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(54) ALUMINUM CASTING ALLOY FOR NEAR NET SHAPED CASTING OF STRUCTURAL OR NON-STRUCTURAL COMPONENTS

(57) The invention provides an aluminum alloy for high pressure die casting that offers an optimized combination of ultimate tensile strengths (UTS), yield strength (YS), tensile elongation (%El), and sufficient ductility for joinability without the necessity of an elaborate and cost intensive heat treatment. For this purpose an aluminum casting alloy for near net shaped casting of structural or non-structural components according to the invention consists of, in % by mass, Zn: 4.5 - 7.5 %, Mg: 0.7 - 2.0 %, Fe: 0.8 - 2.0 %, Si: < 0.3 %, Cu: < 0.1 %, V: ≤ 0.2 %, Ti: ≤ 0.2 %, B: ≤ 0.04 %, balance Al and unavoidable impurities, the sum of the contents of the impurities being ≤ 0.1 %. On the basis of this alloy the invention also provides a method for the manufacture of a cast part which has a yield strength of 180 to 200 MPa, an ultimate tensile strength of 300 to 320 MPa and an elongation of 11 to 14 % and a method for the manufacture of a cast part which has a yield strength of 210 to 400 MPa, an ultimate tensile strength of 340 to 450 MPa and an elongation of 2 to 11 %.

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Description

[0001] The invention relates to an aluminum casting alloy for near net shaped casting of structural or non-structural components.

[0002] All information on contents of the aluminum alloy compositions indicated in the present application are related to mass, unless explicitly stated otherwise. All % data referring to the composition of a aluminum alloy or another alloy mentioned here without referring to a reference unit, should therefore be understood as information in "% by mass" ("mass %").

[0003] Mechanical properties such as tensile strength, yield strength and elongation that are reported here were determined in a tensile test according to ASTM B557 standard unless expressly indicated otherwise.

[0004] From WO 2018/094535 A1, the content of which is incorporated by reference in the present application, an aluminum alloy for near net shaped high pressure die casting of structural components is already known. The alloy contains 2 to 10 % by mass zinc ("Zn"), 0.5 to 5 % by mass magnesium ("Mg"), 0.5 to 5 % by mass iron ("Fe"), ≤ 4 % by mass copper ("Cu"), ≤ 0.5 % by mass titanium ("Ti"), ≤ 0.1 % by mass strontium ("Sr"), ≤ 0.2 % by mass beryllium ("Be"), ≤ 0.5 % by mass zirconium ("Zr"), ≤ 0.5 % by mass vanadium ("V"), 0.5 % by mass chromium ("Cr"), ≤ 0.5 % by mass scandium ("Sc"), ≤ 0.1 % by mass sodium ("Na"), ≤ 0.5 % by mass silicon ("Si"), ≤ 1 % by mass manganese ("Mn"), ≤ 5 % by mass nickel ("Ni"), ≤ 0.5 % by mass boron ("B"), and ≤ 1 % by mass molybdenum ("Mo"), with balance aluminum ("Al"). The alloy may be subjected to heat treatment selected from the group consisting of solutionizing, incubation, aging, and two or more heat treatment steps. According to a preferred embodiment, the alloy known from WO 2018/094535 A1 comprises at least 1,5 % by mass Mg, 4 - 10 % by mass Zn, and 1,5 - 3 % by mass Fe, a first exemplary embodiment of the alloy consisting of 5 % by mass Zn, 2 % by mass Mg, 0.35 % by mass Cu, 1.5 % by mass Fe, and Al as balance and a second exemplary embodiment of the alloy consisting of 5 % by mass, Zn 2 % by mass Mg and 1.5 % by mass Fe, balance Al. Both alloys were cast by high pressure die casting with vacuum assistance, a thin walled part manufactured from the first alloy having a yield strength of 200 MPa, an ultimate tensile strength of 315 MPa and an elongation of 3.80 % in the as-cast state with 21 days of natural aging and a large scale part manufactured from the second alloy showing a yield strength of 201 MPa, an ultimate tensile strength of 312 MPa and an elongation of 4.63 % in the as-cast state.

[0005] Other small scale parts made from the Al-alloy disclosed in WO 2018/094535 A1 consists of alloys with 4.74 to 6.17 by mass % of Zn, 2.1 to 2.24 % by mass of Mg, 0.07 to 0.38 % by mass of Cu, 1.56 to 3.78 % by mass of Fe, 0.02 to 0.24 % by mass of Mn, whereas large scale applications were made of Al-alloys which contain 5.16 to 5.21 % by mass of Zn, 1.54 to 2.0 % by mass of Mg, 0.8 % by mass of Cu, 1.02 to 1.6 % by mass of Fe, 0.04 or 0.035 % by mass of Si, 0.10 to 0.15 % by mass of Ti, 0.13 % by mass of Zr, 0.057 % by mass of V, balance Al.

[0006] Further, WO 2018/094535 A1 discloses side door impact beams made from alloys which contain 5.0 % by mass Zn, 2.0 % by mass Mg, 0 or 0,35 % by mass of Cu, 1.5 % by mass of Fe, and Al as balance respectively. The optimized mechanical properties of the parts which have been alloyed and manufactured in accordance with the specifications given in WO 2018/094535 A1 have been achieved not only by a purposeful adjustment of the contents of the alloying elements but also by equally purposefully heat treating the respective part.

[0007] Also in Korean patent KR 10 1469613 B1 an AlZnMg casting alloy is disclosed. This known alloy consists of 3.0 to 4.5 % by mass Zn, 0.1 to 1.5 % by mass Mg and 0.5 to 1.5 % by mass Fe, balance Al and impurities, wherein the impurities may include contents of Ti, Cr and other elements with a respective content of up to 0.1 % by mass, in particular up to 0.01 % by mass. The exemplary embodiments of the alloy contain 1.88 to 4.05 % by mass of Zn, 0.17 to 1.35 % by mass of Mg, 0.52 to 1.02 % by mass of Fe, balance Al.

[0008] It is common knowledge of an expert in the field of aluminum casting that the mechanical properties of parts cast from aluminum alloys can strongly be influenced by an appropriate heat treatment. For example, aluminum castings can be subjected to a homogenization or solution heat treating to remove inhomogeneities of the structure of the cast part. Further, an annealing treatment ("tempering") can be performed to cause a reduction in strength, while at the same time increasing the ductility. To increase the strength the castings can also be subjected to age hardening or precipitation hardening, which can be performed as "natural aging" by exposing the castings to room temperature for several days, or as "artificial aging", in which the castings are usually also kept at elevated temperatures for several days to intensify and accelerate the hardness-increasing effect. To designate the heat treatment condition of aluminum castings a designation system has been developed, which, for example, is explained in "Introduction to Aluminum Alloys and Tempers," J. Gilbert Kaufman, p 39-76, chapter "Understanding the Aluminum Temper Designation System," DOI-10.1361/iaat2000p039, and in WO 2018/094535 A1 as well.

[0009] Against the background of the prior art the object to be solved by the invention was to provide an aluminum alloy for high pressure die casting that offers a combination of properties that meets the requirements of structural, body-in-white and electrification components (battery enclosures). These requirements include ultimate tensile strengths (UTS), yield strength (YS), tensile elongation (%El) and sufficient ductility for joinability without the necessity of an elaborate and cost intensive heat treatment.

[0010] The further object was to provide a method by means of which parts, which show an optimized combination of mechanical properties can be manufactured by using high pressure die casting in a practice-oriented manner.

[0011] The invention has achieved this object on the one hand by a cast alloy having the features specified in claim 1.

[0012] As a further solution the invention proposes the methods indicated in claims 13 and 14 for the manufacture of cast parts which show an optimized combination of mechanical properties.

[0013] Advantageous embodiments of the invention are defined in the dependent claims and, like the general concept of the invention, are explained in detail in the following.

[0014] According to the invention an aluminum casting alloy for near net shaped casting of structural or non-structural parts thus consists of, in % by mass,

Zn:	4.5	- 7.5 %;
Mg:	0.7	- 2.0 %;
Fe:	0.8	- 2.0 %;
Si:		< 0.3 %;
Cu:		< 0.1 %;
V:		≤ 0.2 %;
Ti:		≤ 0.2 %;
B:		≤ 0.04%;

balance Al and unavoidable impurities, the sum of the contents of the impurities being ≤ 0.1 %.

[0015] Starting from the prior art disclosed in WO 2018/094535 A1, the invention has selected an aluminum alloy which has an optimized combination of strength, ductility, elongation, and joinability. This enables increased lightweighting opportunities of parts cast from the alloy according to the invention due to the higher strength and comparable performance in energy absorption in the event of a crash.

[0016] To this end, the invention has selected the contents of each alloying element as follows:
Zn and Mg are added as strengthening elements through the formation of Mg and Zn rich G.P. Zones ("G.P. Zones" = Guinier-Preston zones, see https://en.wikipedia.org/wiki/Guinier-Preston_zone) that are formed during natural aging.

[0017] The range of 4.5 - 7.5 % by mass Zn and 0.7 - 2.0 % by mass Mg are required to have the necessary combination of strength and ductility.

[0018] In particular, the positive influence Zn has on the strength of the parts cast from the alloy according to the invention can reliably be achieved, if the Zn-content of the alloy according to the invention is at least 4.6 % by mass, preferably at least 4.7 % by mass or at least 4.75 % by mass. To obtain a cast part which has an optimized deformation capacity and elongation the Zn content of the alloy according to the invention can be limited to a maximum of 5.5 % by mass, in particular to a maximum of 5.0 % by mass. However, a high strength variant of the alloy according to the invention can be obtained by setting the minimum Zn content to 5.0 % by mass and the maximum Zn content to 5.5 % by mass. The addition of approximately 5 % by mass Zn also reduces the Al-Fe eutectic point from 1.7 % by mass in the binary alloy to approximately 1.3 % by mass, enabling the alloy according to the invention even in the high strength variant to be a near-eutectic alloy, thereby improving fluidity and reducing hot tearing susceptibility.

[0019] By limiting the Mg content to a maximum of 2.0 % by mass the cast alloy according to the invention shows high elongation properties. In particular, the Mg content can be limited to a maximum of 1.5 % by mass, preferably to 1.0 % by mass for this purpose. By adjusting the Mg content of the alloy according to the invention to at least 0.7 % by mass, in particular at least 0.8 % by mass, the positive influence Mg has on the properties of the alloy according to the invention and the parts cast from this alloy can be used in a particular reliable manner.

[0020] An aluminum casting alloy according to the invention which provides in the as-cast state ("F-temper") an elongation ranging from 11 to 15 % in combination with a yield strength of 140 to 160 MPa and an ultimate tensile strength in the range of 280 to 300 MPa thus, according to the invention, preferably contains 4.6 to 5.0 % by mass Zn and 0.8 to 1.0 % by mass Mg. For further increases in strength for this variant of the alloy according to the invention without a loss in ductility, the cast part cast from aluminum alloy alloyed in this manner be optionally subjected to a T4 treatment. Accordingly, in a first method according to the invention which enables the manufacture of a cast part which has a yield strength of 180 to 200 MPa, an ultimate tensile strength of 300 to 320 MPa, and an elongation of 11 to 14 % the following working steps are performed:

a) Providing an aluminum melt alloyed in accordance with the invention, the melt containing 4.6 to 5.0 % by mass Zn and 0.8 to 1.0 % by mass Mg;

b) Casting a cast part from the aluminum melt;

c) Subjecting the cast part to a T4 temper treatment which involves a solution heat treatment at temperatures of 460 to 480 °C for 1 to 8 h optionally followed by a forced air quench and natural aging for 14 to 75 days.

[0021] As an alternative, a high strength variant of the alloy of the invention can be obtained by adjusting the Zn content of the alloy according to the invention to 5.0 to 5.5 % by mass and the Mg content of the alloy according to the invention to 1.6 to 2.0 % by mass, preferably 1.6 to 1.9 % by mass. The embodiment of the alloy according to the invention alloyed in this way has an ultimate tensile strength of 300 to 340 MPa and a yield strength of 180 to 210 MPa in combination with an elongation of 4 to 7 % in the as-cast state ("F-temper").

[0022] Also here a further increase of the mechanical properties of the parts cast from this embodiment of the alloy according to the invention can be obtained by subjection the cast part to a treatment.

[0023] Accordingly, in a second method according to the invention which enables the manufacture of a cast part which has a yield strength of 210 to 400 MPa, an ultimate tensile strength of 340 to 450 MPa and an elongation of 2 to 11 % the following working steps are performed:

a) Providing an aluminum melt alloyed in accordance with the invention, the melt containing 5.0 to 5.5 % by mass Zn and 1.6 to 2.0 % by mass Mg;

b) Casting a cast part from the aluminum melt;

c) Subjecting the cast part to heat treatment, wherein

c.1) the heat treatment is a T4 temper treatment which involves a solution heat treatment at temperatures of 450 to 480 °C for 2 to 24 h optionally followed by a forced air or water quench and natural aging for 7 to 75 days
or
c.2) the heat treatment is a T7 temper treatment which involves a solution heat treatment at temperatures of 450 to 480 °C for 2 to 24 h followed by forced air or water quench and 1-2 days of natural aging and an artificial aging at temperatures between 120 to 200 °C for 1 to 24 h in single or dual-stage aging.

[0024] In the T4 temper state the parts cast from the alloy alloyed in accordance with the invention containing 5.0 to 5.5 % by mass Zn and 1.6 to 2.0 % by mass Mg have a yield strength of 210 to 230 MPa, an ultimate tensile strength of 340 to 387 MPa, and an elongation of 7 to 11 %, whereas in in the T7 temper state the parts cast from this alloy have a yield strength ranged from 350 to 400 MPa and an ultimate tensile strength from 380 to 450 MPa, while their elongation ranges between 2 - 5 %. Further lightweighting opportunities can exist using the high strength variant of the alloy according to the invention in applications that require the ultrahigh strength given by this alloy, specifically in the T7 condition, but can tolerate lower elongation/ductility.

[0025] It's recommended that, preferably, a minimum of 20 days of natural aging should be given to the parts cast from the alloy according to the invention prior to use in service. Yield strength will continue to gradually increase until approximately 75 days of natural aging, where further natural aging time produces very minor changes in strength. Elongation is not significantly affected by natural aging time.

[0026] 0.8 to 2.0 % by mass Fe is present in the alloy according to the invention to enable the formation of Al-Fe based eutectic phases which improve fluidity and reduce hot tearing susceptibility, thereby making the alloy castable to near-net shape in high pressure die casting. In addition, Fe contents above 1 % by mass will also significantly reduce the susceptibility to die soldering, which improves die life and reduces distortion in the castings. For this purpose, at least 0.8 % by mass Fe are needed, Fe contents of at least 1.0 % by mass being especially advantageous in this regard. Fe contents of more than 2.0 % by mass should be avoided, to prevent the excessive formation of coarse primary Al13Fe4 platelets which are deleterious to alloy ductility. Negative influences of the presence of Fe in the alloy according to the invention can be prevented if, in particular, the Fe content is limited to a maximum of 1.8 % by mass or to a maximum of 1.5 % by mass.

[0027] The Si content should be limited to below 0.3 % by mass, in particular below 0.2 % by mass, to prevent the formation of harmful Fe based intermetallic phases such as β-AlFeSi which would be deleterious to the alloy's ductility. The addition of Si should also be limited to prevent excessive Mg2Si formation, which depletes Mg and reduces the amount of G.P. Zones that are formed during natural aging and would impair alloy strengthening in the F-temper state.

[0028] The Cu content should be restricted to below 0.1 % by mass as it is deleterious to corrosion resistance and increases hot tearing susceptibility.

[0029] V can be optionally added as a modifying agent. Vanadium promotes the formation of the fibrous Al_6Fe eutectic phase in favour of the acicular $Al_{13}Fe_4$, eutectic which will lead to improved ductility. To use this effect, a minimum V content of at least 0.05 % by mass, in particular of at least 0.1 % by mass can be provided. This can counteract the negative effects of slower cooling rates or interactions with Si if present. The maximum of the optional V content is limited to 0.2 % by mass, in particular to 0.1 % by mass, because higher V contents do not efficiently contribute to the properties of the alloy according to the invention.

[0030] Ti can be optionally added in amounts of up to 0.2 % by mass for grain refinement and reduction of hot tearing susceptibility. This effect can already be obtained by adding at least 0,05 % by mass Ti, in particular at least 0.1 % by mass. The maximum of the optional Ti content is limited to 0.2 % by mass, in particular to 0.1 % by mass, because higher Ti contents do not contribute to the properties of the alloy according to the invention.

[0031] The Ti can be added to the melt alloyed in accordance with the invention in the form of an Al-5Ti-1B master alloy, which results in a maximum B content of 0.04 % by mass.

[0032] The remainder of the alloy according to the invention is formed by Al and technically unavoidable impurities. Elements including Na, Ca, K, Li, Ni, Cr and Mn typically belong to these impurities. The content of the respective impurities is set so low that in each case the respective impurity has no influence on the properties of the alloy and the part cast therefrom. For this purpose, the total content of impurities in an alloy according to the invention is limited to 0.1 % by mass.

[0033] The specification for an aluminum casting alloy provided by the invention enables a combination of high ductility and improved strength compared to currently available alloys in the as-cast (F-temper) condition eliminating the need for heat treatments and associated post-processing. However, if the properties present in the as-cast state are not sufficient, they can be further improved by the heat treatments disclosed here.

[0034] The alloy according to the invention is especially suitable to be cast into near-net shape components using High Pressure Die Casting ("HPDC") with or without the application of vacuum. In this regard it turns to be out particularly advantageous that the alloy is based on the Al-Fe eutectic system, which enables the alloy to be castable in HPDC when Fe content exceeds 1 % by mass. Due to the composition targets provided by the invention additional benefits of the alloy according to the invention include an improved recyclability compared to the state of the art primary aluminum alloys as well as superior HPDC die life.

[0035] The alloy H700, based on which the properties shown in Fig. 1a to 2b were determined consists of 4.6 % by mass Zn, 0.8 % by mass Mg, 1.2 % by mass Fe, 0.07 % by mass Si and 0.05 % by mass Ti.

[0036] Figures 1a and 1b show the ultimate tensile strength UTS and the yield strength YS of the H700 in the F-temper state as a function of natural aging time.

[0037] Figures 2a and 2b show a comparison of the ultimate tensile strength UTS, the yield strength YS and the elongation %EL samples made from the H700 alloy in the F-temper state to samples of the current structural die casting alloys AlSi8MnMg and AlSi10MnMg in F-temper (Fig. 2a) and in heat treated T5 or T7 condition (Fig. 2b). The T5 treatment, which the AlSi8MnMg alloy samples were exposed to, consisted of artificial aging at 210 °C for 1 h followed by cooling in still air, whereas the T7 treatment, the AlSi10MnMg alloy samples were exposed to, consisted of solutionizing at 450 °C for 12 hours, heating to 475 °C with a heating rate of 5 °C/h, holding the samples at 475 °C for 7 hours followed by water quenching. After the solutionizing treatment the samples underwent an natural aging ("incubation") treatment for 24 hours followed by an artificial aging in the course of which the samples were held at 120 °C for 24 hours followed by holding the samples at 160 °C for 24 hours.

[0038] FIG. 3 shows representative load-displacement curves from 3-point bend test for the H700 alloy samples in F-temper, for the AlSi8MnMg samples in F-temper and for the AlSi10MnMg samples in the T7 temper state. The 3-point bend test was performed in accordance with the Ford BB119-01 specification, which is a modified version of the VDA 238-100 standard test.

[0039] As can be seen from Figures 4a to 4d the H700 alloy according to the invention showed excellent joinability to both aluminum sheets made of aluminum extrusion alloy 6082-T6 and steel sheets made of dual phase steel DP600, material number according to EN 10027-2:1992-09: 1.0936 using self-piercing rivets (SPR), which is a common practice for joining automotive structural components to form the body-in-white.

[0040] Fig. 4a shows a longitudinal section of a SPR joint between a part made of the H700 according to the invention and the sheet made from the 6082-T7 Al alloy.

[0041] Fig. 4b shows a top view on the SPR joint as seen from the side on which the part cast from the H700 part is arranged.

[0042] Fig. 4c shows a longitudinal section of a SPR joint between a part made of the H700 according to the invention and the sheet made from the CP600 steel alloy. Fig. 4d shows a top view on the SPR joint as seen from the side on which the part cast from the H700 part is arranged.

[0043] There were no cracks in the SPR joints and the interlocking between the rivets and the joining materials were within the acceptable ranges for joining automotive structural parts.

[0044] Fig. 5 shows the development of the yield strength YS of a specimens cast from Al-5Zn-2Mg-1.3Fe alloy according to the invention in response to the duration of a natural aging at room temperature.

[0045] Further specimens cast from the Al-5Zn-2Mg-1.3Fe alloy according to the invention were exposed to

a) a natural aging for 70 days in the as cast condition,

b) a T4 treatment in which the respective specimens were solution annealed at 450 °C for 12 hours, then heated with a heating rate of 5 °C/hour to 475 °C at which temperature the specimen were held for another 4 hours;

c) a T6 treatment in which the respective specimens were

- solution annealed at 450 °C for 12 hours, then heated with a heating rate of 5 °C/hour to 475 °C at which temperature the specimens were held for another 4 to 7 hours,
- forced air cooled or water quenched from the solution annealing temperature to room temperature and naturally aged for 24 hours,
- naturally aged ("incubated") for 24 hours, and
- artificially aged at 120 °C for 24 hours and 170 °C for 3 hours;

d) a T7 treatment in which the respective specimens were

- solution annealed at 450 °C for 12 hours, then heated with a heating rate of 5 °C/hour to 475 °C at which temperature the specimens were held for another 7 to 14 hours,

- forced air cooled or water quenched from the solution annealing temperature to room temperature
- naturally aged ("incubated") for 24 hours, and
- artificially aged at 120 °C for 24 hours and 170 °C for 14 hours.

[0046] The mechanical properties yield strength YS, ultimate tensile strength UTS and Elongation E the respective specimens show after the respective heat treatment are summarized in Table 1.

Table 1

Heat Treatment	YS	UTS	E
	[MPa]	[MPa]	[%]
As cast + natural aging	172	395	6.14
T4	216	366	11.20
T6	414	457	4.58
T7	331	393	6.79

[0047] Finally also the following embodiments of the invention shall be considered to be disclosed:

1. An aluminum casting alloy for near net shaped casting of structural or non-structural components, the aluminum casting alloy consisting of, in % by mass,

Zn:	4.5 - 7.5 %;
Mg:	0.7 - 2.0 %;
Fe:	0.8 - 2.0 %;
Si:	< 0.3 %;
Cu:	< 0.1 %;
V:	≤ 0.2 %;
Ti:	≤ 0.2 %;
B:	≤ 0.04 %;

balance Al and unavoidable impurities, the sum of the contents of the impurities being ≤ 0.1 %.

2. The aluminum casting alloy according to claim 1 **characterized in that** its Zn content is not more than 5.5 % by mass.

3. The aluminum casting alloy according to any of the preceding claims **characterized in that** itsZn content is at least 4.6 % by mass.

4. The aluminum casting alloy according to any of the preceding claims **characterized in that** its Mg content is not more than 1.0 % by mass.

5. The aluminum casting alloy according to any of the preceding claims **characterized in that** its Mg content is at least 0.8% by mass.

6. The aluminum casting alloy according to claim 1 **characterized in that** its Fe content is not more than 1.5 % by mass.

7. The aluminum casting alloy according to any of the preceding claims **characterized in that** its Fe content is at least 1.0 % by mass.

8. The aluminum casting alloy according to any of the preceding claims **characterized in that** its Si content is less than 0,2 % by mass.

9. The aluminum casting alloy according to any of the preceding claims **characterized in that** it contains at least 0.05 % by mass of Ti.

10. The aluminum casting alloy according to any of the preceding claims **characterized in that** it contains at least 0,1 % by mass of V.

11. The aluminum casting alloy according to any of the preceding claims **characterized in that** the alloy contains 4.6 to 5.0 %by mass Zn and 0.8 to 1.0 % by mass Mg and **that** it has in the as-cast state ("F-temper") a yield strength of 140 to 160 MPa, an ultimate tensile strength in the range of 280 to 300 MPa and elongation ranging from 11 to 14 %.

12. The aluminum casting alloy according to any of claims 1 to 10, **characterized in that** the alloy contains 5.0 to 5.5 % by mass Zn and 1.6 to 2.0 % by mass Mg and **that** it has in the as-cast state ("F-temper") a yield strength of 180 to 210 MPa, an ultimate tensile strength in the range of 300 to 340 MPa and an elongation ranging from 4 to 7 %.

13. Method for the manufacture of a cast part which has a yield strength of 180 to 200 MPa, an ultimate tensile strength of 300 to 320 MPa and an elongation of 11 to 14 % comprising the following working steps:

a) Providing an aluminum melt alloyed in accordance with claim 11;

b) Casting a cast part from the aluminum melt;

c) Subjecting the cast part to a T4 temper treatment which involves a solution heat treatment at temperatures of 460 to 480 °C for 1 to 8 h optionally followed by a forced air quench and natural aging for 14 to 75 days.

14. Method for the manufacture of a cast part which has a yield strength of 210 to 400 MPa, an ultimate tensile strength of 340 to 450 MPa and an elongation of 2 to 11 % comprising the following working steps:

d) Providing an aluminum melt alloyed in accordance with claim 12;

e) Casting a cast part from the aluminum melt;

f) Subjecting the cast part to heat treatment, wherein

c.1) the heat treatment is a T4 temper treatment which involves a solution heat treatment at temperatures of 450 to 480 °C for 2 to 24 h optionally

followed by a forced air or water quench and natural aging for 7 to 75 days
or
c.2) the heat treatment is a T7 temper treatment which involves a solution heat treatment at temperatures of 450 to 480 °C for 2 to 24 h followed by forced air or water quench and 1-2 days of natural aging and an artificial aging at temperatures between 120 to 200 °C for 1 to 24 h in single or dual-stage aging.

Claims

1. An aluminum casting alloy for near net shaped casting of structural or non-structural components, the aluminum casting alloy consisting of, in % by mass,

Zn:	4.5 - 7.5 %;	
Mg:	0.7 - 2.0 %;	
Fe:	0.8 - 2.0 %;	
Si:		< 0.3 %;
Cu:		< 0.1 %;
V:		≤ 0.2 %;
Ti:		≤ 0.2 %;
B:		≤ 0.04 %;

balance Al and unavoidable impurities, the sum of the contents of the impurities being ≤ 0.1 %; wherein the alloy contains 5.0 to 5.5 % by mass Zn and 1.6 to 2.0 % by mass Mg and that it has in the as-cast state F-temper a yield strength of 180 to 210 MPa, an ultimate tensile strength in the range of 300 to 340 MPa and an elongation ranging from 4 to 7 %.

2. The aluminum casting alloy according to claim 1 **characterized in that** its Fe content is not more than 1.5 % by mass.

3. The aluminum casting alloy according to any of the preceding claims **characterized in that** its Fe content is at least 1.0 % by mass.

4. The aluminum casting alloy according to any of the preceding claims **characterized in that** its Si content is less than 0.2 % by mass.

5. The aluminum casting alloy according to any of the preceding claims **characterized in that** it contains at least 0.05 % by mass of Ti.

6. The aluminum casting alloy according to any of the preceding claims **characterized in that** it contains at least 0.1 % by mass of V.

7. Method for the manufacture of a cast part which has a yield strength of 210 to 400 MPa, an ultimate tensile strength of 340 to 450 MPa and an elongation of 2 to 11 % comprising the following working steps:

a) Providing an aluminum melt alloyed in accordance with claim 1;
b) Casting a cast part from the aluminum melt;
c) Subjecting the cast part to heat treatment, wherein

c.1) the heat treatment is a T4 temper treatment which involves a solution heat treatment at temperatures of 450 to 480 °C for 2 to 24 h optionally followed by a forced air or water quench and natural aging for 7 to 75 days,
or
c.2) the heat treatment is a T7 temper treatment which involves a solution heat treatment at temperatures of 450 to 480 °C for 2 to 24 h followed by forced air or water quench and 1-2 days of natural aging and an artificial aging at temperatures between 1

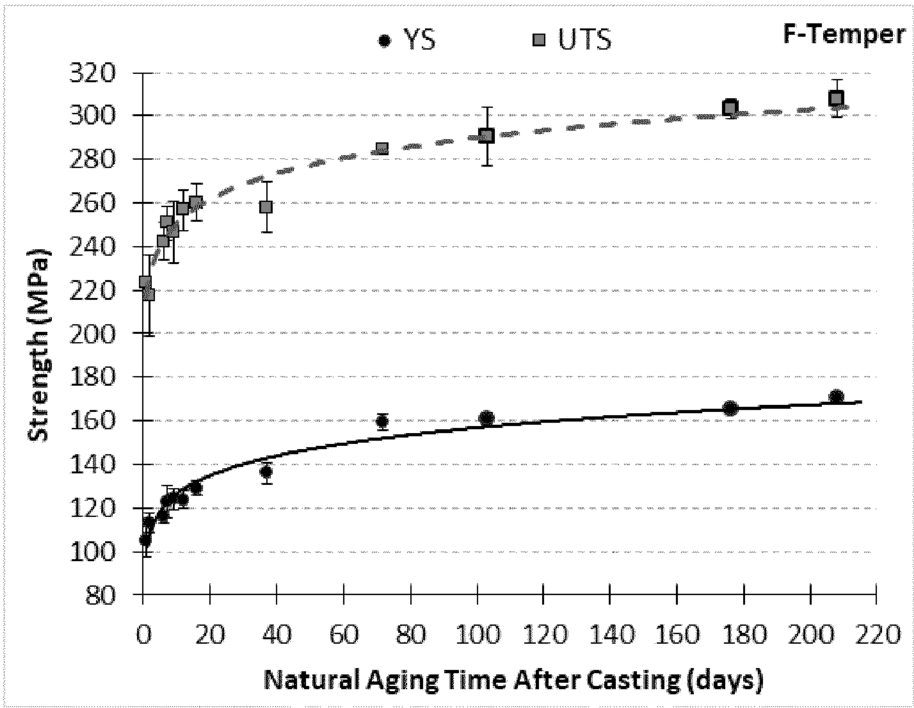
YS
UTS
F-Temper
320
300
280
260
240
220
200
180
160
140
120
100
80
Strength (MPa)
0
20
40
60
80
100
120
140
160
180
200
220
Natural Aging Time After Casting (days)

Fig. 1a

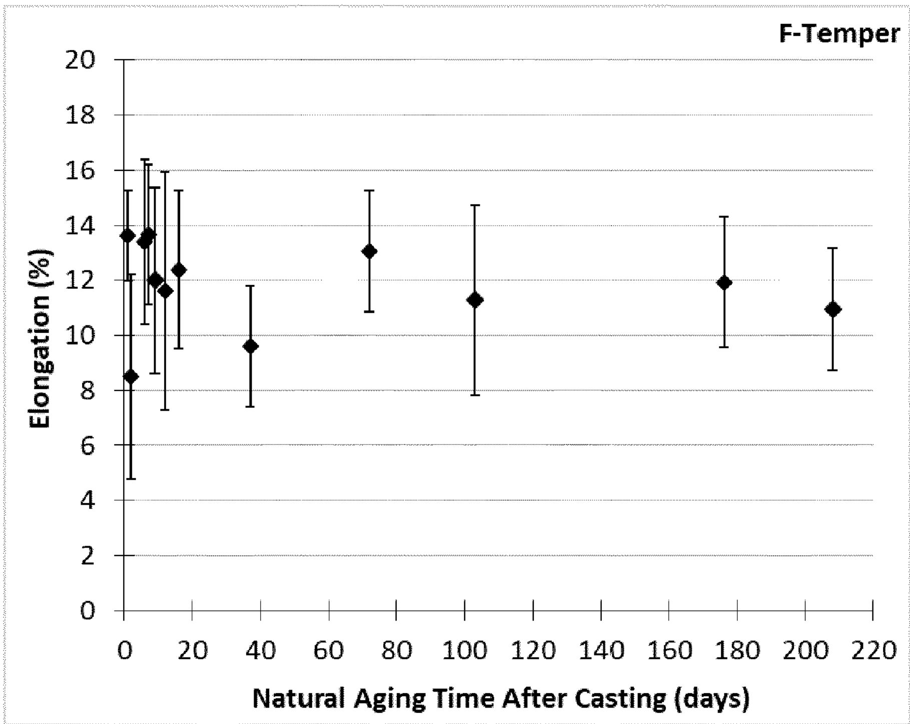
F-Temper
20
18
16
14
12
10
8
6
4
2
0
Elongation (%)
0
20
40
60
80
100
120
140
160
180
200
220
Natural Aging Time After Casting (days)

Fig. 1b

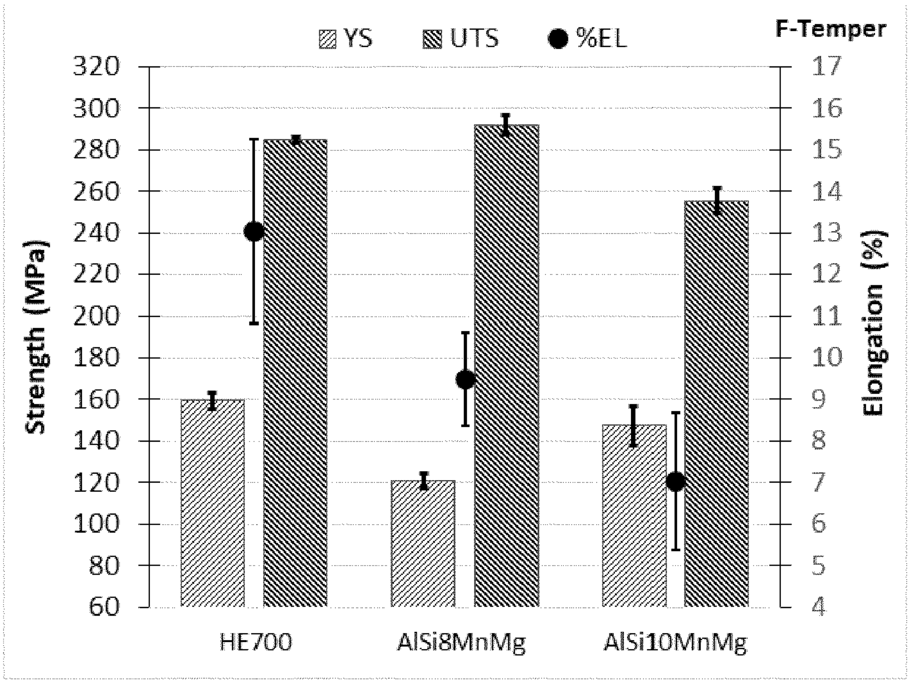
YS
UTS
%EL
F-Temper
Strength (MPa)
Elongation (%)
320
300
280
260
240
220
200
180
160
140
120
100
80
60
17
16
15
14
13
12
11
10
9
8
7
6
5
4
HE700
AlSi8MnMg
AlSi10MnMg

Fig. 2a

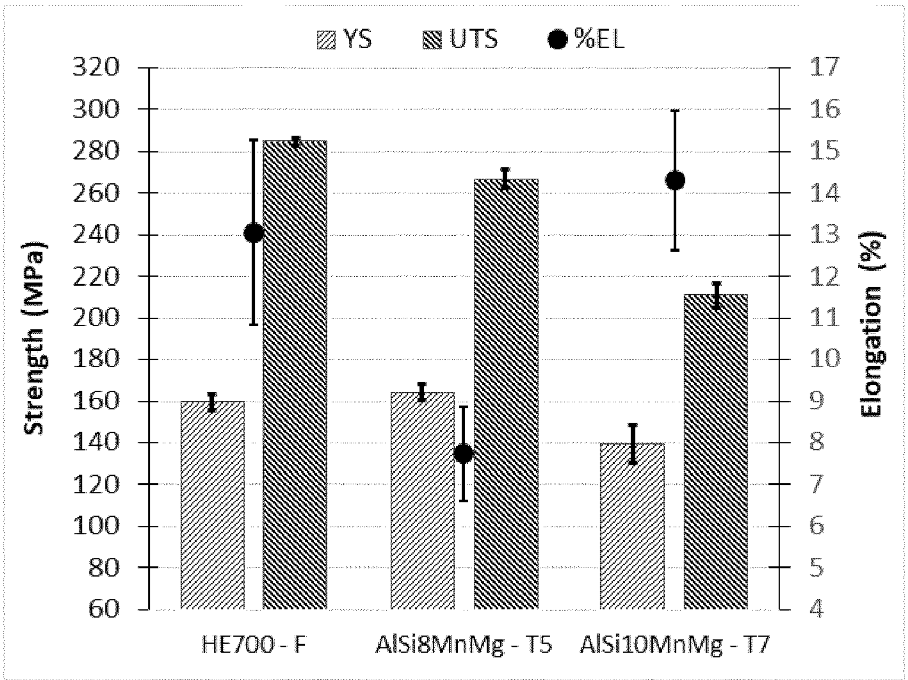
YS
UTS
%EL
Strength (MPa)
Elongation (%)
320
300
280
260
240
220
200
180
160
140
120
100
80
60
17
16
15
14
13
12
11
10
9
8
7
6
5
4
HE700 - F
AlSi8MnMg - T5
AlSi10MnMg - T7

Fig. 2b

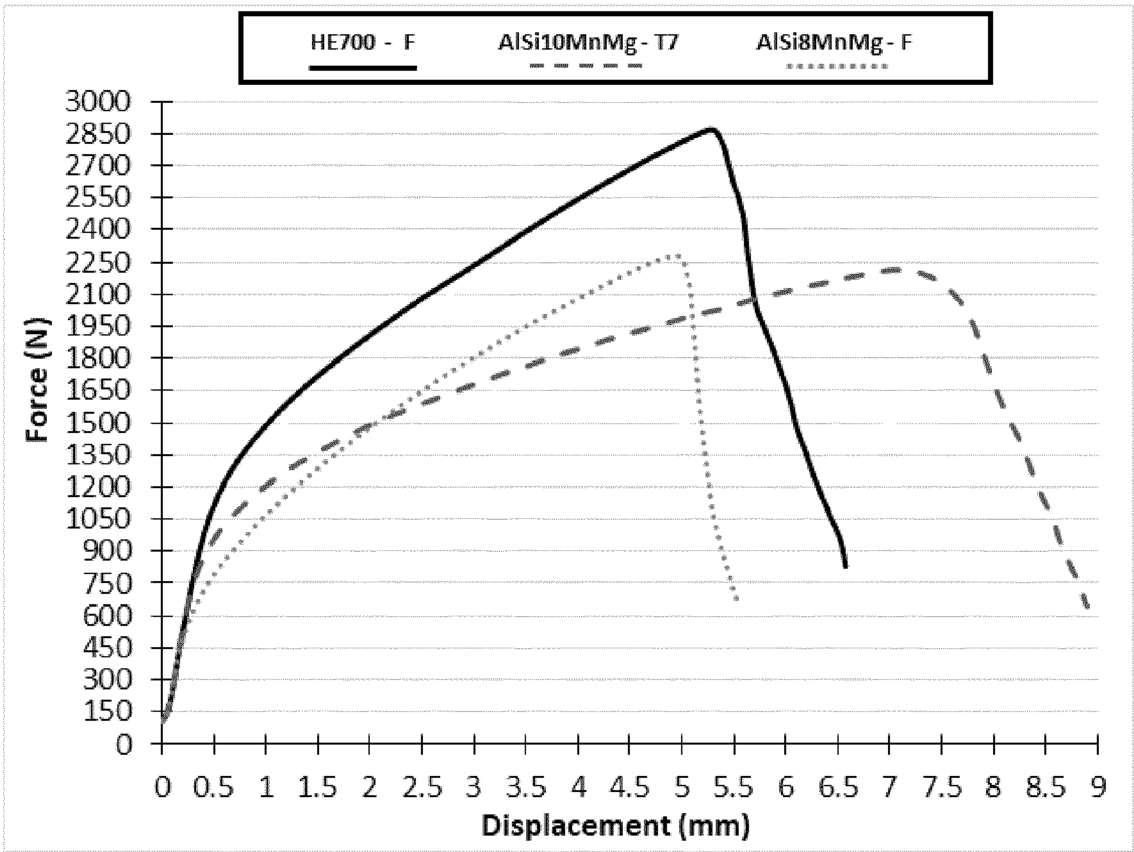
HE700 - F
AlSi10MnMg - T7
AlSi8MnMg - F
Force (N)
3000
2850
2700
2550
2400
2250
2100
1950
1800
1650
1500
1350
1200
1050
900
750
600
450
300
150
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
Displacement (mm)

Fig. 3

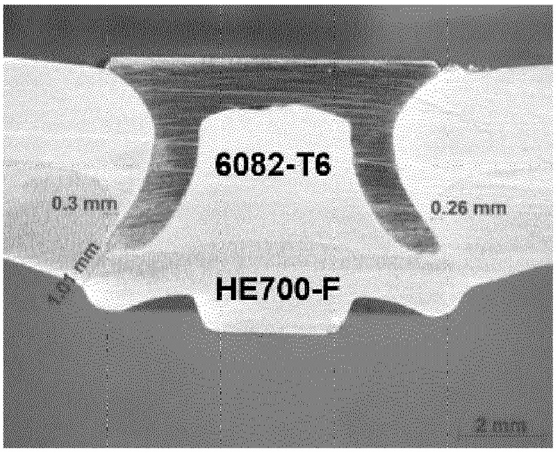

Fig. 4a

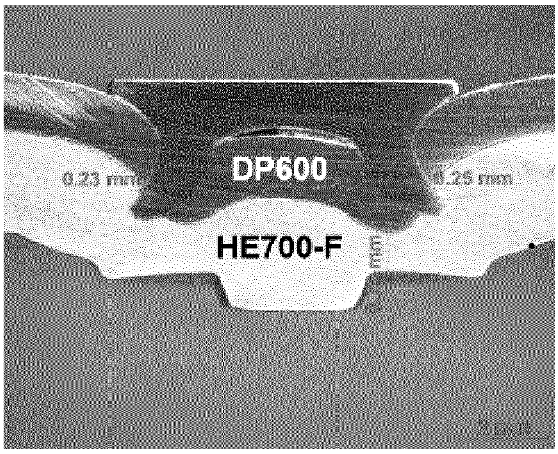

Fig. 4c

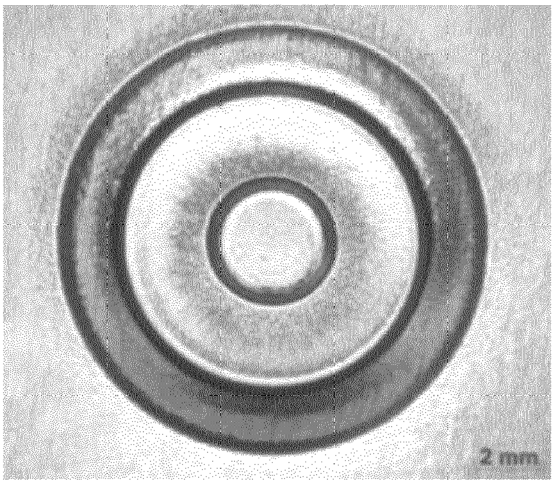

Fig. 4b

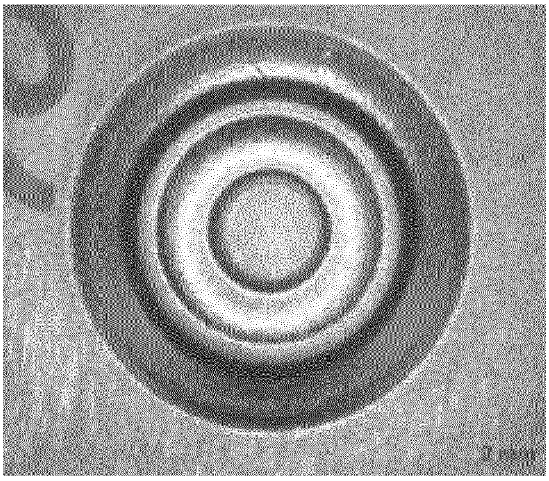

Fig. 4d

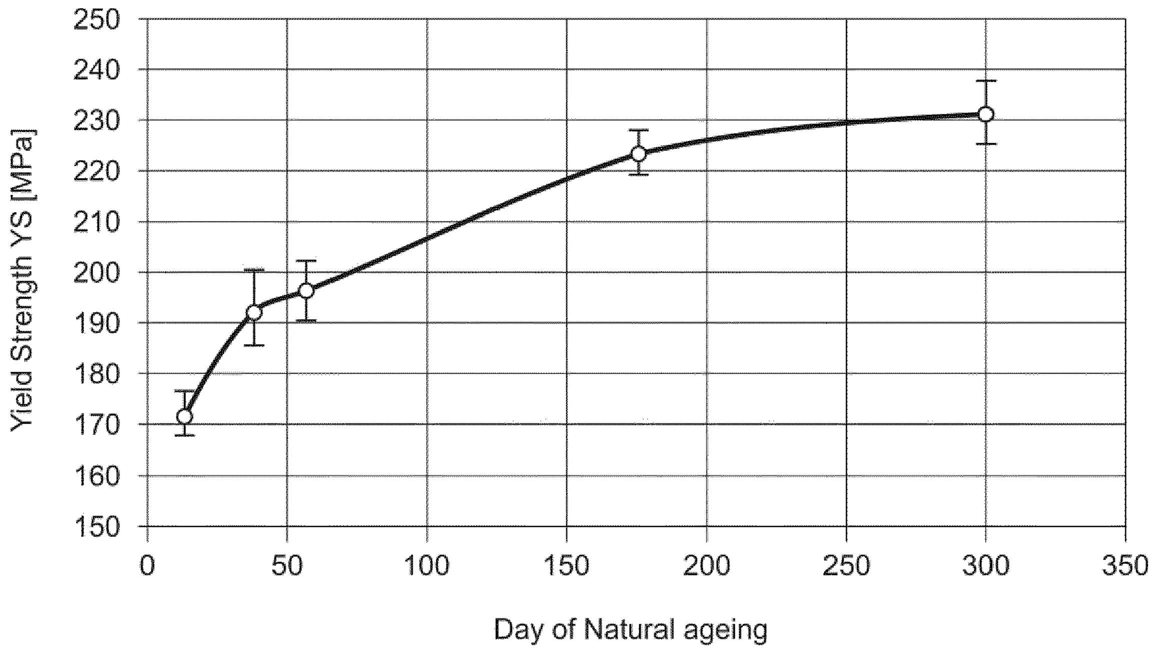
250
240
230
220
210
200
190
180
170
160
150
Yield Strength YS [MPa]
0
50
100
150
200
250
300
350
Day of Natural ageing

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 22 20 1912

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2019/376166 A1 (SHANKAR SUMANTH [CA] ET AL) 12 December 2019 (2019-12-12) * paragraphs [0075] - [0103], [0111]; claim 1; tables 5, 9, 15 * -----	1-7	INV. C22C1/02 C22C21/10 C22F1/053 C21D9/00 B22D21/04 C21D1/56
A	US 2015/218678 A1 (KIM KI TAE [KR] ET AL) 6 August 2015 (2015-08-06) * paragraphs [0022], [0023]; claims 1-5; table 2 * -----	1-7	

TECHNICAL FIELDS SEARCHED (IPC)

C22C
C22F
C21D
B22D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	4 January 2023	Rausch, Elisabeth

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2019376166 A1	12-12-2019	BR 112019010957 A2	01-10-2019
		CA 3045163 A1	31-05-2018
		CN 110234776 A	13-09-2019
		EP 3615702 A1	04-03-2020
		JP 2020501028 A	16-01-2020
		KR 20190091301 A	05-08-2019
		US 2019376166 A1	12-12-2019
		WO 2018094535 A1	31-05-2018
US 2015218678 A1	06-08-2015	KR 20140025043 A	04-03-2014
		US 2015218678 A1	06-08-2015
		WO 2014030915 A1	27-02-2014

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Patent documents cited in the description

- WO 2018094535 A1 **[0004] [0005] [0006] [0008] [0015]**
- KR 101469613 B1 **[0007]**

Non-patent literature cited in the description

- Understanding the Aluminum Temper Designation System. **J. GILBERT KAUFMAN.** Introduction to Aluminum Alloys and Tempers. 39-76 **[0008]**