bell jar for melting, and then the Al-10Er intermediate alloy was stirred for 5 min till the intermediate alloy was completely melted, and then the melt was left still for 12 min, and a blast furnace component analytical test was performed. High pressure casting was performed at 690°C after the test passed. An injections peed was 3 m/s, a casting pressure was 80 MPa, a ratio of a release agent was 1: 100, and a die temperature was 230°C. The die used in a production process was a die-casting test bar die, and an obtained casting was labeled as A3.

Example 4

[0032] The embodiment of the present invention provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 9.5% of Si, 0.25% of Mg, 0.6% of Mn, 0.15% of Ti, 0.15% of Cu, 0.02% of V, 0.05% of Er, 0.025% of Sr, 0.12% of Fe, 0.3% of other impurities and the balance of Al.

[0033] Preparation and die-casting processes for the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy of the embodiment include the following steps:

1) drying: prepared raw materials: pure aluminum, pure Si, pure Mg, an Al-10Mn intermediate alloy, an Al-10Ti

intermediate alloy, an Al-50Cu intermediate alloy, an Al-10Er intermediate alloy and an Al-5V intermediate alloy were pre-heated to 200°C for drying treatment; and

2) smelting: a furnace was heated to 755°C to melt the pure aluminum, then the Al-10Ti, Al-50Cu, Al-10Mn, Al-5V and pure Si alloys were added into the furnace, the furnace was cooled to 690°C after the intermediate alloys were melted, the pure Mg was pressed into a bottom area of a crucible by using a bell jar for melting, and then a melt was stirred for 5 min. Then the melt was heated to 720°C, nitrogen at a pressure of 0.4 MPa was introduced into the melt, a refining agent powder accounting for 0.4% of total weight of the melt was brought in, and nitrogen was introduced with a gas flow of 0.5 at 300r/min for 10 min to deslag and degas. Then the melt was left still for 12 min, and slagging-off treatment was completed; after refining was completed, the Al-10Er intermediate alloy was pressed into the bottom area of the crucible by using the bell jar for melting, and then the Al-10Er intermediate alloy was stirred for 5 min till the intermediate alloy was completely melted, and then the melt was left still for 12 min, and a blast furnace component analytical test was performed. High pressure casting was performed at 690°C after the test passed. An injections peed was 3 m/s, a casting pressure was 80 MPa, a ratio of a release agent was 1: 100, and a die temperature was 230°C. The die used in a production process was a die-casting test bar die, and an obtained casting was labeled as A4.

Example 5

[0034] The embodiment of the present invention provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 9.5% of Si, 0.25% of Mg, 0.6% of Mn, 0.15% of Ti, 0.15% of Cu, 0.02% of V, 0.05% of La, 0.025% of Sr, 0.12% of Fe, 0.3% of other impurities and the balance of Al.

[0035] Preparation and die-casting processes for the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy of the embodiment include the following steps:

1) drying: prepared raw materials: pure aluminum, pure Si, pure Mg, an Al-10Mn intermediate alloy, an Al-10Ti intermediate alloy, an Al-50Cu intermediate alloy, an Al-10La intermediate alloy and an Al-5V intermediate alloy were pre-heated to 200°C for drying treatment; and

2) smelting: a furnace was heated to 720°C to melt the pure aluminum, then the furnace was heated to 755°C and the Al-10Ti, Al-50Cu, Al-10Mn, Al-5V and pure Si alloys were added into the furnace, the furnace was cooled to 690°C after the intermediate alloys were melted, the pure Mg was pressed into a bottom area of a crucible by using a bell jar for melting, and then the pure Mg was stirred for 5 min. Then the melt was heated to 720°C, nitrogen at a pressure of 0.4 MPa was introduced into the melt, a refining agent powder accounting for 0.4% of total weight of the melt was brought in, and nitrogen was introduced with a gas flow of 0.5 at 300r/min for 10 min to deslag and degas. Then the melt was left still for 12 min, and slagging-off treatment was completed; after refining was completed, the Al-10La intermediate alloy was pressed into the bottom area of the crucible by using the bell jar for melting, and then the Al-10La intermediate alloy was stirred for 5 min till the intermediate alloy was completely melted, and then the melt was left still for 12 min, and a blast furnace component analytical test was performed. High pressure casting was performed at 690°C after the test passed. An injections peed was 3 m/s, a casting pressure was 80 MPa, a ratio of a release agent was 1: 100, and a die temperature was 230°C. The die used in a production process was a die-casting test bar die, and an obtained casting was labeled as A5.

Example 6

[0036] The embodiment of the present invention provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 9.5% of Si, 0.25% of Mg, 0.6% of Mn, 0.15% of Ti, 0.15% of Cu, 0.02% of V, 0.05% of Ce, 0.025% of Sr, 0.12% of Fe, 0.3% of other impurities and the balance of Al.

[0037] Preparation and die-casting processes for the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy of the embodiment include the following steps:

1) drying: prepared raw materials: pure aluminum, pure Si, pure Mg, an Al-10Mn intermediate alloy, an Al-10Ti intermediate alloy, an Al-50Cu intermediate alloy, an Al-10Ce intermediate alloy and an Al-5V intermediate alloy were pre-heated to 200°C for drying treatment; and

2) smelting: a furnace was heated to 720°C to melt the pure aluminum, then the furnace was heated to 755°C and the Al-10Ti, Al-50Cu, Al-10Mn, Al-5V and pure Si alloys were added into the furnace, the furnace was cooled to 690°C after the intermediate alloys were melted, the pure Mg was pressed into a bottom area of a crucible by using a bell jar for melting, and then the pure Mg was stirred for 5 min. Then the melt was heated to 720°C, nitrogen at a

pressure of 0.4 MPa was introduced into the melt, a refining agent powder accounting for 0.4% of total weight of the melt was brought in, and nitrogen was introduced with a gas flow of 0.5 at 300r/min for 10 min to deslag and degas. Then the melt was left still for 12 min, and slagging-off treatment was completed; after refining was completed, the Al-10Ce intermediate alloy was pressed into the bottom area of the crucible by using the bell jar for melting, and then the Al-10Ce intermediate alloy was stirred for 5 min till the intermediate alloy was completely melted, and then the melt was left still for 12 min, and a blast furnace component analytical test was performed. High pressure casting was performed at 690°C after the test passed. An injections peed was 3 m/s, a casting pressure was 80 MPa, a ratio of a release agent was 1: 100, and a die temperature was 230°C. The die used in a production process was a die-casting test bar die, and an obtained casting was labeled as A6.

Example 7

[0038] The embodiment of the present invention provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 10% of Si, 0.5% of Mg, 0.8% of Mn, 0.2% of Ti, 0.5% of Cu, 0.1% of V, 0.15% of La, 0.05% of Sr, 0.12% of Fe, 0.3% of other impurities the balance of Al.

[0039] Preparation and die-casting processes for the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy of the embodiment include the following steps:

- 1) drying: prepared raw materials: pure aluminum, pure Si, pure Mg, an Al-10Mn intermediate alloy, an Al-10Ti intermediate alloy, an Al-50Cu intermediate alloy, an Al-10La intermediate alloy and an Al-5V intermediate alloy were pre-heated to 200°C for drying treatment; and
- 2) smelting: a furnace was heated to 755°C to melt the pure aluminum, then the Al-10Ti, Al-50Cu, Al-10Mn, Al-5V and pure Si alloys were added into the furnace, the furnace was cooled to 690°C after the intermediate alloys were melted, the pure Mg was pressed into a bottom area of a crucible by using a bell jar for melting, and then a melt was stirred for 5 min. Then the melt was heated to 720°C, nitrogen at a pressure of 0.4 MPa was introduced into the melt, a refining agent powder accounting for 0.4% of total weight of the melt was brought in, and nitrogen was introduced with a gas flow of 0.5 at 300r/min for 10 min to deslag and degas. Then the melt was left still for 12 min, and slagging-off treatment was completed; after refining was completed, the Al-10La intermediate alloy was pressed into the bottom area of the crucible by using the bell jar for melting, and then the intermediate alloy was stirred for 5 min till the intermediate alloy was completely melted, and then the melt was left still for 12 min, and a blast furnace component analytical test was performed. High pressure casting was performed at 690°C after the test passed. An injections peed was 3 m/s, a casting pressure was 80 MPa, a ratio of a release agent was 1: 100, and a die temperature was 230°C. The die used in a production process was a die-casting test bar die, and an obtained casting was labeled as A7.

Example 8

[0040] The embodiment of the present invention provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 8% of Si, 0.1% of Mg, 0.5% of Mn, 0.05% of Ti, 0.05% of Cu, 0.01% of V, 0.01% of La, 0.01% of Sr, 0.12% of Fe, 0.3% of other impurities the balance of Al.

[0041] Preparation and die-casting processes for the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy of the embodiment include the following steps:

- 1) drying: prepared raw materials: pure aluminum, pure Si, pure Mg, an Al-10Mn intermediate alloy, an Al-10Ti intermediate alloy, an Al-50Cu intermediate alloy, an Al-10La intermediate alloy and an Al-5V intermediate alloy were pre-heated to 200°C for drying treatment; and
- 2) smelting: a furnace was heated to 755°C to melt the pure aluminum, then the Al-10Ti, Al-50Cu, Al-10Mn, Al-5V and pure Si alloys were added into the furnace, the furnace was cooled to 690°C after the intermediate alloys were melted, the pure Mg was pressed into a bottom area of a crucible by using a bell jar for melting, and then a melt was stirred for 5 min. Then the melt was heated to 720°C, nitrogen at a pressure of 0.4 MPa was introduced into the melt, a refining agent powder accounting for 0.4% of total weight of the melt was brought in, and nitrogen was introduced with a gas flow of 0.5 at 300r/min for 10 min to deslag and degas. Then the melt was left still for 12 min, and slagging-off treatment was completed; after refining was completed, the Al-10La intermediate alloy was pressed into the bottom area of the crucible by using the bell jar for melting, and then the intermediate alloy was stirred for 5 min till the intermediate alloy was completely melted, and then the melt was left still for 12 min, and a blast furnace component analytical test was performed. High pressure casting was performed at 690°C after the test passed. An

injections speed was 3 m/s, a casting pressure was 80 MPa, a ratio of a release agent was 1: 100, and a die temperature was 230°C. The die used in a production process was a die-casting test bar die, and an obtained casting was labeled as A8.

Comparative example 1

[0042] The comparative example of the present invention provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 8.0% of Si, 0.25% of Mg, 0.6% of Mn, 0.15% of Ti, 0.15% of Cu, 0.025% of Sr, 0.12% of Fe, 0.3% of other impurities and the balance of Al.

[0043] Preparation and die-casting processes for the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy of the comparative example include the following steps:

- 1) drying: prepared raw materials: pure aluminum, pure Si, pure Mg, an Al-10Mn intermediate alloy, an Al-10Ti intermediate alloy and an Al-50Cu intermediate alloy were pre-heated to 200°C for drying treatment; and
- 2) smelting: a furnace was heated to 755°C to melt the pure aluminum, then the Al-10Ti, Al-50Cu, Al-10Mn and pure Si alloys were added into the furnace, the furnace was cooled to 690°C after the intermediate alloys were melted, the pure Mg was pressed into a bottom area of a crucible by using a bell jar for melting, and then a melt was stirred for 5 min. Then a melt was heated to 720°C, nitrogen at a pressure of 0.4 MPa was introduced into the melt, a refining agent powder accounting for 0.4% of total weight of the melt was brought in, and nitrogen was introduced with a gas flow of 0.5 at 300r/min for 10 min to deslag and degas. Then the melt was left still for 12 min, slagging-off treatment was completed, and a blast furnace component analytical test was performed. High pressure casting was performed at 690°C after the test passed. The die-casting process parameters and the die used for die casting were the same as those in the example 1, and the casting A9 was obtained.

Comparative example 2

[0044] The comparative example of the present invention provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 9.5% of Si, 0.25% of Mg, 0.6% of Mn, 0.15% of Ti, 0.15% of Cu, 0.025% of Sr, 0.12% of Fe, 0.3% of other impurities and the balance of Al.

[0045] Preparation and die-casting processes for the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy of the comparative example include the following steps:

- 1) drying: prepared raw materials: pure aluminum, pure Si, pure Mg, an Al-10Mn intermediate alloy, an Al-10Ti intermediate alloy and an Al-50Cu intermediate alloy were pre-heated to 200°C for drying treatment; and
- 2) smelting: a furnace was heated to 755°C to melt the pure aluminum, then the Al-10Ti, Al-50Cu, Al-10Mn and pure Si alloys were added into the furnace, the furnace was cooled to 690°C after the intermediate alloys were melted, the pure Mg was pressed into a bottom area of a crucible by using a bell jar for melting, and then a melt was stirred for 5 min. Then the melt was heated to 720°C, nitrogen at a pressure of 0.4 MPa was introduced into the melt, a refining agent powder accounting for 0.4% of total weight of the melt was brought in, and nitrogen was introduced with a gas flow of 0.5 at 300r/min for 10 min to deslag and degas. Then the melt was left still for 12 min, slagging-off treatment was completed, and a blast furnace component analytical test was performed. High pressure casting was performed at 690°C after the test passed. The die-casting process parameters and the die used for die casting were the same as those in the example 1, and the casting A10 was obtained.

Comparative example 3

[0046] The embodiment of the present invention provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 8.0% of Si, 0.25% of Mg, 0.6% of Mn, 0.15% of Ti, 0.15% of Cu, 0.15% of V, 0.05% of La, 0.025% of Sr, 0.12% of Fe, 0.3% of other impurities and the balance of Al.

[0047] Preparation and die-casting processes for the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy of the embodiment include the following steps:

- 1) drying: prepared raw materials: pure aluminum, pure Si, pure Mg, an Al-10Mn intermediate alloy, an Al-10Ti intermediate alloy, an Al-50Cu intermediate alloy, an Al-10La intermediate alloy and an Al-5V intermediate alloy were pre-heated to 200°C for drying treatment; and
- 2) smelting: a furnace was heated to 755°C to melt the pure aluminum, then the Al-10Ti, Al-50Cu, Al-10Mn, Al-5V and pure Si alloys were added into the furnace, the furnace was cooled to 690°C after the intermediate alloys were

melted, the pure Mg was pressed into a bottom area of a crucible by using a bell jar for melting, and then a melt was stirred for 5 min. Then the melt was heated to 720°C, nitrogen at a pressure of 0.4 MPa was introduced into the melt, a refining agent powder accounting for 0.4% of total weight of the melt was brought in, and nitrogen was introduced with a gas flow of 0.5 at 300r/min for 10 min to deslag and degas. Then the melt was left still for 12 min, and slagging-off treatment was completed; after refining was completed, the Al-10La intermediate alloy was pressed into the bottom area of the crucible by using the bell jar for smelting, and then the Al-10La intermediate alloy was stirred for 5 min till the intermediate alloy was completely melted, and then the melt was left still for 12 min, and a blast furnace component analytical test was performed. High pressure casting was performed at 690°C after the test passed. The die-casting process parameters and the die used for die casting were the same as those in the example 1, and the casting A11 was obtained.

Comparative example 4

[0048] The comparative example of the present invention provide a high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, including the following components in percentage by weight: 8.0% of Si, 0.25% of Mg, 0.6% of Mn, 0.15% of Ti, 0.15% of Cu, 0.02% of V, 0.2% of La, 0.025% of Sr, 0.12% of Fe, 0.3% of other impurities and the balance of Al.

[0049] Preparation and die-casting processes for the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy of the comparative example include the following steps:

1) drying: prepared raw materials: pure aluminum, pure Si, pure Mg, an Al-10Mn intermediate alloy, an Al-10Ti intermediate alloy, an Al-50Cu intermediate alloy, an Al-10La intermediate alloy and an Al-5V intermediate alloy were pre-heated to 200°C for drying treatment; and

2) smelting: a furnace was heated to 755°C to melt the pure aluminum, then the Al-10Ti, Al-50Cu, Al-10Mn, Al-5V and pure Si alloys were added into the furnace, the furnace was cooled to 690°C after the intermediate alloys were melted, the pure Mg was pressed into a bottom area of a crucible by using a bell jar for melting, and then a melt was stirred for 5 min. Then the melt was heated to 720°C, nitrogen at a pressure of 0.4 MPa was introduced into the melt, a refining agent powder accounting for 0.4% of total weight of the melt was brought in, and nitrogen was introduced with a gas flow of 0.5 at 300r/min for 10 min to deslag and degas. Then the melt was left still for 12 min, and slagging-off treatment was completed; after refining was completed, the Al-10La intermediate alloy was pressed into the bottom area of the crucible by using the bell jar for melting, and then the intermediate alloy was stirred for 5 min till the intermediate alloy was completely melted, and then the melt was left still for 12 min, and a blast furnace component analytical test was performed. High pressure casting was performed at 690°C after the test passed. The die-casting process parameters and the die used for die casting were the same as those in the example 1, and the casting A12 was obtained.

[0050] Mechanical properties of the castings A1-A12 prepared in the examples 1-8 and the comparative examples 1-4 are tested, and the test results are shown in Table 1. It can be found by comparing the mechanical properties of the castings A1, A2, A3 and A9 that by independently adding the element V or the rare earth element Er, the strength and ductility of the alloy are obviously improved, the tensile strength is increased by 27 MPa to the maximum extent, and the improved amplitude of the ductility reaches 24.1%. By adding the elements V and Er simultaneously, the plasticity of the alloy is more obviously improved, and the ductility of the casting is significantly increased from 8.7% (A9) to 14.9% (A3) with an increase amplitude of 71.2%. The above rule can also be found by comparing the mechanical properties of the castings A4 and A10. By means of compound addition of the elements V and Er, the plasticity of the die-casting aluminum alloy with high Si content (9.5 wt%) is significantly improved, so that the ductility is increased from 6.5 (the casting A10) to 12.9% (the casting A4), and the characteristics of high strength and high toughness of the alloy are satisfied. It is found by comparing the mechanical properties of the castings A4, A5, A6 and A10 that by means of compound addition of V and rare earth elements Er, La and Ce, the plasticity and tensile strength of the die-casting aluminum alloy can be significantly improved. The tensile strength of the castings A4-A6 is about 281 MPa, the ductility is about 12.8%, and compared with the casting A10, the tensile strength and the ductility are respectively increased by 16.5% and 97%. Thus, it is illustrated that the three RE rare earths included in the patent have significant effects to the alloy. It can be known by comparing the mechanical properties of the castings A5, A7, A8, A11 and A12 that within a range of composition of the alloy provided by the patent, by means of compound addition of V and rare earth elements, the yield strength of the die-casting aluminum alloy can be greater than 120 MPa, the tensile strength thereof can be greater than 260 MPa and the ductility thereof can be greater than 10% (the castings A5, A7 and A8), reflecting excellent mechanical properties of the alloy within the range of composition of the alloy provided by the patent. When V in the alloy reaches 0.15 (the casting A11) or the rare earth elements reach 0.2 (the casting A12), which exceeds the range of the patent, the ductility and the tensile strength of the alloy are significantly reduced, and particularly, the ductility of

the alloy is reduced to be less than 8%, so that the high-strength and high-toughness die-casting aluminum alloy material cannot be obtained. In conclusion, in the range of composition of the alloy involved in the present invention, by adding the element V and RE elements (La, Er and Ce), the die-casting Al-Si alloy features high strength and high toughness in a non-heat treatment condition.

Table 1 Tensile mechanical properties of castings A1-A12

Gro up	Major components	Yield strength/(MPa)	Tensile strength/(MPa)	Ductility/ %
A1	Al8Si0.02V	121	265	10.5
A2	Al8Si0.05Er	125	279	10.8
A3	Al8Si0.02V0.05 Er	129	281	14.9
A4	Al9.5Si0.02V0.0 5Er	135	283	12.9
A5	Al9.5Si0.02V0.0 5La	131	282	12.7
A6	Al9.5Si0.02V0.0 5Ce	136	281	13.0
A7	Al10Si0.1V0.15 La	155	315	10.5
A8	Al8Si0.01V0.01 La	123	267	13.2
A9	Al8 Si	121	252	8.7
A1 0	Al9.5Si	136	241	6.5
A1 1	Al9.5Si0.15V0.0 5La	134	251	7.9
A1 2	Al9.5Si0.02V0.2 La	145	265	7.5

[0051] Microstructures of the castings A1-A12 respectively prepared in the above-mentioned examples 1-8 and comparative examples 1-4 are observed. The microstructures are shown in FIG. 1. It is found by comparing structures in A1(a), A2(b), A3(c) and A9(i) that with introduction of V and the rare earth element Er, the eutectic Si structure is obviously refined. When the alloy does not contain V and Er, the eutectic Si in the structure of the casting is of a layered structure in FIG. 1 (i), with a particle size of about 4 μm . With introduction of the element V or Er, the eutectic Si structure is transformed from being lamellar to being granular, and the particle size is significantly decreased to 1 μm , as shown in FIG. 1(a) and FIG. 1(b). By compound addition of V and Er, the size of the eutectic Si in the structure is further decreased, and the eutectic Si is a much smaller vermiform structure, as shown in FIG. 1 (c). Change of structural characteristics is closely related to change of mechanical properties. It is apparent that by introducing the elements V and Er, the eutectic Si structure can be significantly refined, and its shape is changed, so that the performance of the alloy changes significantly. It can be found by comparing structures of A4 and A10 that the compound action of the elements V and Er is also effective to the alloy structure with the high Si content. When the Si content is 9.5 wt.% and elements V and Er are not added into the alloy, the eutectic Si structure in the structure is in a thick broken line shape, and the maximum size of the fold line-shaped structure can reach up to 10 μm (as shown in FIG. 1 (j)). With introduction of the elements V and Er in the alloy, the eutectic Si structure in the alloy is significantly refined to be vermiform (as shown in FIG. 1 (d)), but there are block eutectic Si structures partially, which somewhat affects the plasticity of the alloy. Therefore, the plasticity of the alloy A3 is superior to that of the alloy A4. It is found by comparing the structures of the castings A4, A5, A6, A7, A8 and A10 that in the range of the alloy provided by the patent, by means of compound addition of the element V and the rare earth elements Er, La and Ce, the thick broken line-shaped structure in the die-casting aluminum alloy can disappear, so that the performance of the alloy is guaranteed. It can be known by comparing the structures of the castings A5, A11 and A12 that by adding excessive element V, second phases AIV can appear in the alloy structures, and by adding excessive rare earth elements, second phases AIIa can appear in the alloys. These second phases will reduce the plasticity of the alloys greatly. Generally, by introducing the compound action of the elements V and RE into the alloy provided by the patent, eutectic Si particles in the structures are finer and dispersive, and the shapes are greatly improved, so that the alloy has excellent mechanical properties due to the structural characteristic.

[0052] The above is merely embodiments of the present invention and does not hence limit the patent range of the present invention. Equivalent structures or equivalent flow conversions made by means of the description of the present invention are applied to other related technical fields directly or indirectly, which is, in a similar way, comprised in the protection scope of the patent of the present invention.

Claims

1. A high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy, comprising the following components in percentage by weight: 8.0-10.0% of Si, 0.1-0.5% of Mg, 0.5-0.8% of Mn, 0.05-0.5% of Cu, 0.05-0.2% of Ti, 0.01-0.05% of Sr, 0.01-0.1% of V, 0.01-0.15% of RE, less than 0.2% of Fe, less than or equal to 0.4% of other impurities and the balance of Al.
2. The high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy according to claim 1, wherein the element RE comprises one or more of elements La, Ce and Er.
3. A method for preparing the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy according to claim 1, comprising the following steps:

S1: drying: pre-heating prepared raw materials: pure Al, pure Si, pure Mg, an Al-Mn intermediate alloy, an Al-Ti intermediate alloy, an Al-Cu intermediate alloy, an Al-RE intermediate alloy and an Al-V intermediate alloy for drying treatment; and

S2: smelting: adding the Al-Ti intermediate alloy, the Al-Cu intermediate alloy, the Al-Mn intermediate alloy, the Al-V intermediate alloy and pure Si after melting the pure Al by means of preliminary heating, and performing cooling after melting the intermediate alloys; pressing the pure Mg into a bottom of a melt for melting, and performing secondary heating on the alloy melt to refine the alloy melt after completely melting the pure Mg; and then pressing the Al-RE intermediate alloy into the bottom of the melt for melting, and leaving the melt still after completely melting the melt to obtain the high-strength and high-toughness non-heat-treatable die-casting aluminum-silicon alloy.

4. The method according to claim 3, wherein a pre-heating temperature in S1 is 190-210°C.
5. The method according to claim 3, wherein a preliminary heating temperature in S2 is 750-760°C.
6. The method according to claim 3, wherein a cooling temperature in S2 is 680-700°C.
7. The method according to claim 3, wherein a secondary heating temperature in S2 is 720-730°C.
8. The method according to claim 3, wherein the refining in S2 specifically comprises: introducing nitrogen with a refining agent powder into the melt by using a rotary blowing device for injection refining, performing deslagging and degassing treatments, then leaving the melt still for 10-15 min, and completing slagging-off treatment to obtain the refined melt.
9. The method according to claim 8, wherein process parameters for the rotary blowing device are as follows: a degassing revolution is 300-350 r/min; a degassing time is 5-10 min, a pressure of a gas source during degassing is 0.35 ± 0.05 MPa, and a gas flow is 0.2-0.8 sccm.
10. The method according to claim 8, wherein the used refining agent comprises one of magnesium chloride and calcium chloride.

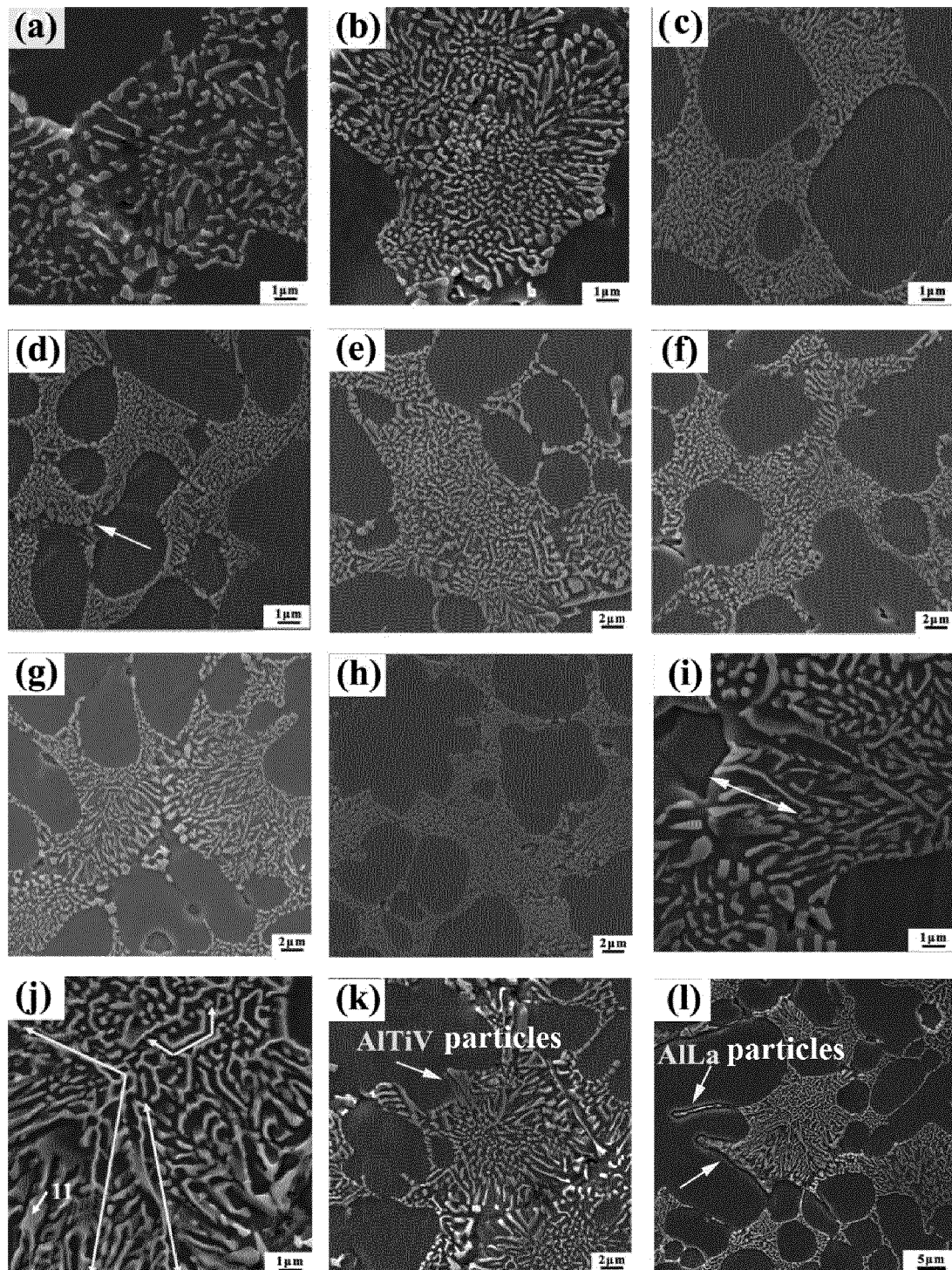


FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2022/118853

A. CLASSIFICATION OF SUBJECT MATTER C22C 21/04(2006.01)i; C22C 1/03(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) C22C; B22D 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) CNABS; CNTXT; WPABS; WPABSC; VEN; VCN; ENTXTC; USTXT; WOTXT; EPTXT; CJFD; CNKI; 读秀, DUXIU; ISI_Web of Science; Elsevier Science; STN on the web; 上海交通大学, 凤阳爱尔思轻合金精密成型有限公司, 彭立明, 袁灵洋, 杨磊, 肖刚, 杨超, 铝硅, 合金, 铝, Al, 硅, Si, 镁, Mg, 锰, Mn, 铜, Cu, 钛, Ti, 锆, Sr, 钒, V, 稀土, RE, 镧, La, 铈, Ce, 钇, Er, 非热处理, 细化, 变质, 汽车, aluminium silicon alloy, aluminum, silicon, magnesium, manganese, copper, titanium, strontium, vanadium, rare earth, lanthanum, cerium, erbium, automotive																		
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>PX</td> <td>CN 114411020 A (SHANGHAI JIAO TONG UNIVERSITY et al.) 29 April 2022 (2022-04-29) claims 1-10</td> <td>1-10</td> </tr> <tr> <td>Y</td> <td>CN 104831129 A (FENGYANG L-S LIGHT ALLOY NET FORMING CO., LTD. et al.) 12 August 2015 (2015-08-12) description, paragraphs [0003]-[0013]</td> <td>1-10</td> </tr> <tr> <td>Y</td> <td>CN 105316542 A (GUANGDONG HONGTU TECHNOLOGY (HOLDINGS) CO., LTD.) 10 February 2016 (2016-02-10) description, paragraphs [0005]-[0012]</td> <td>1-10</td> </tr> <tr> <td>Y</td> <td>CN 104294495 A (NINGBO RUIMING MACHINERY CO., LTD.) 21 January 2015 (2015-01-21) description, paragraphs [0007]-[0010]</td> <td>1-10</td> </tr> <tr> <td>Y</td> <td>CN 108754256 A (SHANGHAI JIAO TONG UNIVERSITY et al.) 06 November 2018 (2018-11-06) description, paragraphs [0002]-[0065]</td> <td>3-10</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	PX	CN 114411020 A (SHANGHAI JIAO TONG UNIVERSITY et al.) 29 April 2022 (2022-04-29) claims 1-10	1-10	Y	CN 104831129 A (FENGYANG L-S LIGHT ALLOY NET FORMING CO., LTD. et al.) 12 August 2015 (2015-08-12) description, paragraphs [0003]-[0013]	1-10	Y	CN 105316542 A (GUANGDONG HONGTU TECHNOLOGY (HOLDINGS) CO., LTD.) 10 February 2016 (2016-02-10) description, paragraphs [0005]-[0012]	1-10	Y	CN 104294495 A (NINGBO RUIMING MACHINERY CO., LTD.) 21 January 2015 (2015-01-21) description, paragraphs [0007]-[0010]	1-10	Y	CN 108754256 A (SHANGHAI JIAO TONG UNIVERSITY et al.) 06 November 2018 (2018-11-06) description, paragraphs [0002]-[0065]	3-10
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.																		
<table border="1"> <tr> <td> * Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “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 </td> <td> “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 </td> </tr> <tr> <td> Date of the actual completion of the international search 25 October 2022 </td> <td> Date of mailing of the international search report 24 November 2022 </td> </tr> <tr> <td> 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 </td> <td> Authorized officer Telephone No. </td> </tr> </table>	* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “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 25 October 2022	Date of mailing of the international search report 24 November 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.												
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Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2022/118853

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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