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(54) **7XXX SERIES ALUMINUM ALLOY OR PLATE, MANUFACTURING METHOD THEREFOR, PROCESSING METHOD THEREFOR, AND APPLICATION THEREOF**

(57) The invention relates to a 7xxx series aluminum alloy or sheet. The 7xxx series aluminum alloy or sheet comprise, by weight, Zn in 5.1-10.0%, Mg in 2.0-3.2%, Cu in 1.2-3.0%, Fe in 0-0.5%, Si in 0-0.4%, Ti in 0-0.2%, Cr in 0-0.1%, Zr in 0-0.055%, Mn in 0-0.25%, other grain size controlling element(s) in 0-0.30%, and Al in balance. The 7xxx series aluminum alloy sheet is particularly suitable for integrated hot forming-quenching processing. The invention also relates to a process of producing and a process of processing the 7xxx series aluminum alloy or sheet and use of the 7xxx series aluminum alloy or sheet in producing vehicle parts.

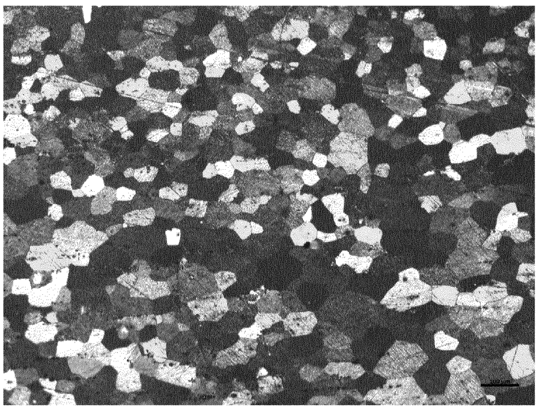

FIG. 1

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Description

Technical Field

[0001] The invention relates to the field of nonferrous metals, and particularly relates to a 7xxx series aluminum alloy or sheet. The invention also relates to a process of producing the 7xxx series aluminum alloy or sheet, a process of processing same and use thereof for producing vehicle parts.

Background

[0002] In recent years, the automobile industry has been rapidly developed, and the demand for lightweight automobiles is also greatly influenced by energy, environment and the like. The weight of the automobile body accounts for about 40% of the total weight of the automobile, such that the lightweight of the automobile body plays a decisive role in the lightweight of the whole automobile. The lightweight of the automobile body is increasingly interested by the automobile producing technology. Currently, aluminum alloy sheets commonly used for the automobile body are mainly 5xxx and 6xxx series aluminum alloys with relatively lower strength. The 7xxx series aluminum alloy has high strength but low formability at room temperature, which limits the wide use thereof in vehicle bodies.

[0003] In the traditional hot forming process, in order to ensure the formability and the strength of parts, a sheet blank is heated to the required temperature and then transferred into a die for hot forming, and then the formed parts are subjected to conventional solid solution treatment and aging strengthening treatment to obtain parts with final properties. The process has the disadvantages of complicated procedures, long duration, being difficult to ensure the dimensional accuracy of the parts after heat treatment and relatively high production cost. The integrated hot forming-quenching process is a composite process combining heat treatment and hot forming of aluminum alloy, which combines the forming process and the heat treatment process and realizes forming and controls performance by means of a same set of molds. The process improves the plasticity of the material in the forming process while ensuring the strength of the material. The aluminum alloy sheet after the completion of solid solution treatment is quickly transferred to a water-cooled mold, the mold is quickly closed for forming and kept closed after forming to finish quenching the part in the mold, then the sheet is finally subjected to aging treatment to improve the strength. The process is a novel process with the greatest prospect in the hot forming of high-strength aluminum alloy sheets, which can solve the problems of poor forming plasticity, large resilience and shape distortion during heat treatment.

[0004] Although the integrated hot forming-quenching process has been commercialized up to date, it is mainly used on high-strength steel, 5xxx and 6xxx series aluminum alloys, such as AA5754, AA6016, AA6111, and the like. The process improves the formability of the original sheet through an aluminum alloy hot stamping process so as to produce parts with more complex shapes. It is known that 5xxx and 6xxx aluminum alloy parts have strength lower than 300 MPa, which cannot satisfy the high strength requirement of vehicle body structural parts. The 7xxx series high-strength aluminum alloy with better mechanical property is mainly used in the field of aerospace but is less used in the vehicle body, so that the related research and application are still in starting stage.

Summary of Invention

[0005] The inventors of the present invention have discovered that the integrated hot forming-quenching process has strict requirement on the properties of the 7xxx series aluminum alloy sheet, particularly the short-time solid solubility, low quenching sensitivity, good hot forming and age hardening, and the like. But the present 7xxx series aluminum alloy sheets do not meet all these requirements yet.

[0006] The inventors of the present invention have found a 7xxx-series aluminum alloy with a specific alloy composition, whose sheet is particularly suitable for the use in an integrated hot forming-quenching process after painstaking research. The present invention has been completed based on this finding.

[0007] Specifically, the present invention relates to the following aspects.

1. A 7xxx series aluminum alloy (preferably sheet) comprising, by weight, Zn in 5.1-10.0%, Mg in 2.0-3.2%, Cu in 1.2-3.0%, Fe in 0-0.5%, Si in 0-0.4%, Ti in 0-0.2%, Cr in 0-0.1%, Zr in 0-0.055%, Mn in 0-0.25%, other grain size controlling element(s) in 0-0.30%, and Al in balance.

2. The 7xxx-series aluminum alloy (preferably sheet) according to any of the preceding or subsequent aspects, having a chemical composition, by weight, of Zn in 5.4 - 7.6%, Mg in 2.0-2.7%, Cu in 1.6 - 2.3%, Fe in 0-0.4%, Si in 0-0.3%, Ti in 0.01-0.15%, Cr in 0-0.05%, Zr in 0-0.05%, Mn in 0-0.25%, other grain size controlling element(s) in 0-0.25%, and Al in balance.

3. The 7xxx-series aluminum alloy (preferably sheet) according to any one of the preceding or subsequent aspects, having a chemical composition, by weight, of Zn in 7.6-9.6%, Mg in 2.1-3.1%, Cu in 1.4-2.6%, Fe in 0-0.4%, Si in 0-0.3%, Ti in 0.01-0.15%, Cr in 0-0.05%, Zr in 0-0.05%, Mn in 0-0.25%, other grain size controlling element(s) in 0-0.25%, and Al in balance.

4. The 7xxx series aluminum alloy (preferably sheet) according to any of the preceding or subsequent aspects, having a chemical composition, by weight, of Zn in 5.1-6.7%, Mg in 2.0-2.9%, Cu in 1.2-2.6%, Fe in 0-0.5%, Si in 0-0.4%, Cr in 0-0.1%, Zr in 0-0.05%, Mn in 0-0.25%, and Al in balance.

5. The 7xxx series aluminum alloy (preferably sheet) according to any of the preceding or subsequent aspects, having a chemical composition, by weight, of Zn in 5.4 - 6.5%, Mg in 2.0-2.7%, Cu in 1.6 - 2.3%, Fe in 0-0.4%, Si in 0-0.3%, Cr in 0-0.05%, Zr in 0-0.05%, Mn in 0-0.15%, and Al in balance.

6. The 7xxx series aluminum alloy (preferably sheet) according to any one of the preceding or subsequent aspects, comprising Fe in 0.05-0.4%, Si in 0.05-0.3%, Cr in 0.001-0.05%, Zr in 0.001-0.04%, Mn in 0.001-0.15%, and other grain size controlling element(s) in 0-0.15%.

7. The 7xxx-series aluminum alloy (preferably sheet) according to any one of the preceding or subsequent aspects, comprising Cr in 0-0.05%, Zr in 0-0.04%, Mn in 0-0.15%, and other grain size controlling element(s) in 0-0.15%, and/or having a combined content by weight of Cr, Mn, Zr and other grain size controlling element(s) (preferably Cr, Mn, and Zr, such as present alone, or present as a mixture of two or more) of ≤ 0.25% (preferably ≤ 0.20% or ≤ 0.15%).

8. The 7xxx series aluminum alloy sheet according to any one of the preceding or subsequent aspects, having an average grain size of 10-100 μm (preferably 15-70 μm) and/or a thickness of 0.5-10.0 mm (preferably 1.0-4.0 mm), after maintaining the temperature at 450-510 °C for 5-20 min.

9. The 7xxx series aluminum alloy sheet according to any one of the preceding or subsequent aspects, having at least one of the following properties:

(1) being suitable for an integrated hot forming-quenching process,
(2) being able of completing the solid solution treatment at 450-510 °C within 5-20 min,
(3) low quenching sensitivity, and
(4) being in the cold-rolled-state, O-state or T4-state sheet.

10. The 7xxx series aluminum alloy sheet according to any one of the preceding or subsequent aspects, having a yield strength >400 MPa (preferably >480 MPa), a tensile strength >450 MPa (preferably >520 MPa) and an elongation >6.5% (preferably >5.5%), after maintaining the temperature at 450-510 °C for 5-20 min, followed by an air quenching, a mold quenching or a water quickening and then an artificial peak aging or a paint-baking treatment.

11. A process of producing a 7xxx series aluminum alloy sheet, comprising the steps of carrying out homogenization treatment, hot rolling treatment and cold rolling treatment on a 7xxx series aluminum alloy cast ingot, to obtain the 7xxx series aluminum alloy sheet, wherein the 7xxx series aluminum alloy cast ingot has a chemical composition of, by weight, 5.1-10.0% of Zn, 2.0-3.2% of Mg, 1.2-3.0% of Cu, 0-0.5% of Fe, 0-0.4% of Si, 0-0.2% of Ti, 0-0.1% of Cr, 0-0.055% of Zr, 0-0.30% of Mn and the balance of Al.

12. The process according to any one of the preceding or subsequent aspects, wherein the homogenization treatment comprises: heating the 7xxx series aluminum alloy ingot to 375-460 °C (preferably 400-450 °C), maintaining the temperature for 0-15 hours (preferably 5-10 hours), then heating to 465-490 °C (preferably 470-490 °C or 470-485 °C), maintaining the temperature for 10-48 hours (preferably 10-36 hours or 16-36 hours), then cooling to room temperature by air quenching or being cooled together with the furnace, wherein the heating rate is 15-75 °C/h (preferably 25-75 °C/h or 25-50 °C/h). And/or the hot rolling treatment comprises hot rough rolling and hot finish rolling to 4-14 mm (preferably 4-8 mm or 6-10 mm), at a final rolling temperature of 200-460 °C (preferably 250-350 °C, 300-460 °C or 350-450 °C), and coiling followed by air quenching to room temperature. And/or the cold rolling treatment comprises cold rolling to 0.5-10.0 mm (preferably 1.0-4.0 mm) to obtain the 7xxx series aluminum alloy sheet (in a cold-rolled-state). And/or the process further comprises a step of box annealing or continuous annealing of the 7xxx series aluminum alloy sheet in the cold-rolled-state to obtain an O-state or a T4-state alloy sheet. And/or the process further comprises a step of maintaining the temperature of the homogenized ingot at 300-480 °C

(preferably 380-460 °C) for 2-30 hours (preferably 3-20 hours) before the hot rolling treatment.

13. An integrated hot forming-quenching processing process, comprising a step of subjecting a 7xxx-series aluminum alloy sheet according to any one of the preceding or subsequent aspects or a 7xxx-series aluminum alloy sheet produced by the process according to any one of the preceding or subsequent aspects to an integrated hot forming-quenching processing.

14. A vehicle part (particularly an automobile part), made of the 7xxx-series aluminum alloy sheet according to any one of the preceding or subsequent aspects or produced by the processing process according to any one of the preceding or subsequent aspects.

15. A vehicle provided with the vehicle part according to any one of the preceding or subsequent aspects.

Technical effects

[0008] The aluminum alloy sheet provided by the invention has one of the following beneficial effects or a combination thereof:

(1) being suitable for an integrated hot forming-quenching process;
(2) excellent short-time solid solubility;
(3) excellent quenching sensitivity;
(4) excellent age hardening or paint bake hardening; and
(5) excellent hot formability.

Description of Drawings

[0009]

FIG. 1 shows the grain structure of the alloy sheet of Example A1 after solid solution treatment at 480 °C for 5 min.

FIG. 2 shows the grain structure of the alloy sheet of Example A3 after solid solution treatment at 480 °C for 5 min.

FIG. 3 shows the grain structure of the alloy sheet of comparative example C5 after solid solution treatment at 480 °C for 5 min.

FIG. 4 shows the grain structure of the alloy sheet of Example A4 after solid solution treatment at 480 °C for 5 min.

FIG. 5 shows the grain structure of the C1 alloy sheet of comparative example after solid solution treatment at 480 °C for 5 min.

FIG. 6 shows the grain structure of the alloy sheet of Example A5 after solid solution treatment at 480 °C for 5 min.

FIG. 7 shows the grain structure of the alloy sheet of comparative example C2 after solid solution treatment at 480 °C for 5 min.

FIG. 8 shows the grain structure of the alloy sheet of comparative example C3 after solid solution treatment at 480 °C for 5 min.

FIG. 9 shows the grain structure of the alloy sheet of Example A6 after solid solution treatment at 480 °C for 5 min.

FIG. 10 shows the microstructure of the alloy sheet according to Example A15 observed by SEM after solid solution treatment at 480 °C for 10 min.

FIG. 11 shows the microstructure of the alloy sheet according to comparative example C7 observed by SEM after solid solution treatment at 480 °C for 10 min.

FIG. 12 shows the microstructure of the alloy sheet according to comparative example C10 observed by SEM after solid solution treatment at 480 °C for 10 min.

FIG. 13 shows the microstructure of the alloy sheet according to comparative example C12 observed by SEM after solid solution treatment at 480 °C for 10 min.

Embodiments of the Invention

[0010] The embodiments of the present invention will be illustrated in more detail below, but it should be understood that the scope of the invention is not limited by the embodiments but is defined by the claims appended.

[0011] All publications, patent applications, patents, and other references mentioned in this specification are herein incorporated by reference in their entirety. Unless defined otherwise, all technical and scientific terms used herein are understood same as the meanings commonly known to those skilled in the art. In case of conflict, definitions according to the present specification will control.

[0012] When the specification introduces materials, substances, processes, steps, devices, components, or the like initiated with "known to those ordinary skill in the art", "prior art", or the like, it is intended that the subject matter so initiated encompass not only those conventionally used in the art at the time of filing this application, but also those may not be so commonly used at the present time, but will become known in the art as being suitable for a similar purpose.

[0013] In the context of this specification, the term "substantially" means a deviation acceptable or considered as reasonable by a person skilled in the art, such as within $\pm$ 5%, within $\pm$ 1%, within $\pm$ 0.5% or within $\pm$ 0.1%.

[0014] In the context of the present specification, when describing a process of producing a 7xxx-series aluminum alloy sheet, the temperature generally refers to the temperature of the material itself during the treatment (such as annealing, homogenization or hot rolling), unless particularly specified.

[0015] In the context of the present specification, the expression "the balance being Al" means "the balance being Al and unavoidable impurities", unless otherwise specified, as being obvious to those skilled in the art.

[0016] In the context of the present specification, artificial peak aging may be carried out in any manner known to those skilled in the art, without any particular limitation. For example, the aging may be carried out by maintain the temperature at 100-130 °C for 5-48 h.

[0017] In the context of the present specification, the baking treatment may be carried out in any manner known to the person skilled in the art, without particular limitation. For example, the treatment may be carried out by maintain the temperature at 170-190 °C for 20-40 min.

[0018] In the context of the present specification, the method of measuring the yield strength refers to ASTM E8/E8M-16ae1 standard.

[0019] In the context of the present specification, the method of measuring the ultimate tensile strength refers to ASTM E8/E8M-16ae1 standard.

[0020] In the context of the present specification, the method of measuring the elongation refers to ASTM E8/E8M-16ae1 standard.

[0021] In the context of this specification, the method of measuring the average grain size refers to ASTM E112-13 standard.

[0022] All percentages, parts, ratios, etc. involved in this specification are calculated by weight, and pressures are gauge pressures, unless explicitly indicated.

[0023] In the context of this specification, any two or more embodiments of the invention may be combined in any manner, and the resulting solution is a part of the original disclosure of this specification and is within the scope of the invention.

[0024] According to an embodiment of the invention, the invention relates to a 7xxx-series aluminum alloy, in particular a 7xxx-series aluminum alloy in the form of a sheet (i.e. a 7xxx-series aluminum alloy sheet). The 7xxx series aluminum alloy sheet is particularly suitable for integrated hot forming-quenching processing. Generally, the aluminum alloy sheet has medium or high strength.

[0025] According to an embodiment of the invention, the 7xxx series aluminum alloy or sheet has a chemical composition of, by weight, 5.1-10.0% of Zn, 2.0-3.2% of Mg, 1.2-3.0% of Cu, 0-0.5% of Fe, 0-0.4% of Si, 0-0.2% of Ti, 0-0.1% of Cr, 0-0.055% of Zr, 0-0.25% of Mn, 0-0.30% of other grain size controlling element(s), and the balance of Al.

[0026] In the context of this specification, "other grain size controlling element(s)" means any trace element (other than Cr, Zr, and Mn) known to those skilled in the art to be useful in adjusting (increasing or decreasing) the grain size of an aluminum alloy. Specific examples of other grain size controlling element(s) comprise Er, Sc, Hf, Dy, Gd, and the like. These other grain size controlling element(s) may be used alone or as combination of two or more.

[0027] Without being limited by any theory, the inventors believe that controlling the contents of Fe and Si can reduce the whole costs of preparation and subsequent use of the raw alloy material and has a certain effect on refining the grain structure. In addition, the inventors of the invention also think that based on the requirement of the aluminum alloys for the integrated hot forming-quenching process, the contents of main alloy elements Zn, Mg and Cu are strictly controlled to reduce the high-temperature residual Al_2CuMg phase, such that the residual second phase in the alloy sheet can be quickly dissolved back into the matrix during the heating and short-time heat preservation stages of the integrated hot forming-quenching process and the hot formability as well as the subsequent mechanical property of the alloy can be ensured. Moreover, the inventors of the invention also think that strict control of the contents of the grain size controlling elements such as Cr, Zr and Mn, and the like, can ensure the alloy sheet has relatively lower quenching sensitivity and simultaneously control the grain size of the alloy. So, the sheet can have relatively larger supersaturation degree of the matrix and finer grain structure after high-temperature solid solution treatment and mold quenching. After subsequent artificial peak aging or baking treatment, the final alloy sheet has a yield strength >400 MPa, a tensile strength >450 MPa, and an elongation >6.5%.

[0028] According to an embodiment of the invention, the 7xxx-series aluminum alloy or sheet has a chemical composition of, by weight, Zn in 5.4-7.6%, Mg in 2.0-2.7%, Cu in 1.6-2.3%, Fe in 0-0.4%, Si in 0-0.3%, Ti in 0.01-0.15%, Cr in 0-0.05%, Zr in 0-0.05%, Mn in 0-0.25%, and Al in balance.

[0029] According to an embodiment of the invention, the 7xxx-series aluminum alloy or sheet has a chemical composition of, by weight, Zn in 7.6-9.6%, Mg in 2.1-3.1%, Cu in 1.4-2.6%, Fe in 0-0.4%, Si in 0-0.3%, Ti in 0.01-0.15%, Cr in 0-0.05%, Zr in 0-0.05%, Mn in 0-0.25%, and Al in balance.

[0030] According to an embodiment of the invention, the 7xxx-series aluminum alloy or sheet has a chemical composition of, by weight, 5.1-6.7% of Zn, 2.0-2.9% of Mg, 1.2-2.6% of Cu, 0-0.5% of Fe, 0-0.4% of Si, 0-0.1% of Cr, 0-0.05% of Zr, 0-0.25% of Mn, and the balance of Al.

[0031] According to an embodiment of the invention, conforming to the requirements by the integrated hot forming-quenching process on the solid solubility and quenching sensitivity of aluminum alloy sheet, the 7xxx series aluminum alloy or sheet preferably comprises 5.4-6.5 wt% of Zn, 2.0-2.7 wt% of Mg, 1.6-2.3 wt% of Cu, 0-0.4 wt% of Fe, 0-0.3 wt% of Si, 0-0.05 wt% of Cr, 0-0.05 wt% of Zr, 0-0.15 wt% of Mn and the balance of Al.

[0032] According to an embodiment of the present invention, the 7xxx-series aluminum alloy or sheet comprises 0.05-0.4% of Fe, 0.05-0.3% of Si, 0.001-0.05% of Cr, 0.001-0.04% of Zr, 0.001-0.15% of Mn, and 0-0.15% of other grain size controlling element(s).

[0033] According to an embodiment of the present invention, the 7xxx-series aluminum alloy or sheet comprises 0-0.05% of Cr, 0-0.04% of Zr, 0-0.25% of Mn, and 0-0.15% of other grain size controlling element(s).

[0034] According to the invention, Cr, Mn, Zr and the other grain size controlling element(s) are each grain size controlling elements, preferably Cr, Mn and Zr. These grain size controlling elements may be used alone or as a combination of two or more. According to an embodiment of the invention, the combined content by weight of these grain size controlling elements (referring to the content by weight of an element for the case of being used alone) is generally ≤0.30%, preferably ≤0.25% or ≤0.15%, when used alone or in combination.

[0035] According to an embodiment of the invention, the 7xxx series aluminum alloy sheet generally has an average grain size of 10-100 μm, preferably 15-70 μm, after maintaining the temperature at 450-510 °C for 5-20 min.

[0036] According to an embodiment of the invention, the 7xxx-series aluminum alloy sheet generally has a thickness in the range of 0.5-10.0 mm, preferably 1.0-4.0 mm.

[0037] According to an embodiment of the invention, the 7xxx-series aluminum alloy sheet is particularly suitable for integrated hot forming-quenching processing.

[0038] According to an embodiment of the invention, the 7xxx aluminum alloy sheet has rapid solid solubility, namely, a solution treatment thereof can be rapidly completed by maintaining the temperature at 450-510 °C for 5-20 min.

[0039] According to an embodiment of the invention, the 7xxx-series aluminum alloy sheet has a low quenching sensitivity.

[0040] According to an embodiment of the invention, the 7xxx-series aluminum alloy sheet is in cold-rolled-state, O-state or T4-state.

[0041] According to an embodiment of the invention, the 7xxx series aluminum alloy sheet generally has a yield strength >400 MPa, preferably >480 MPa, after maintaining the temperature at 450-510 °C for 5-20 min followed by subsequent air quenching, mold quenching or water quenching, and then artificial peak aging or baking treatment.

[0042] According to an embodiment of the invention, the 7xxx aluminum alloy sheet generally has a ultimate tensile strength of >450MPa, preferably >520 MPa, after maintaining the temperature at 450-510 °C for 5-20 min followed by subsequent air quenching, mold quenching or water quenching, and then artificial peak aging or paint baking treatment.

[0043] According to an embodiment of the invention, the 7xxx aluminum alloy sheet generally has an elongation of >6.5%, preferably >5.5%, after maintaining the temperature at 450-510 °C for 5-20min followed by subsequent air quenching, mold quenching or water quenching, and then artificial peak aging or paint baking treatment.

[0044] According to an embodiment of the invention, the invention further relates to a process of producing the 7xxx series aluminum alloy sheet. The process can be used for producing any 7xxx series aluminum alloy sheet of the invention as described above.

[0045] According to an embodiment of the present invention, the producing process comprises the steps of subjecting a 7xxx series aluminum alloy ingot to a homogenization treatment, a hot rolling treatment and a cold rolling treatment to obtain the 7xxx series aluminum alloy sheet. Here, the 7xxx series aluminum alloy ingot is an ingot of any of the 7xxx series aluminum alloys of the present invention as described above. For example, the 7xxx series aluminum alloy ingot has a chemical composition of, by weight, 5.1-10.0% of Zn, 2.0-3.2% of Mg, 1.2-3.0% of Cu, 0-0.5% of Fe, 0-0.4% of Si, 0-0.2% of Ti, 0-0.1% of Cr, 0-0.055% of Zr, 0-0.30% of Mn and the balance of Al.

[0046] According to an embodiment of the present invention, in the producing process, the homogenization treatment may be carried out in any manner known to those skilled in the art, without any particular limitation. For example, the 7xxx series aluminum alloy ingot is heated to 375-460 °C (preferably 400-450 °C) and maintained for 0-15 h (preferably 5-10 h), then heated to 465-490 °C (preferably 470-490 °C or 470-485 °C) and maintained for 10-48 h (preferably 10-36 h or 16-36 h), and then cooled to room temperature by air quenching or being cooled together with the furnace. Here, the homogenization treatment generally has a temperature rising rate of 15-75 °C/h, preferably of 25-75 °C/h or 25-50 °C/h.

[0047] According to an embodiment of the present invention, in the producing process, the hot rolling treatment may be carried out in any manner known to those skilled in the art, without any particular limitation. For example, it is general to conduct hot rough rolling and hot finish rolling to 4-14 mm, preferably to conduct hot rough rolling and hot finish rolling to 4-8 mm or 6-10 mm. Here, the hot rolling treatment has a finishing temperature of 200-460 °C, preferably 250-350 °C, 300-460 °C or 350-450 °C. Then, the hot-rolled sheet was curled and air-quenched to room temperature.

[0048] According to an embodiment of the present invention, in the producing process, the cold rolling treatment may be carried out in any manner known to those skilled in the art, without any particular limitation. For example, it is generally cold-rolled to 0.5-10.0 mm, preferably to 1.0-4.0 mm, to obtain the 7xxx-series aluminum alloy sheet. In this case, the 7xxx series aluminum alloy sheet is obtained in cold-rolled state.

[0049] According to an embodiment of the invention, the producing process further comprises a step of box annealing or continuous annealing the cold-rolled 7xxx-series aluminum alloy sheet to obtain the 7xxx-series aluminum alloy sheet in O-state or T4-state. Here, the box annealing may be carried out in any manner known to those skilled in the art, without any particular limitation. For example, the box annealing can generally have operating conditions of placing the aluminum alloy coil into a box-type annealing furnace to be heated to a temperature of 300-450 °C at a heating rate of 25-50 °C/h, maintaining the temperature for 0.5-3 h, and then cooling. The continuous annealing may be carried out in any manner known to those skilled in the art, without any particular limitation. For example, the continuous annealing can generally have operating conditions of passing a coil of aluminum alloy strip through a continuous annealing furnace with a furnace temperature of 400-500 °C at a speed of 10-80 m/min, then cooling and coiling.

[0050] According to an embodiment of the invention, the producing process further comprises a step of maintain the temperature of the homogenized ingot at 300-480 °C for 2-30h before the hot rolling treatment. Preferably, the homogenized ingot is maintained at a temperature of 380-450 °C for 3-20 h.

[0051] According to an embodiment of the present invention, there is also provided an integrated hot forming-quenching processing process, comprising a step of subjecting the 7xxx-series aluminum alloy sheet according to any one of the preceding embodiments or the 7xxx-series aluminum alloy sheet produced by the producing process according to any one of the preceding embodiments to an integrated hot forming-quenching processing. Here, the integrated hot forming-quenching process may be carried out in any manner known to those skilled in the art, without any particular limitation, and thus a detailed description thereof is omitted here.

[0052] According to an embodiment of the invention, the invention also relates to a vehicle part, in particular an automobile part. Here, the vehicle part may be made of a 7xxx-series aluminum alloy sheet according to any one of the preceding embodiments. The process for producing the vehicle part may be any process known to those skilled in the art, without any particular limitation, and the process may be any process of the integrated hot forming-quenching processes according to any one of the preceding embodiments.

[0053] According to an embodiment of the present invention, the present invention also relates to a vehicle comprising the vehicle part according to any one of the preceding embodiments.

Examples

[0054] The present invention will be described in further detail below for examples and comparative examples, but the present invention is not limited to the following examples.

[0055] The 7xxx aluminum alloy cooling sheet was prepared by a process comprising the following steps. Preparing an alloy cast ingot by an industrial semi-continuous process, wherein the alloy cast ingots were subjected to homogenization treatment according to the characteristics of the trace elements contained in the cast ingots. The homogenization process comprises maintaining the temperature of the alloy cast ingots at 400 °C for 10 hours, followed by maintaining the temperature at 470 °C for 24 hours, with an increasing rate of the temperature of 50 °C/h. Then air quenching the alloy cast ingots to room temperature. Maintaining the temperature of the homogenized blank at 440 °C for 8 hours then carrying out hot rough rolling and hot finish rolling to 6 mm in thickness, with a final rolling temperature at 300 °C. Then coiling and air quenching the hot-rolled coil of the alloy to room temperature. Finally, carrying out cold rolling (a cold rolling-to-intermediate annealing-to-cold rolling process can be selected depending on specific conditions, namely cold rolling the intermediate annealing state, called as a CAC state cold-rolled sheet) on the hot-rolled coil of the alloy to obtain the cold-rolled alloy sheet with a final thickness of 2 mm. The cold-rolled coil can also be optionally subjected to box annealing or continuous annealing to obtain an O-state or T4-state sheet.

[0056] The alloy composition ranges for Examples A1-A11 were as follows: 5.1-6.7% of Zn, 2.0-2.9% of Mg, 1.2-2.6% of Cu, 0-0.5% of Fe, 0-0.4% of Si, 0-0.1% of Cr, 0-0.05% of Zr, 0-0.25% of Mn, 0-0.25% of other grain size controlling element(s) and the balance of Al. The specific chemical compositions of the alloys of Examples A1-A11 and comparative examples C1-C6, as well as the corresponding sheet states, were shown in Table 1.

[0057] Based on the characteristics of the integrated hot forming-quenching process, the alloy sheets of Examples A1-A11 and comparative examples C1-C6 were subjected to a fast solution treatment at 480 °C for 5 min (the industrial production can carry out on-line continuous solution treatment) followed by two extreme cooling modes of water quenching (WQ) or air quenching (AQ). Then T6 peak aging (PA) at 120 °C for 24 hours and baking treatment (BH) at 180 °C for 30 min were carried out, respectively. The sheets treated by different processes were subjected to tensile property tests. Meanwhile, a loss coefficient R of the yield strengths of the alloy sheet obtained respectively by the air quenching and the water quenching aging was introduced, namely: ((yield strength obtained by water quenched sample)-(yield strength obtained by air quenched sample))/(yield strength obtained by water quenched sample), and the corresponding calculation equation was R = (WQ-AQ)/WQ, calculated in %. Through the tensile test and calculation, the alloy sheets of Examples A1-A11 should have yield strength >400 MPa, tensile strength >450 MPa, elongation >6.5%, and yield strength loss coefficients R ≤ 20%. The property results are shown in Table 2.

Table 1: Alloy sheet compositions of Examples A1-A11 and comparative examples C1-C6

Alloy	Zn	Mg	Cu	Fe	Si	Cr	Zr	Mn	Al	State
A1 (Ex. 1)	5.63	2.73	1.59	0.10	0.02	0.0021	0.0003	0.005	balance	2mm, cold-rolled-state
A2 (Ex. 2)	6.11	2.40	2.19	0.09	0.02	0.0027	0.0002	0.004	balance	2mm, cold-rolled-state
A3 (Ex. 3)	5.52	2.59	1.72	0.30	0.20	0.0015	0.0003	0.004	balance	2mm, cold-rolled-state
A4 (Ex. 4)	5.52	2.53	1.70	0.21	0.12	0.0015	0.0452	0.004	balance	2mm, cold-rolled-state
A5 (Ex. 5)	5.69	2.66	1.69	0.23	0.13	0.0442	0.0002	0.005	balance	2mm, cold-rolled-state
A6 (Ex. 6)	5.73	2.72	1.82	0.25	0.12	0.0024	0.0003	0.122	balance	2mm, cold-rolled-state
A7 (Ex. 7)	5.71	2.68	1.79	0.24	0.11	0.0481	0.0001	0.004	balance	1mm, cold-rolled-state
A8 (Ex. 8)	5.65	2.70	1.73	0.21	0.14	0.0425	0.0003	0.003	balance	4mm, cold-rolled-state
A9 (Ex. 9)	5.70	2.68	1.64	0.24	0.11	0.0441	0.0002	0.005	balance	2mm CAC state
A10 (Ex. 10)	5.69	2.63	1.67	0.23	0.13	0.0472	0.0003	0.004	balance	2mm O-state
A11 (Ex. 11)	5.59	2.71	1.70	0.26	0.14	0.0435	0.0001	0.003	balance	2mm T4-state
C1 (C.Ex. 1)	5.60	2.60	1.60	0.10	0.03	0.0032	0.0791	0.004	balance	2mm, cold-rolled-state
C2 (C.Ex. 2)	5.75	2.65	1.72	0.24	0.12	0.1241	0.0006	0.004	balance	2mm, cold-rolled-state
C3 (C.Ex. 3)	5.71	2.56	1.60	0.10	0.03	0.1811	0.0002	0.004	balance	2mm, cold-rolled-state
C4 (C.Ex. 4)	5.71	2.73	1.79	0.21	0.13	0.0019	0.0003	0.263	balance	2mm, cold-rolled-state
C5 (C.Ex. 5)	5.67	2.54	1.52	0.02	0.01	0.0054	0.0001	0.003	balance	2mm, cold-rolled-state
C6 (C.Ex. 6)	5.49	1.42	0.28	0.25	0.12	0.0011	0.0002	0.003	balance	2mm, cold-rolled-state

Table 2: Properties of alloy sheets of Examples A1-A11 and comparative examples C1-C6

	Treatment	Yield Strength, MPa	Tensile Strength, MPa	Elongation, %	(WQ-AQ)/WQ %
A1 (Ex. 1)	WQ+PA	493	553	16.6	3.45
	AQ+PA	476	523	7.1	
	WQ+BH	460	507	12.5	8.04
	AQ+BH	423	479	9.5	
A2 (Ex. 2)	WQ+PA	503	568	17.3	2.78
	AQ+PA	489	539	9.4	
	WQ+BH	477	546	13.7	12.6
	AQ+BH	417	481	9.2	
A3 (Ex. 3)	WQ+PA	490	546	14.7	4.90
	AQ+PA	466	534	9.7	
	WQ+BH	460	513	13.8	5.00
	AQ+BH	437	506	12.9	
A4 (Ex. 4)	WQ+PA	505	564	15.4	6.73
	AQ+PA	471	527	6.5	
	WQ+BH	482	532	12.5	12.24
	AQ+BH	423	490	12.38	
A5 (Ex. 5)	WQ+PA	535	586	14.2	14.58
	AQ+PA	457	506	10.1	
	WQ+BH	497	550	12.5	17.30
	AQ+BH	411	478	11.0	
A6 (Ex. 6)	WQ+PA	507	571	16.0	10.06
	AQ+PA	456	524	9.6	
	WQ+BH	467	521	11.8	10.49
	AQ+BH	418	499	14.2	
A7 (Ex. 7)	WQ+PA	543	589	13.4	14.92
	AQ+PA	462	511	9.6	
	WQ+BH	489	530	13.5	14.93
	AQ+BH	416	476	11.7	
A8 (Ex. 8)	WQ+PA	536	576	14.6	12.87
	AQ+PA	467	516	9.4	
	WQ+BH	496	546	12.9	16.73
	AQ+BH	413	471	11.4	
A9 (Ex. 9)	WQ+PA	528	576	14.7	12.50
	AQ+PA	462	511	9.8	
	WQ+BH	494	541	12.9	17.21
	AQ+BH	409	481	11.3	

(continued)

	Treatment	Yield Strength, MPa	Tensile Strength, MPa	Elongation, %	(WQ-AQ)/WQ %
A10 (Ex. 10)	WQ+PA	537	588	14.1	12.66
	AQ+PA	469	517	10.5	
	WQ+BH	498	538	12.7	17.07
	AQ+BH	413	485	11.1	
A11 (Ex. 11)	WQ+PA	531	578	13.7	10.36
	AQ+PA	476	527	9.6	
	WQ+BH	494	529	12.5	14.78
	AQ+BH	421	491	10.5	
C1 (C.Ex. 1)	WQ+PA	474	538	18.9	22.36
	AQ+PA	368	465	14.5	
	WQ+BH	437	495	14.4	34.55
	AQ+BH	286	404	19.9	
C2 (C.Ex. 2)	WQ+PA	533	589	14.0	34.90
	AQ+PA	347	456	10.1	
	WQ+BH	497	550	12.5	38.63
	AQ+BH	305	425	11.8	
C3 (C.Ex. 3)	WQ+PA	492	560	17.2	46.54
	AQ+PA	263	416	18.6	
	WQ+BH	442	515	14.0	53.85
	AQ+BH	204	362	15.4	
C4 (C.Ex. 4)	WQ+PA	507	571	16.0	10.06
	AQ+PA	456	524	9.6	
	WQ+BH	467	521	11.8	16.70
	AQ+BH	389	468	15.1	
C5 (C.Ex. 5)	WQ+PA	470	512	18.6	12.77
	AQ+PA	410	448	6.4	
	WQ+BH	451	502	12.5	17.30
	AQ+BH	373	431	8.5	
C6 (C.Ex. 6)	WQ+PA	369	417	16.3	-
	AQ+PA	385	429	15.0	
	WQ+BH	188	309	20.8	3.72
	AQ+BH	181	276	20.2	

[0058] As seen from Table 2, the alloy sheets of Examples A1-A11 of the invention showed significantly higher tensile properties than those of the comparative examples C1-C6, with yield strength >400 MPa, tensile strength >450 MPa, elongation >6.5% and yield strength loss coefficients R ≤ 20%.

[0059] The Example A1, Example A2 and Example A3 had substantially similar compositions of main alloy elements, for which the contents of trace elements of Cr, Zr and Mn were substantially zero, resulting in a low quenching sensitivity, and a yield strength loss coefficient R ≤ 15%.

[0060] The alloy of Example A1 and the alloy of Example A2 had lower contents of Fe and Si elements than the alloy of Example A3. The comparative example C5 was prepared using high-purity aluminum as a raw material thus had the lowest Fe and Si elements contents in the alloy. However, high contents of Fe and Si can effectively inhibit the growth of the grains in the sheet, which is beneficial to regulate and control the grain structure. After solution treatment, the sheets of the A1 alloy, the A3 alloy and the C5 alloy had average grain sizes, of 64 μm, 61 μm and 109 μm, respectively, as shown in Figs. 1-3. Meanwhile, although the yield strength loss coefficient R of comparative example C5 was less than 20%, the strength of the C5 alloy sheet was significantly lower than those of the Example A1 alloy, Example A2 alloy and Example A3 alloy treated by the corresponding processes due to larger grain size of the alloy sheet.

[0061] The alloy of Example A4 contained 0.0452% of trace element Zr. Compared with the alloy of example A3 without trace element Zr, the average grain size of the alloy sheet of A4 was greatly reduced to about 37 μm (as shown in Fig.4) after solution treatment, but the quenching sensitivity was increased with yield strength loss coefficient of 6.73% and 12.24% that was significantly higher than those of A3 alloy (4.9% and 5.0%). The results showed that the addition of Zr element would increase the quenching sensitivity of the alloy. For example, the comparative example Cl had higher Zr content of 0.0791%, whose average grain size was further reduced to about 25 μm (as shown in Fig. 5) but the quenching sensitivity was significantly increased compared with Example A4 with R values increased to 22.36% and 34.55%. The strength of air quenched alloys sheets after solution treatment decreased significantly. The addition of trace element Zr was beneficial to control the grain size of the sheet but should be properly controlled, otherwise, the quenching sensitivity would be greatly increased, which might significantly reduce the mechanical property of the alloy.

[0062] The alloy of Example A5 and the alloys of Examples A7-A11 all contain trace amount of Cr in amounts of no more than about 0.05%. As shown in Fig. 6, compared with the alloy of Example A3 without Cr, the average grain size of Example A5 was reduced from 61 μm to 39 μm. The quenching sensitivity of the corresponding sheet was increased but the yield loss coefficient R was still within 20%. Although the average grain size of the sheet was reduced with the increase of Cr element, the quenching sensitivity was significantly increased. For example, the average grain sizes of comparative example C2 sheet (0.1241% Cr) and comparative example C3 (0.1811% Cr, being an amount of a conventional 7075 alloy) were respectively reduced to 32 μm and 27 μm (Figs. 7 and 8), while the yield strength loss coefficients R were significantly increased to 34.9% and 38.63 for C2, and 46.54% and 53.85% for C3, respectively. The strength of air quenched alloys sheets after solution treatment decreased significantly. Therefore, the addition of trace element Cr should also be cautious, wherein an appropriate amount of Cr element could effectively control the grain structure of the sheet, otherwise, the quenching sensitivity of the alloy might be increased significantly, leading to the reduce of alloy strength.

[0063] In addition, the alloys of Examples A7-A11 had substantially similar compositions, but different preparation processes and sheet thicknesses. Accordingly, the quenching sensitivity of the alloys did not significantly change, and the mechanical properties were substantially similar.

[0064] The alloy of example A6 contains 0.122% Mn. Similarly, the addition of a trace amount of Mn effectively reduced the average grain size of the sheet alloy to 24 μm (Fig. 9), but slightly increased the quenching sensitivity of the alloy sheet compared with example A3, with R values of 10.06% and 10.49%, respectively. However, the effect of Mn on quenching sensitivity of the alloy was much weaker than Cr in equal amount (as shown in example C2). Increasing the Mn content to 0.263% (comparative example C4 alloy), the quenching sensitivity of the alloy was further increased with larger yield strength loss coefficient R.

[0065] Compare the comparative example C6 with examples A1-A11, the alloy showed lower content of main elements Cu and Mg in the alloy leaded to a significantly lower strength than the others Because of the lower content of Cu element, the stability of strengthening phase during high-temperature baking treatment (BH) was poor, resulting in lower strength of the sample after baking treatment. However, due to the absence of trace elements such as Cr, Zr, Mn and the like, comparative example C6 showed lower quenching sensitivity.

[0066] The alloy composition ranges of Examples A12-A25 were as follows: 7.6 - 9.6% of Zn, 2.1-3.1% of Mg, 1.4-2.6% of Cu, 0-0.4% of Fe, 0-0.3% of Si, 0.01-0.15% of Ti, 0-0.05% of Cr, 0-0.05% of Zr, 0-0.25% of Mn, 0-0.25% of other grain size controlling element(s) and the balance of Al. The specific chemical compositions of the alloys of Examples A12-A25 and comparative examples C7-C12, as well as the corresponding sheet states, were shown in Table 3.

Table 3: Alloy sheet compositions of Examples A12-A25 and comparative examples C7-C12

Alloy	Zn	Mg	Cu	Fe	Si	Cr	Zr	Mn	Al	State
A12 (Ex. 12)	7.76	2.13	2.09	0.09	0.03	0.0021	0.0002	0.0022	balance	2mm, cold-rolled-state
A13 (Ex. 13)	7.73	2.23	1.93	0.24	0.12	0.0025	0.0002	0.0043	balance	2mm, cold-rolled-state
A14 (Ex. 14)	8.18	2.10	1.52	0.09	0.031	0.0057	0.0003	0.0034	balance	2mm, cold-rolled-state

(continued)

Alloy	Zn	Mg	Cu	Fe	Si	Cr	Zr	Mn	Al	State
A15 (Ex. 15)	9.01	2.38	2.23	0.09	0.032	0.0057	0.0002	0.0036	balance	2mm, cold-rolled-state
A16 (Ex. 16)	8.37	2.55	1.95	0.17	0.084	0.0060	0.0450	0.0058	balance	2mm, cold-rolled-state
A17 (Ex. 17)	8.98	2.86	1.99	0.17	0.081	0.0059	0.0490	0.0060	balance	1mm, cold-rolled-state
A18 (Ex. 18)	9.22	2.91	1.96	0.17	0.076	0.0061	0.0430	0.0056	balance	4mm, cold-rolled-state
A19 (Ex. 19)	8.70	2.69	2.50	0.18	0.076	0.0067	0.0400	0.0059	balance	2mm CAC state
A20 (Ex. 20)	8.94	2.77	1.54	0.18	0.076	0.0061	0.0480	0.0060	balance	2mm O-state
A21 (Ex. 21)	8.91	2.14	2.02	0.19	0.073	0.0059	0.0460	0.0058	balance	2mm T4-state
A22 (Ex. 22)	8.99	2.83	2.19	0.17	0.082	0.0480	0.0003	0.0060	balance	2mm, cold-rolled-state
A23 (Ex. 23)	8.95	2.73	1.98	0.16	0.078	0.0440	0.0004	0.0055	balance	2mm, cold-rolled-state
A24 (Ex. 24)	9.19	2.53	2.09	0.15	0.081	0.0052	0.0002	0.1310	balance	2mm, cold-rolled-state
A25 (Ex. 25)	8.91	2.59	1.98	0.16	0.078	0.0050	0.0003	0.2450	balance	2mm, cold-rolled-state
C7 (C.Ex. 7)	8.95	2.13	2.21	0.18	0.083	0.0053	0.1210	0.0051	balance	2mm, cold-rolled-state
C8 (C.Ex. 8)	9.01	2.09	2.11	0.16	0.081	0.0051	0.0920	0.0051	balance	2mm, cold-rolled-state
C9 (C.Ex. 9)	8.93	2.19	2.22	0.19	0.083	0.0049	0.0750	0.0051	balance	2mm, cold-rolled-state
C10 (C.Ex. 10)	8.99	2.10	2.13	0.15	0.075	0.212	0.0003	0.0056	balance	2mm, cold-rolled-state
C11 (C.Ex. 11)	9.11	2.23	2.19	0.18	0.080	0.125	0.0004	0.0061	balance	2mm, cold-rolled-state
C12 (C.Ex. 12)	8.83	1.98	2.22	0.17	0.073	0.0049	0.0005	0.3360	balance	2mm, cold-rolled-state

[0067] Based on the characteristics of the integrated hot forming-quenching process, the alloy sheets of Examples A12-A25 and comparative examples C7-C12 were subjected to fast solution treatment at 480 °C for 10 min (the industrial production can carry out on-line continuous solution treatment) followed by water quenching (WQ) or air quenching (AQ). Then T6 peak aging (PA) at 120 °C for 24 hours and baking treatment (BH) at 185°C for 25 min were carried out, respectively. The heat-treated sheets treated were subjected to tensile property tests and the loss coefficients R of the strengths were calculated. Through test and calculation, the alloy sheets of Examples A12-A27 had yield strength >480 MPa, tensile strength >520 MPa, elongation >5.5%, and yield strength loss coefficient R ≤ 15%. The property results are shown in Table 4.

Table 4: Properties of Examples A12-A25 and comparative examples C7-C12

	Treatment	Yield Strength, MPa	Tensile Strength, MPa	Elongation, %	(WQ-AQ)/WQ %
A12 (Ex. 12)	WQ+PA	553	574	16.6	3.80
	AQ+PA	532	564	6.3	
	WQ+BH	558	584	11.0	8.60
	AQ+BH	510	537	7.1	
A13 (Ex. 13)	WQ+PA	549	563	10.2	5.46
	AQ+PA	519	559	6.8	
	WQ+BH	528	554	11.1	6.44
	AQ+BH	494	521	9.2	

(continued)

	Treatment	Yield Strength, MPa	Tensile Strength, MPa	Elongation, %	(WQ-AQ)/WQ %
A14 (Ex. 14)	WQ+PA	544	580	16.8	4.04
	AQ+PA	522	553	6.4	
	WQ+BH	518	544	9.9	4.25
	AQ+BH	496	537	5.8	
A15 (Ex. 15)	WQ+PA	545	608	13.1	0.92
	AQ+PA	540	592	5.94	
	WQ+BH	549	589	9.9	7.65
	AQ+BH	507	549	5.8	
A16 (Ex. 16)	WQ+PA	553	619	13.2	2.53
	AQ+PA	539	600	8.6	
	WQ+BH	570	604	8.4	6.67
	AQ+BH	532	567	5.8	
A17 (Ex. 17)	WQ+PA	561	622	10.9	0.89
	AQ+PA	556	591	6.1	
	WQ+BH	601	637	8.5	13.14
	AQ+BH	522	534	6.0	
A18 (Ex. 18)	WQ+PA	545	612	13.3	1.28
	AQ+PA	538	583	5.7	
	WQ+BH	565	598	9.6	11.5
	AQ+BH	500	544	5.9	
A19 (Ex. 19)	WQ+PA	564	630	13.2	2.83
	AQ+PA	548	583	6.6	
	WQ+BH	570	605	9.6	9.30
	AQ+BH	517	545	6.6	
A20 (Ex. 20)	WQ+PA	544	616	15.2	2.02
	AQ+PA	533	583	7.8	
	WQ+BH	558	598	10.2	11.83
	AQ+BH	492	537	10.6	
A21 (Ex. 21)	WQ+PA	520	587	16.7	-
	AQ+PA	522	571	7.3	
	WQ+BH	546	574	12.5	10.26
	AQ+BH	490	523	6.1	
A22 (Ex. 22)	WQ+PA	521	577	16.2	2.11
	AQ+PA	510	559	7.6	
	WQ+BH	541	564	12.3	9.80
	AQ+BH	488	520	6.3	

(continued)

	Treatment	Yield Strength, MPa	Tensile Strength, MPa	Elongation, %	(WQ-AQ)/WQ %
A23 (Ex. 23)	WQ+PA	512	581	15.2	0.20
	AQ+PA	511	570	7.6	
	WQ+BH	540	570	13.8	7.78
	AQ+BH	498	521	6.8	
A24 (Ex. 24)	WQ+PA	511	565	15.2	0.20
	AQ+PA	510	550	6.6	
	WQ+BH	542	563	13.5	9.78
	AQ+BH	489	525	6.2	
A25 (Ex. 25)	WQ+PA	509	555	15.5	1.57
	AQ+PA	501	545	7.7	
	WQ+BH	541	558	13.9	11.28
	AQ+BH	480	513	6.8	
C7 (C.Ex. 7)	WQ+PA	553	619	13.2	24.23
	AQ+PA	419	486	17.8	
	WQ+BH	570	604	8.4	35.44
	AQ+BH	368	456	6.5	
C8 (C.Ex. 8)	WQ+PA	552	610	12.8	21.74
	AQ+PA	432	488	16.7	
	WQ+BH	566	599	8.7	33.57
	AQ+BH	376	460	6.9	
C9 (C.Ex. 9)	WQ+PA	549	611	13.1	18.94
	AQ+PA	445	494	17.5	
	WQ+BH	568	602	9.0	31.87
	AQ+BH	387	466	7.3	
C10 (C.Ex. 10)	WQ+PA	553	619	13.2	30.02
	AQ+PA	387	456	17.9	
	WQ+BH	570	604	8.4	41.40
	AQ+BH	334	427	5.5	
C11 (C.Ex. 11)	WQ+PA	553	619	13.2	27.67
	AQ+PA	400	441	18.2	
	WQ+BH	570	604	8.4	38.42
	AQ+BH	351	452	5.3	
C12 (C.Ex. 12)	WQ+PA	553	619	13.2	25.32
	AQ+PA	413	478	17.3	
	WQ+BH	570	604	8.4	37.13
	AQ+BH	358	459	5.6	

[0068] As seen from Table 4, the alloy sheets of Examples A12-A25 of the invention showed significantly higher tensile properties than those of the alloy sheets of comparative examples C7-C12, with yield strength >480 MPa, tensile strength >520 MPa, elongation >5.5% and yield strength loss coefficient R ≤ 15%. On the other hand, the comparative examples C7-C12 showed higher quenching sensitivity and significantly larger yield strength loss coefficients R, due to the excessive addition of trace elements such as Cr, Mn and Zr.

[0069] The alloys of Examples A12-A15 showed relatively low quenching sensitivity with a yield strength loss coefficient less than 8%, due to the absence of trace elements such as Cr, Mn, Zr and the like.

[0070] The alloys of Example A16-A21 added about 0.05% of Zr, similar to Example A4, and showed slightly increased yield strength loss coefficients R in the cases of water quenching and air quenching with subsequent baking treatment, indicating that the quenching sensitivity of the alloys was increased with the addition of Zr element. Also, with the increase of Zr contents, the quenching sensitivity increases dramatically, and the strength loses significantly. For example, the comparative examples C7-C9 sheets present significant increase in yield strength loss coefficients, especially for comparative alloy C7 with the highest Zr content whose yield strength loss coefficients was as high as 24.23% and 35.44%. The quenching sensitivity was increased dramatically, and the strength was significant lost.

[0071] Examples A22 and A23 contained 0.048% and 0.044% Cr. Similar to Examples A16-A21, the yield strength loss coefficients R for the cases of water quenching and air quenching with subsequent baking treatment (i.e., WQ + BH and AQ + BH) were also increased slightly, but with relatively little effect. With the increase of the Cr content, such as comparative examples C10 and C11 with 0.212% and 0.125% Cr, the R values of the alloy sheets were sharply increased up to 30.02%, 41.40%, 27.67% and 38.42%, respectively. The corresponding strengths were sharply decreased, wherein the yield strength for the AQ + PA sample was less than 400 MPa, and the yield strength for the AQ + BH sample was even lower. The excessive addition of the Cr element significantly deteriorates the quenching sensitivity of the alloy.

[0072] The alloy of Example A24 and the alloy of Example A25 respectively contained 0.131% of Mn element and 0.245% of Mn element, and similarly, the yield strength loss coefficients R for the cases of water quenching and air quenching with subsequent baking treatment (namely WQ + BH and AQ + BH) of the alloy sheets were slightly increased, while the influence on the mechanical property was not very obvious. However, with the increase of Mn content to 0.336%, the quenching sensitivity of the alloy was significantly deteriorated, wherein the corresponding R values of the sheet were increased to 25.32% and 37.13%, and the alloy strength was greatly reduced.

[0073] The microstructures (characterized by SEM) of solution treated (480 °C, 10min) and air quenched sheets of Example A15 (containing no trace elements), C7 (containing 0.121% Zr), C10 (containing 0.212% Cr) and C12 (containing 0.336% Mn) were shown in Fig. 10-13, respectively. Obviously, Example A15 had relatively cleaner microstructure both the inside the grain and at grain boundary, where no residual second phase existed except for the residual massive Al_7Cu_2Fe phase (as shown in Fig. 10). However, in the cases of comparative examples C7, C10 and C12 added with trace elements Cr, Zr and Mn, the quenching sensitivity of the alloy sheets was increased, and fine second phase particles were present in the microstructure rather than the remaining Al_7Cu_2Fe phase (see Figs. 11 to 13).

[0074] Therefore, the addition of trace elements such as Cr, Mn, Zr and the like will form fine dispersed phases that have strong regulation and control effect on the grain structure to reduce the average grain size of the alloy effectively. However, these elements will also significantly affect the quenching sensitivity of the alloy and have disadvantages to the mechanical property of the alloy. As a result, these trace elements should be added in appropriate amounts to regulate the grain structure depending on the actual grain size requirement.

[0075] The preferred embodiments of the present invention are illustrated above, while it should be noted that, for those skilled in the art, many modifications and optimization could be made without departing from the principle of the present invention, and these modifications and optimization should also be regarded as the protection scope of the present invention.

Claims

1. A 7xxx series aluminum alloy (preferably sheet) comprising, by weight, Zn in 5.1-10.0%, Mg in 2.0-3.2%, Cu in 1.2-3.0%, Fe in 0-0.5%, Si in 0-0.4%, Ti in 0-0.2%, Cr in 0-0.1%, Zr in 0-0.055%, Mn in 0-0.25%, other grain size controlling element(s) in 0-0.30%, and Al in balance.

2. The 7xxx-series aluminum alloy (preferably sheet) according to claim 1, having a chemical composition, by weight, of Zn in 5.4 - 7.6%, Mg in 2.0-2.7%, Cu in 1.6 - 2.3%, Fe in 0-0.4%, Si in 0-0.3%, Ti in 0.01-0.15%, Cr in 0-0.05%, Zr in 0-0.05%, Mn in 0-0.25%, other grain size controlling element(s) in 0-0.25%, and Al in balance.

3. The 7xxx-series aluminum alloy (preferably sheet) according to claim 1, having a chemical composition, by weight, of Zn in 7.6-9.6%, Mg in 2.1-3.1%, Cu in 1.4-2.6%, Fe in 0-0.4%, Si in 0-0.3%, Ti in 0.01-0.15%, Cr in 0-0.05%, Zr in 0-0.05%, Mn in 0-0.25%, other grain size controlling element(s) in 0-0.25%, and Al in balance.

4. The 7xxx series aluminum alloy (preferably sheet) according to any one of claims 1-3, having a chemical composition, by weight, of Zn in 5.1-6.7%, Mg in 2.0-2.9%, Cu in 1.2-2.6%, Fe in 0-0.5%, Si in 0-0.4%, Cr in 0-0.1%, Zr in 0-0.05%, Mn in 0-0.25%, and Al in balance.

5. The 7xxx series aluminum alloy (preferably sheet) according to any one of claims 1-4, having a chemical composition, by weight, of Zn in 5.4 - 6.5%, Mg in 2.0-2.7%, Cu in 1.6 - 2.3%, Fe in 0-0.4%, Si in 0-0.3%, Cr in 0-0.05%, Zr in 0-0.05%, Mn in 0-0.15%, and Al in balance.

6. The 7xxx series aluminum alloy (preferably sheet) according to any one of claims 1-5, comprising Fe in 0.05-0.4%, Si in 0.05-0.3%, Cr in 0.001-0.05%, Zr in 0.001-0.04%, Mn in 0.001-0.15%, and other grain size controlling element(s) in 0-0.15%.

7. The 7xxx-series aluminum alloy (preferably sheet) according to any one of claims 1-6, comprising Cr in 0-0.05%, Zr in 0-0.04%, Mn in 0-0.15%, and other grain size controlling element(s) in 0-0.15%, and/or having a combined content by weight of Cr, Mn, Zr and other grain size controlling element(s) (preferably Cr, Mn, and Zr, such as present alone, or present as a mixture of two or more) of ≤ 0.25% (preferably ≤ 0.20% or ≤ 0.15%).

8. The 7xxx series aluminum alloy sheet according to any one of claims 1-7, having an average grain size of 10-100 μm (preferably 15-70 μm) and/or a thickness of 0.5-10.0 mm (preferably 1.0-4.0 mm), after maintaining the temperature at 450-510 °C for 5-20 min.

9. The 7xxx series aluminum alloy sheet according to any one of claims 1-8, having at least one of the following properties:

(1) being suitable for an integrated hot forming-quenching process,
(2) being able of completing the solid solution treatment at 450-510 °C within 5-20 min,
(3) low quenching sensitivity, and
(4) being in the cold-rolled-state, O-state or T4-state sheet.

10. The 7xxx series aluminum alloy sheet according to any one of claims 1-9, having a yield strength >400 MPa (preferably >480 MPa), a tensile strength >450 MPa (preferably >520 MPa) and an elongation >6.5% (preferably >5.5%), after maintaining the temperature at 450-510 °C for 5-20 min, followed by an air quenching, a mold quenching or a water quenching and then an artificial peak aging or a paint-baking treatment.

11. A process of producing a 7xxx series aluminum alloy sheet, comprising the steps of carrying out homogenization treatment, hot rolling treatment and cold rolling treatment on a 7xxx series aluminum alloy cast ingot, to obtain the 7xxx series aluminum alloy sheet, wherein the 7xxx series aluminum alloy cast ingot has a chemical composition of, by weight, 5.1-10.0% of Zn, 2.0-3.2% of Mg, 1.2-3.0% of Cu, 0-0.5% of Fe, 0-0.4% of Si, 0-0.2% of Ti, 0-0.1% of Cr, 0-0.055% of Zr, 0-0.30% of Mn and the balance of Al.

12. The process according to claim 11, wherein the homogenization treatment comprises: heating the 7xxx series aluminum alloy ingot to 375-460 °C (preferably 400-450 °C), maintaining the temperature for 0-15 hours (preferably 5-10 hours), then heating to 465-490 °C (preferably 470-490 °C or 470-485 °C), maintaining the temperature for 10-48 hours (preferably 10-36 hours or 16-36 hours), then cooling to room temperature by air quenching or being cooled together with the furnace, wherein the heating rate is 15-75 °C/h (preferably 25-75 °C/h or 25-50 °C/h). And/or the hot rolling treatment comprises: hot rough rolling and hot finish rolling to 4-14 mm (preferably 4-8 mm or 6-10 mm), at a final rolling temperature of 200-460 °C (preferably 250-350 °C, 300-460 °C or 350-450 °C), and coiling followed by air quenching to room temperature, and/or the cold rolling treatment comprises: cold rolling to 0.5-10.0 mm (preferably 1.0-4.0 mm) to obtain the 7xxx series aluminum alloy sheet (in a cold-rolled-state), and/or the process further comprises a step of box annealing or continuous annealing of the 7xxx series aluminum alloy sheet in the cold-rolled-state to obtain an O-state or a T4-state alloy sheet, and/or the process further comprises a step of maintaining the temperature of the homogenized ingot at 300-480 °C (preferably 380-450 °C) for 2-30 hours (preferably 3-20 hours) before the hot rolling treatment.

13. An integrated hot forming-quenching processing process, comprising a step of subjecting a 7xxx-series aluminum alloy sheet according to any one of claims 1-10 or a 7xxx-series aluminum alloy sheet produced by the process according to claim 11 or 12 to an integrated hot forming-quenching processing.

14. A vehicle part (particularly an automobile part), made of the 7xxx-series aluminum alloy sheet according to any one of claims 1-10 or produced by the processing process according to claim 13.

15. A vehicle provided with the vehicle part according to claim 14.

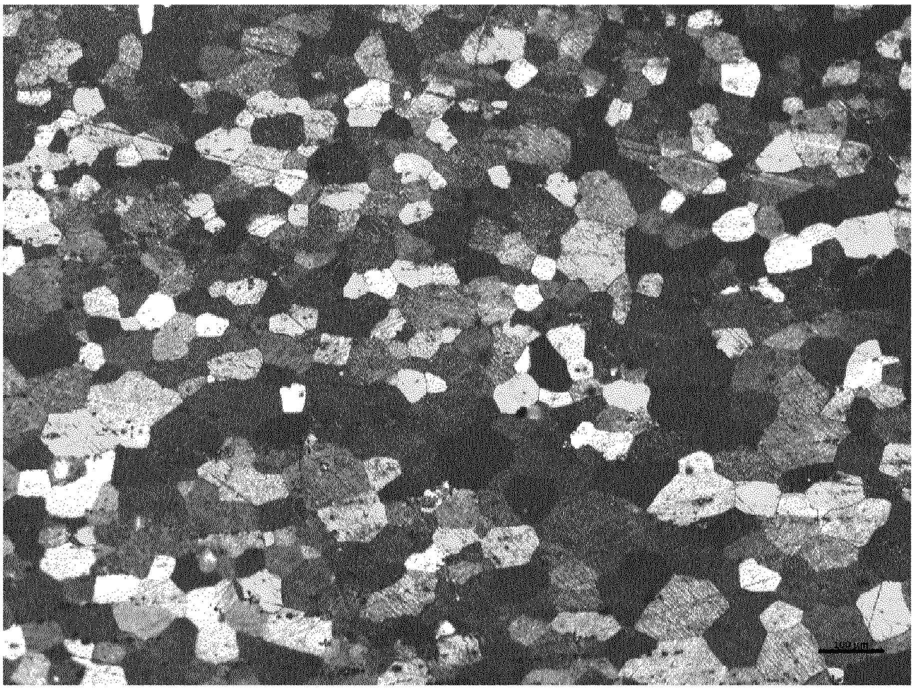

FIG. 1

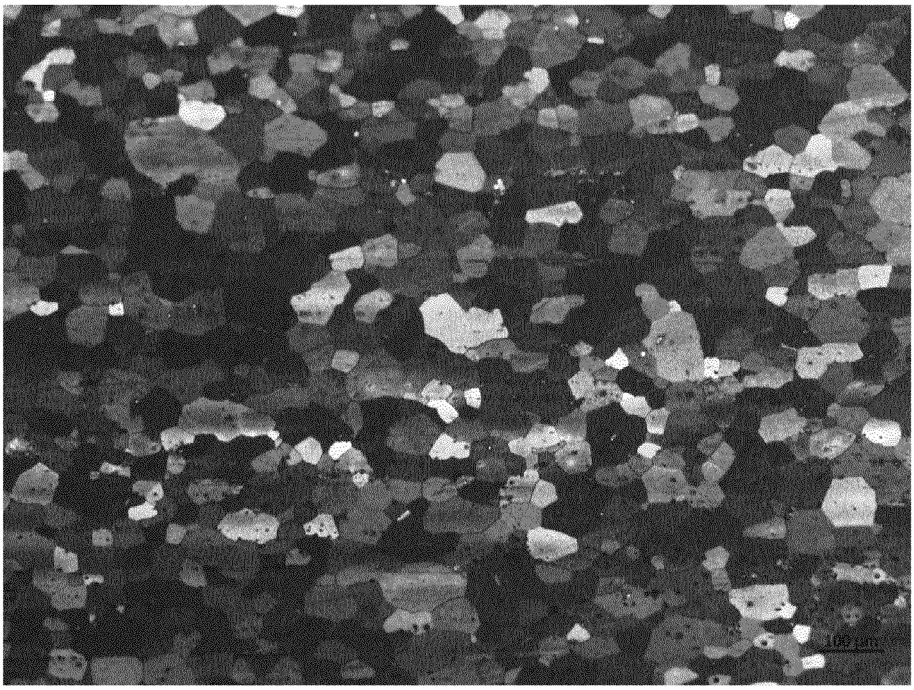

FIG. 2

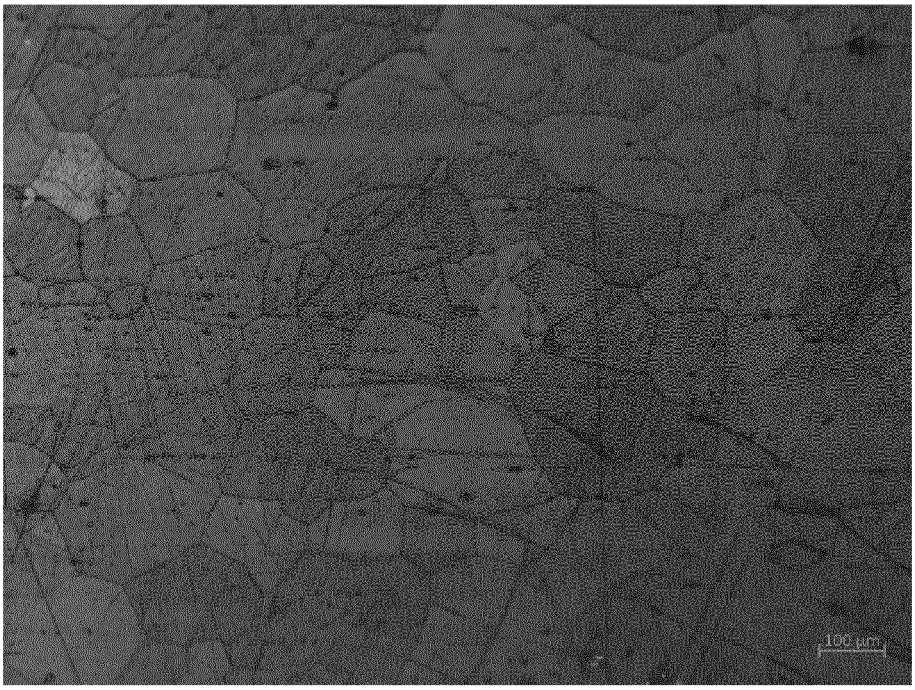

FIG. 3

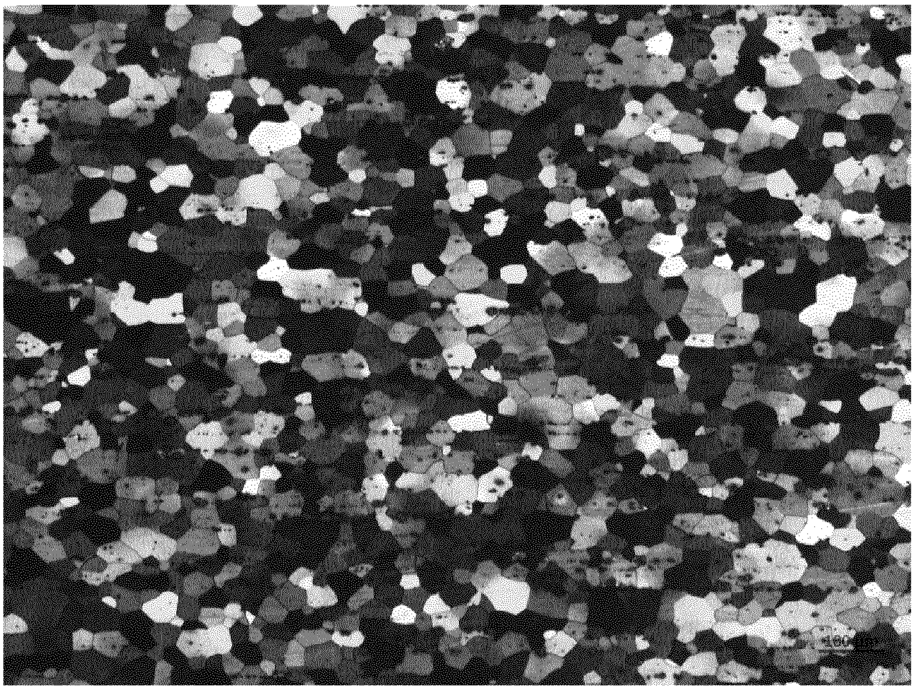

FIG. 4

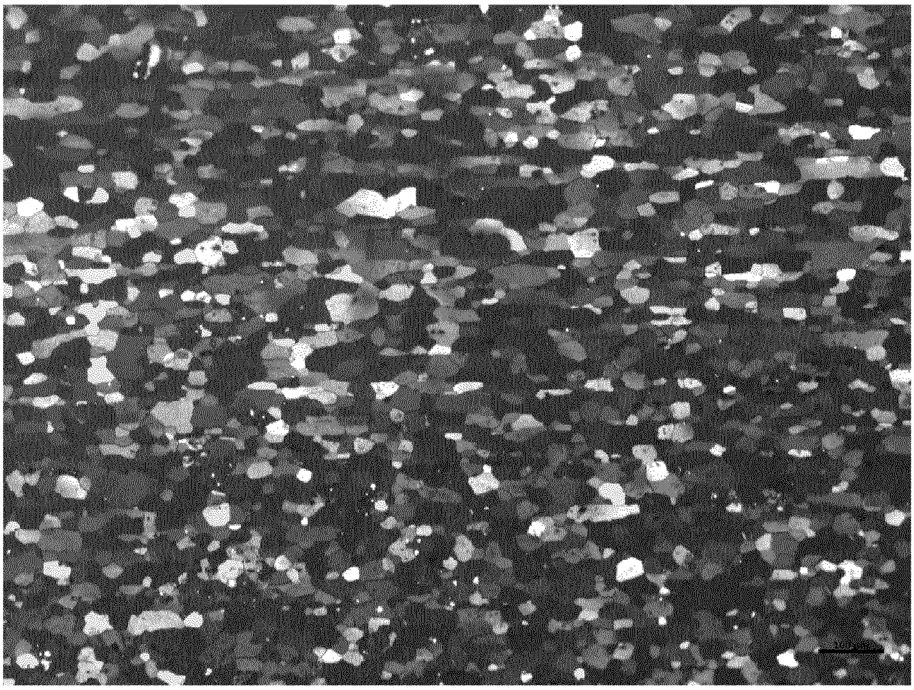

FIG. 5

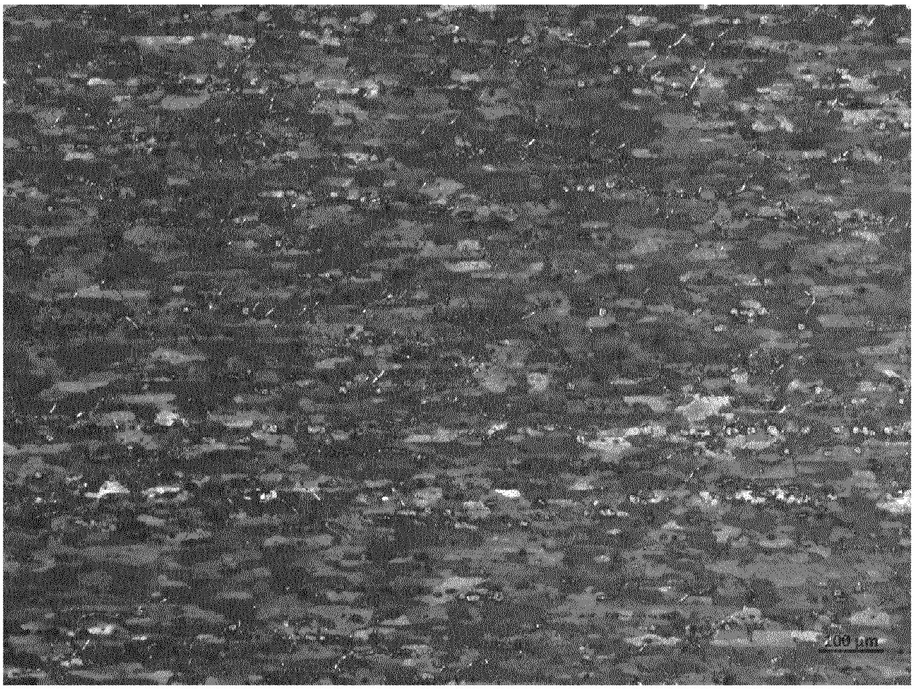

FIG. 6

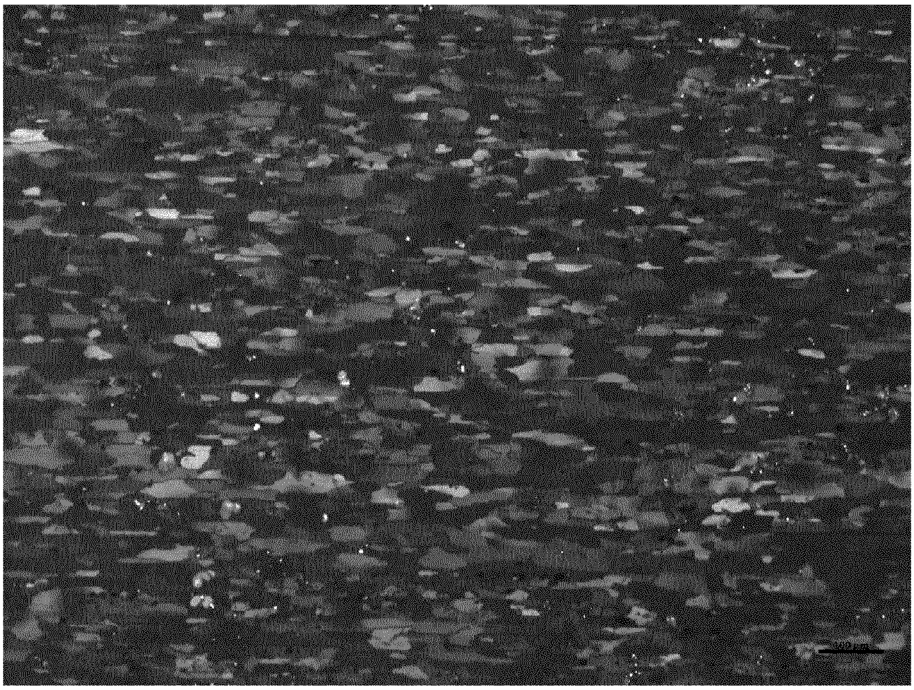

FIG. 7

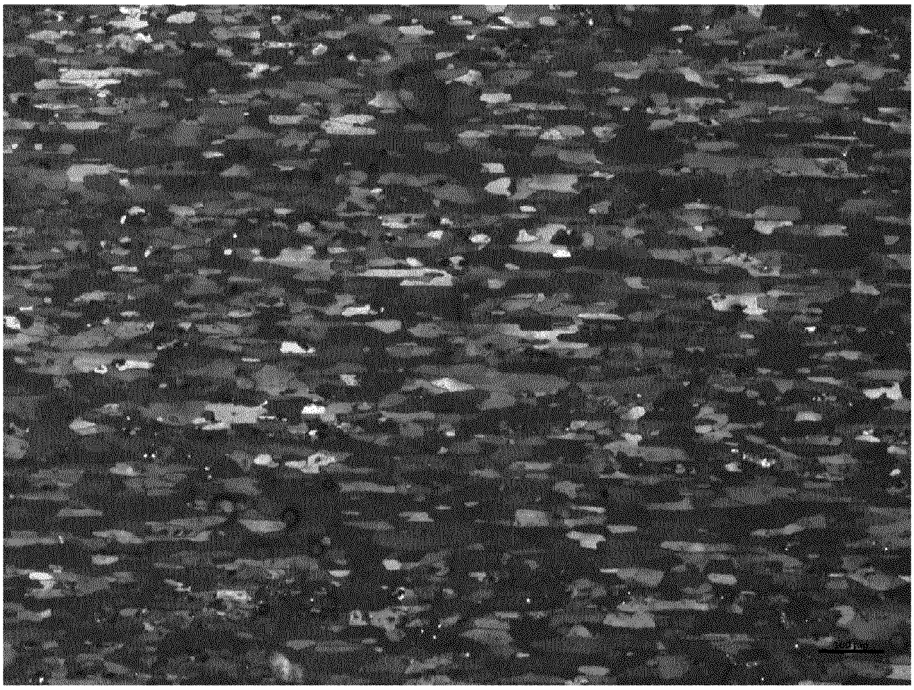

FIG. 8

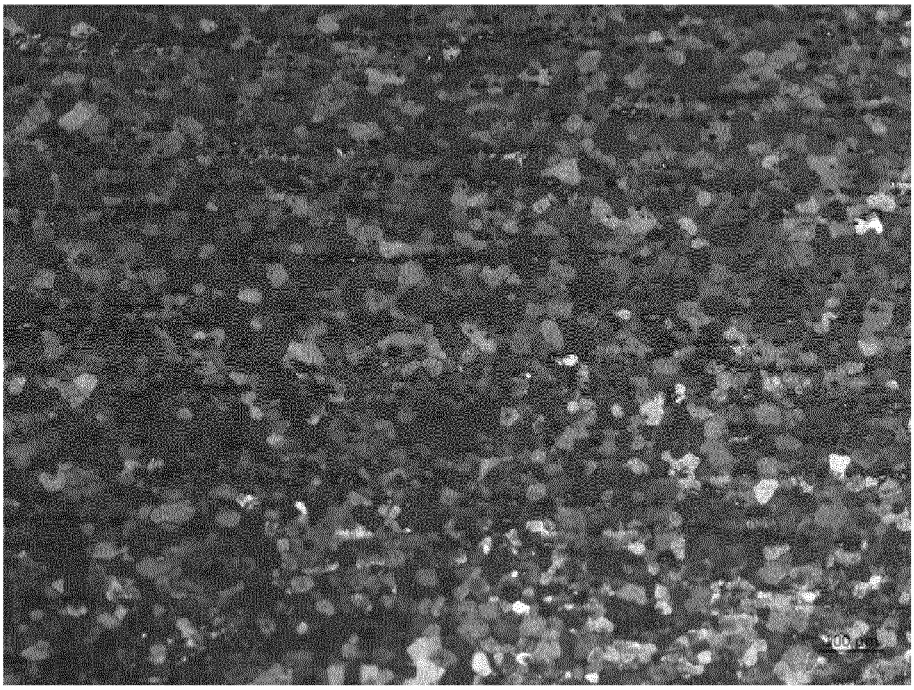

FIG. 9

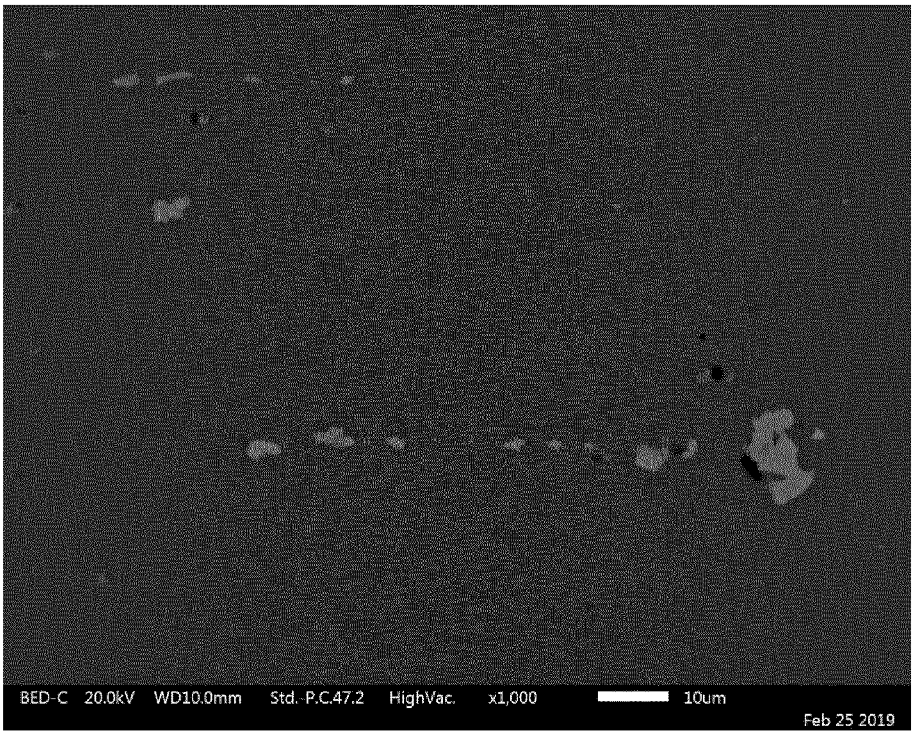

FIG. 10

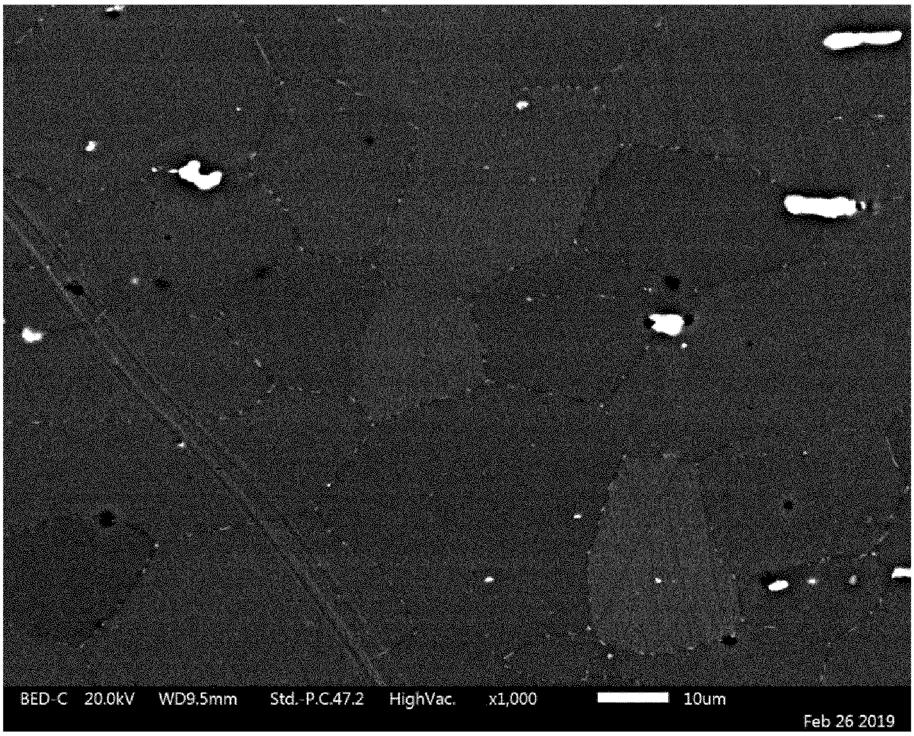
BED-C 20.0kV WD9.5mm Std.-P.C.47.2 HighVac. x1,000 10um
Feb 26 2019

FIG. 11


BED-C 20.0kV WD9.5mm Std.-P.C.47.2 HighVac. x1,000 10um
Feb 26 2019

FIG. 12

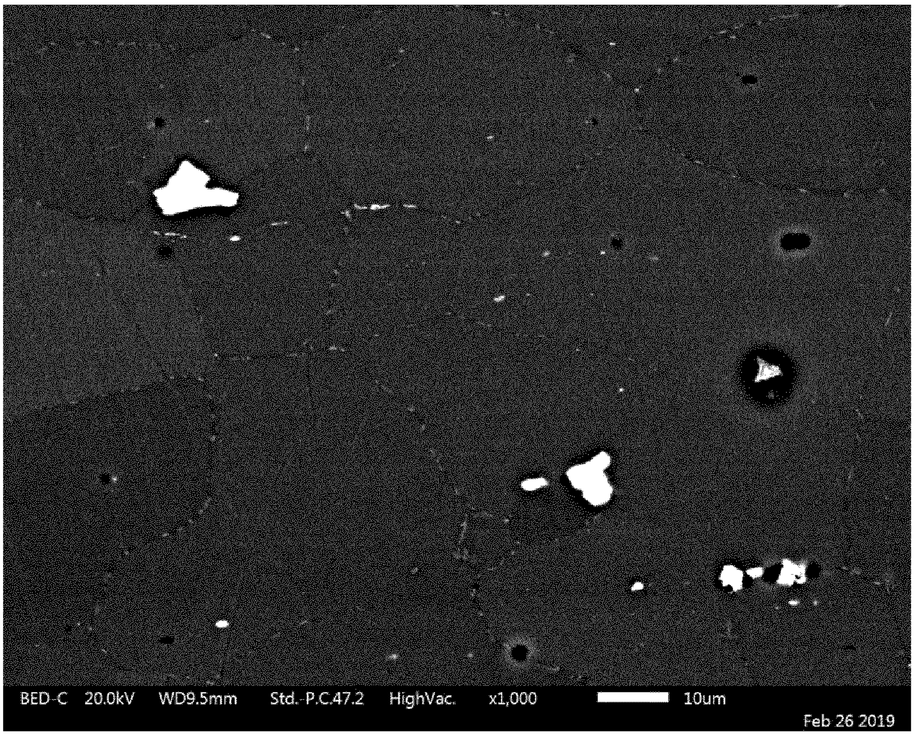

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/137405

A. CLASSIFICATION OF SUBJECT MATTER

C22C 21/10(2006.01)i; C22F 1/053(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; C22F

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, DWPI, SIPOABS, USTXT, WOTXT, JPTXT, EPTXT, STN: 中铝, 吴浩, 刘成, 黄鸣东, 郑志凯, 周泽宇, 7xxx, Al-Zn-Mg-Cu, 7系, 固溶, 均匀化, 淬火, 热轧, 冷轧, 模具, 一体化, zn, zinc, mg, magnesium, cu, copper, solution, quenching, mo?ld, integrat+, hot 1w forming, "7" 1w series, cold 1w rolling, hot 1w rolling, homogen+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 110885942 A (CHALCO MATERIAL APPLICATION RES INSTITUTE CO., LTD.) 17 March 2020 (2020-03-17) description, paragraphs [0005]-[0012] and [0024]	1-15
X	CN 107406925 A (NOVELIS INC.) 28 November 2017 (2017-11-28) description, paragraphs [0010]-[0015], [0059]-[0060], [0073]-[0088]	1-5, 8-15
Y	CN 107406925 A (NOVELIS INC.) 28 November 2017 (2017-11-28) description, paragraphs [0010]-[0015], [0059]-[0060], [0073]-[0088]	6-15
Y	CN 102066596 A (ALERIS ALUMINUM KOBLENZ GMBH) 18 May 2011 (2011-05-18) description, paragraph [0049]	6-15
X	JP 7-252573 A (KOBE STEEL LTD.) 03 October 1995 (1995-10-03) claim 1	1-2, 4-7, 11, 13-15
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X	CN 102459673 A (ALERIS ALUMINUM KOBLENZ GMBH et al.) 16 May 2012 (2012-05-16) claim 1	1-3, 6-7, 14-15

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

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
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- "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	Date of mailing of the international search report
01 March 2021	**17 March 2021**

Name and mailing address of the ISA/CN	Authorized officer
China National Intellectual Property Administration (ISA/CN) **No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088** **China**	
Facsimile No. **(86-10)62019451**	Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/137405

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	CN 108138274 A (NOVELIS INC.) 08 June 2018 (2018-06-08) entire document	1-15
A	CN 110305719 A (HUBEI YONGZHE HOT STAMPING PARTS CO., LTD.) 08 October 2019 (2019-10-08) entire document	1-15

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

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Information on patent family members

International application No.
PCT/CN2020/137405

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				HU	E042400	T2	28 June 2019
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				HR	P20190548	T1	31 May 2019
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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