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(54) Title: 6XXX-SERIES ALUMINIUM ALLOY FORGING STOCK MATERIAL AND METHOD OF MANUFACTURING THERE-
OF

(57) Abstract: The invention relates to 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 0.04-0.28%, 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. The invention relates also to a method of manufacturing such 6xxx-series hot-rolled aluminium alloy forging stock material. Furthermore, the invention relates to a method of forging a shaped product from the 6xxx-series aluminium alloy forging stock material.



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6xxx-series aluminium alloy forging stock material and method of manufacturing thereof

5 FIELD OF THE INVENTION

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
10 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

15 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.

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.%:
20

	Si	0.7% – 1.3%
	Mg	0.6% – 1.2%
	Fe	<0.50%
	Cu	<0.10%
25	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.

5 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%

10 Cu <0.10%

Mn 0.50% – 1.0%

Zr 0.05% - 0.20%

Cr <0.25%

Zn <0.20%

15 Ti <0.10%,

balance impurities and aluminium.

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.

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.

5 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.

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DESCRIPTION OF THE INVENTION

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.

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

20 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.

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.

25 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 0.04% – 0.28%,
5 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%,
10 impurities each <0.05%, total <0.2%, balance aluminium,
and wherein in the hot-rolled condition it has a substantially unrecrystallized microstructure.

The careful balance of alloying composition and the microstructure in the hot-rolled condition allows for the subsequent production of forged products having a
15 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
20 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.

25 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.

The purposive addition of Mg and Si strengthens the aluminium alloy due to
30 precipitation hardening of elemental Si and Mg₂Si 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%.

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%
5 to provide sufficient strength to the final product. A preferred upper-limit for the Mg content is 0.85%, and more preferably 0.80%.

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
10 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.

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
15 product. Preferably the aluminium alloy has at least 0.08% of Cu, and more preferably at least 0.12%. A preferred upper-limit for the Cu-content is 0.27%, and more preferably at most 0.24%.

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
20 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.

25 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.

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-
30 content is about 0.16%.

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%.

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.

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.

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.

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.

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	0.04% – 0.28%,
25	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%,
30	impurities each <0.05%, total <0.2%, balance aluminium, and with preferred narrower ranges as herein described and as claimed.	

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,
- 5 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.

10 The careful balance of alloying composition and providing a substantially unrecrystallized 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
15 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
20 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.

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,
25 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
30 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.

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 Mg₂Si 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.

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.

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.

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 suppresses the coarse precipitation of secondary phases such as Si and Mg₂Si 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.

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.

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

5 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
10 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
15 520°C to 560°C, and is preferably just above the solvus temperature of the Mg₂Si 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
20 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
25 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;

30 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.

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.

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.

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.

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.

10 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.

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.

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.

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. 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 0.04% – 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.
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 0.08% to 0.27%, and preferably 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%.
- 5
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%.
- 10
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;
 - 15 - 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.
- 20
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.
- 25
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
 - 30 - 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 | 0.04% – 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.

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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.%,

10

Si 0.65% – 1.4%,
Mg 0.60% – 0.95%,
Mn 0.40% – 0.80%,
Cu 0.04% – 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%,

15

impurities each <0.05%, total <0.2%, balance aluminium,

20

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.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/063109

A. CLASSIFICATION OF SUBJECT MATTER

INV. C22C21/02 C22C21/08 C22F1/05
ADD.

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/089503 A1 (INAGAKI YOSHIYA [JP] ET AL) 15 April 2010 (2010-04-15) tables 1-3	1-17
A	----- EP 1 458 898 A1 (DAIMLER CHRYSLER AG [DE]; CORUS ALUMINIUM NV [BE]) 22 September 2004 (2004-09-22) example 1 -----	1-17



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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2010089503	A1	15-04-2010	DE 112008000587 T5	07-01-2010
			JP 5180496 B2	10-04-2013
			JP 2008223108 A	25-09-2008
			KR 20090109590 A	20-10-2009
			US 2010089503 A1	15-04-2010
			WO 2008114680 A1	25-09-2008

EP 1458898	A1	22-09-2004	AT 294252 T	15-05-2005
			AU 2002352255 A1	09-07-2003
			DE 10163039 C1	24-07-2003
			EP 1458898 A1	22-09-2004
			ES 2239261 T3	16-09-2005
			US 2005095167 A1	05-05-2005
			US 2008078480 A1	03-04-2008
			WO 03054243 A1	03-07-2003
