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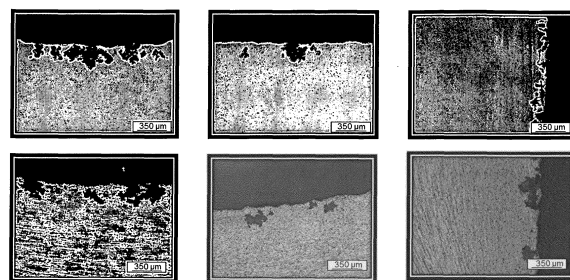
(54) **Ultra high strength products forged from 6xxx aluminium alloys having excellent corrosion resistance**

(57) An aluminium alloy forged product obtained by following steps:

- casting a billet from a 6xxx aluminium alloy comprising:
Si: 0.7-1.3 wt. %; Fe : \leq 0.5 wt. %; Cu: 0.1-1.5 wt. %; Mn: 0.4-1.0 wt. %; Mg: 0.6-1.2 wt. %; Cr: 0.05-0.25 wt.%; Zr: 0.05-0.2 wt. %; Zn: \leq 0.2 wt.%; Ti: \leq 0.2 wt.% , the rest being aluminium and inevitable impurities;
- homogenising the cast billet, at a temperature T_H , which is 5°C to 80°C lower than solidus temperature T_s , in the range of typically 500-560°C, for a duration between 2 and 10 hours;
- quenching said billet down to room temperature by using water quench system;
- heating the homogenised billet to a temperature between ($T_s - 5^\circ\text{C}$) and ($T_s - 125^\circ\text{C}$);
- extruding said billet through a die to produce a solid section with an exit temperature (typically 530°C) lower than T_s (typically 550°C), and with an extruding ratio of at least 8;
- quenching the extruded product down to room temperature by using water quench system;
- stretching the extruded product to obtain a plastic deformation typically between 0.5% and 10%;
- heating cut-to-length extruded rod to forging temperature, typically between 400 and 520°C;
- forging in heated mould between 150 and 350°C;
- separate solutionising at a temperature between 530 and 560°C for durations between 2 min. and 1 hour;
- water quenching the forged and solutionised material down to room temperature;

- room temperature ageing for a duration between 6 hours and 30 days;
- ageing to T6 temper by a one-or multiple-step heat treatment at temperatures ranging from 150 to 200°C for holding times ranging from 2 to 20 hours.

AA 6082 T6 – Max. surface attack depth (390 microns) / Max. end grain attack depth (320 microns)



Invention T6 – Max. surface attack depth (310 microns) / Max. end grain attack depth (380 microns)

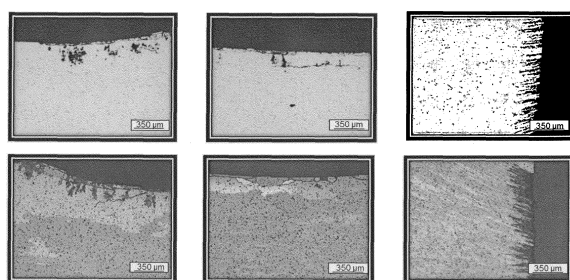


Figure 1

Description

[0001] The invention relates to ultra-high strength AA6xxx-series aluminium alloy forgings particularly suitable for automotive, rail or transportation structural components, exhibiting an ultimate tensile strength UTS typically higher than 400 MPa in T6 temper, preferably higher than 450 MPa, and excellent corrosion resistance.

More particularly such forgings are produced through a manufacturing process which, besides including subsequent extrusion and forging steps, includes multiple solutionising and quench steps in order to achieve, after ultimate age hardening, high strength and excellent corrosion resistance on Cu-doped AA6xxx-series alloys.

[0002] Unless otherwise stated, all information concerning the chemical composition of the alloys is expressed as a percentage by weight based on the total weight of the alloy. "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. Unless otherwise stated, the definitions of metallurgical tempers listed in the European standard EN 515 will apply. Static tensile mechanical characteristics, in other words, the ultimate tensile strength R_m (or UTS), the tensile yield strength at 0.2% plastic elongation $R_{p0.2}$ (or YTS), and elongation A% (or E%), are determined by a tensile test according to NF EN ISO 6892-1.

[0003] Aluminium alloy compositions and tempers have been developed for obtaining satisfying strength and corrosion behavior 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 obtained from extruded rough products.

In order to achieve tensile properties in excess of 400 MPa in 6xxx alloys, it is essential to maximise both the ageing response through an adequate solutionising of solute elements, predominantly Mg, Si and Cu, while maximising retention of the fibrous structure through minimal recrystallisation.

[0004] Said 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.

To achieve adequate solutionising, according to the prior art, highly alloyed 6xxx alloys are usually separately solutionised and quenched after the ultimate hot forming step (in this case forging). Such a solution can be found in the patent application EP 2548933 A1 by "Nissan Motor Co". When alloys are strongly alloyed it is often required to apply an extended solutionising treatment (in excess of 90min) at high temperature (530-560°C) in order to achieve excellent solutionising. Such a case is described in the patent application JP2012-097321 by "Furukawa Sky Aluminium-Corp". The corollary 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.

[0005] The invention relates to forgings manufactured through a process including, besides subsequent extrusion and forging steps, multiple solutionising and quench steps, to achieve excellent solutionising and strong retention of the fibrous structure on 6xxx type alloys, achieving typically, after last step age hardening (T6 temper), an ultimate tensile strength UTS higher than 400 MPa, and preferably higher than 450 MPa, and an excellent corrosion resistance.

[0006] Solidus T_s 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 T_s .

[0007] According to the prior art, high strength forgings obtained from extruded rough products, and from 6xxx-series aluminium alloys characterised by a minimum Silicon content of 0.7 % and minimum Magnesium content of 0.6 %, for example of the AA 6082, 6182, 6110, or 6056 type, are produced by:

- a) casting one of the following aluminium alloys AA6082, 6110, 6182 or 6056 acc. to AA standard or to a restricted composition within 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 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 (400-520°C);
- i) forging in heated mould (150-350°C);
- j) separate solutionising at 530-560°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 to 200°C for holding times ranging from 2 to 20 hours.

[0008] However, ultimate tensile strengths achieved with this processing route do not exceed 450MPa. Generally speaking, 400MPa is a maximum especially when ageing has to be shifted away from peak ageing T66 in order to guarantee minimum elongation values higher than 10 %.

[0009] The applicant decided to develop a novel combination of 6xxx-series alloy and process which secures an ultimate tensile strength higher than 400 MPa, preferably higher than 450MPa, and even higher than 480 MPa.

[0010] A first object of the invention is an aluminium alloy forged product obtained by following steps:

- a) casting a billet from a 6xxx aluminium alloy comprising:

Si: 0.7-1.3 wt. %; Fe : \leq 0.5 wt. %; Cu: 0.1-1.5 wt. %; Mn: 0.4-1.0 wt. %; Mg: 0.6-1.2 wt. %; Cr: 0.05-0.25 wt.%; Zr: 0.05-0.2 wt. %; Zn: \leq 0.2 wt.%; Ti: \leq 0.2 wt.% , 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 T_s , typically T_H in the range of 500-560°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 ($T_s - 5^\circ\text{C}$) and ($T_s - 125^\circ\text{C}$);

- e) extruding said billet through a die to produce a solid section with an exit temperature (typically 530°C) lower than T_s (typically 550°C), in order 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 and 520°C;

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

- j) separate solutionising at a temperature between 530 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 to 200°C for holding times ranging from 2 to 20 hours.

[0011] According to the invention, the aluminium alloy extruded product is obtained by casting a billet from a 6xxx aluminium alloy comprising: Si: 0.7-1.3 wt. %; Fe: \leq 0.5 wt. %; Cu: 0.1-1.5 wt. %; Mn: 0.4-1.0 wt. %; Mg: 0.6-1.2 wt. %; Cr: 0.05-0.25 wt.%; Zr: 0.05-0.2 wt. %; Zn: \leq 0.2 wt.%; Ti: \leq 0.2 wt.%, the rest being aluminium and inevitable impurities.

The aluminium alloy according to the invention is of the AlMgSi type, which, compared with other such as e.g. AlZnMg alloys, provides an excellent combination of high tensile strength and resistance to corrosion.

[0012] The process according to the invention consists in particular in replacing conventional homogenising followed by slow cooling, heating and extruding followed again by slow cooling of AA6xxx alloy billets, by high temperature homogenising and quenching followed by heating, extruding and quenching again, and does not comprise a separate post-extrusion solution heat treatment, because, as a result of steps b) and c), most part of the alloying elements which contribute to the formation of hardening particles are in solid solution in the lattice of the extrudate.

[0013] The present invention therefore provides a process to manufacture a range of 6xxx alloys with superior mechanical properties, especially if applied to a sufficiently copper-doped AlMgSiCu, with strength levels in excess of 400 MPa and even 450 or 480 MPa, hitherto not achieved through a conventional route. In addition, good extrudability and forgeability is maintained because the limitation with extrusion speed due to premature speed cracking resulting from incipient melting is minimised due to a higher level of dissolution of constituent particles while ensuring precipitation and controlled coarsening of dispersoid phases prior to extrusion.

[0014] According to the invention, a billet 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-doped alloy derived from the said AA6xxx aluminium alloys.

[0015] This alloy has preferably a high Cu content, typically between 0.1 and 1.5 wt. %, more preferably between 0.4 and 1.2 wt. %, even more preferably between 0.6 and 1.0 wt. %. Dispersoid elements, Mn with a content of 0.4-1.0 wt. %, Cr with a content of 0.05-0.25 wt. % and Zr with a content of 0.05-0.2 wt. %, are added to control recrystallization and maximize the retention of fibrous structure of the extrudate and the forged component.

[0016] Si and Mg content are defined so as to ensure high level of dissolved Mg₂Si while minimising presence of undissolved Mg₂Si in the forged component after ultimate solutionising step, with a maximum content of 0.5 wt.%. For example, when solutionising at 550°C is applied at the ultimate step of the invention, the content of dissolved Mg is 0.623 wt.%, dissolved Si is 0.977 wt.% and undissolved Mg₂Si 0.45wt.%.

[0017] Si is combined with Mg to form Mg₂Si. The precipitation of Mg₂Si contributes to increasing the strength of the final aluminium alloy forged product.

[0018] If the Si content is less than 0.7 wt.%, 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 wt.%, tensile strength will be at most 450 MPa and with less than 1.1wt.% it will be lower than 480 MPa.

[0019] On the other hand, if the Si content is more than 1.3 wt.%, the level of undissolved Mg₂Si is too high and extrudability is reduced as well as corrosion resistance and toughness of the resultant final forged product.

[0020] Mg is combined with Si to form Mg₂Si. Therefore Mg is indispensable for strengthening the product of the present invention. If the Mg content is lower than 0.7 wt.%, the effect is too weak. On the other hand, if the Mg content is higher than 1.2 wt.%, the billet becomes difficult to be extruded and the extruded bar to be forged. Moreover, a large amount of Mg₂Si particles tends to precipitate during quenching process after the solution treatment. In addition, the Mg content is preferably between 0.7 wt.% and 1.1 wt.% and more preferably between 0.8 wt.% and 1.0 wt.%.

[0021] 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. Especially, if the Fe content is higher than 0.5 wt.% 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 wt.% and more preferably, lower than or equal to 0.2 wt.%.

[0022] Mn also combines with Al to form intermetallic compounds which control recrystallisation. However, if the Mn content is less than 0.4 wt.%, the effect is not sufficient. On the other hand, if the content of Mn is higher than 1.0 wt.%, 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 wt.% and 0.9 wt.% and more preferably between 0.5 wt.% and 0.7 wt.%.

[0023] The cast billet according to the invention is homogenised for a duration between 2 and 10 hours at a temperature between 5°C and 80°C lower than solidus, and then water quenched.

[0024] The homogenised and quenched cast billet to be extruded is heated to a soaking temperature T_h below the solidus temperature T_s , between $T_s-5^\circ\text{C}$ and $T_s-125^\circ\text{C}$. For example, solidus temperature is near 575°C for alloys AA6082 and AA6182. The billets are preferably heated and held at the soaking temperature during ten seconds to several minutes.

[0025] The billet is then introduced in the extrusion press and extruded through a die to form a solid extruded product or extrudate. The extrusion speed is controlled to have an extrudate surface exit temperature lower than solidus temperature T_s , respectively 530 and 550°C approximately. The exit temperature should be high enough to merely avoid precipitation. Practically, the targeted extrudate surface temperature is commonly ranging from 530°C to 550°C, to have an extrusion speed compatible with a satisfying productivity and 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. The extrusion ratio (starting cross-sectional area divided by final cross-sectional area) is at least 8 to maximize the fibrous structure of the extrudate.

[0026] The extruded product is then water quenched at the exit of the extrusion press, i.e. in an area located between 500 mm and 5 m of the exit from the die. It is cooled down to room temperature with an intense cooling device, for example a device projecting sprayed water or a water based cooling liquid on the extrudate.

[0027] The extrudate is then stretched to obtain a plastic deformation typically between 0.5% and 10%, preferably up to 5%, in order to have stress-relieved straight profiles.

[0028] The extruded bar is then cut to length, heated to forging temperature, typically between 400 and 520°C, and then forged in a heated mould typically between 150 and 350°C.

[0029] After forging, parts undergo a separate solutionising at a temperature between 530 and 560°C for a duration comprised between 2 min. and 1 hour and then water quenched with an intense cooling device, for example a device projecting sprayed water or a water based cooling liquid, down to room temperature.

[0030] The product is then aged at room temperature for a duration between 6 hours and 30 days, after which artificial ageing is applied to achieve T6 temper by a one-or multiple-step heat treatment at temperatures ranging from 150 to

200°C for holding times ranging from 2 to 20 hours.

[0031] The process according to the invention allows to obtain forged products made from Cu-doped 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 Mg₂Si content comprised between 1.2 wt. % and 1.6 wt. %, Si excess up to 0.7%, particularly if comprised between 0.2 wt. % and 0.7 wt. %, and especially if copper content lies between 0.4 wt.% and 1.5 wt.%, which gives a solvus to solidus temperature difference approximately equal to or even lower than 10°C, and renders such alloy almost impossible to extrude when processed according to the prior art route.

[0032] As this alloy comprises, further to Mn, additional dispersoid elements zirconium, between 0.05 and 0.2 wt. %, and Cr, between 0.05 and 0.25 wt. %, the microstructures of the extrudates show a strong fibrous retention providing an additional strengthening contribution, considered important in meeting such high mechanical property values. After having applied the process according to the invention to Cu doped AlMgSiCu aluminium alloys, the applicant was able to obtain forged components having at T6 temper ultimate tensile strengths higher than 450 MPa, even higher than 480 MPa.

[0033] Mechanical properties achieved in T6 temper on invention forgings after manufacturing according to the aforementioned process were significantly higher than by using conventional process on AA 6082 and displayed a far higher tolerance to solutionising conditions i.e. increased ease of solutionising at low temperature and soaking time and high resistance to recrystallization.

[0034] 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.

[0035] Such forged products are particularly suitable as automotive body structure or chassis-suspension parts and especially suspension arms.

EXAMPLE

[0036] Forged suspension arms were made from two 6xxx aluminium alloys, the first one being of the AA6082 type, the other one according to the invention, starting from extruded round bars with a diameter of 40 mm.

Said bars were extruded by following two different process routes: the current prior art route for AA6082 alloys and the route according to the invention for others.

[0037] The chemical compositions of these alloys are shown on Table I in weight %.

Table I

	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Pb	V	Zr
AA6082	1.112	0.197	0.061	0.744	0.807	0.193	0.003	0.012	0.029	0.001		
Invention	1.3	0.16	0.74	0.53	0.89	0.1	0.04	0.008	0.019	0.0011	0.011	0.13

[0038] Homogenised cast billets having a diameter of 308 mm and a length of 1200 mm were heated, introduced into an extrusion press and pressed to form 40 mm in diameter bars.

[0039] Forged suspension arms were obtained by following a conventional route for AA6082 alloys:

- homogenising the cast billet at a temperature T_H close to 480°C, for a duration of 5 hours;
- cooling said billet down to room temperature;
- heating the homogenised billet to a temperature T_h close to 500°C;
- extruding said billet through a die to produce round bars with an exit temperature close to 530°C;
- cooling the extruded product down to room temperature;
- stretching the extruded product to obtain a plastic deformation close to 1%;
- heating cut-to-length extruded rod to forging temperature, close to 500°C;
- forging in mould heated close to 300°C;
- separate solutionising at a temperature close to 530°C for 30 min.;
- water quenching the forged material with an intense cooling device down to room temperature;
- room temperature ageing for a duration of 1 day;
- ageing to T6 temper by a one-step heat treatment at 175°C for 8 hours.

[0040] Forged suspension arms were obtained by following the route according to the invention for other ones ("Invention"):

- a) homogenising the cast billet at a temperature T_H close to 520°C, for a duration of 5 hours;
- b) quenching said billet down to room temperature by using water quench system;
- c) heating the homogenised billet to a temperature T_h close to 500°C;
- d) extruding said billet through a die to produce round bars with an exit temperature close to 530°C;
- e) quenching the extruded product down to room temperature by using water quench system;
- f) stretching the extruded product to obtain a plastic deformation close to 1%;
- g) heating cut-to-length extruded rod to forging temperature close to 500°C;
- h) forging in heated mould close to 300°C;
- i) separate solutionising at a temperature close to 550°C for 30 min.;
- j) quenching the forged material with an intense cooling device down to room temperature;
- k) room temperature ageing for a duration of 1 day;
- l) ageing to T6 temper by a one-step heat treatment at 170°C for 8 hours.

[0041] Tensile test specimens were machined in the suspension arms. Table 2 shows the ultimate tensile strength (UTS), the yield strength (YS) and the elongation of forged products.

Table 2

Alloy	Solutionising	Ageing	Temper	Rm [MPa]	Rp0,2 [MPa]	A [%]
AA 6082	530°C/30 min.	175°C/8h	T6	378	358	11
AA 6082	530°C/30 min.	175°C/8h	T6	376	354	12.5
Invention	550°C/30 min.	170°C/8h	T6	481	452	13
Invention	550°C/30 min.	170°C/8h	T6	484	456	12

[0042] The results of table 2 show that the process route according to the invention enables the manufacture of aluminium alloy forged products having significantly higher strength (UTS and YS) than products obtained by a conventional route, and similar elongation.

[0043] Corrosion tests were performed using the ISO 11846B test for 24 hours of exposure time on suspension arms as above, the ones obtained from AA6082 alloy following the prior art route, the other ones according to the invention.

[0044] Figure 1 shows no significant difference for products according to the invention, with a maximum surface attack depth of 310 microns and a maximum end grain attack depth of 380 microns for the product according to the invention compared to respectively 390 and 320 microns for AA6082 alloys processed through a prior art route.

[0045] These results show that the process route according to the invention enables the manufacture of aluminium alloy extruded products having simultaneously better strength (UTS and YS) and equivalent corrosion resistance than products obtained by a conventional route.

Claims

1. An aluminium alloy forged product obtained by following steps:

- a) casting a billet from a 6xxx aluminium alloy comprising:

Si: 0.7-1.3 wt. %; Fe: \leq 0.5 wt. %; Cu: 0.1-1.5 wt. %; Mn: 0.4-1.0 wt. %; Mg: 0.6-1.2 wt. %; Cr: 0.05-0.25 wt. %; Zr: 0.05-0.2 wt. %; Zn: \leq 0.2 wt. %; Ti: \leq 0.2 wt. %, 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 T_s , typically T_H in the range of 500-560°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 ($T_s - 5^\circ\text{C}$) and ($T_s - 125^\circ\text{C}$);
- e) extruding said billet through a die to produce a solid section with an exit temperature (typically 530°C) lower than T_s (typically 550°C), 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 and 520°C;
- i) forging in heated mould between 150 and 350°C;
- j) separate solutionising at a temperature between 530 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 to 200°C for holding times ranging from 2 to 20 hours.

2. An aluminium alloy forged product according to claim 1 **characterised in that** said 6xxx aluminium alloy comprises Cu: 0.4-1.2 wt.%, preferably 0.6-1.0 wt.%.
3. An aluminium alloy forged product according to claim 1 or 2 **characterised in that** said 6xxx aluminium alloy comprises Si: 0.9-1.3 wt.%, preferably 1.1-1.3 wt.%.
4. An aluminium alloy forged product according to any of claims 1 to 3 **characterised in that** said 6xxx aluminium alloy comprises Mg: 0.7-1.1 wt.%, preferably 0.8-1.0 wt.%.
5. An aluminium alloy forged product according to any of claims 1 to 4 **characterised in that** said 6xxx aluminium alloy comprises Mn: 0.5-0.9 wt.%, preferably 0.5-0.7 wt.%.
6. An aluminium alloy forged product according to any of claims 1 to 5 **characterised in that** Fe ≤ 0.3 wt. %, preferably ≤ 0.2 wt. %.
7. An aluminium alloy forged product according to any of claims 1 to 6 **characterised in that** its ultimate tensile strength is higher than 400 MPa, preferably higher than 450MPa, and more preferably higher than 480 MPa.
8. An aluminium alloy forged product according to any of claims 1 to 7 **characterised in that** it is an automotive body-structure part.
9. An aluminium alloy forged product according to any of claims 1 to 7 **characterised in that** it is an automotive chassis-suspension part.
10. An aluminium alloy forged product according to any of claims 1 to 7 **characterised in that** it is an automotive suspension arm.
11. A process for manufacturing an aluminium alloy forged product according to any of claims 1 to 10 comprising the following steps:

a) casting a billet from a 6xxx aluminium alloy comprising:

Si: 0.7-1.3 wt. %; Fe: ≤ 0.5 wt. %; Cu: 0.1-1.5 wt. %; Mn: 0.4-1.0 wt. %; Mg: 0.6-1.2 wt. %; Cr: 0.05-0.25 wt. %; Zr: 0.05-0.2 wt. %; Zn: ≤ 0.2 wt.%; Ti: ≤ 0.2 wt.% , 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 T_s , typically T_H in the range of 500-560°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 ($T_s - 5^\circ\text{C}$) and ($T_s - 125^\circ\text{C}$);

e) extruding said billet through a die to produce a solid section with an exit temperature lower than T_s (typically 530°C) lower than T_s (typically 550°C), 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 and 520°C;

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

j) separate solutionising at a temperature between 530 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;

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

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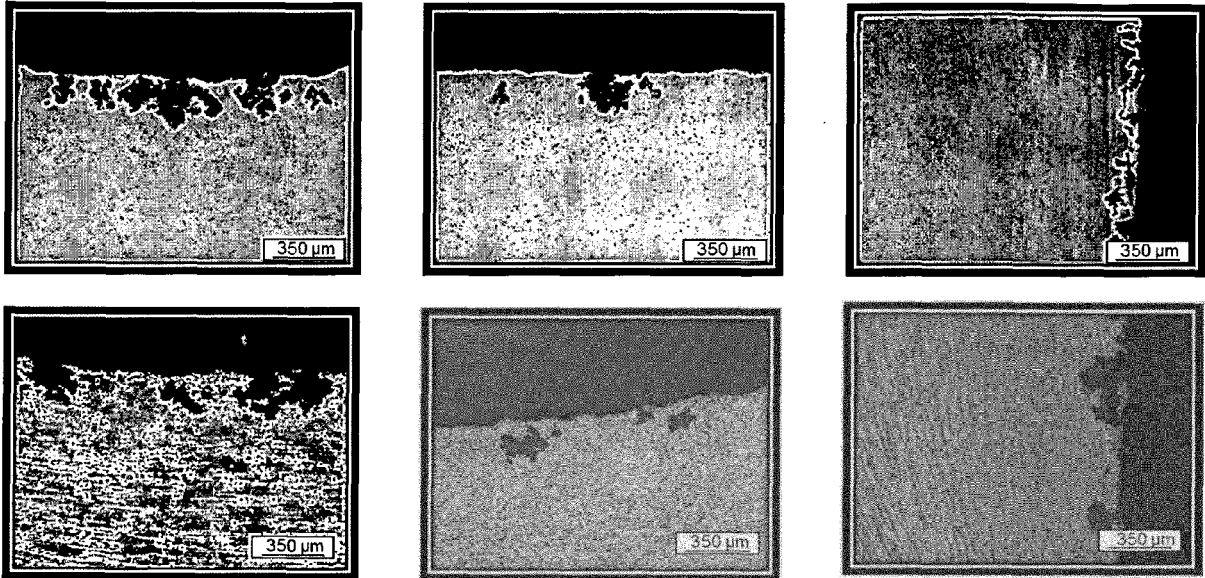
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AA 6082 T6 – Max. surface attack depth (390 microns) / Max. end grain attack depth (320 microns)



Invention T6 – Max. surface attack depth (310 microns) / Max. end grain attack depth (380 microns)

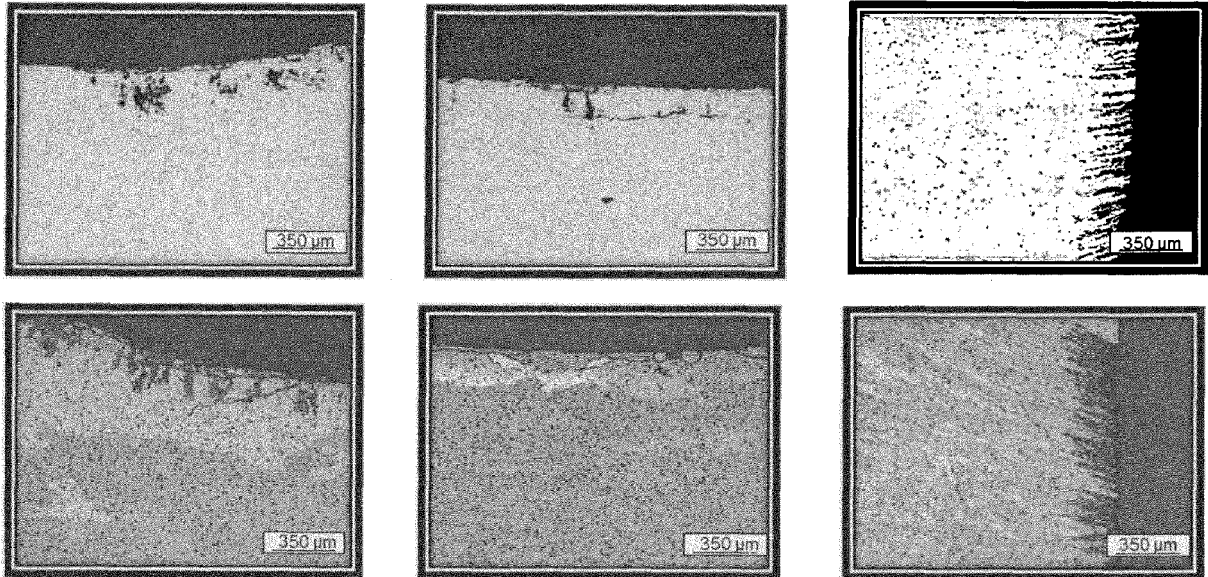


Figure 1



EUROPEAN SEARCH REPORT

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			C22C C22F
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		29 April 2015	González Junquera, J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

**ANNEX TO THE EUROPEAN SEARCH REPORT
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The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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