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(54) Titre : ALLIAGE DE COULEE SOUS PRESSION
(54) Title: DIE CASTING ALLOY

(57) **Abrégé/Abstract:**

The invention relates to a die casting alloy on an aluminum-silicon base with a composition consisting of: 8.5 to 11.5 wt.% of silicon; 0.1 to 0.5 wt.% of magnesium; 0.3 to 0.8 wt.% of manganese; 0.02 to 0.5 wt.% of iron; 0.005 to 0.5 wt.% of zinc; 0.02 to 0.3 wt.% of molybdenum; 0.1 to 0.5 wt.% of copper; 0.02 to 0.15 wt.% of titanium; 0.02 to 0.3 wt.% of zirconium, 5 to 250 ppm of phosphorus, 10 to 200 ppm of gallium and the remainder of aluminum and unavoidable impurities. The alloy can be produced with a recycling rate of 50 %.

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(54) Title: DIE CASTING ALLOY

(54) Bezeichnung: DRUCKGUSSLEGIERUNG

(57) Abstract: The invention relates to a die casting alloy on an aluminum-silicon base with a composition consisting of: 8.5 to 11.5 wt.% of silicon; 0.1 to 0.5 wt.% of magnesium; 0.3 to 0.8 wt.% of manganese; 0.02 to 0.5 wt.% of iron; 0.005 to 0.5 wt.% of zinc; 0.02 to 0.3 wt.% of molybdenum; 0.1 to 0.5 wt.% of copper; 0.02 to 0.15 wt.% of titanium; 0.02 to 0.3 wt.% of zirconium, 5 to 250 ppm of phosphorus, 10 to 200 ppm of gallium and the remainder of aluminum and unavoidable impurities. The alloy can be produced with a recycling rate of 50 %.

(57) Zusammenfassung: Die Erfindung betrifft eine Druckgusslegierung auf Aluminium-Silizium Basis mit einer Zusammensetzung bestehend aus: 8, 5 bis 11, 5 Gew.-% Silizium; 0,1 bis 0,5 Gew.-% Magnesium; 0,3 bis 0,8 Gew.-% Mangan; 0,02 - 0,5 Gew.-% Eisen; 0,005 - 0,5 Gew.-% Zink; 0,02 bis 0,3 Gew.-% Molybdän; 0,1 bis 0,5 Gew.-% Kupfer; 0,02 bis 0,15 Gew.-% Titan; 0,02 bis 0,3 Gew.-% Zirkon, 5 bis 250 ppm Phosphor, 10 bis 200 ppm Gallium und der Rest Aluminium und unvermeidbare Verunreinigungen. Die Legierung ist mit einem Recyclinganteil von 50 % herstellbar.



WO 2017/182102 A1

Die Casting Alloy

The invention relates to a die-cast alloy based on aluminium and silicon, in particular for use in lightweight vehicle structural parts.

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The ever higher demands for lightweight construction in the automotive industry are taken into account with the alloy of the invention. The use of a material having higher strength makes it possible for the designer to realize more thin-walled and hence more lightweight structures. A further step towards low fuel
10 consumption in the car can be realized in this manner.

Alloys of the type AlSi10Mg or AlSi7Mg belong to the cast alloys used most widely in the industry.

15 At this point two die-cast alloys known from the state of the art and used in automotive engineering may be mentioned which have been developed by the applicant itself.

EP 1 612 286 B1 discloses an AlSi alloy which has high extension values even in
20 the cast state without further heat treatment. Good values for the yield strength and tensile strength can be achieved with this alloy for die-cast parts in the cast state so that the alloy is suitable particularly for manufacturing safety components in automotive engineering. For this alloy known from the state of the art, it has been shown that due to the addition of molybdenum or combined addition of
25 molybdenum and zirconium, the required values for tensile strength and yield strength are achieved.

EP 0 687 742 B1 likewise discloses a die-cast alloy based on aluminium-silicon, which is used in particular for safety components in automotive engineering.
30 Different to the alloy from EP 1 612 286 B1, the die-cast pieces manufactured are subjected to a heat treatment. It has been established for this alloy that the increased strength values achieved are dependent to a great extent on the

- 2 -

magnesium content and this content is therefore to be tolerated very tightly in the manufacture.

Further AlSi alloys known from the state of the art are cited in EP 2 653 579 B1
5 and in EP 2 735 621 A1. Both alloys define the iron proportion at a maximum 0.2% by weight.

Starting from the alloy described in EP 0 687 742 B1, the object consists in developing a high-strength aluminium die-cast alloy which shows improved
10 mechanical characteristic values with regard to tensile strength, yield strength and elongation at break. Furthermore, the alloy of the invention should have good castability, no increased tendency to adhesion, no increased risk of tendency to heat cracks and no restriction with regard to mould filling capacity.

15 It is a further object to develop a high-strength aluminium die-cast alloy having the properties mentioned above, wherein the aluminium base of the alloy may contain a proportion of at least 50% of secondary metal (recycling material).

According to the invention, this object is achieved by a die-cast alloy, based on
20 aluminium-silicon, consisting of:

- 8.5 to 11.5% by weight silicon
- 0.1 to 0.5% by weight magnesium
- 0.3 to 0.8% by weight manganese
- 0.02-0.5% by weight iron
- 25 0.005-0.5% by weight zinc
- 0.1 to 0.5% by weight copper
- 0.02 to 0.3% by weight molybdenum
- 0.02 to 0.3% by weight zirconium
- 0.02 to 0.25% by weight titanium
- 30 3 to 50 ppm boron
- 10 to 200 ppm gallium

optionally 30 to 300 ppm strontium or 5 to 30 ppm sodium or 1 to 30 ppm calcium for permanent modification and 5 to 250 ppm phosphorus and/or 0.02 to

- 3 -

0.25% by weight titanium, and 3 to 50 ppm boron for grain refinement, with the remainder being aluminium and unavoidable impurities.

Further embodiments are described in the dependent patent claims.

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In one embodiment, the alloy of the invention contains 0.15-0.5% by weight iron.

In a further embodiment, the alloy of the invention contains 0.05 to 0.20% by weight molybdenum.

10

In a further embodiment, the alloy of the invention contains by 0.05 to 0.20% by weight zirconium.

In a further embodiment, the alloy of the invention contains 60 to 120 ppm gallium.

15

In a further embodiment, the alloy of the invention contains 0.3 to 0.5% by weight manganese.

In a further embodiment, the alloy of the invention contains 0.2 to 0.4% by weight zinc.

20

In a further embodiment, the alloy of the invention contains 0.15 to 0.25% by weight copper.

25 In a further embodiment, the alloy of the invention contains 8.5 to 10.0% by weight silicon.

In a further embodiment, the alloy of the invention contains 0.3 to 0.4% by weight magnesium.

30

The die-cast alloy of the invention is preferably used for die-casting crash-relevant or strength-relevant structural parts in automotive engineering.

- 4 -

The suitable strength of an aluminium die-cast alloy is achieved, in addition to the choice of the combination of alloying elements, also by a specific heat treatment. The alloy of the invention is subjected to a T6 heat treatment comprising solution annealing, air quenching or water quenching and artificial ageing. It could thus be established that, compared to the alloy from EP 0 687 742 B1, high yield strengths of just over 200 N/mm² may be achieved.

The alloy of the invention has fatigue strength after the T6 heat treatment, that is, there is no self-hardening.

Furthermore, it is possible to achieve yield strengths of up to 280 N/mm² due to a T6 heat treatment when using high annealing temperatures of 530°C, in which subsequently water quenching is effected.

Furthermore, the alloy of the invention may be subjected to a T7 heat treatment.

For die-cast parts in the material state T6 or T7, improved values for tensile strength, the yield strength and the elongation at break can be achieved with the alloy composition of the invention.

Compared to the alloy from EP 0 687 742 B1, it could be established that the choice of content of copper of 0.1 to 0.5% by weight, preferably 0.15 to 0.25% by weight, is responsible for improving the mechanical characteristic values of the alloy. According to EP 0 687 742 B1, the introduction of copper during melting down are to be avoided, since copper has a disadvantageous influence on corrosion resistance. The composition of the alloy of the invention was selected so that the production of corrosion-promoting phases, such as for example Al₂Cu, is avoided. A salt-spray alternating test (ISO 9227) and an intergranular corrosion test (ASTM G110-92) served to investigate tendency to corrosion. A comparable corrosion resistance to that of the alloy from EP 1 612 286 B1 already used in automotive engineering, but which restricts the copper content expressly to a maximum 0.1% by weight copper, could be established. Further elements, which improve the mechanical characteristic values, in particular extension, are the choice of molybdenum content and the addition of zirconium. The addition of

- 5 -

at least 0.08% zirconium effects an increase in extension values without a drop in strength of the material. This effect is achieved by a high-melting phase. In this context the time factor plays a particular part. Size and extent of high-melting phases are always dependent on the solidification conditions. In die-casting, solidification usually starts even in the casting chamber, continues during mould filling and ends in thick-walled regions, often only after component removal. The alloy of the invention has been developed for these processes. Only in the die-casting process do the deposits have the correct size and extent to show optimum material characteristic values after a T6 heat treatment.

10

If molybdenum is added at the same time, these two elements work together and an increase in strength is additionally achieved. An increase of these elements above 0.2% does not have a positive effect on the characteristic values of the material.

15 The addition of gallium to the alloy of the invention showed a similar effect. With addition of gallium, in addition to zirconium and molybdenum, a finer structure could be achieved, in particular with slightly increased iron content.

20 The addition of Mo, Zr and Ga plays a particular part if recycling material, say secondary aluminium, is used for manufacturing the alloy. At an iron content of 0.2% it is possible to minimize the damaging effect of iron on elongation at break. A significantly finer structure is produced in which AlMgFeSi phases are smaller and distributed more uniformly.

25 The slightly increased iron content is taken into account by reducing the manganese proportion, otherwise the danger of sludge formation exists in the holding furnace on the casting machine. The tendency to adhesion of the alloy drops nevertheless, since iron just like manganese thus has a positive effect and the reduction of Mn is over-compensated by the Fe content.

30

In addition, the production of so-called beta phases is avoided due to the MnFe proportion, that is, lamellar AlMnFeSi deposits, whereby the ductility of the material is

- 6 -

decisively reduced. Such deposits are known under the microscope as so-called iron needles.

5 The alpha AlMnFeSi deposits are formed to be very fine in the alloy of the invention due to the addition of the elements Mo, Zr and Ga, so that their damaging effect on extension values and tendency to corrosion may be minimized.

10 An improvement in castability and an increase in elongation at break were achieved due to the selected, low proportion of zinc in conjunction with the other elements of the invention. Generally a zinc content of up to 0.5% by weight still shows no effect on material characteristic values. However, the castability of the alloy which is improved with respect to EP 0 687 742 B1 has an effect on the surface quality of the components and thus on the material characteristic values.

15 The addition of strontium or sodium leads to a fine-grained deposit of silicon, which results in the formation of a modified eutectic, and likewise has a positive influence on the strength and extension of the alloy of the invention.

20 Grain refinement is preferably carried out for the alloy of the invention. Hence, preferably 1 to 30 ppm phosphorus may be added to the alloy. Alternatively or additionally, the alloy may also contain titanium and boron for grain refinement, wherein the addition of titanium and boron is effected via a master alloy with 1 to 2% by weight Ti and 1 to 2% by weight B, remainder aluminium. The aluminium master alloy preferably contains 1.3 to 1.8% by weight Ti and 1.3 to 1.8% by weight B and has a Ti/B weight ratio of about 0.8 to 1.2. The content of the master alloy in the alloy of the invention is preferably adjusted to 0.05 to 0.5% by weight.

30 Within the framework of the investigations it was possible to manufacture the alloy of the invention with a recycling proportion of 50-70%.

High-grade recycling material, such as for example scrap metal of wheels, extruded profiles, sheet metals and also cuttings and the use of a tried and tested tilting-drum

- 7 -

furnace for melting the alloy, is necessary for this. The demands of crash-relevant structural components could be fulfilled up to an iron content of 0.25%, use in strength-relevant structural components was possible up to an iron content of 0.40%.

- 5 Suitability for welding could be investigated in TIG welding tests. The alloy of the invention could be riveted without cracks in spite of its high strength in die-rivet tests.

Comparative example

- 10 The compositions of an exemplary alloy from EP 0 687 742 B1 (alloy 1) and two exemplary embodiments (alloys A, B) of the alloy of the invention are compared below. The details are in % by weight. Using these two alloys, the mechanical characteristic values (R_m , $R_{p0.2}$ and A_5) were measured on die-cast 3 mm plates. In all tests, the same T6 heat treatment was used with air quenching and with water
- 15 quenching. In each case the average value of about 30 tension tests is shown.

	Si	Fe	Cu	Mn	Mg	Zn
Alloy 1	10.15	0.110	0.0006	0.658	0.355	0.0013
Alloy A	9.41	0.114	0.197	0.49	0.340	0.296
Alloy B	9.01	0.227	0.198	0.440	0.349	0.351

	Ti	B	Sr	Zr	Mo
Alloy 1	0.050	0.001	0.020	0.002	0.0
Alloy A	0.110	0.0003	0.023	0.117	0.087
Alloy B	0.150	0.0049	0.0175	0.102	0.108

	Ga	P
Alloy 1	0.0050	0.0009

- 8 -

	Ga	P
Alloy A	0.0092	0.0020
Alloy B	0.0104	0.0034

Results achieved

T6 heat treatment, quenching in air

	Rm [N/mm²]	Rp_{0.2} [N/mm²]	A₅ [%]
Alloy 1	236	167	7.9
Alloy A	288	209	11.0
Alloy B	280	189	9.6

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T6 heat treatment, quenching in water

	Rm [N/mm²]	Rp_{0.2} [N/mm²]	A₅ [%]
Alloy 1	326	241	7.9
Alloy A	332	257	10.0
Alloy B	348	264	8.2

PATENT CLAIMS

1. A die-cast alloy, based on aluminum-silicon, consisting of:
 - 8.5 to 11.5% by weight silicon
 - 0.1 to 0.5% by weight magnesium
 - 0.3 to 0.8% by weight manganese
 - 0.02-0.5% by weight iron
 - 0.005-0.5% by weight zinc
 - 0.1 to 0.5% by weight copper
 - 0.02 to 0.3% by weight molybdenum
 - 0.02 to 0.3% by weight zirconium
 - 10 to 200 ppm gallium
 - optionally
 - 30 to 300 ppm strontium or 5 to 30 ppm sodium or 1 to 30 ppm calcium for permanent modification and 5 to 250 ppm phosphorus and/or 0.02 to 0.25% by weight titanium, and
 - 3 to 50 ppm boron for grain refinement,
 - with the remainder being aluminum and unavoidable impurities.
2. The die-cast alloy according to claim 1, characterized by 0.15-0.5% by weight iron.
3. The die-cast alloy according to any one of the preceding claims, characterized by 0.05 to 0.20% by weight molybdenum.
4. The die-cast alloy according to any one of the preceding claims, characterized by 0.05 to 0.20% by weight zirconium.
5. The die-cast alloy according to any one of the preceding claims, characterized by 60 to 120 ppm gallium.
6. The die-cast alloy according to any one of the preceding claims, characterized by 0.3 to 0.5% by weight manganese.

- 10 -

7. The die-cast alloy according to any one of the preceding claims,
characterized by 0.2 to 0.4% by weight zinc.
- 5 8. The die-cast alloy according to any one of the preceding claims,
characterized by 0.15 to 0.25% by weight copper.
9. The die-cast alloy according to any one of the preceding claims,
characterized by 8.5 to 10.0% by weight silicon.
- 10 10. The die-cast alloy according to any one of the preceding claims,
characterized by 0.3 to 0.4% by weight magnesium.
11. Use of a die-cast alloy according to any one of the preceding claims, for
15 die-casting crash-relevant or strength-relevant structural parts in
automotive engineering.