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(71) Applicant: **Dubai Aluminium PJSC**
**Dubai (AE)**

(72) Inventors:
- **Allan, Feras**
  **24920 Dubai (AE)**
- **Stoyanov, Peio Todorov**
  **CA 91364 Los Angeles (US)**
- **Bin Kalban, Abdulla Mohammad Jassim**
  **24920 Dubai (AE)**

(74) Representative: **Schmidt, Martin Peter**
**IXAS Conseil**
**22 avenue René Cassin**
**69009 Lyon (FR)**

# (54) ALUMINIUM-SILICON CASTING ALLOY, AND CASTINGS MADE FROM SAID ALLOY

(57) Aluminium casting alloy, comprising, expressed in weight percent,
from 3.5 % to 4.5 % of silicon ;
from 0.35 % to 0.55 % of magnesium ;
from 0.05 % to 0.25 % of chromium ;
from 0.05 % to 0.30 % of nickel ;
from 0.005 % to 0.020 % of strontium ;
not more than 0.12 % of iron ;
not more than 0.15 % of titanium ;
not more than 0.05 % of manganese ;
other impurities not more than 0.02 % each and not more than 0.10 % in total,
the remainder being aluminium.

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## Description

### Technical field of the invention

**[0001]** The invention relates to the field of metallurgy of aluminium alloys, and more precisely to aluminium - silicon casting alloys. The invention also relates to castings, that is to say to cast and solidified pieces, made from said alloy. The invention also relates to heat-treatments applicable to aluminium-silicon alloy castings. The invention also relates to certain cast pieces produced by casting said alloy into a given shape and heat-treating the solidified piece. These cast pieces, also called castings, need to comply with certain requirements, such as high mechanical strength, high elongation and high corrosion resistance.

**[0002]** The invention relates in particular to aluminium - silicon casting alloys with a rather low silicon content, not exceeding about 5 weight percent, and containing a small amount of magnesium.

### Prior art

**[0003]** Casting alloys of the AlSi5Mg type (according to DIN 1725-2) are known for a long time. They are age-hardenable. In the early handbook « Aluminium und Aluminiumlegierungen » published in 1965 (Springer Verlag) by D. Altenpohl (see p. 811), a solution heat treatment between 525 °C and 530 °C (5h) and an artificial ageing to a T6-like temper after water quench between 155 °C and 160 °C for 10 h is disclosed for this alloy.

**[0004]** Since then, many studies documented in the patent litterature have explored the properties of Al-Si alloys with low magnesium content in a wide range of composition. As an example, US 2011/011 6966 and JP 2011/162 883 (Toyota) disclose an aluminium alloy composition with 3.5 % to 7.5 % of silicon, 0.45 % to 0.8 % magnesium, and 0.05 % to 0.035 % chromium ; these documents teach that a silicon content above 4.5 % is preferred. EP 3 175 009 (KSM Castings) discloses an alloy composition with Si 3.8 % to 5.8 %, magnesium 0.1 % to 0.6 %, and chromium 0.05 % to 1.3 %. EP 3 370 900 (Mubea Performance Wheels) describes a composition with silicon from 3.5% to 5.0 %, magnesium 0.2 % to 0.7 %, and titanium 0.07 % to 0.12 %.

**[0005]** US 2019/011 8251 (GM Global Technology) discloses an alloy for low pressure die casting and gravity casting containing silicon from 4 % to 7 %, manganese less than 0.5 %, chromium between 0.15 % and 0.5 %, and magnesium not exceeding 0.8 %. US 10,612,116 (GM Global Technology) discloses an composition range silicon 4 % to 6 %, chromium 0.2 % to 0.4 %, magnesium 0.1 % to 0.5 %; the use of this alloy is recommended for wheels.

**[0006]** CN 106 319 299 (Citic Dicastal) described two alloys with the following compositions : Si 4.0 %, Mg 0.4 %, Cr 0.10 %, B 0.01 % with an elongation of 12 % and a yield strength of 280 MPa in T6 temper, and Si 0.4 %, Mg 0.6 %, Cr 0.15 %, B 0.001 % with an elongation of 11 % and a yield strength of 290 MPa in T6 temper.

**[0007]** On the high silicon edge, JP 2015/045 033 (Nissin Kogyo) discloses a die casting alloy with 4.5 % to 7.5 % silicon, 0.25 % to 0.75 % magnesium, and zinc up to 0.3 %.

**[0008]** On the low silicon edge, EP 2 700 727 (KSM Castings) describes an alloy composition with 3.0 % to 3.8 % of silicon, 0.3 % to 0.6 % magnesium, 0.25 % to 0.35 % of chromium ; this alloy can be heat treated to a T6 temper. EP 2 954 081 (KSM Castings) discloses a casting alloy with silicon from 3.0 % to 3.8 %, magnesium from 0.3 % to 0.6 %, chromium 0.05 % to 0.25 %, and strontium between 0.010 % and 0.030 %.

**[0009]** These alloys can be used in particular in T6-like tempers, i.e. after solution heat treatment and age hardening to peak stength, where they usually exhibit mechanical properties which represent a certain compromise between mechanical strength and elongation at rupture, knowing that these two properties are usually following a conflicting path when optimizing the composition of the alloy or the heat treatment conditions of the cast piece : it is usually not difficult to increase one of the two properties while decreasing at the same time the other one. These alloys can in particular be used for making wheels, in particular for cars and trucks. Their resistance to atmospheric corrosion is usually good. For this specific use, there is however an additional requirement, namely corrosion resistance in contact with water and seawater.

**[0010]** There is now a need for aluminium-based casting alloys that have higher mechanical strength and, at the same time, higher elongation, and that also have an excellent corrosion resistance. This is the problem addressed by the present invention.

### Objects of the invention

**[0011]** According to the invention, the aluminium casting alloy comprises, expressed in weight percent:

from 3.5 % to 4.5 % of silicon ;
from 0.35 % to 0.55 % of magnesium ;
from 0.05 % to 0.25 % of chromium ;

from 0.05 % to 0.30 % of nickel ;
from 0.005 % to 0.020 % of strontium ;
not more than 0.12 % of iron ;
not more than 0.15 % of titanium ;
not more than 0.05 %, and preferably not more than 0.03 %, of manganese ;
other impurities not more than 0.02 each and not more than 0.10 in total,
the remainder being aluminium.

**[0012]** This alloy is the first object of the present invention.

**[0013]** A second object of the invention is an aluminium alloy casting made from this alloy, presenting the following set of properties : yield strength $R_{p0,2}$ is comprised between about 255 MPa and about 300 MPa, tensile strength $R_m$ is comprised between about 340 MPa and about 370 MPa, and elongation at fracture is comprised between about 11.0 % and about 20.0 %.

**[0014]** A third object of the invention is a process for obtaining an aluminium casting according to the second objet of the invention, comprising solidifying a liquid aluminium casting alloy according to the first object, carrying out a solution heat treatment of 4 h to 10 h at a temperature comprised between 535 °C and 555 °C, and preferably of 4 h to 8 h between 540 °C and 550 °C, followed by quenching and artifial aging treatment of 4 h to 10 h at a temperature between 150 °C and 170 °C, and preferably of 6 h to 8 h at a temperature between 160 °C and 170 °C.

## Description

**[0015]** All percentage values or ppm (parts per million) values are given in weight percent or weight ppm, respectively. All temper designations are according to EN 1706 *« Aluminium and aluminium alloys. Casting. Chemical composition and mechanical properties* ». In particular, this standard defines T6 temper as « *solution heat treated and fully artificially aged* ». All mechanical properties refer to the definitions, test pieces and measurement conditions of ISO 6892-1 « *Metallic materials - Tensile Testing - Part 1 : Method of test at room temperature* ».

**[0016]** According to the invention, the aluminium casting alloy comprises, expressed in weight percent:

from 3.5 % to 4.5 % of silicon ;
from 0.35 % to 0.55 % of magnesium ;
from 0.05 % to 0.25 % of chromium ;
from 0.05 % to 0.30 % of nickel ;
from 0.005 % to 0.020 % of strontium ;
not more than 0.12 % of iron ;
not more than 0.15 % of titanium ;
not more than 0.05 %, and preferably not more than 0.03 %, of manganese ;
other impurities not more than 0.02 each and not more than 0.10 in total,
the remainder being aluminium.

**[0017]** In preferred embodiments, which can be combined with each other, and with all the other variants end embodiments presented below :

- the silicon content is comprised between 3.7 % and 4.3 % ;
- the strontium content does not exceed 0.015 % ;
- the chromium content does not exceed 0.20 %, and still more preferably the chromium content is comprised between 0.06 % and 0.15 % ;
- the nickel content is comprised between 0.08 % and 0.22 % ;
- the manganese content is comprised between 0.001% and 0.03 % ;
- other impurities do not exceed 0.015 each and 0.10 in total (and preferably do not exceed 0.09 in total).

**[0018]** Concerning magnesium, the inventors have tested an alloy with 0.60 % of magnesium, and did not achieve a satisfactory improvement of mechanical properties.

**[0019]** Concerning chromium, the optimum value is 0.10 %.

**[0020]** In a first variant, this allow further comprises from 0.05 % to 0.20 % of copper, and preferably between 0.07 % and 0.15 %.

In a second variant, this alloy further comprises from 0.05 % to 0.30 % of silver, and preferably between 0.05 % and 0.20 %.

**[0021]** In a third variant, this alloy further comprises from 0.05 % to 0.20 % of copper and from 0.05 % to 0.30 % of silver; it preferably comprises between 0.07 % and 0.15 % of copper and between 0.05 % and 0.20 % of silver.

**[0022]** These additions may lead to improved mechanical properties in T6 temper. They also tend to modify the flowability of the liquid metal, which may be an important parameter for casting certain types of parts involving molds of complex shape. More precisely, the addition of 0.1 % of silver has been found to lead to an increase of flow length, but flow length decreases above 0.3 % of silver.

**[0023]** The alloy composition, in all of its variants and embodiments, can comprise controlled amounts of certain minor elements ; these controlled amount can result from the voluntary addition of said minor elements, or from the control of their impurity level.

**[0024]** In such an advantageous embodiment, the calcium content is less than 200 ppm ; this increases the corrosion resistance of the castings in certain tempers.

**[0025]** In another andvantageous embodiment vanadium does not exceed 0.02 %, and/or gallium does not exceed 0.02 %.

**[0026]** In another preferred embodiment, which can be combined with each of the two foregoing advantageous embodiments, and preferably with both, the iron content is below 0.10 %; this low iron content leads to a higher elongation at rupture of the castings, which is desirable.

**[0027]** In another advantageous embodiment, a minor addition of manganese, the concentration of which must not exceed the specified maximum value, may be desirable. For this reason the preferentiel manganese range is between 0.001% and 0.03 %, and preferably between 0.005 % and 0.003 %. The inventors have found that this presence of a minute amout of manganese promotes the formation of Mn-Fe intermetallic phases which act as strain hardeners ; this increases strenghth of the castings, but does not lead to a decrease in elongation at rupture.

**[0028]** In another advantageous embodiment, titanium is introduced into the alloy in the form of an $AlTi_3$ master alloy or another master alloy that does not contain boron, but not as $TiB_2$. The casting alloy according to the invention can be used for making cast parts, also called castings, using various casting processes, depending on the purpose. These casting techniques are known as such ; in general the liquid metal is admitted into a die (possibly under pressure), where is solidifies. Advantageously, casting of remelting ingots can be carried out as open casting or direct chill casting. Casting of parts, such as wheels, suspension parts - subframes, cross members, knuckles can be carried out in particular by low pressure die casting, by gravity die casting or counter pressure die casting.

**[0029]** Cast parts according to the invention can be heat treated in various ways. An advantageous heat treatment comprises a specific combination of solution heat treatment and artificial ageing. In this way, a T6 like temper can be obtained. This temper is a particularly interesting one for making parts that need to exhibit both high mechanical strength and high elongation ; such parts are in particular wheels for cars and trucks.

**[0030]** An advantageous process for obtaining such a heat treated aluminium casting comprises a first step of solution heat treatment of about 4 h to about 10 h at a temperature comprised between about 535 °C and about 555 °C, and preferably of 4 h to 8 h between 540 °C and 550 °C. This solution heat treatment can be terminated by quenching.

**[0031]** In a second step, the casting is submitted to artificial ageing of about 4 h to about 10 h at a temperature between about 150 °C and about 170 °C, and preferably of 6 h to 9 h at a temperature between 160 °C and 170 °C.

**[0032]** The inventors have found that for the alloy composition according to the invention, the duration of the ageing treatment is a particularly critical parameter that determines the mechanical properties of the cast part. For this reason, the most preferred ageing conditions are betwen 6 h and 8 h at a temperature between 160 °C and 170 °C.

**[0033]** In this way, aluminium alloy castings in T6-like tempers with the following set of properties can be obtained : yield strength $R_{p0,2}$ is comprised between about 255 MPa and about 310 MPa, tensile strength $R_m$ is comprised between about 340 MPa and about 370 MPa, and elongation at fracture is comprised between about 11.0 % and about 20.0 %.

**[0034]** In an advantageous embodiment, yield strength $R_{p0,2}$ is comprised between about 255 MPa and about 285 MPa, tensile strength is $R_m$ comprised between about 340 MPa and about 370 MPa, and elongation at fracture is comprised between about 14.0 % and about 20.0 %.

**[0035]** In another advantageous embodiment, yield strength $R_{p0,2}$ is comprised between 265 MPa and 280 MPa, tensile strength is $R_m$ comprised between 350 MPa and 365 MPa, and elongation at fracture is comprised between 15.0 % and 18.0 %.

**[0036]** In still more advantageous embodiment, which is particularly useful for wheels of cars and trucks, the solution heat treatment is carried out at a temperature comprised between 541 °C and 549 °C for a duration comprised between 5 h and 7 h, and/or the artificial ageing is carried out a temperature comprised between 157 °C and 163 °C for a duration between 6 h and 9 h.

**[0037]** The artifical ageing treatment can also be carried out in two or more steps at different temperatures ; this will however render the industrial production more complex.

**Examples**

Examples 1 to 6 :

**[0038]** A base alloy composition was prepared with the following target composition :
Si 4.0 %, Mg 0.50 %, Fe < 0.12 %, Ti 0.12 %, Sr 0.0080 %.

**[0039]** The following amounts of elements were added : Cr 0.10 % and Ni 0.15 %.

**[0040]** The alloy was cast in a mould. After solidification the following heat treatment was applied : solution heat treatment of 6 hours at 545 °C followed by artifical ageing at varying conditions, as explained in Table 1 which summarizes the results.

[Table 1]

| Example | Ex 1 | Ex 2 | Ex 3 | Ex 4 | Ex 5 | Ex 6 |
|---|---|---|---|---|---|---|
| Artifical ageing | 5h at 160°C | 7h at 160°C | 8h at 160°C | 4h at 170°C | 6h at 170°C | 7h at 170°C |
| Yield strength $R_{p0,2}$ [MPa] | 240.75 | 257.33 | 272.00 | 221.75 | 299.00 | 305.33 |
| Scattering on $R_{p0,2}$ [MPa] | (3.77) | (2.87) | (4.08) | (2.17) | (5.10) | (1.70) |
| Tensile strength $R_m$ [MPa] | 340.00 | 347.67 | 357.33 | 328.50 | 368.00 | 370.67 |
| Scattering on $R_m$ [MPa] | (2.00) | (0.94) | (3.77) | (0.83) | (3.08) | (1.89) |
| Elongation without necking $A_g$ [%] | 15.39 | 14.67 | 13.38 | 16.69 | 10.68 | 10.15 |
| Scattering on $A_g$ [%] | (0.32) | (0.33) | (0.45) | (0.95) | (0.89) | (0.74) |
| Elongation at fracture A [%] | 19.18 | 18.79 | 16.69 | 20.16 | 12.87 | 11.29 |
| Scattering on A [%] | (1.34) | (1.09) | (0.46) | (0.82) | (1.94) | (1.63) |

Examples 7 and 8 :

**[0041]** The same base alloy as for examples 1 to 6 was used, but with the addition of the following amounts of elements : Cr 0.10 % and Ni 0.15 % and Cu 0.10 %.

**[0042]** The alloy was cast in a mould. After solidification the following heat treatment was applied : solution heat treatment of 6 hours at 545 °C followed by artifical ageing at varying conditions, as explained in Table 2 which summarizes the results.

[Table 2]

| Example | Ex 7 | Ex 8 |
|---|---|---|
| Artifical ageing | 6h at 170°C | 7h at 170°C |
| Yield strength $R_{p0,2}$ [MPa] | 306.75 | 310.5 |
| Scattering on $R_{p0,2}$ [MPa] | (4.82) | (3.5) |
| Tensile strength $R_m$ [MPa] | 377.75 | 380.5 |
| Scattering on $R_m$ [MPa] | (3.11) | (0.5) |
| Elongation without necking $A_g$ [%] | 11.34 | 10.76 |
| Scattering on $A_g$ [%] | (0.37) | (0.22) |
| Elongation at fracture A [%] | 12.96 | 12.03 |
| Scattering on A [%] | (1.75) | (0.27) |

Examples 9 and 10 :

**[0043]** Example 9 is the same chemical composition as examples 1 to 6.

**[0044]** Example 10 is the same chemical composition as examples 7 and 8.

**[0045]** Examples 9 and 10 have been submitted to the same solution heat treatment as in Examples 1 to 8, namely 6 h at 545 °C.

**[0046]** Examples 9 and 10 have then been submitted to a two-step ageing treatment, as follows : a first step of 1 h at 110 °C, and a second step of 2 h at 170°C.

**[0047]** Examples are summarized in Table 3.

[Table 3]

| Example | Ex 9 | Ex 10 |
|---|---|---|
| Artifical ageing | 1h at 110°C + 2h at 170°C | 1h at 110°C ° 2h at 170°C |
| Yield strength $R_{p0,2}$ [MPa] | 281.33 | 237.00 |
| Scattering on $R_{p0,2}$ [MPa] | (4.50) | (7.26) |
| Tensile strength $R_m$ [MPa] | 357.67 | 343.33 |
| Scattering on $R_m$ [MPa] | (4.19) | (4.03) |
| Elongation without necking $A_g$ [%] | 12.61 | 15.73 |
| Scattering on $A_g$ [%] | (0.33) | (1.48) |
| Elongation at fracture A [%] | 15.96 | 16.57 |
| Scattering on A [%] | (1.61) | (2.14) |

## Claims

1. Aluminium casting alloy, comprising, expressed in weight percent,
from 3.5 % to 4.5 % of silicon ;
from 0.35 % to 0.55 % of magnesium ;
from 0.05 % to 0.25 % of chromium ;
from 0.05 % to 0.30 % of nickel ;
from 0.005 % to 0.020 %, and preferably from 0.005 % to 0.015 % of strontium ;
not more than 0.12 %, and preferably less than 0.10 % of iron ;
not more than 0.15 % of titanium ;
not more than 0.05 %, and preferably not more than 0.03 %, of manganese ;
other impurities not more than 0.02 % each and not more than 0.10 % in total,
the remainder being aluminium.

2. Aluminium casting alloy according to claim 1, wherein the silicon content is comprised between 3.7 % and 4.3 %.

3. Aluminium casting alloy according to claim 1 or 2, wherein the chromium content does not exceed 0.20 %, and preferably is comprised between 0.06 % and 0.15 %.

4. Aluminium casting alloy according to any of claims 1 to 3, wherein the nickel content is comprised between 0.08 % and 0.22 %.

5. Aluminium casting alloy according to any of claims 1 to 4, wherein the manganese content is comprised between 0.001 % and 0.03 %.

6. Aluminium casting alloy according to any of claims 1 to 5, further comprising from 0.05 % to 0.20 % of copper, and preferably from 0.07 % to 0.15 % of copper.

7. Aluminium casting alloy according to any of claims 1 to 6, further comprising from 0.05 % to 0.30 % of silver, and preferably from 0.05 % to 0.20 % of silver.

8. Aluminium casting alloy according to any of claims 1 to 7, wherein the calcium content is less than 200 ppm.

9. Aluminium casting alloy according to any of claims 1 to 8, wherein vanadium does not exceed 0.02 %, and/or gallium does not exceed 0.02 %.

10. Aluminium alloy casting made from a casting alloy according to any of claims 1 to 9.

11. Aluminium alloy casting according to claim 10, having in the T6 temper a yield strength $R_{p0,2}$ comprised between 255 MPa and 310 MPa, a tensile strength $R_m$ comprised between 340 MPa and 370 MPa, and an elongation at fracture comprised between 11 % and 20 %.

12. Aluminium alloy casting according to claim 11, having in the T6 temper a yield strength $R_{p0,2}$ comprised between 265 MPa and 280 MPa, a tensile strength $R_m$ comprised between 350 MPa and 365 MPa, and an elongation at fracture comprised between 15.0 % and 18.0 %.

13. Process for obtaining an aluminium casting according to claim 10 or 11, comprising solidifying a liquid aluminium casting alloy according to any of claims 1 to 9 in a mould, carrying out a solution heat treatment of 4 h to 10 h at a temperature comprised between 535 °C and 555 °C, and preferably of 4 h to 8 h between 540 °C and 550 °C, followed by quenching and artifial aging treatment of 4 h to 10 h at a temperature between 150 °C and 170 °C, and preferably of 6 h to 8 h at a temperature between 160 °C and 170 °C.

14. Process according to claim 12, wherein the solution heat treatment is carried out at a temperature comprised between 541 °C and 549 °C for a duration comprised between 5 h and 7 h, and/or the artificial ageing is carried out a temperature comprised between 157 °C and 163 °C for a duration between 6 h and 9 h.

15. Process according to claim 12 or 13, wherein titanium is introduced into said liquid aluminium casting alloy using an $AlTi_3$ master alloy or another master alloy that does not contain boron.

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# EUROPEAN SEARCH REPORT

Application Number
EP 21 17 8006

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| Y,D | EP 3 162 460 A1 (MUBEA PERFORMANCE WHEELS GMBH [AT]) 3 May 2017 (2017-05-03) | 1-10 | INV. C22C1/02 |
| A | * paragraphs [0051] - [0055] * | 11-15 | B22D21/00 C22C1/03 |
| Y,D | EP 2 954 081 A1 (KSM CASTINGS GROUP GMBH [DE]) 16 December 2015 (2015-12-16) | 1-10 | C22C21/02 C22C21/04 |
| A | * paragraphs [0004] - [0018] * | 11-15 | C22F1/043 |
| A,D | WO 2010/007484 A1 (TOYOTA MOTOR CO LTD [JP]; KAWAHARI HIROSHI [JP] ET AL.) 21 January 2010 (2010-01-21) * paragraphs [0036] - [0056]; examples 1-1; table 1 * | 1-15 | |
| A | DE 10 2017 103148 A1 (KSM CASTINGS GROUP GMBH [DE]) 7 September 2017 (2017-09-07) * paragraphs [0034] - [0035] * | 1-15 | |

TECHNICAL FIELDS SEARCHED (IPC)

C22C
B22D
C22F

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 2 November 2021 | Barenbrug-van Druten |

CATEGORY OF CITED DOCUMENTS

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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 21 17 8006

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02-11-2021

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| EP 3162460 A1 | 03-05-2017 | AU 2016351164 A1 | 31-05-2018 |
| | | BR 112018008345 A2 | 30-10-2018 |
| | | CN 108290210 A | 17-07-2018 |
| | | EP 3162460 A1 | 03-05-2017 |
| | | EP 3370900 A1 | 12-09-2018 |
| | | JP 6824264 B2 | 03-02-2021 |
| | | JP 2019501777 A | 24-01-2019 |
| | | KR 20180067565 A | 20-06-2018 |
| | | US 2018305793 A1 | 25-10-2018 |
| | | WO 2017076801 A1 | 11-05-2017 |
| EP 2954081 A1 | 16-12-2015 | BR 112015016608 A2 | 11-07-2017 |
| | | CN 104968817 A | 07-10-2015 |
| | | DE 102014101317 A1 | 07-08-2014 |
| | | DE 112014000689 A5 | 15-10-2015 |
| | | EP 2954081 A1 | 16-12-2015 |
| | | JP 6448550 B2 | 09-01-2019 |
| | | JP 2016513172 A | 12-05-2016 |
| | | MX 359907 B | 16-10-2018 |
| | | US 2015307969 A1 | 29-10-2015 |
| | | WO 2014121785 A1 | 14-08-2014 |
| WO 2010007484 A1 | 21-01-2010 | CN 102089450 A | 08-06-2011 |
| | | JP 2010018875 A | 28-01-2010 |
| | | US 2011116966 A1 | 19-05-2011 |
| | | WO 2010007484 A1 | 21-01-2010 |
| DE 102017103148 A1 | 07-09-2017 | CN 108699639 A | 23-10-2018 |
| | | DE 102017103148 A1 | 07-09-2017 |
| | | DE 112017001083 A5 | 22-11-2018 |
| | | EP 3423606 A1 | 09-01-2019 |
| | | JP 2019512051 A | 09-05-2019 |
| | | US 2019055628 A1 | 21-02-2019 |
| | | WO 2017148468 A1 | 08-09-2017 |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- US 20110116966 A **[0004]**
- JP 2011162883 A **[0004]**
- EP 3175009 A **[0004]**
- EP 3370900 A **[0004]**
- US 20190118251 A **[0005]**
- US 10612116 B **[0005]**
- CN 106319299 **[0006]**
- JP 2015045033 A **[0007]**
- EP 2700727 A **[0008]**
- EP 2954081 A **[0008]**


### Non-patent literature cited in the description


- **D. ALTENPOHL.** Aluminium und Aluminiumlegierungen. Springer Verlag, 1965, 811 **[0003]**