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(54) METHOD OF MANUFACTURING A HIGH-STRENGTH 6XXX-SERIES FORGING MATERIAL

VERFAHREN ZUR HERSTELLUNG VON EINER HOCHFESTEN 6XXX SERIE SCHMIEDELEGIERUNG

PROCÉDÉ DE FABRICATION D’UN ALLIAGE DE 6XXX SERIES DE HAUTE RÉSISTANCE POUR FORGER.

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(73) Proprietor: **Aleris Aluminum Duffel BVBA**
2570 Duffel (BE)

(72) Inventor: **Ebzeeva, Svetlana Emirovna**
B-2570 Duffel (BE)

(74) Representative: **Müller Schupfner & Partner**
Patent- und Rechtsanwaltspartnerschaft mbB
Bavariaring 11
80336 München (DE)

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Description

[0001] The invention relates to high-strength AA6xxx-series aluminium alloy forgings particularly suitable for automotive, rail or transportation structural components, exhibiting a balance in high strength and corrosion resistance.

[0002] "6xxx aluminium alloy" or "6xxx alloy" designate an aluminium alloy having magnesium and silicon as major alloying elements. "AA6xxx-series aluminium alloy" designates any 6xxx aluminium alloy listed in "International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys" published by The Aluminum Association, Inc.

[0003] Unless otherwise stated, the definitions of metallurgical tempers listed in the European standard EN 515 will apply.

[0004] For any description of alloy compositions or preferred alloy compositions, all references to percentages are by weight percent unless otherwise indicated.

[0005] The term "up to" and "up to about" and "≤", as employed herein, explicitly includes, but is not limited to, the possibility of zero weight-percent of the particular alloying component to which it refers. For example, up to 0.25% Zn and ≤ 0.25% Zn may include an alloy having no Zn.

[0006] Aluminium alloy compositions and tempers have been developed for obtaining satisfying strength and corrosion behaviour in car components such as chassis-suspension or body structure parts, but also rail or transportation structural components in particular when they are made from forgings.

[0007] In order to achieve tensile properties in excess of 400 MPa in 6xxx alloys, it is important to maximise both the ageing response through an adequate solutionising of solute elements, predominantly Mg, Si and Cu. And the recrystallisation is controlled through the addition of dispersoid elements, typically Mn, Cr and Zr and appropriate homogenisation temperatures. It is also controlled through alloy processing conditions, which are defined so as to minimise stored-energy and thereby maximise recrystallization temperature.

[0008] To achieve adequate solutionising, according to the prior art, highly alloyed 6xxx alloys are usually separately solutionised and quenched after the final forging step. Such a solution can be found in the patent application EP-2548933-A1 (Nis-san Motor). When alloys are strongly alloyed it is often required to apply an extended solutionising treatment (in excess of 90min) at high temperature (530°C-560°C) in order to achieve excellent solutionising. Such a case is described in the patent application JP2012-097321 (Furukawa-Sky Aluminium). The key to this is that extended recrystallization will occur on highly alloyed alloys (unless significant dispersoid additions are made) as they are brought to a fully solutionised temper and the additional strength gained by improved solutionising shall be mitigated by recovery and recrystallisation.

[0009] According to the prior art, high strength forgings obtained from extruded semifinished products, and from 6xxx-series aluminium alloys characterised by a minimum Si-content of 0.7% and minimum Mg-content of 0.6%, for example of the AA6082, AA6182, AA6110, or AA6056 type, are produced by:

a) casting one of the following aluminium alloys AA6082, AA6110, AA6182 or AA6056 or to a restricted composition within the AA standard;

b) homogenising;

c) cooling to room temperature;

d) heating a homogenised cast billet to a temperature 50°C to 100°C lower than solidus temperature (approx. 575°C);

e) extruding said billet through a die to produce a solid section profile with an exit temperature (typically 500°C) lower than solidus (typically 550°C), in order to try to avoid incipient melting due to non-equilibrium melting of eutectic phases in profile hot-spots but still allowing to dissolve part of the constituent particles;

f) cooling to room temperature;

g) stretching;

h) heating cut-to-length extruded rod to forging temperature, typically 400°C-520°C;

i) forging in heated mould (150°C-350°C);

j) separate solutionising at 530°C-560°C for durations between 30 min. and 90 min.;

k) water quenching the forged material down to room temperature;

l) room temperature ageing;

m) ageing to T6 temper by a one- or multiple-step heat treatment at temperatures ranging from 150°C to 200°C for holding times ranging from 2 to 20 hours.

[0010] However, ultimate tensile strengths achieved with this processing route do not exceed 450 MPa. Generally speaking, 400 MPa is a maximum especially when artificial ageing has to be shifted away from peak ageing T6 in order to guarantee minimum elongation values higher than 10 %.

[0011] European patent document EP-3018226-A1 (Constellium Valais) proposes a combination of 6xxx-series alloy and a process which intends to secure an ultimate tensile strength higher than 400 MPa, preferably higher than 450 MPa, and even higher than 480 MPa. This combination provides an aluminium alloy forged product obtained by the following steps:

a) casting an extrusion billet from a 6xxx aluminium alloy comprising: Si: 0.7-1.3%; Fe: ≤ 0.5%; Cu: 0.1-1.5%; Mn: 0.4-1.0%; Mg: 0.6-1.2%; Cr: 0.05-0.25%; Zr: 0.05-0.2%; Zn: ≤ 0.2%; Ti: ≤ 0.2%, the rest being aluminium and inevitable impurities;

b) homogenising the cast billet at a temperature T_H which is 5°C to 80°C lower than solidus temperature Ts, typically T_H in the range of 500°C-560°C, for a duration between 2 and 10 hours to ensure high level of dissolution of constituent particles while ensuring precipitation and controlled coarsening of dispersoid phases;

c) quenching said billet down to room temperature by using water quench system;

d) heating the homogenised billet to a temperature T_h between (Ts-5°C) and (Ts-125°C);

e) extruding said billet through a die to produce a solid section with an exit temperature (typically 530°C) lower than Ts (typically 550°C), in order to try to avoid incipient melting due to non-equilibrium melting of eutectic phases in profile hot-spots but still allowing to dissolve part of the constituent particles, and with an extruding ratio of at least 8;

f) quenching the extruded product down to room temperature by using water quench system;

g) stretching the extruded product to obtain a plastic deformation typically between 0.5% and 10%, preferably up to 5%;

h) heating cut-to-length extruded rod to forging temperature, typically between 400°C and 520°C;

i) forging in heated mould between 150°C and 350°C;

j) separate solutionising at a temperature between 530°C and 560°C for durations between 2 min. and 1 hour;

k) water quenching the forged and solutionised material down to room temperature;

l) room temperature ageing for a duration between 6 hours and 30 days;

m) ageing to T6 temper by a one-or multiple-step heat treatment at temperatures ranging from 150°C to 200°C for holding times ranging from 2 to 20 hours.

[0012] And wherein solidus Ts is the temperature below which the alloy exhibits a solid fraction equal to 1. Solvus defines the temperature, which is the limit of solid solubility in the equilibrium phase diagram of the alloy. For high strength requirements, eutectic alloying elements such as Si, Mg and Cu should be added to form precipitated hardening phases. However, the addition of alloying elements generally results in a decrease in the difference between solidus and solvus temperatures. When the content of eutectic alloying elements is higher than a critical value, the solidus to solvus range of the alloy becomes a narrow "window", with typically a solidus to solvus difference lower than 20°C, and consequently the solution heat treatment of the aforementioned elements usually achieved during extrusion cannot be obtained without observing incipient melting. Indeed local temperature gradients achieved during extrusion and forging, generally exceed 20°C implying that, as solvus is reached, parts of the product will display temperatures in excess of solidus Ts.

[0013] It is an object of the present invention to provide an improved method, or at least to provide an alternative method to the one disclosed in EP-3018226, for a combination of 6xxx-series alloy and a process which secures a balance of high strength and good corrosion resistance.

[0014] This and other objects and further advantages are met or exceeded by the present invention providing a method of manufacturing a forged product, the method comprising the following processing steps:

a. casting of a rolling ingot from a 6xxx aluminium alloy comprising: Si: 0.65-1.4%; Mg: 0.6-1.2%; Cu: up to 1.5%; Mn: 0.4-1.0%; Fe: up to 0.5%; Cr: up to 0.25%; Zr: up to 0.2%; Zn: up to 0.25%; Ti: up to 0.2%, the rest being aluminium and inevitable impurities (typically at a level of each ≤0.05% and total ≤0.25%);

b. homogenising the cast ingot at a temperature T_H which is 5°C to 80°C lower than solidus temperature Ts, typically T_H in the range of 460°C to 570°C, and preferably 500°C to 570°C, for a duration between 2 and 24 hours to ensure high level of dissolution of constituent particles while ensuring precipitation and minimised coarsening of dispersoid phases;

c. rapid cooling of said ingot down to ambient or room temperature, for example by using a water quench system; the average cooling rate from T_H to below 300°C is preferably in a range of 80-250°C/h to ensure the formation of only metastable phases;

d. heating the homogenised ingot to a temperature T_h between (Ts-5°C) and (Ts-125°C), and preferably between 400°C and 520°C;

e. hot-rolling the heated ingot in one or more rolling passes to a hot-mill exit gauge in the range of 2 to

40 mm, preferably 2 to 30 mm, and wherein the hot-mill exit temperature is in the range of 200°C to 360°C, and preferably in a range of 200°C to 280°C, to ensure that the hot-rolled feedstock has a substantially unrecrystallized microstructure;

f. heating cut-to-length rolled feedstock to forging temperature, typically between 400°C and 560°C;

g. forging, preferably in a heated mould between 150°C and 350°C;

h. separate solutionising at a temperature between 460°C and 560°C, preferably between 520°C and 560°C, and for durations between 20 sec. and 5 hours, preferably between 1 min. and 1 hour;

i. quenching the forged and solutionised material down to ambient temperature;

j. optionally room temperature ageing for a duration up to 30 days, and preferably between 6 hours and 30 days;

k. artificially ageing to T6 temper by a one- or multiple-step heat treatment at temperatures ranging from 150°C to 210°C for holding times ranging from 1 to 20 hours.

[0015] According to the invention, the aluminium rolled product is obtained by casting a rolling ingot from a 6xxx aluminium alloy comprising: Si: 0.65-1.40%; Mg: 0.6-1.2%; Cu: ≤1.5%; Mn: 0.4-1.0%; Fe: ≤0.5%; Cr: ≤0.25%; Zr: ≤0.2%; Zn: ≤0.25%; Ti: ≤0.2%, the rest being aluminium and inevitable. The aluminium alloy according to the invention is of the AlMgSi type, which, compared with others such as e.g. AlZ-nMg alloys, provides an excellent combination of high tensile strength and resistance to corrosion.

[0016] The aluminium alloy can be provided as an ingot or slab for fabrication into a hot-rolled feedstock using casting techniques regular in the art for casting rolling products, e.g. DC-casting, EMC-casting, EMS-casting, and preferably having an ingot thickness in a range of about 220 mm or more, e.g. 300 mm or 350 mm. After casting the hot-rolling feedstock, the as-cast ingot is commonly scalped to remove segregation zones near the as-cast surface of the ingot. In an embodiment thin gauge slabs resulting from continuous casting, e.g. belt casters or roll casters, also may be used, and having a thickness of up to about 40 mm.

[0017] The process according to the invention consists in particular in replacing conventional homogenising followed by slow cooling, re-heating and extruding followed again by slow cooling of the AA6xxx alloy extrusion billets, by high temperature homogenising and raid cooling followed by heating in combination with hot-rolling instead of extrusion and controlling the hot-mill exit temperature, and the process does not comprise a separate post-rolling solution heat treatment, because as a result of the claimed processing steps b. and c., the larger part of the alloying elements which contribute to the formation of hardening particles are in solid solution in the lattice of the hot-rolled feedstock.

[0018] The present invention therefore provides a process to manufacture a range of 6xxx alloys with high mechanical properties, especially if applied to a sufficiently copper-containing AlMgSiCu, with strength levels in excess of 400 MPa and even 450 or 480 MPa, in combination with a good corrosion resistance.

[0019] According to the invention, an ingot is provided resulting from casting a 6xxx aluminium alloy, i.e. an aluminium alloy having magnesium and silicon as major alloying elements. Preferably, this aluminium alloy is a high-strength 6xxx aluminium alloy, such as AA6082, AA6182, AA6056, AA6110 or any copper-containing alloy derived from the said AA6xxx aluminium alloys.

[0020] This alloy has preferably a Cu content up to 1.5%. In an embodiment the Cu-content is in a range of 0.2% to 1.5%, preferably 0.35% to 1.2%, and more preferably 0.5% to 1.0%, and provides a very high strength in combination with a good corrosion resistance. In another embodiment the Cu-content is up to 0.3%, preferably in a range of 0.04% to 0.28%, and more preferably 0.09% to 0.27%, and provides still a high strength (somewhat lower than for the embodiment with very high Cu level) in combination with an excellent corrosion resistance. For both embodiments of Cu-levels one or more dispersoid forming elements are present, in particular Mn with a content of 0.4-1.0%, Cr up to 0.25% and preferably with a content of 0.05-0.25%, and Zr up to 0.25% and preferably with a content of 0.05-0.2%, are added to control recrystallization and maximize homogeneity of the grain size of the rolled and the forged component.

[0021] Si and Mg content are defined so as to ensure high level of dissolved or redissolved Mg_2Si while minimising presence of undissolved Mg_2Si in the forged component after the final solutionising step, preferably with a maximum content of 0.5%.

[0022] Si is combined with Mg to form Mg_2Si. The precipitation of Mg_2Si contributes to increasing the strength of the final aluminium alloy forged product.

[0023] If the Si content is less than 0.65%, the final product does not have a sufficiently high strength, it means a tensile strength not higher than 400 MPa. If it is lower than 0.9%, tensile strength will be at most 450 MPa and with less than 1.1% it will be lower than 480 MPa.

[0024] On the other hand, if the Si content is more than 1.40%, the level of undissolved Mg_2Si is too high and rollability is reduced as well as corrosion resistance and toughness of the resultant final forged product.

[0025] Mg is combined with Si to form Mg_2Si. Therefore Mg is indispensable for strengthening the product of the present invention. If the Mg content is lower than 0.7%, the effect is too weak. On the other hand, if the Mg content is higher than 1.2%, the ingot becomes difficult to be roll and the rolled feedstock to be forged. Moreover, a large amount of Mg_2Si particles tends to precipitate during quenching process after the solution treatment. In addition, the Mg content is preferably between 0.7% and 1.1% and more preferably between 0.8% and 1.0%.

[0026] Fe is an impurity and combines with other elements to form intermetallic compounds. These precipitated particles lower fracture toughness and fatigue strength of the final forged product. In particular, when the Fe content is higher than 0.5% it is difficult to obtain an aluminium alloy forged product with both high strength and high toughness as required for automotive structure and suspension applications. Preferably, its content is lower than or equal to 0.3% and more preferably, lower than or equal to 0.25%.

[0027] Mn forms intermetallic compounds, for example Al_6Mn, which controls recrystallisation. However, if the Mn content is less than 0.4%, the effect is not sufficient. On the other hand, if the content of Mn is higher than 1.0%, coarse precipitated particles are formed and both the workability and the toughness of the aluminium alloy are reduced. The Mn content is preferably between 0.5% and 0.9% and more preferably between 0.5% and 0.7%.

[0028] In the invention the 6xxx-series aluminium alloy consists of: Si: 0.65-1.4%; Mg: 0.6-1.2%; Cu: up to 1.5%; Mn: 0.4-1.0%; Fe: up to 0.5%; Cr: up to 0.25%; Zr: up to 0.2%; Zn: up to 0.25%; Ti: up to 0.2%, the rest being aluminium and inevitable impurities (typically at a level of each ≤0.05% and total ≤0.25%), and with preferred narrower compositional ranges as herein described and claimed.

[0029] The cast ingot for rolling according to the invention is homogenised between 2 and 24 hours at a temperature between 5°C and 80°C lower than solidus, and then rapidly cooled for example water quenched. More preferably the homogenization is performed at a temperature range of 480°C to 520°C. In the presence of a high volume fraction of Mn-, Zr, and Cr-containing dispersoids it is preferred to homogenize below 520°C in order to avoid any coarsening of these particles. The soaking times for homogenization should be at least about 2 hours, and more preferably at least about 4 hours. A preferred upper-limit for the homogenization soaking time is about 15 hours.

[0030] The homogenised and quenched rolling ingot is heated to a soaking temperature T_h below the solidus temperature Ts, between Ts-5°C and Ts-125°C. For example, solidus temperature is near 575°C for the alloys AA6082 and AA6182. The ingots are preferably heated and held at the soaking temperature for several minutes up to about 2 hours.

[0031] In a next processing step the ingot is being hot-rolled in one or more rolling steps to a final gauge in a range of 2 mm to 40 mm, preferably 2 mm to 30 mm, and more preferably of 2 mm to 20 mm. The hot-rolling process is carefully controlled such that the hot-mill exit-temperature of the feedstock is in a range of 200°C to 360°C, and preferably in a range of 200°C to 280°C, to ensure that the hot-rolled feedstock has a substantially unrecrystallized microstructure. A hot-mill exit temperature in this temperature ranges suppresses in the feedstock the coarse precipitation of secondary phases such as Si and Mg_2Si and AlMgCu-phases and thereby enabling a balance of high strength and good ductility in the final forged product. At a too high hot-mill exit-temperature of the feedstock the grain size in the final forged product is also too coarse.

[0032] On a preferred basis the hot-mill entry-temperature is in a range of 400°C to 550°C, and preferably in a range of 435°C to 535°C and more preferably below 500°C, in order to reach the desired hot-mill exit-temperature.

[0033] After the hot-rolling operation the feedstock can be coiled or cut-to-length.

[0034] The balance of alloying composition and providing a substantially unrecrystalized microstructure in the hot-rolled condition allows for the subsequent production of forged products having a good balance in high-strength and ductility and corrosion resistance. The use of hot-rolled feedstock allows for the production of much wider forged products compared to the use of extruded feedstock material. Furthermore, the manufacturing of rolled feedstock is a robust production process enabling a more cost efficient production of high-volume forging feedstock compared to an extrusion process requiring dedicated extrusion dies and wherein only billets of limited dimensions can be processed. In addition hot-rolled feedstock provides a more homogeneous microstructure in the product and avoids the occurrence of so-called profile hot-spots which may frequently occur in an extrusion process due to for example non-equilibrium melting of eutectic phases as a result of temperature fluctuations across the profile in the extrusion process.

[0035] Next the rolled feedstock is cut-to-length and heated to the forging temperature, typically between 400°C and 560°C. Next the feedstock is forged, typically die-forged, and preferably in a heated mould of typically between 150°C and 350°C.

[0036] After forging the parts undergo a separate solutionising at a temperature between 460°C and 560°C, preferably between 520°C to 560°C, for a duration between 20 sec. and 5 hours and then quenched, for example using a device projecting sprayed water or a water based cooling liquid, down to room temperature. The solutionising time is dependent on the thickness of the forged product, whereby thin products commonly require is shorter time at elevated temperature.

[0037] The product is optionally naturally aged at room temperature for a duration up to 30 days, and preferably between 6 hours and 30 days. Thereafter artificial ageing is applied to achieve T6 temper by a one-or multiple-step heat treatment at temperatures ranging from 150°C to 210°C for holding times ranging from 1 to 20 hours.

[0038] The process according to the invention allows for obtaining forged products made from Cu-containing

6xxx alloys, which were until now very difficult to solutionise because of their very narrow solvus-solidus temperature window and the risk of recrystallization during ultimate separate solutionising prior to final age-hardening treatment. This process is particularly well suited to alloys with Mg_2Si content comprised between 1.2% and 1.6%, Si excess up to 0.7%, particularly if comprised between 0.2% and 0.7%, and especially if copper content lies up to 1.5%, which gives a solvus to solidus temperature difference approximately equal to or even lower than 10°C, and renders such alloy very difficult to extrude when processed according to the prior art route.

[0039] As this alloy comprises further to the Mn preferably a purposive addition of one or more additional dispersoid forming elements, viz. Zr between 0.05% and 0.25% and Cr between 0.05% and 0.25%, either Cr or Zr alone or Cr+Zr in combination, the microstructures of the rolled feedstock shows a strong fibrous retention providing an additional strengthening contribution, considered important in meeting high mechanical property values. After having applied the process according to the invention in particular to 0.2% or more Cu containing AlMgSiCu aluminium alloys, the forged components have at T6 temper ultimate tensile strengths higher than 400 MPa, even higher than 430 MPa.

[0040] Mechanical properties achieved in T6 temper on the forgings after manufacturing according to the aforementioned process were significantly higher than by using conventional process for AA6082 or AA6182 and displayed a far higher tolerance to solutionising conditions i.e. increased ease of solutionising at low temperature and soaking time. Moreover a forged product manufactured according to the invention also displays a limited sensitivity to intergranular corrosion as assessed according to ISO 11846B and opposed to what the copper level would lead a corrosion expert to expect.

[0041] In another aspect of the invention it relates to a method of use and to the use of cast, homogenized and hot-rolled feedstock material, viz. the resultant intermediate product obtained by the claimed process steps a. to e., for manufacturing forged products via the claimed process steps f. to k, and with preferred embodiments described herein.

[0042] The forged product can be used as structural member on automotive vehicle structural members as well as in non-automotive structural members.

[0043] The automotive vehicle structural members include side impact beams, B-pillar inner and outer members, A-pillar outer members, tunnel reinforcements, door belt reinforcement members, hinge reinforcement members. Such forged products are particularly suitable as chassis-suspension parts and especially suspension arms.

Claims

1. A process for manufacturing an aluminium alloy forged product comprising the following steps:

a) casting of a rolling ingot from a 6xxx aluminium alloy comprising: Si: 0.65-1.4%; Mg: 0.6-1.2%; Cu: up to 1.5%; Mn: 0.4-1.0%; Fe: ≤ 0.5%; Cr: up to 0.25%; Zr: up to 0.2%; Zn: ≤ 0.25%; Ti: ≤ 0.2%, the rest being aluminium and inevitable impurities;

b) homogenising the cast ingot at a temperature T_H which is 5°C to 80°C lower than solidus temperature Ts, typically T_H in the range of 460°C to 570°C, for a duration between 2 and 24 hours to ensure high level of dissolution of constituent particles while ensuring precipitation and minimised coarsening of dispersoid phases;

c) rapid cooling said ingot down to room temperature;

d) heating the homogenised ingot to a temperature T_h between (Ts-5°C) and (Ts-125°C);

e) hot-rolling the re-heated ingot in one or more rolling passes to a hot-mill exit gauge in the range of 2 to 40 mm, and wherein the hot-mill exit temperature is in the range of 200°C to 360°C to ensure that the hot-rolled feedstock has a substantially unrecrystallized microstructure;

f) heating cut-to-length rolled feedstock to forging temperature, typically between 400°C and 560°C;

g) forging, preferably in heated mould between 150°C and 350°C;

h) separate solutionising at a temperature between 460°C and 560°C, preferably between 520°C and 560°C, and a duration between 20 sec. and 5 hours;

i) quenching the forged and solutionised material;

j) optionally room temperature ageing for a duration up to 30 days, and preferably between 6 hours and 30 days;

k) artificially ageing to T6 temper by a one- or multiple-step heat treatment at temperatures ranging from 150°C to 210°C for holding times ranging from 1 to 20 hours.

2. Method according to claim 1, wherein the hot-mill entry temperature is in a range of 440°C to 535°C.

3. Method according to claim 1 or 2, wherein the hot-mill exit temperature is in a range of 200°C to 280°C.

4. Method according to any one of claims 1 to 3, wherein the 6xxx aluminium alloy comprises Cu: 0.2%-1.5%, preferably 0.35%-1.2%, and more preferably 0.5%-1.0%.

5. Method according to any one of claims 1 to 3, wherein the 6xxx aluminium alloy comprises Cu: up to

0.30%, preferably 0.04% - 0.28%, more preferably 0.09%-0.27%.

6. Method according to any one of claims 1 to 5, wherein the 6xxx aluminium alloy comprises Si: 0.9%-1.3%, preferably 1.1%-1.3%.

7. Method according to any of claims 1 to 6, wherein the 6xxx aluminium alloy comprises Mg: 0.7%-1.1%, preferably 0.8%-1.0%.

8. Method according to any of claims 1 to 7, wherein the 6xxx aluminium alloy comprises Mn: 0.5-0.9%, preferably 0.5%-0.7%.

9. Method according to any of claims 1 to 8, wherein the ultimate tensile strength of the aluminium alloy forged product is higher than 400 MPa, preferably higher than 430MPa, and more preferably higher than 450 MPa.

10. Method according to any of claims 1 to 9, wherein the aluminium alloy forged product is an automotive body-structure part.

11. Method according to any of claims 1 to 9, wherein the aluminium alloy forged product is an automotive chassis-suspension part.

12. Method according to any of claims 1 to 9, wherein the aluminium alloy forged product is an automotive suspension arm.

Patentansprüche

1. Verfahren zur Herstellung eines geschmiedeten Aluminiumlegierungsprodukts, das die folgenden Schritte umfasst:

   a) Gießen eines Walzblocks aus einer 6xxx-Aluminiumlegierung, die umfasst: Si: 0,65-1,4%; Mg: 0,6-1,2%; Cu: bis 1,5%; Mn: 0,4-1,0%; Fe: ≤ 0,5%; Cr: bis 0,25%; Zr: bis 0,2%; Zn: ≤ 0,25%; Ti: ≤ 0,2%, der Rest Aluminium und unvermeidliche Verunreinigungen;
   b) Homogenisieren des gegossenen Blocks bei einer Temperatur T_H, die 5°C bis 80°C niedriger als die Solidustemperatur Ts ist, typischerweise T_H im Bereich von 460°C bis 570°C, für eine Dauer zwischen 2 und 24 Stunden, um einen hohen Grad an Auflösung von Komponententeilchen zu gewährleisten, während die Ausscheidung und minimierte Vergröberung von Dispersoid-Phasen gewährleistet wird;
   c) schnelles Abkühlen des Blocks auf Raumtemperatur;
   d) Erwärmen des homogenisierten Blocks auf eine Temperatur T_h zwischen (Ts-5°C) und (Ts-125°C);
   e) Warmwalzen des wieder erwärmten Blocks in einem oder mehreren Walzdurchgängen auf eine Warmwalzwerk-Austrittsstärke im Bereich von 2 bis 40 mm, und wobei die Warmwalzwerk-Austrittstemperatur im Bereich von 200°C bis 360°C liegt, um zu gewährleisten, dass das warmgewalzte Ausgangsmaterial eine im Wesentlichen nicht rekristallisierte Mikrostruktur hat;
   f) Erwärmen des zugeschnittenen gewalzten Ausgangsmaterials auf Schmiedetemperatur, typischerweise zwischen 400°C und 560°C;
   g) Schmieden, vorzugweise in einer erwärmten Form, zwischen 150°C und 350°C;
   h) getrenntes Lösungsglühen bei einer Temperatur zwischen 460°C und 560°C, vorzugsweise zwischen 520°C und 560°C, und einer Dauer zwischen 20 Sekunden und 5 Stunden;
   i) Abschrecken des geschmiedeten und lösungsgeglühten Materials;
   j) optional Auslagern bei Raumtemperatur für eine Dauer von bis zu 30 Tagen, und vorzugsweise zwischen 6 Stunden und 30 Tagen;
   k) Warmauslagern auf T6-Zustand durch eine ein- oder mehrstufige Wärmebehandlung bei Temperaturen von 150°C bis 210°C für Haltezeiten von 1 bis 20 Stunden.

2. Verfahren nach Anspruch 1, wobei die Warmwalzwerk-Eintrittstemperatur in einem Bereich von 440°C bis 535°C liegt.

3. Verfahren nach Anspruch 1 oder 2, wobei die Warmwalzwerk-Austrittstemperatur in einem Bereich von 200°C bis 280°C liegt.

4. Verfahren nach einem der Ansprüche 1 bis 3, wobei die 6xxx-Aluminiumlegierung Cu: 0,2%-1,5%, vorzugsweise 0,35%-1,2%, und noch bevorzugter 0,5%-1,0% umfasst.

5. Verfahren nach einem der Ansprüche 1 bis 3, wobei die 6xxx-Aluminiumlegierung Cu: bis 0,30%, vorzugsweise 0,04% - 0,28%, noch bevorzugter 0,09%-0,27% umfasst.

6. Verfahren nach einem der Ansprüche 1 bis 5, wobei die 6xxx-Aluminiumlegierung Si: 0,9%-1,3%, vorzugsweise 1,1%-1,3% umfasst.

7. Verfahren nach einem der Ansprüche 1 bis 6, wobei die 6xxx-Aluminiumlegierung Mg: 0,7%-1,1 %, vorzugsweise 0,8%-1,0% umfasst.

8. Verfahren nach einem der Ansprüche 1 bis 7, wobei die 6xxx-Aluminiumlegierung Mn: 0,5-0,9%, vor-

zugsweise 0,5%-0,7% umfasst.

9. Verfahren nach einem der Ansprüche 1 bis 8, wobei die endgültige Zugfestigkeit des geschmiedeten Aluminiumlegierungsprodukts höher als 400 MPa, vorzugsweise höher als 430 MPa, und noch bevorzugter höher als 450 MPa ist.

10. Verfahren nach einem der Ansprüche 1 bis 9, wobei das geschmiedete Aluminiumlegierungsprodukt ein Fahrzeugkarosserie-Strukturteil ist.

11. Verfahren nach einem der Ansprüche 1 bis 9, wobei das geschmiedete Aluminiumlegierungsprodukt ein Fahrzeugrahmen-Aufhängungsteil ist.

12. Verfahren nach einem der Ansprüche 1 bis 9, wobei das geschmiedete Aluminiumlegierungsprodukt ein Fahrzeug-Querlenker ist.

Revendications

1. Procédé pour fabriquer un produit forgé en alliage d'aluminium, comprenant les étapes suivantes consistant à :

a) couler d'un lingot cylindrique à partir d'un alliage d'aluminium de la série 6xxx comprenant : Si : 0,65-1,4 % ; Mg : 0,6-1,2 % ; Cu : jusqu'à 1,5 % ; Mn : 0,4-1,0 % ; Fe : ≤ 0,5 % ; Cr : jusqu'à 0,25 % ; Zr : jusqu'à 0,2 % ; Zn : ≤ 0,25 % ; Ti : ≤ 0,2 %, le reste étant de l'aluminium et des impuretés inévitables ;
b) homogénéiser le lingot coulé à une température T_H qui est de 5° C à 80° C plus basse qu'une température de solidus T_s, T_H étant typiquement dans la plage de 460° C à 570° C, pendant une durée entre 2 et 24 heures pour assurer un niveau élevé de dissolution des particules constitutives tout en assurant une précipitation est une minimisation de grossissement des phases dispersées ;
c) refroidir rapidement ledit lingot jusqu'à température ambiante ;
d) chauffer le lingot homogénéiser à une température T_h entre (Ts-5°C) et (Ts-125°C) ;
e) laminer à chaud le lingot réchauffé dans une ou plusieurs passes de laminage jusqu'à une épaisseur de sortie de laminoir à chaud dans la plage de 2 à 40 mm, et dans lequel la température de sortie du laminoir à chaud est dans la plage de 200° C à 360° C pour assurer que le produit laminé à chaud présente une microstructure sensiblement sans recristallisation ;
f) chauffer le produit laminé coupé à longueur jusqu'à une température de forgeage, typiquement entre 400° C et 560° C ;
g) forger, de préférence dans un moule chauffé entre 150° C et 350° C ;
h) mettre en solution séparée à une température entre 460° C et 560° C, de préférence entre 520° C et 560° C, et à une durée entre 20 secondes et 5 heures ;
i) tremper le matériau forgé et mis en solution ;
j) en option, vieillissement à température ambiante pendant une durée allant jusqu'à 30 jours, et de préférence entre 6 heures et 30 jours ;
k) vieillissement artificiel jusqu'à une température T6 par traitement à chaud en une seule passe ou en une multiplicité de passe à des températures allant de 150° C à 210° C pendant des temps de maintien allant de 1 à 20 heures.

2. Procédé selon la revendication 1, dans lequel la température d'entrée du laminoir à chaud est dans une plage de 440° C à 535° C.

3. Procédé selon la revendication 1 ou 2, dans lequel la température de sortie du laminoir à chaud est dans une plage de 200° C à 280° C.

4. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel l'alliage d'aluminium de la série 6xxx comprend : Cu : 0,2 %-1,5 %, de préférence 0,35 %-1,2 %, et de manière plus préférée 0,5 %-1,0 %.

5. Procédé selon l'une quelconque des revendications 1 à 3, dans lequel l'alliage d'aluminium de la série 6xxx comprend : Cu : jusqu'à 0,30 % de préférence 0,04 %-0,28 %, et de manière plus préférée 0,09 %-0,27 %.

6. Procédé selon l'une quelconque des revendications 1 à 5, dans lequel l'alliage d'aluminium de la série 6xxx comprend : Si : 0,9 %-1,3 %, de préférence 1,1 %-1,3%.

7. Procédé selon l'une quelconque des revendications 1 à 6, dans lequel l'alliage d'aluminium de la série 6xxx comprend : Mg : 0,7 %-1,1 %, de préférence 0,8 %-1,0 %.

8. Procédé selon l'une quelconque des revendications 1 à 7, dans lequel l'alliage d'aluminium de la série 6xxx comprend : Mn : 0,5-0,9 %, de préférence 0,5 %-0,7 %.

9. Procédé selon l'une quelconque des revendications 1 à 8, dans lequel la résistance ultime à la traction du produit forgé en alliage d'aluminium est supérieure à 400 MPa, de préférence supérieure à 430 MPa, et de manière plus préférée supérieure à 450 MPa.

10. Procédé selon l'une quelconque des revendications

1 à 9, dans lequel le produit forgé en alliage d'aluminium est une partie structurelle d'un corps d'automobile.

11. Procédé selon l'une quelconque des revendications 1 à 9, dans lequel le produit forgé en alliage d'aluminium est une partie du châssis d'une automobile.

12. Procédé selon l'une quelconque des revendications 1 à 9, dans lequel le produit forgé en alliage d'aluminium est un bras de suspension pour automobile.

REFERENCES CITED IN THE DESCRIPTION

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