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(54) Title: METHOD OF MANUFACTURING A STRUCTURAL ALUMINIUM ALLOY PART

(57) Abstract: The invention relates to a method for the manufacture of forming a structural part from a 7xxx- series aluminium alloy sheet, said structural part formed in a shaping operation using a strip of rolled aluminium alloy sheet, the method comprising the following steps: (i) cutting the aluminium alloy sheet to obtain an aluminium alloy sheet blank; (ii) heating the aluminium alloy sheet blank to a temperature of more than 450°C; (iii) shaping the heated aluminium alloy sheet blank to obtain the structural part; (iv) cooling of the shaped structural part; and (v) heat treating of the cooled and shaped structural part.



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METHOD OF MANUFACTURING A STRUCTURAL ALUMINIUM ALLOY PART

FIELD OF THE INVENTION

The invention relates to a method for the manufacture of forming a structural part from a high-strength 7xxx-series aluminium alloy, said structural part being formed in a shaping operation using a strip of rolled aluminium alloy sheet. The invention is also directed to an automobile structural part formed by this method, in particular to a pillar reinforcement, for example to a B-pillar reinforcement or a tunnel.

BACKGROUND TO THE INVENTION

As will be appreciated herein below, except as otherwise indicated, alloy designations and temper designations refer to the Aluminum Association designations in Aluminum Standards and Data and the Registration Records, as published by the Aluminum Association in 2007.

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

In the production of cars in particular aluminium alloys the 6xxx- and 5xxx-series alloys have been used to produce body panels, whereas the load-bearing structural parts such as door beams and pillar reinforcements are commonly made from steel due to its higher strength. For example the B-pillar reinforcement, which plays an important role in protecting the occupants of a vehicle in a side impact incident, is currently produced from ultra high-strength steel, for example boron steel. Such a B-pillar is manufactured from a rolled steel sheet in a hot stamp forming operation.

European patent document EP-0952067-A2 disclosed a bodywork B-column or B-pillar for an automobile made from an aluminium alloy in a die-casting operation.

US-4,035,891 discloses a method of making a one-piece wheel starting from a blank made from an aluminium sheet product of the 6xxx-series, and wherein the blank is hot stamped at a temperature of about 475°C, which is below the solution heat treatment temperature of the subject alloy, to form the minor flange of the rim and the wheel, while the major flange of the rim is obtained by subsequently press-forming.

DESCRIPTION OF THE INVENTION

It is an object of the invention to provide a suitable aluminium sheet forming or shaping method which can be applied to high-strength aluminium alloys, and which can be used in particular to produce structural parts for automobile applications.

These and other objects and further advantages are met or exceeded by the present invention in which there is provided a method for the manufacture of forming a structural part from a 7xxx-series aluminium alloy sheet, said structural part being formed in a shaping operation of a strip of rolled aluminium alloy sheet, typically a cold rolled aluminium alloy sheet having a gauge in the range of about 0.4 to 8 mm, and preferably about 0.5 to 5 mm, the method comprising the following sequential steps of:

- a.) cutting the aluminium alloy sheet to obtain an aluminium alloy sheet blank;
- b.) heating the aluminium alloy sheet blank to a temperature of more than 350°C but at a temperature lower than the solidus temperature of the subject alloy, and whereby heat-up rates can be applied that are regular in the art, and followed by transfer of the heated blank to the forming tool,
- c.) shaping the heated aluminium alloy sheet blank to obtain the structural part;
- d.) rapid cooling of the shaped structural part to avoid undesirable precipitation out of various secondary phases in the aluminium alloy;
- e.) heat treating of the cooled and shaped structural part.

The shaped structural part may be trimmed from any excess material from the alloy sheet following the cooling operation and prior to any subsequent further heat treatment operation.

The rolled aluminium alloy sheet may be obtained by methods known in the art, and which include continuous casting or DC-casting of a rolling stock, homogenisation and/or preheating of the rolling stock, hot rolling and/or cold rolling to a final gauge typically in the range of about 0.4 to 8 mm. Depending on the alloy composition and the amount of cold work an intermediate anneal may be used before or during the cold rolling operation.

It has been found that 7xxx-series alloys when processed according to the invention are ductile enough at higher temperatures to be shaped in a stamping, a pressing, a deep-drawing or press-forming operation. The method according to the invention allows for the production of aluminium alloy structural parts having a very high strength while having equivalent or superior side impact performance compared to a structural part of similar geometry made of steel, for example a boron steel. A further advantage of aluminium alloy structural parts compared to steel structural parts is the significantly reduced mass of the parts even if the thickness of the aluminium alloy structural parts is higher than the thickness of the steel structural parts. Thus for example a boron steel sheet of 2.0 mm thickness may be replaced by an AA7136 aluminium alloy sheet of about 3.5 mm thickness without compromising the side impact performance of a B-pillar reinforcement, and thereby realizing a weight saving of about 35% to 40%.

In one embodiment of the invention the method is applied to a 7xxx-series aluminium alloy sheet which is Cu-free, meaning for the purpose of this invention that it has a Cu-content of less

than 0.3 wt.%, and preferably less than about 0.2 wt.%. A particular suitable aluminium alloy for this process and the intended structural application is an aluminium alloy having a composition within the window of AA7021. Although the AA7021 registration defines a Cu-content of maximum 0.25 wt.%, it is preferred to process aluminium alloys having a lower upper-limit, for
5 example of less than about 0.2 wt.%, and more preferably of less than about 0.15 wt.% Cu.

In a preferred embodiment of processing the Cu-free 7xxx-series aluminium alloy sheet, the aluminium alloy sheet blank is heated to a temperature at which solutionizing occurs, thus the heating of the blank has the effect of a solution heat treatment to achieve the dissolving of as much as practically possible any of M- and T-phases which may have precipitated out during
10 cooling from a homogenisation treatment or during a hot working operation or any other intermediate thermal treatment before the rolled product was rolled to final gauge. Such a solution heat treatment is preferably carried out at a temperature of more than about 400°C, and more preferably to a temperature in a range of about 420 to 510°C. A more preferred upper-limit is about 490°C. The duration of this heating or the soaking time is preferably in a range of a few
15 minutes to less than about 2 hours, and preferably less than about 1 hour.

The heated blank is subsequently transferred to the forming tool in which the structural part is shaped. The shaping operation can be done for example by means of deep-drawing, pressing or press forming. In the transfer of the aluminium alloy sheet blank may lose some heat, but at the beginning of the shaping operation the temperature should be higher than 200°C, and ideally
20 be more than 250°C.

Immediately after the shaping operation the structural part is rapidly cooled for example by means water such as water quenching or water spray quenching.

In a preferred embodiment when processing Cu-free 7xxx-series aluminium alloy sheet the shaping operation and the cooling operation are combined. This can be obtained for example by
25 means of using relatively cold forming tools, e.g. dies, such that during the shaping operation the heated blank is formed while simultaneously being rapidly cooled, more in particular quenched. In order to obtain optimum cooling of the stamped structural part, it is possible to maintain the stamped product in the forming tool until it is cooled to a temperature of less than 120°C, and preferably to a temperature of less than about 80°C. This kind of combined shaping, e.g. by
30 means of stamping, and cooling of the blank is also referred to as press-quenching. An advantage of press-quenching is the reduced spring back in the structural part. In accordance with the invention it has been found that the Cu-free 7xxx-series aluminium alloy have a very low quench sensitivity and consequently can be quenched in the forming tool without criticality.

After the rapid cooling operation either by press-quenching or the use of water, the
35 structural part is in a W-temper.

Thereafter the structural part is aged to bring achieve the desired mechanical properties such as strength and physical properties in the structural part. Ageing can be done by natural ageing, typically at ambient temperatures. In a preferred mode the ageing is carried out by means of artificial aging. Artificial aging can bring the structural part for example to a peak strength (T6) or to an over-aged temper (T7). Artificial ageing is preferably carried out by holding the structural part for about 3 to 20 hours at a temperature in the range of about 90 to 200°C. Artificial ageing can also be carried out as a single ageing treatment, but also in a two-step or even three-step ageing treatment, for example by holding the structural part for about 5 hours at about 100°C, then for about 4 hours at about 145°C, and then for about 3 hours at about 170°C followed by rapid cooling. Alternatively a non-isothermal ageing practice as disclosed in WO-2007/106772-A2 can be applied.

Optionally, prior to the artificial ageing treatment the structural part can be subjected to a cold forming operation to reduce any possible distortions in the structural part introduced during the rapid cooling operation.

In another embodiment of the method according to the invention it is being applied to 7xxx-series aluminium alloy sheet having a purposive addition of copper as alloying element. Typically the Cu-content is more than 0.3 wt.%, and preferably more than about 0.8 wt.%. Aluminium alloys in particular suitable for this embodiment are aluminium alloys within the compositional ranges of AA7136, AA7081, AA7085, AA7050, and AA7055-series alloys. Some of these registered aluminium alloys have very strict upper-limits for the Si and Fe-contents. However, it has been found that in the method according to this invention the Si and Fe levels are less critical and the upper-limits can be raised to about 0.25 wt.% and about 0.35 wt.% respectively.

In a preferred embodiment of processing the Cu-containing 7xxx-series aluminium alloy sheet, the aluminium alloy sheet blank is heated to a temperature in the range of about 350°C to 440°C, and typically for a period of a few minutes to about 1 hour. The temperature applied is below the temperature to obtain a substantial solutionizing effect.

The heated blank is subsequently transferred to the forming tool in which the structural part is shaped. The shaping operation can be done for example by means of deep-drawing, pressing or press forming. The shaping operation can be done for example by means of deep-drawing, pressing or press forming. In the transfer of the aluminium alloy sheet blank may lose some heat, but at the beginning of the shaping operation the temperature should be higher than 200°C, and ideally be more than 250°C. Press forming is typically applied at a strain rate of 0.01/s to 0.1/s. Optionally, the forming tools to shape the structural part may be heated to a temperature of about 200°C to 440°C, and preferably to about 300°C to 400°C. Ideally the forming tools are about 20°C to 30°C below the heating temperature of the aluminium alloy

sheet blank. The heating of the forming tools is to prevent too fast cooling of the aluminium alloy sheet blank during the hot forming operation. Following to shaping operation the structural part is cooled. Ideally the structural part are cooled while still in the forming dies to reduce the amount of distortion in the part.

5 Thereafter the cooled shaped structural part is subjected to a solution heat treatment followed by rapid cooling for example by means water such as water quenching or water spray quenching. Such a solution heat treatment is preferably carried out at a temperature of more than 450°C but at a temperature lower than the solidus temperature of the subject alloy, and more preferably to a temperature in a range of 450°C to 490°C. A typical solution heat treatment
10 temperature would be about 475°C. The duration of this heating or the soaking time is preferably in a range of about 3 to 150 min, more preferably in a range of about 5 to 40 min.

 Thereafter the structural part is aged to bring achieve the desired mechanical properties such as strength and physical properties in the structural part. Ageing can be done by natural ageing, typically at ambient temperatures. In a preferred mode the ageing is carried out by
15 means of artificial aging. Artificial aging can bring the structural part for example to a peak strength (T6) or to an over-aged temper (T7). Artificial ageing is preferably carried out by holding the structural part for about 3 to 20 hours at a temperature in the range of about 90°C to 200°C. Artificial ageing can also be carried out as a single ageing treatment, but also in a two-step or even three-step ageing treatment, for example by holding the structural part for about 5 hours at
20 about 100°C, then for about 4 hours at about 145°C, and then for about 3 hours at about 170°C followed by rapid cooling.

 Optionally, prior to the artificial ageing treatment the structural part can be subjected to a cold forming operation, e.g. a cold press forming operation, to reduce any possible distortions in the structural part introduced during the rapid cooling operation.

25 The method according to this invention may be used to manufacture structural parts from a 7xxx-series aluminium alloy sheet is an automobile structural part. More in particular a structural part selected from the group comprising: a bumper, door beam, roof beam, side beam, instrumental panel support beam, pillar reinforcement, tunnel, and B-pillar reinforcement.

 In a further aspect of the invention it relates to a structural part, such as an automobile
30 structural part formed by the method according to this invention.

 Having now fully described the invention, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made without departing from the spirit or scope of the invention as herein described.

CLAIMS

1. A method for the manufacture of forming a structural part from a 7xxx-series aluminium alloy sheet, said structural part being formed in a shaping operation using a strip of rolled aluminium alloy sheet, the method comprising the following steps:
- 5
- a.) cutting the aluminium alloy sheet to obtain an aluminium alloy sheet blank;
 - b.) heating the aluminium alloy sheet blank to a temperature of more than 350°C;
 - c.) shaping the heated aluminium alloy sheet blank to obtain the structural part;
 - d.) cooling of the stamped structural part;

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 - e.) heat treating of the cooled and stamped structural part.
2. The method according to claim 1, wherein the 7xxx-series aluminium alloy sheet has a Cu-content of less than 0.3 wt.%, and preferably less than 0.2 wt.%.
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3. The method according to claim 1, wherein the 7xxx-series aluminium alloy has a Cu-content of more than 0.3 wt.%, and preferably of more than 0.8 wt.%.
4. The method according to claims 1 and 2, wherein during step b.) the aluminium alloy sheet blank is heated to a temperature of more than 410°C, and preferably in the range of 420 to
- 20
- 510°C.
5. The method according to claims 1 and 2, wherein step c.) and d.) are combined such that the heated aluminium alloy sheet blank is stamped using a cold tool.
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6. The method according to claims 1 and 3, wherein during step b.) the aluminium alloy sheet blank is heated to a temperature in the range of 350 to 450°C.
7. The method according to claims 1 and 3, wherein during step e.) the cooled and shaped structural part is solution heat treated at a temperature in the range of 450 to less than the
- 30
- solidus temperature of the aluminium alloy.
8. The method according to any one of claims 1 to 7, wherein the stamped structural part is trimmed to remove excess material from the aluminium alloy sheet blank prior to further heat treating.
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9. The method according to any one of claims 1 to 8, wherein the structural part from a 7xxx-series aluminium alloy sheet is an automobile structural part, in particular a structural part selected from the group comprising: bumper, door beam, roof beam, side beam, instrumental panel support beam, pillar reinforcement, tunnel, and B-pillar reinforcement.

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/054631

A. CLASSIFICATION OF SUBJECT MATTER

INV. B21D22/02 B21D37/16 B21D53/88 C22C21/00 C22C21/04
C22C21/12

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)

B21D C22C

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	column 11, line 7 - line 48; claims 1, 2, 5, 11, 13, 15, 18; figures 1, 2	2, 4, 5
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A	abstract; claims 1, 6-8, 10-13; figures 1-3	3, 6, 7
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A	page 12, line 1 - line 12	2, 4, 5
X	US 3 212 941 A (O'BRIEN PAUL R) 19 October 1965 (1965-10-19)	1
A	abstract; claims 1-10; figure 22	2-9
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 Further documents are listed in the continuation of Box C. See patent family annex.

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- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- * & * document member of the same patent family

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/054631

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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A	abstract; claims; figures 1-5 -----	4-8
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Information on patent family members

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