(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 464 659 B2

(12) NEW EUROPEAN PATENT SPECIFICATION
After opposition procedure

(45) Date of publication and mention of the opposition decision:
12.07.2023 Bulletin 2023/28

(45) Mention of the grant of the patent:
11.03.2020 Bulletin 2020/11

(21) Application number: **17725993.4**

(22) Date of filing: **31.05.2017**

(51) International Patent Classification (IPC):
C22C 21/02 *(2006.01)* ***C22C 21/08*** *(2006.01)*
C22F 1/05 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
C22C 21/02; C22C 21/08; C22F 1/05

(86) International application number:
PCT/EP2017/063109

(87) International publication number:
WO 2017/207603 (07.12.2017 Gazette 2017/49)

(54) 6XXX-SERIES ALUMINIUM ALLOY FORGING STOCK MATERIAL AND METHOD OF MANUFACTING THEREOF

6XXX-SERIEN-ALUMINIUMLEGIERUNGSSCHMIEDEROHMATERIAL UND VERFAHREN ZUR HERSTELLUNG DAVON

MATÉRIAU DE STOCKAGE FORGÉ EN ALLIAGE D’ALUMINIUM DE LA SÉRIE 6XXX ET SON PROCÉDÉ DE FABRICATION

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **01.06.2016 EP 16172448**

(43) Date of publication of application:
10.04.2019 Bulletin 2019/15

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

(72) Inventor: **EBZEEVA, Svetlana Emirovna**
2570 Duffel (BE)

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

(56) References cited:
EP-A1- 1 458 898 **EP-A1- 2 811 042**
JP-A- 2006 274 415 **US-A1- 2010 089 503**

- **P. Sherstnev, I. Flitta , C. Sommitsch, M. Hacksteiner , T. Ebner: "The effect of the initial rolling temperature on the microstructure évolution during and after hot rolling of AA6082", Int J Mater Form, 2008, pages 395-398,**

EP 3 464 659 B2

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a 6xxx-series aluminium alloy forging stock material. The invention relates also to a method of manufacturing such 6xxx-series aluminium alloy forging stock material. Furthermore, the invention relates to a method of hot-shaping, in particular by means of forging, a shaped product from said 6xxx-series aluminium alloy forging stock material. The 6xxx-series aluminium alloy material can be used to manufacture forged automotive vehicle structural parts.

BACKGROUND OF THE INVENTION

[0002] There are several 6xxx-series aluminium alloys known in the art and extruded into feedstock for a subsequent forging operation at elevated temperature into various structural components.

[0003] An aluminium alloy very often used for making forged product is the alloy AA6082 as registered with the Aluminum Association and having the following composition, in wt.%:

Si	0.7% - 1.3%
Mg	0.6% - 1.2%
Fe	<0.50%
Cu	<0.10%
Mn	0.40% - 1.0%
Cr	<0.25%
Zn	<0.20%
Ti	<0.10%,

balance impurities and aluminium. Forged products made from the AA6082 alloy in a T6 condition achieve high mechanical properties.

[0004] Another alloy used for making forgings is the AA6182 having the following composition, in wt.%:

Si	0.9% - 1.3%
Mg	0.7% - 1.2%
Fe	<0.50%
Cu	<0.10%
Mn	0.50% - 1.0%
Zr	0.05% - 0.20%
Cr	<0.25%
Zn	<0.20%
Ti	<0.10%,

balance impurities and aluminium.

[0005] Patent document EP-2644725-B1 (Kobe) discloses a production process for an aluminium alloy forged material comprising (in wt.%): 0.6-1.2% Mg, 0.7-1.5% Si, 0.1-0.5% Fe, 0.01-0.1% Ti, 0.3-1.0% Mn, one or both of 0.1-0.4% Cr and 0.05-0.2% Zr, less than 0.1% Cu, less than 0.05% Zn, remainder aluminium and inevitable impurities, and comprising the steps of casting an ingot of such an alloy, extruding the ingot at a temperature in the range of 450°C to 540°C to provide forging feedstock, heating the extruded forging feedstock for more than 0.75 hours at 500°C to 560°C, forging the forging feedstock into a desired shape at a temperature of 450°C to 560°C, solution heat treating of the forged material followed and quenching and artificial ageing.

[0006] Patent document WO-2015/146654-A1 (Kobe) discloses a production process for an aluminium alloy forged material containing (in wt.%): 0.70-1.50% Mg, 0.80-1.30% Si, 0.30-0.90% Cu, 0.10-0.40% Fe, 0.005-0.15% Ti, and optionally one or more elements selected from 0.10-0.60% Mn, 0.10-0.45% Cr and 0.05-0.30% Zr, balance aluminium and unavoidable impurities, and comprising the steps of casting an ingot, extruding the ingot to provide forging feedstock, forging the forging feedstock into a desired shape at elevated temperature, solution heat treating of the forged material followed and quenching and artificial ageing.

[0007] US 2010/0089503 A1 also discloses 6xxx-series aluminum alloy forging stock material.

[0008] It is an object of the invention to provide a 6xxx-series aluminium alloy forging feedstock material for manufacturing forged products having a good balance in strength and ductility. It is another object of the invention to provide a method of manufacturing a 6xxx-series aluminium alloy forging feedstock material for manufacturing forged products having a good balance in strength and ductility.

DESCRIPTION OF THE INVENTION

[0009] As will be appreciated herein below, except as otherwise indicated, aluminium alloy and temper designations refer to the Aluminium Association designations in Aluminum Standards and Data and the Registration Records, as published by the Aluminium Association in 2016 and are well known to the persons skilled in the art. The temper designations are laid down in European standard EN515.

[0010] For any description of alloy compositions or preferred alloy compositions, all references to percentages are by weight percent unless otherwise indicated.

[0011] The term "up to" and "up to about", 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 may include an alloy having no Zn.

[0012] As used herein, the term "about" when used to describe a compositional range or amount of an alloying addition means that the actual amount of the alloying addition may vary from the nominal intended amount due to factors such as standard processing variations as understood by those skilled in the art.

[0013] This and other objects and further advantages are met or exceeded by the present invention providing a hot-rolled semi-finished 6xxx-series aluminium alloy forging stock material suitable for manufacturing automotive vehicle structural parts, and having a final thickness in the range of 2 mm to 30 mm, preferably 2 mm to 20 mm, and more preferably of 2 mm to 15 mm, and having a composition comprising of, in wt.%,

Si	0.65% - 1.4%,
Mg	0.60% - 0.95%,
Mn	0.40% - 0.80%,
Cu	0.12% - 0.28%,
Fe	up to 0.5%,
Cr	up to 0.18%,
Zr	up to 0.20%,
Ti	up to 0.15%,
Zn	up to 0.25%,

impurities each <0.05%, total <0.2%, balance aluminium,
and wherein in the hot-rolled condition it has a substantially unrecrystallized microstructure.

[0014] The careful balance of alloying composition and the microstructure in the hot-rolled condition allows for the subsequent production of forged products having a good balance in strength and ductility. 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 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.

[0015] With substantially unrecrystallized microstructure we mean that more than 85%, preferably more than 90%, and more preferably more than 95%, of microstructure across the thickness of the hot-rolled rolled product is substantially unrecrystallized.

[0016] The purposive addition of Mg and Si strengthens the aluminium alloy due to precipitation hardening of elemental Si and Mg_2Si formed under the co-presence of Mg. In order to provide a sufficient strength level in the final product the Si content should be at least 0.65%, and preferably at least 0.8%, and more preferably at least 0.90%. A preferred upper-limit for the Si content is 1.30%, and more preferably 1.25%.

[0017] Substantially for the same reason as for the Si content, the Mg content should be at least 0.60%, and preferably at least 0.65%, and more preferably at least 0.70% to provide sufficient strength to the final product. A preferred upper-limit for the Mg content is 0.85%, and more preferably 0.80%.

[0018] The addition of Mn serves to provide the required microstructure in the alloy product and increases strength and ductility. At least 0.40% Mn should be present and preferably at least 0.50%, and more preferably at least 0.55%. The Mn-content should not exceed 0.80%, preferably it does not exceed 0.70%, and more preferable it does not exceed 0.65%, in order to provide the right balance in strength, toughness and ductility.

[0019] The purposive addition of Cu is an essential feature of this invention in order to arrive at the required balance of mechanical and physical properties in the final product. The aluminium alloy has at least 0.12% of Cu. A preferred upper-limit for the Cu-content is 0.27%, and more preferably at most 0.24%.

[0020] It is important that the Fe-content in the aluminium alloy product should not exceed about 0.5%, and preferably it should not exceed about 0.35%, in order to maintain the balance of properties. A too high Fe-content has an adverse effect on the toughness and ductility of the final product. A more preferred upper-limit for the Fe content is 0.30%. A lower Fe-content is favourable for the ductility of the alloy product. A lower limit for the Fe-content is about 0.1%, and more preferably about 0.15%. A too low Fe content makes the aluminium alloy product too expensive.

[0021] In order to control the grain structure both during the hot-rolling operation and during a subsequent hot-shaping operation it is preferred to have a purposive addition of Zr alone or Cr alone or a combination of Zr and Cr.

[0022] In an embodiment the Zr addition is preferably in a range of 0.05% to 0.20%. A preferred lower limit for the Zr-content is 0.06%. A preferred upper-limit for the Zr-content is about 0.16%.

[0023] In an embodiment the Cr-content should be in a range of 0.06% to 0.18%. A preferred upper-limit for the Cr-content is about 0.14%, preferably about 0.12%, and more preferably 0.09%.

[0024] In another embodiment there is a combined addition of Zr and Cr, each of the alloying elements Cr and Zr are in the range as herein described and the sum of the combined addition of Zr+Cr does not exceed 0.30%, and preferably it does not exceed 0.25%. The combined addition of Zr and Cr is most efficient in suppressing grain growth and controlling the grain size in the final forged product.

[0025] Zinc is an impurity element that can be tolerated up to about 0.25%, preferably up to 0.10%, and is more preferably as low as possible, e.g. 0.05% or less.

[0026] Titanium can be added to the aluminium alloy product amongst others for grain refiner purposes during casting of the alloy ingots. The addition of Ti should not exceed about 0.15%, and preferably it should not exceed 0.1%. A preferred lower limit for the Ti addition is 0.01 %, and typically a preferred upper-limit for Ti is 0.05%, and can be added as a sole element or, as known in the art, with boron or carbon serving as a casting aid, for grain size control.

[0027] Unavoidable impurities can be present each up to about 0.05% and the total is up to about 0.20%, the balance is made with aluminium.

[0028] In a preferred embodiment the aluminium alloy product has a composition consisting of, in wt.%,

Si	0.65% - 1.4%,
Mg	0.60% - 0.95%,
Mn	0.40% - 0.80%,
Cu	0.12% - 0.28%,
Fe	up to 0.5%,
Cr	up to 0.18%,
Zr	up to 0.20%,
Ti	up to 0.15%,
Zn	up to 0.25%,

impurities each <0.05%, total <0.2%, balance aluminium, and with preferred narrower ranges as herein described and as claimed.

[0029] In a further aspect of the invention it relates to a method of manufacturing the hot-rolled semi-finished 6xxx-series aluminium alloy forging stock material of this invention, the method comprising the steps of:

a. casting of an ingot forming hot-rolling feedstock,
b. homogenisation of the cast ingot at a temperature in the range of 460°C to 580°C,
c. hot-rolling in one or more rolling passes to a final gauge in the range of 2 to 30 mm, and wherein the hot-mill exit temperature is in the range of 200°C to 360°C.

[0030] The careful balance of alloying composition and providing a substantially unrecrystalized microstructure in the hot-rolled condition allows for the production of forged products having a good balance in strength and ductility. 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 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.

[0031] 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 cast 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. 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. Grain refiners such as those containing titanium and boron, or titanium and carbon, may also be used as is known in the art. After casting the hot-rolling feedstock, the as-cast ingot is commonly scalped to remove segregation zones near the cast surface of the ingot.

[0032] Homogenisation should be performed at a temperature of 460°C or more. If the homogenisation temperature is less than 460°C, reduction of ingot segregation and homogenisation may be insufficient. This results in insufficient dissolution of Mg_2Si components which contribute to strength, whereby formability may be decreased. Homogenisation is preferably performed at a temperature of 480°C or more. The homogenisation temperature should not exceed 570°C, and preferably it does not exceed 560°C. More preferably the homogenisation is performed in 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 homogenise below 520°C in order to avoid any coarsening of these particles.
The heat-up rates that can be applied are those which are regular in the art.

[0033] The soaking times for homogenisation should be at least about 2 hours, and more preferably at least about 4 hours. A preferred upper-limit for the homogenisation soaking time is about 24 hours, and more preferably 15 hours.

[0034] In an embodiment the cast ingot is homogenised at the temperature and soaking times as herein set out and then quenched to below 100°C using water quench system to ensure a high level of dissolution of constituent particles, and subsequently re-heating to hot mill entry temperature.

[0035] 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 30 mm, preferably 2 mm to 20 mm, and more preferably of 2 mm to 15 mm. The method according to this invention avoids the need for further down-gauging via cold rolling. The hot-rolling process is carefully controlled such that the hot-mill exit-temperature is in a range of 200°C to 360°C, and preferably in a range of 230°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 supresses 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 the grain size in the final forged product is too coarse, e.g. an average grain size of more than 90 micron.

[0036] 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.

[0037] After the hot-rolling operation the feedstock can be coiled or cut-to-length.

[0038] Thereafter the forging feedstock material at final gauge can be processed into a desired shaped product via a hot-shaping process, in particular into an automotive vehicle structural part, using the following processing steps:

d. solution heat treating ("SHT") of the hot-rolled semi-finished 6xxx-series aluminium alloy forging feedstock material at final gauge, and preferably followed by a quenching operation to a temperature of lower than 70°C. The solution heat-treatment is performed typically in the same temperature range as for the homogenisation of the cast ingot, viz. in a range of 460°C to 560°C, but typically with a shorter soaking time of up to about 5 hours, e.g. about 0,5 hour or about 1 hour. In a preferred embodiment the solution heat-treatment temperature is in a range of 520°C to 560°C, and is preferably just above the solvus temperature of the Mg_2Si and Si phases. Following solution heat-treatment the material is preferably rapidly cooled or quenched to below 70°C.

e. optionally re-heating the solution heat treated material to the hot-shaping temperature or alternatively the solution heat-treated material is not cooled to ambient temperature but instead directly hot-shaped by minimizing any heat loss in the transfer from the solution heat-treatment furnace to the hot-shaping press;

f. hot-shaping into a desired shaped product, preferably by means of forging, e.g. die-forging, and wherein preferably the forging-dies are pre-heated, and preferably the forging operation is performed at a temperature at which the feedstock is in a range of 400°C to 560°C, and rapidly cooled, preferably using a water quench. This results in a substantially recrystallized microstructure of the forged product. The forged product is optionally naturally aged at room temperature for a duration up to 30 hours, and preferably between 5 hours and 30 days, followed by artificial ageing;

g. artificially ageing of the hot-formed shaped product to reach final properties, preferably by applying one or more ageing steps, and wherein at least one of the ageing steps consists of holding the hot-formed shaped product at a temperature between 150°C and 210°C for a period of 0.5 hours to 20 hours, and preferably of 0.5 hours to 10 hours.

[0039] In an embodiment the hot-formed or forged product is subjected to a solution heat-treatment (SHT), preferably at a temperature of about 460°C to 560°C, preferably about 500°C to 560°C, for 20 minutes to 8 hours, preferably 20 minutes to 2 hours, and quenched to below 70°C, prior to artificially ageing which would bring said product after ageing to a T6X condition by applying one or more ageing steps, and wherein at least one of the ageing steps consists of holding the hot-formed shaped product at a temperature between 150°C and 210°C for a period of 0.5 hours to 15 hours. For example 8 hours at 175°C or 10 hours at 160°C.

[0040] The invention intends to encompass several alternative production routes for manufacturing forged products using the hot-rolled feedstock material, e.g. non-limitative production routes comprising at least the following sequential processing steps:

Route A: SHT of the hot-rolled feedstock, forging, optional quench of the forged product, and artificial ageing.

Route B: SHT of the hot-rolled feedstock, forging at the SHT temperature range, quench of the forged product, and artificial ageing.

Route C: SHT of the hot-rolled feedstock, quenching, re-heating to forging temperature, forging, optional quenching of the forged product, and artificial aging.

Route D: SHT of the hot-rolled feedstock, quenching, re-heating to forging temperature, forging, optional quenching of the forged product, SHT and quenching of the SHT product, and artificial aging.

[0041] In a further aspect of the invention it relates to a forged structural member made from the hot-rolled semi-finished 6xxx-series aluminium alloy forging stock or obtained by the method of manufacturing forged products using such hot-rolled 6xxx-series forging stock, and having a substantially recrystallized microstructure. With substantially recrystallized microstructure we mean that more than 90%, preferably more than 95%, and more preferably more than 97%, of microstructure across the thickness of the forged product is substantially recrystallized.

[0042] In an embodiment the forged product in T6x-condition has an equivalent bending angle in the LT-direction of 60° or more, preferably of 70° or more, and more preferably of 80° or more, when measured at 2 mm sheet material in accordance with VDA 238-100 of December 2010. The bending angle is an indication for the ductility of forged material, whereby a higher bending angle indicates a higher ductility. A high ductility as engineering parameter is desired for applications of the forged product where it should be resistant to impact at high velocity, in particular in crash situations of the vehicle. The tensile yield strength of the forged product in this condition is at least 330 MPa and preferably at least 335 MPa.

[0043] In an embodiment the forged product in T6x-condition has a tensile yield strength in the L-direction of at least 350 MPa, and preferably of at least 360 MPa.

[0044] The forged product can be used as structural member on automotive vehicle structural members as well as in non-automotive structural members.

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.

[0045] Furthermore, the invention relates to the use of a cast, homogenized and hot-rolled feedstock material, viz. the resultant intermediate product obtained by the described process steps a. to c., for manufacturing of forged products via the described process steps d. to g., and with preferred embodiments described herein.

[0046] The invention is not limited to the embodiments described before, which may be varied widely within the scope of the invention as defined by the appending claims.

Claims

1. Hot-rolled semi-finished 6xxx-series aluminium alloy forging stock material having a thickness in the range of 2 mm to 30 mm, and having a composition comprising of, in wt.%,

Si	0.65% - 1.4%,
Mg	0.60% - 0.95%,
Mn	0.40% - 0.80%,
Cu	0.12% - 0.28%,

(continued)

Fe	up to 0.5%,
Cr	up to 0.18%,
Zr	up to 0.20%,
Ti	up to 0.15%,
Zn	up to 0.25%,

impurities each <0.05%, total <0.2%, balance aluminium, and wherein it has a substantially unrecrystallized microstructure.

2. Hot-rolled semi-finished 6xxx-series aluminium alloy forging stock material according to claim 1, wherein the Cu-content is in a range of 0.12% to 0.27%.

3. Hot-rolled semi-finished 6xxx-series aluminium alloy forging stock material according to claim 1 or 2, wherein the Mn-content is in a range of 0.50% to 0.70%.

4. Hot-rolled semi-finished 6xxx-series aluminium alloy forging stock material according to any one of claims 1 to 3, wherein the Si-content is in a range of 0.8% to 1.30%.

5. Hot-rolled semi-finished 6xxx-series aluminium alloy forging stock material according to any one of claims 1 to 4, wherein the Mg-content is in a range of 0.70% to 0.90%, preferably in a range of 0.70% to 0.85%.

6. Hot-rolled semi-finished 6xxx-series aluminium alloy forging stock material according to any one of claims 1 to 5, wherein the Cr-content is in the range of 0.06% to 0.18%, preferably 0.06% to 0.14%.

7. Hot-rolled semi-finished 6xxx-series aluminium alloy forging stock material according to any one of claims 1 to 6, wherein the Zr-content is in the range of 0.05% to 0.20%, and preferably in the range of 0.05% to 0.16%.

8. Method of manufacturing hot-rolled semi-finished 6xxx-series aluminium alloy forging stock according to any one of claims 1 to 7, the method comprising the steps of:

- casting of an ingot forming hot-rolling feedstock and having a composition according to any one of claims 1 to 7;
- homogenisation of the cast ingot at a temperature in the range of 460°C to 570°C;
- hot-rolling in one or more rolling passes to a hot-mill exit gauge in the range of 2 to 30 mm, and wherein the hot-mill exit temperature is in the range of 200°C to 360°C.

9. Method according to claim 8, wherein the hot-mill entry temperature is in a range of 400°C to 550°C, preferably 435°C to 535°C, and more preferably 435°C to below 500°C.

10. Method of manufacturing forged products using hot-rolled semi-finished 6xxx-series aluminium alloy forging stock, comprising the steps of

- solution heat treating of the hot-rolled semi-finished 6xxx-series aluminium alloy forging stock material according to claim 8 or 9;
- hot-shaping into a shaped product and having a substantially recrystallized microstructure; and
- artificially ageing of the shaped product, preferably to a T6x-condition.

11. Method according to claim 10, wherein the shaped product is artificially aged to a T6x-condition.

12. Method according to claim 10 or 11, wherein the hot shaping is by means of forging, more preferably by means of die-forging.

13. Method according to any one of claims 10 to 12, wherein said shaped product is solution heat treated after the hot-shaping into a shaped product but prior to artificially ageing.

14. Method according to any one of claims 10 to 13, wherein the shaped product, preferably a forged product, after artificially ageing has a bending angle of at least 60°, preferably of at least 70°, when measured at a 2 mm product in accordance with VDA 238-100.

15. Method according to any one of claims 10 to 14, wherein the shaped product, preferably a forged product, after artificially ageing has a tensile yield strength of at least 330 MPa.

16. Use of a hot-rolled semi-finished 6xxx-series aluminium alloy forging stock material having a thickness in the range of 2 mm to 30 mm, and having a composition comprising of, in wt.%,

Si	0.65% - 1.4%,
Mg	0.60% - 0.95%,
Mn	0.40% - 0.80%,
Cu	0.12% - 0.28%,
Fe	up to 0.5%,
Cr	up to 0.18%,
Zr	up to 0.20%,
Ti	up to 0.15%,
Zn	up to 0.25%,

impurities each <0.05%, total <0.2%, balance aluminium,
and wherein it has a substantially unrecrystallized microstructure and obtained by the method according to any one of claims 8 or 9 in the manufacturing of forged products, preferably die-forged products, having a substantially recrystallized microstructure.

17. Use according to claim 16 of a hot-rolled semi-finished 6xxx-series aluminium alloy forging stock material having a thickness in the range of 2 mm to 30 mm, and having a composition comprising of, in wt.%,

Si	0.65% - 1.4%,
Mg	0.60% - 0.95%,
Mn	0.40% - 0.80%,
Cu	0.12% - 0.28%,
Fe	up to 0.5%,
Cr	up to 0.18%,
Zr	up to 0.20%,
Ti	up to 0.15%,
Zn	up to 0.25%,

impurities each <0.05%, total <0.2%, balance aluminium,
and wherein it has a substantially unrecrystallized microstructure and obtained by the method according to any one of claims 8 or 9 in the manufacturing of forged products, preferably die-forged products, according to any one of claims 10 to 15.

Patentansprüche

1. Warmgewalztes halbfertiges Schmiederohmaterial aus Aluminiumlegierung der 6xxx-Serie mit einer Dicke im Bereich von 2 mm bis 30 mm und mit einer Zusammensetzung, die in Gew.-% umfasst,

Si	0,65% - 1,4%,
Mg	0,60% - 0,95%,
Mn	0,40% - 0,80%,
Cu	0,12% - 0,28%,
Fe	bis zu 0,5%,
Cr	bis zu 0,18%,

(fortgesetzt)

Zr	bis zu 0,20%,
Ti	bis zu 0,15%,
Zn	bis zu 0,25%,

Verunreinigungen je <0,05%, insgesamt <0,2%, Rest Aluminium,
und wobei es eine im Wesentlichen unrekristallisierte Mikrostruktur hat.

2. Warmgewalztes halbfertiges Schmiederohmaterial aus Aluminiumlegierung der 6xxx-Serie nach Anspruch 1, wobei der Cu-Gehalt in einem Bereich von 0,12% bis 0,27% liegt.

3. Warmgewalztes halbfertiges Schmiederohmaterial aus Aluminiumlegierung der 6xxx-Serie nach Anspruch 1 oder 2, wobei der Mn-Gehalt in einem Bereich von 0,50% bis 0,70% liegt.

4. Warmgewalztes halbfertiges Schmiederohmaterial aus Aluminiumlegierung der 6xxx-Serie nach einem der Ansprüche 1 bis 3, wobei der Si-Gehalt in einem Bereich von 0,8% bis 1,30% liegt.

5. Warmgewalztes halbfertiges Schmiederohmaterial aus Aluminiumlegierung der 6xxx-Serie nach einem der Ansprüche 1 bis 4, wobei der Mg-Gehalt in einem Bereich von 0,70% bis 0,90%, vorzugsweise in einem Bereich von 0,70% bis 0,85% liegt.

6. Warmgewalztes halbfertiges Schmiederohmaterial aus Aluminiumlegierung der 6xxx-Serie nach einem der Ansprüche 1 bis 5, wobei der Cr-Gehalt im Bereich von 0,06% bis 0,18%, vorzugsweise 0,06% bis 0,14% liegt.

7. Warmgewalztes halbfertiges Schmiederohmaterial aus Aluminiumlegierung der 6xxx-Serie nach einem der Ansprüche 1 bis 6, wobei der Zr-Gehalt im Bereich von 0,05% bis 0,20%, und vorzugsweise im Bereich von 0,05% bis 0,16% liegt.

8. Verfahren zur Herstellung eines warmgewalzten halbfertigen Schmiederohmaterials aus Aluminiumlegierung der 6xxx-Serie nach einem der Ansprüche 1 bis 7, wobei das Verfahren folgende Schritte umfasst:

- Gießen eines Blocks, der ein Warmwalz-Ausgangsmaterial bildet und eine Zusammensetzung nach einem der Ansprüche 1 bis 7 hat;
- Homogenisierung des Gussblocks bei einer Temperatur im Bereich von 460°C bis 570°C;
- Warmwalzen in einem oder mehreren Walzdurchgängen auf eine Warmwalzwerk-Austrittsdicke im Bereich von 2 bis 30 mm, und wobei die Warmwalzwerk-Austrittstemperatur im Bereich von 200°C bis 360°C liegt.

9. Verfahren nach Anspruch 8, wobei die Warmwalzwerk-Eintrittstemperatur in einem Bereich von 400°C bis 550°C, vorzugsweise 435°C bis 535°C, und bevorzugter 435°C bis unter 500°C liegt.

10. Verfahren zur Herstellung von geschmiedeten Produkten unter Verwendung eines warmgewalzten halbfertigen Schmiederohmaterials aus Aluminiumlegierung der 6xxx-Serie, das folgende Schritte umfasst

- Lösungsglühen des warmgewalzten halbfertigen Schmiederohmaterials aus Aluminiumlegierung der 6xxx-Serie nach Anspruch 8 oder 9;
- Warmumformen in ein umgeformtes Produkt, das eine im Wesentlichen rekristallisierte Mikrostruktur hat; und
- Warmaushärten des umgeformten Produkts, vorzugsweise in einen T6x-Zustand.

11. Verfahren nach Anspruch 10, wobei das umgeformte Produkt auf einen T6x-Zustand warm ausgehärtet wird.

12. Verfahren nach Anspruch 10 oder 11, wobei das Warmumformen durch Schmieden, bevorzugter durch Gesenkschmieden erfolgt.

13. Verfahren nach einem der Ansprüche 10 bis 12, wobei das umgeformte Produkt nach dem Warmumformen aber vor dem Warmaushärten in ein umgeformtes Produkt lösungsgeglüht wird.

14. Verfahren nach einem der Ansprüche 10 bis 13, wobei das umgeformte Produkt, vorzugsweise ein geschmiedetes Produkt, nach dem Warmaushärten einen Krümmungswinkel von mindestens 60°, vorzugsweise mindestens 70° hat, wenn es in einem 2 mm Produkt gemäß VDA 238-100 gemessen wird.

15. Verfahren nach einem der Ansprüche 10 bis 14, wobei das umgeformte Produkt, vorzugsweise ein geschmiedetes Produkt, nach dem Warmaushärten eine Streckgrenze von mindestens 330 MPa hat.

16. Verwendung eines warmgewalzten halbfertigen Schmiederohmaterials aus Aluminiumlegierung der 6xxx-Serie mit einer Dicke im Bereich von 2 mm bis 30 mm und mit einer Zusammensetzung, die in Gew.-% umfasst

Si	0,65% - 1,4%,
Mg	0,60% - 0,95%,
Mn	0,40% - 0,80%,
Cu	0,12% - 0,28%,
Fe	bis zu 0,5%,
Cr	bis zu 0,18%,
Zr	bis zu 0,20%,
Ti	bis zu 0,15%,
Zn	bis zu 0,25%,

Verunreinigungen je <0,05%, insgesamt <0,2%, Rest Aluminium,
und wobei es eine im Wesentlichen unrekristallisierte Mikrostruktur hat und durch das Verfahren nach einem der Ansprüche 8 oder 9 erhalten wird, bei der Herstellung von geschmiedeten Produkten, vorzugsweise gesenkgeschmiedeten Produkten, die eine im Wesentlichen rekristallisierte Mikrostruktur haben.

17. Verwendung nach Anspruch 16 eines warmgewalzten halbfertigen Schmiederohmaterials aus Aluminiumlegierung der 6xxx-Serie mit einer Dicke im Bereich von 2 mm bis 30 mm und mit einer Zusammensetzung, die in Gew.-% umfasst

Si	0,65% - 1,4%,
Mg	0,60% - 0,95%,
Mn	0,40% - 0,80%,
Cu	0,12% - 0,28%,
Fe	bis zu 0,5%,
Cr	bis zu 0,18%,
Zr	bis zu 0,20%,
Ti	bis zu 0,15%,
Zn	bis zu 0,25%,

Verunreinigungen je <0,05%, insgesamt <0,2%, Rest Aluminium,
und wobei es eine im Wesentlichen unrekristallisierte Mikrostruktur hat und durch das Verfahren nach einem der Ansprüche 8 oder 9 erhalten wird, bei der Herstellung von geschmiedeten Produkten, vorzugsweise gesenkgeschmiedeten Produkten nach einem der Ansprüche 10 bis 15.

Revendications

1. Matériau de base à forger, laminé à chaud semi-fini en alliage d'aluminium de la série 6xxx ayant une épaisseur dans la plage de 2 mm à 30 mm, et ayant une composition comprenant, en pourcentage en poids :

Si	0,65 % à 1,4 %,
Mg	0,60 % à 0,95 %,
Mn	0,40 % à 0,80 %,
Cu	0,12 % à 0,28 %,

(suite)

Fe	jusqu'à 0,5 %,
Cr	jusqu'à 0,18 %,
Zr	jusqu'à 0,20 %,
Ti	jusqu'à 0,15 %,
Zn	jusqu'à 0,25 %,

des impuretés, chacune < 0,05 % et au total > 0,2 %,
le reste étant de l'aluminium,
et dans lequel le matériau a une microstructure sensiblement non recristallisée.

2. Matériau de base à forger, laminé à chaud semi-fini en alliage d'aluminium de la série 6xxx selon la revendication 1, dans lequel la teneur en Cu est dans une plage de 0,12 % à 0,27 %.

3. Matériau de base à forger, laminé à chaud semi-fini en alliage d'aluminium de la série 6xxx selon la revendication 1 ou 2, dans lequel la teneur en Mn est dans une plage de 0,50 % à 0,70 %.

4. Matériau de base à forger, laminé à chaud semi-fini en alliage d'aluminium de la série 6xxx selon l'une quelconque des revendications 1 à 3, dans lequel la teneur en Si est dans une plage de 0,8 % à 1,30 %.

5. Matériau de base à forger, laminé à chaud semi-fini en alliage d'aluminium de la série 6xxx selon l'une quelconque des revendications 1 à 4, dans lequel la teneur en Mg est dans une plage de 0,70 % à 0,90 %, de préférence dans une plage de 0,70 % à 0,85 %.

6. Matériau de base à forger, laminé à chaud semi-fini en alliage d'aluminium de la série 6xxx selon l'une quelconque des revendications 1 à 5, dans lequel la teneur en Cr est dans la plage de 0,06 % à 0,18 %, de préférence 0,06 % à 0,14 %.

7. Matériau de base à forger, laminé à chaud semi-fini en alliage d'aluminium de la série 6xxx selon l'une quelconque des revendications 1 à 6, dans lequel la teneur en Zr est dans la plage de 0,05 % à 0,20 %, et de préférence dans la plage de 0,05 % à 0,16 %.

8. Procédé de fabrication d'un matériau de base à forger, laminé à chaud semi-fini en alliage d'aluminium de la série 6xxx selon l'une quelconque des revendications 1 à 7, le procédé comprenant les étapes consistant à :

- couler un lingot formant un matériau de base pour laminage à chaud et ayant une composition selon l'une quelconque des revendications 1 à 7 ;
- homogénéiser le lingot coulé à une température dans la plage de 460° C à 570° C ;
- laminer à chaud dans une ou plusieurs passes de laminage pour donner en sortie de laminage à chaud un matériau calibré dans la plage de 2 à 30 mm, et dans lequel la température de sortie du laminage à chaud est dans la plage de 200° C à 360° C.

9. Procédé selon la revendication 8, dans lequel la température d'entrée du laminage à chaud est dans une plage de 400° C à 550° C, de préférence 435° C à 535° C, et de façon plus préférée 435° C à moins de 500° C.

10. Procédé de fabrication de produits forgés en utilisant un matériau de base à forger, laminé à chaud semi-fini en alliage d'aluminium de la série 6xxx, comprenant les étapes consistant à :

- traiter à chaud en solution le matériau de base à forger, laminé à chaud semi-fini en alliage d'aluminium de la série 6xxx selon la revendication 8 ou 9 ;
- former à chaud pour donner un produit formé ayant une microstructure sensiblement recristallisée ; et
- faire vieillir artificiellement le produit formé, de préférence à une condition T6x.

11. Procédé selon la revendication 10, dans lequel le produit formé est vieilli artificiellement à une condition T6x.

12. Procédé selon la revendication 10 ou 11, dans lequel la mise en forme à chaud a lieu au moyen de forgeage, de préférence au moyen d'un forgeage en matrice.

13. Procédé selon l'une quelconque des revendications 10 à 12, dans lequel ledit produit mis en forme est traité à chaud en solution après la mise en forme à chaud pour donner un produit formé mais avant un vieillissement artificiel.

14. Procédé selon l'une quelconque des revendications 10 à 13, dans lequel le produit formé, de préférence un produit forgé, présente après vieillissement artificiel un angle de cintrage d'au moins 60°, de préférence d'au moins 70°, lorsqu'on le mesure sur un produit de 2 mm en accord avec la norme VDA 238-100.

15. Procédé selon l'une quelconque des revendications 10 à 14, dans lequel le produit formé, de préférence un produit forgé, présente après vieillissement artificiel une résistance à la rupture en traction d'au moins 330 MPa.

16. Utilisation d'un matériau de base à forger, laminé à chaud semi-fini en alliage d'aluminium de la série 6xxx ayant une épaisseur dans la plage de 2 mm à 30 mm, et ayant une composition comprenant, en pourcentage en poids :

Si	0,65 % à 1,4 %,
Mg	0,60 % à 0,95 %,
Mn	0,40 % à 0,80 %,
Cu	0,12 % à 0,28 %,
Fe	jusqu'à 0,5 %,
Cr	jusqu'à 0,18 %,
Zr	jusqu'à 0,20 %,
Ti	jusqu'à 0,15 %,
Zn	jusqu'à 0,25 %,

des impuretés, chacune < 0,05 % et au total > 0,2 %,
le reste étant de l'aluminium,
et dans lequel le matériau à une microstructure sensiblement non recristallisée et est obtenu par le procédé selon l'une quelconque des revendications 8 ou 9, pour la fabrication de produits forgés, de préférence de produits forgés en matrice, ayant une microstructure sensiblement recristallisée.

17. Utilisation selon la revendication 16 d'un matériau de base à forger, laminé à chaud semi-fini en alliage d'aluminium de la série 6xxx ayant une épaisseur dans la plage de 2 mm à 30 mm, et ayant une composition comprenant, en pourcentage en poids :

Si	0,65 % à 1,4 %,
Mg	0,60 % à 0,95 %,
Mn	0,40 % à 0,80 %,
Cu	0,12 % à 0,28 %,
Fe	jusqu'à 0,5 %,
Cr	jusqu'à 0,18 %,
Zr	jusqu'à 0,20 %,
Ti	jusqu'à 0,15 %,
Zn	jusqu'à 0,25 %,

des impuretés, chacune < 0,05 % et au total > 0,2 %,
le reste étant de l'aluminium,
et dans lequel le matériau a une microstructure sensiblement non recristallisée et est obtenu par le procédé selon l'une quelconque des revendications 8 ou 9, dans la fabrication de produits forgés, de préférence de produits forgés en matrice, selon l'une quelconque des revendications 10 à 15.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 2644725 B1, Kobe **[0005]**
- WO 2015146654 A1, Kobe **[0006]**
- US 20100089503 A1 **[0007]**