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(54) **Titre : ALLIAGE DE COULEE SOUS PRESSION A BASE D'Al-Si, CONTENANT EN PARTICULIER DE L'ALUMINIUM
SECONDAIRE**
(54) **Title: DIECASTING ALLOY BASED ON Al-Si, COMPRISING PARTICULARLY SECONDARY ALUMINIUM**

(57) **Abrégé/Abstract:**

A diecasting alloy based on Al-Si, comprising especially secondary aluminium, is disclosed. In order to be able to meet high demands on strength, ductility and corrosion resistance, it is proposed that the diecasting alloy comprise 6 to 12% by weight of silicon (Si), at least 0.3% by weight of iron (Fe), at least 0.25% by weight of manganese (Mn), at least 0.1% by weight of copper (Cu), 0.24 to 0.8% by weight of magnesium (Mg) and 0.40 to 1.5% by weight of zinc (Zn), and that the diecasting alloy comprise 50 to 300 ppm of strontium (Sr) and/or 20 to 250 ppm of sodium (Na) and/or 20 to 350 ppm of antimony (Sb), and at least one of the following constituents: titanium (Ti) to an extent of not more than 0.2% by weight; not more than 0.3% by weight of zirconium; not more than 0.3% by weight of vanadium (V); and as the remainder aluminium and unavoidable impurities resulting from the production, where the total content of Fe and Mn in the diecasting alloy together is not more than 1.5% by weight, the quotient of the percentages by weight of Fe and Mn is 0.35 to 1.5, and the quotient of the percentages by weight of Cu and Mg is 0.2 to 0.8.

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(54) **Title:** DIECASTING ALLOY BASED ON AL-SI, COMPRISING PARTICULARLY SECONDARY ALUMINIUM(54) **Bezeichnung** : DRUCKGUSSLEGIERUNG AUF AL-SI-BASIS, AUFWEISEND INSBESONDERE
SEKUNDÄRALUMINIUM

(57) **Abstract:** A diecasting alloy based on Al-Si, comprising especially secondary aluminium, is disclosed. In order to be able to meet high demands on strength, ductility and corrosion resistance, it is proposed that the diecasting alloy comprise 6 to 12% by weight of silicon (Si), at least 0.3% by weight of iron (Fe), at least 0.25% by weight of manganese (Mn), at least 0.1% by weight of copper (Cu), 0.24 to 0.8% by weight of magnesium (Mg) and 0.40 to 1.5% by weight of zinc (Zn), and that the diecasting alloy comprise 50 to 300 ppm of strontium (Sr) and/or 20 to 250 ppm of sodium (Na) and/or 20 to 350 ppm of antimony (Sb), and at least one of the following constituents: titanium (Ti) to an extent of not more than 0.2% by weight; not more than 0.3% by weight of zirconium; not more than 0.3% by weight of vanadium (V); and as the remainder aluminium and unavoidable impurities resulting from the production, where the total content of Fe and Mn in the diecasting alloy together is not more than 1.5% by weight, the quotient of the percentages by weight of Fe and Mn is 0.35 to 1.5, and the quotient of the percentages by weight of Cu and Mg is 0.2 to 0.8.

(57) **Zusammenfassung:** Es wird eine Druckgusslegierung auf Al-Si-Basis, aufweisend insbesondere Sekundäraluminium, gezeigt. Um hohen Ansprüchen an Festigkeit, Duktilität und Korrosionsbeständigkeit gerecht werden zu können, wird vorgeschlagen, dass die Druckgusslegierung 6 bis 12 Gew.-% Silizium (Si), mindestens 0,3 Gew.-% Eisen (Fe), mindestens 0,25 Gew.-% Mangan (Mn), mindestens 0,1 Gew.-% Kupfer (Cu), 0,24 bis 0,8 Gew.-% Magnesium (Mg) und 0,40 bis 1,5 Gew.-% Zink (Zn) aufweist, und dass die Druckgusslegierung 50 bis 300 ppm Strontium (Sr) und/oder 20 bis 250 ppm Natrium (Na) und/oder 20 bis 350 ppm Antimon (Sb), sowie wenigstens einen der folgenden Bestandteile zu maximal 0,2 Gew.-% Titan (Ti); maximal 0,3 Gew.-% Zirkon; maximal 0,3 Gew.-% Vanadium (V); und als Rest Aluminium sowie herstellungsbedingt unvermeidbare Verunreinigungen aufweist, wobei der Gesamtanteil von Fe und Mn an der Druckgusslegierung zusammen maximal 1,5 Gew.-%, der Quotient der Gewichtsprozent von Fe und Mn 0,35 bis 1,5 und der Quotient der Gewichtsprozent von Cu und Mg 0,2 bis 0,8 betragen.

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Diecasting Alloy Based on Al-Si, Comprising Particularly
Secondary Aluminium

Technical Field

The invention relates to a die-casting alloy on the basis of Al-Si, particularly having secondary aluminum.

State of the Art

Inexpensive die-casting alloys can be obtained from scrap aluminum, for example, but generally contain undesirably high levels of contaminants in the form of iron, copper, and zinc alloy components, in disadvantageous manner (EP1111077A1). This not only leads to reduced ductility potential, but rather can also have negative influences on strength as well as quenching sensitivity of the die-casting alloy. The most varied measures for reciprocal weighting of the alloy elements, as well as diverse suggestions for additives are known from the state of the art - particularly in order to thereby compensate for the negative influences of the contaminants.

For example, a die-casting alloy having 5 to 13 wt.-% Si, having maximally 0.5 wt.-% Mg, having 0.1 to 1.0 wt.-% Mn, and having 0.1 to 2.0 wt.-% Fe is known from JP9-003610. In this connection, Mn is supposed to suppress the formation of Al-Fe-Si needle crystals, for example, in order to prevent a reduction in strength. Furthermore, in order to obtain the casting properties, Mg is supposed to be kept to a content as low as possible, maximally 0.5 wt.-%. Cu and Zn contaminants, as these usually occur in significant amounts in the case of secondary aluminum, are not taken into consideration by the die-casting alloy in JP9-003610.

DE102004013777B4 proposes a die-casting alloy having 5 to 18 wt.-% Si, having 0.15 to 0.45 wt.-% Mn, having 0.2 to 0.6 wt.-% Fe, having 0.3 to 0.5 wt.-% Mg, possibly having 0.1 to 0.5 wt.-% Cu, and having 4 to 5 wt.-% Zn. The content of maximally 0.5 wt.-% magnesium is supposed to prevent the formation of Mg-Fe "pi" phases, in order to thereby obtain stretchability. Cu is supposed to improve the heat strength of the alloy, whereby the content of zinc is supposed to be restricted to 4 to 5 wt.-%, in order to thereby adjust the strength and quenching sensitivity of the alloy. However, it is disadvantageous that such a composition of alloy elements can demonstrate low corrosion

resistance, particularly because of the comparatively high zinc content, and this can lead to restrictions of the die-cast parts produced from it, in terms of safety technology.

Furthermore, a die-casting alloy having 9 to 11 wt.-% Si, having maximally 0.6 wt.-% Fe, having 0.2 to 0.6 wt.-% Mn, having 0.05 to 0.4 wt.-% Cu, having 0.2 to 0.35 wt.-% Mg, and having maximally 0.35 wt.-% Zn, is known from DE102009012073A1. It is true that DE102009012073A1 concerns itself with secondary aluminum - because of the lower limits of permissible Cu and Zn contents, which are set to be comparatively low, the bandwidth of secondary aluminum that can be used is comparatively restricted. Furthermore, such a composition cannot allow comparatively great strength, ductility, and castability, particularly since Zn as a contaminant is supposed to be limited to a small value. Something similar is also known from DE102005061668A1, according to which the Zn content in the die-casting alloy is to be kept to below 0.05 wt.-%.

Presentation of the Invention

It is therefore the task of the invention to create a die-casting alloy on the basis of Al-Si, proceeding from the state

of the art described initially, which alloy can allow die-cast parts that meet great demands with regard to strength, ductility, and chemical reaction resistance, particularly corrosion resistance, despite the use of secondary aluminum. Furthermore, this die-casting alloy is supposed to be able to ensure not only complex forming, in terms of die-casting technology, but also excellent demoldability, and offer excellent processability for the components produced from it.

The invention accomplishes the stated task in that the die-casting alloy contains

6 to 12 wt.-% silicon (Si),
at least 0.3 wt.-% iron (Fe),
at least 0.25 wt.-% manganese (Mn),
at least 0.1 wt.-% copper (Cu),
0.24 to 0.8 wt.-% magnesium (Mg) and
0.40 to 1.5 wt.-% zinc (Zn),

and that the die-casting alloy contains

50 to 300 ppm strontium (Sr) and/or
20 to 250 ppm sodium (Na) and/or
20 to 350 ppm antimony (Sb),

as well as at least one of the following components, at maximally 0.2 wt.-% titanium (Ti);

maximally 0.3 wt.-% zirconium;

maximally 0.3 wt.-% vanadium (V);

and aluminum as the remainder, as well as production-related unavoidable contaminants,

wherein the total proportion of Fe and Mn in the die-casting alloy, together, amounts to maximally 1.5 wt.-%, the quotient of the weight percents of Fe and Mn amounts to 0.35 to 1.5, and the quotient of the weight percents of Cu and Mg amounts to 0.2 to 0.8.

By means of permitting comparatively high wt.-% contaminants, as is also proposed, according to the invention, for iron, copper, and zinc, a cost-advantageous die-casting alloy on the basis of Al-Si can be made available, because essentially, the proportion of primary aluminum is reduced or actually dispensed with, and thereby secondary aluminum can be used to a greater extent for the production of cast parts. However, this only becomes possible in that the alloy components of the casting alloy are forced to remain within certain content limits, according to the invention, in order to thereby approach the parameters known for primary aluminum (for example strength values, ductility values, chemical reaction resistance, processability and/or castability).

Fe, Mn:

For example, a quotient of weight percents of Fe and Mn of 0.35 to 1.5 can lead to the result that despite a comparatively high iron content, the formation of the β phase (for example $\text{Al}_5\text{FeSi}/\text{Al}_{8.9}\text{Fe}_2\text{Si}_2$) in the structure, which precipitates in the form of fine needles, can be clearly reduced. An increasing occurrence of the α phase can be expected, which can be present due to the manganese content, according to the invention, of at least 0.25 wt.-%, as $\text{Al}_{15}(\text{FeMn})_3\text{Si}_2$. This α phase crystallizes in globulite form, and because of its compact structure can have a clearly more advantageous influence on the ductility than is known for the needle-shaped β phases. A die-casting alloy having comparatively great ductility can be ensured in this way. In general, however, it should still be mentioned that because of this ratio of Fe/Mn, in combination with great cooling speeds (for example by means of accelerated cooling), its phases and thereby its influence on the structure can be kept comparatively low. If, in addition, the total proportion of Fe and Mn in the die-casting alloy is restricted to maximally 1.5 wt.-%, the formation of coarse α phases can also be further reduced, even if the high cooling speeds that are usually carried out in die-casting methods are applied. The concentration provisions

regarding Fe and Mn can therefore be beneficial for the ductility of the die-casting alloy, in particular.

Cu, Mg:

By means of introduction and/or adjustment of a magnesium excess, in that the quotient of the weight percents of Cu and Mg amounts to 0.2 and 0.8, and taking into consideration that at least 0.1 wt.-% Cu and 0.24 to 0.8 wt.-% Mg are provided, the copper present can essentially be bound in the Q phase ($\text{Al}_5\text{Cu}_2\text{Mg}_8\text{Si}_6$) that preferentially forms. This concentration provision can therefore prevent the formation of phases susceptible to corrosion, such as, for example, the tao phase ($\text{Al}_5\text{Cu}_4\text{Zn}$) or the theta phase (Al_2Cu) in the structure, so that despite comparatively high weight percents of Cu, which fact is utilized, according to the invention, for improving the heat hardening of the die-casting alloy, great corrosion resistance can also be maintained. Furthermore, because of this magnesium excess, the hardening mechanism of the alloy can be improved, because part of the Mg is bound in the Q phase ($\text{Al}_5\text{Cu}_2\text{Mg}_8\text{Si}_6$), and thereby limits known in this regard, which occur as the result of excessive precipitation of Mg_2Si pre-phases, can be overcome. The concentration provisions concerning Cu and Mg can therefore satisfy particularly great demands of the die-casting alloy with

regard to strength and chemical reaction resistance.

Furthermore, improved processability, for example with regard to the weldability and rivetability of components composed of this die-casting alloy, can be achieved by means of the proposed concentration ratio of Cu and Mg.

Mg, Fe, Mn:

Furthermore, it was possible to determine that the introduction and/or adjustment of the aforementioned magnesium excess with regard to Cu can also be utilized to bind the increased Fe content of the die-casting alloy in a pi phase ($\text{Al}_8\text{FeMg}_3\text{Si}_6$). In this way, on the one hand it was possible to reduce the β phase (for example $\text{Al}_5\text{FeSi}/\text{Al}_{8.9}\text{Fe}_2\text{Si}_2$), which impairs ductility, because less Fe is available for formation of this β phase, but in particular, on the other hand, it was also possible to reduce the Mn content in the die-casting alloy, because the pi phase (for example $\text{Al}_8\text{FeMg}_3\text{Si}_6$) can be used for absorption of Fe. Die-casting problems, which generally have to be accepted as the result of a increased Mn content for compensation of Fe effects, can thereby be reduced. Complex forming and also excellent demoldability can be ensured by means of the particular content limits of Mg, Fe, Mn, in combination with their concentration provisions.

Zn:

The strength of the alloy, determined, for example, by means of an interaction of the pre-phases Mg_2Si and the Q phase

$(Al_5Cu_2Mg_8Si_6)$, can be further improved by means of mixed crystal hardening, using embedded zinc. For this purpose, zinc must be adjusted within the content limits of 0.40 to 1.5 wt.-%.

Furthermore, this can be beneficial for the ductility of the die-casting alloy. In this way, a possible negative influence of a comparatively high Mg content on the ductility of the die-casting alloy can be reduced. Furthermore, the content limits of Zn, according to the invention, can distinguish themselves in the improvement in castability of the die-casting alloy, thereby making it possible to compensate impairments, in this regard, to a great extent, on the basis of the proposed content limits of Mn in the die-casting alloy.

The die-casting alloy on the basis of Al-Si, which is balanced in terms of the alloy components Fe, Mn, Cu, Mg, and Zn, can therefore combine comparatively great ductility, corrosion resistance, strength, castability, and processability with one another, and thereby overcome parameter limits known from the state of the art, even if the die-casting alloy contains

secondary aluminum and/or the latter is added to it, or comparatively high contents of contaminants are brought about thereby.

For purposes of permanent modification, the die-casting alloy can contain 50 to 300 ppm strontium (Sr) and/or 20 to 250 ppm sodium (Na) and/or 20 to 350 ppm antimony (Sb). Optionally, maximally 0.2 wt.-% titanium (Ti) and/or maximally 0.3 wt.-% zirconium and/or maximally 0.3 wt.-% vanadium (V) can prove to be advantageous for grain refinement of the die-casting alloy. The die-casting alloy can be supplemented to 100 wt.-%, in each instance, with Al, whereby this die-casting alloy can also contain process-related unavoidable contaminants. In general, it should be mentioned that the die-casting alloy can contain contaminants at maximally 0.1 wt.-% per contaminant, and at most 1 wt.-% in total.

For the sake of completeness, it should be mentioned that secondary aluminum is understood to be aluminum or an aluminum alloy obtained from scrap aluminum. Furthermore, for the same reason, it should be mentioned that the measurement unit ppm is understood to mean weight ppm.

Strength, ductility, processability, and chemical reaction resistance of the die-casting alloy can be further improved if this alloy contains 0.3 to 1.0 wt.-% iron (Fe), 0.25 to 1.0 wt.-% manganese (Mn), and 0.1 to 0.6 wt.-% copper (Cu).

If the die-casting alloy fulfills the order relation

$$\text{wt.-% Mg} > 0.2 + 0.12 \times (\text{wt.-% Fe} / \text{wt.-% Mn})$$

in terms of its composition, a simple method provision for increasing the proportion of the π phase (for example $\text{Al}_8\text{FeMg}_3\text{Si}_6$) in the structure of the die-casting alloy can be present. Increased Fe components can be compensated in this way, thereby making it possible to maintain excellent castability of the die-casting alloy at a reduced Mn component. Furthermore, this π phase can be converted into an α phase, which is harmless for the required properties of the die-casting alloy, by means of solution annealing.

The die-casting alloy can be further improved with regard to the ductility, strength, and corrosion resistance that can be achieved for it if the total proportion of Fe and Mn in the die-casting alloy, together, amounts to maximally 1.2 wt.-%, the quotient of the weight percents of Fe and Mn amount to 0.5 to

1.25, and the quotient of the weight percents of Cu and Mg amounts to 0.2 to 0.5.

If the die-casting alloy contains 9.5 to 11.5 wt.-% silicon (Si) and/or 0.35 to 0.6 wt.-% iron (Fe) and/or 0.3 to 0.75 wt.-% manganese (Mn) and/or 0.1 to 0.4 wt.-% copper (Cu) and/or 0.24 to 0.5 wt.-% magnesium (Mg) and/or 0.40 to 1.0 wt.-% zinc (Zn), narrower limit ranges for a die-casting alloy on the basis of Al-Si, which is improved in terms of its mechanical strength and/or chemical resistance, occur. In general, it should be mentioned that by means of the proposed content of Si, the flow properties of the melt can be improved, and brittle primary silicon phases can be avoided. In this way, it can also be made possible to die-cast even comparatively thin-walled components. For this purpose, 9.5 to 11.5 wt.-% silicon (Si) can prove to be particularly advantageous.

Way to Implement the Invention

In the following, the invention will be explained in greater detail, using exemplary embodiments:

For proof of the effects achieved, thin-walled cast components were produced from different die-casting alloys, using the die-casting method. The compositions of the alloys investigated are listed in Table 1.

Alloy No.	Composition	Fe/Mn	Cu/Mg
1	AlSi10Mn0.5Fe0.1Mg0.4	0.2	0
2	AlSi10Mn0.5Fe0.5Mg0.4Cu0.25Zn0.75	1	0.63

Table 1: Overview of alloys investigated

The alloy 1 is a die-casting alloy composed of primary aluminum with a low degree of contamination. Alloy 2, in contrast, demonstrates a significant degree of contaminants of iron and copper alloy components, which can be introduced by secondary aluminum, for example.

The alloys or the die-cast parts or test bodies produced from them were subjected to T7 heat treatment with one hour at 460°C, solution annealing, quenching with water, and two hours of hot aging at 220°C. The finished test bodies were finally investigated with regard to their mechanical properties. For this purpose, the tensile strength R_m , the yield strength $R_{p0.2}$,

and the elongation to rupture A_5 were determined in a tensile test. The measurement values obtained are summarized in Table 2.

Alloy No.	$R_{p0.2}$ [MPa]	R_m [MPa]	A_5 [%]
1	155	230	14.3
2	160	240	13.8

Table 2: Mechanical characteristic values of the alloys investigated

Studies of the die-casting alloy No. 2 showed that the formation of an undesirable beta phase during solidification can be avoided by means of the adjusted iron component and manganese content. The copper component can also be completely bound in the Q phase by means of a magnesium component, thereby achieving comparatively great corrosion resistance. On the basis of this combination of elements, increased strength and elongation to rupture of 13.8% can be achieved, despite the iron content of 0.5 wt.-%. The comparatively high zinc content leads to an increase in strength, without any negative influence on the mechanical properties.

As can now be seen in a comparison of the two die-casting alloys 1 and 2 according to Table 2, these two alloys demonstrate similar mechanical properties, although alloy 2 has a clearly higher iron and copper content as compared with alloy 1.

It has therefore been shown that the concentration conditions proposed for a die-casting alloy according to the invention make it possible to ensure comparatively great ductility, corrosion resistance, strength, castability, and processability.

We Claim:

1. Die-casting alloy on the basis of Al-Si, wherein the die-casting alloy contains

6 to 12 wt.-% silicon (Si),
 at least 0.3 wt.-% iron (Fe),
 at least 0.25 wt.-% manganese (Mn),
 at least 0.1 wt.-% copper (Cu),
 0.24 to 0.8 wt.-% magnesium (Mg) and
 0.40 to 1.5 wt.-% zinc (Zn), and that

the die-casting alloy contains

50 to 300 ppm strontium (Sr) and/or
 20 to 250 ppm sodium (Na) and/or
 20 to 350 ppm antimony (Sb),
 as well as at least one of the following components, at
 maximally 0.2 wt.-% titanium (Ti);
 maximally 0.3 wt.-% zirconium;
 maximally 0.3 wt.-% vanadium (V);
 and aluminum as the remainder, as well as production-
 related unavoidable contaminants,

wherein the total proportion of Fe and Mn in the die-casting alloy, together, amounts to maximally 1.5 wt.-%, the quotient of the weight percents of Fe and Mn amount to 0.35 to 1.5, and the quotient of the weight percents of Cu and Mg amounts to 0.2 to 0.8.

2. Die-casting alloy according to claim 1, wherein the die-casting alloy contains secondary aluminum.

3. Die-casting alloy according to claim 1 or claim 2, characterized in that the die-casting alloy contains

0.3 to 1.0 wt.-% iron (Fe),
 0.25 to 1.0 wt.-% manganese (Mn) and

0.1 to 0.6 wt.-% copper (Cu).

4. Die-casting alloy according to any one of claims 1 to 3, characterized in that the die-casting alloy fulfills the order relation

$$\text{wt.-% Mg} > 0.2 + 0.12 \times (\text{wt.-% Fe} / \text{wt.-% Mn})$$

in terms of its composition.

5. Die-casting alloy according to any one of claims 1 to 4, characterized in that the total proportion of Fe and Mn in the die-casting alloy, together, amounts to maximally 1.2 wt.-%, the quotient of the weight percents of Fe and Mn amounts to 0.5 to 1.25, and the quotient of the weight percents of Cu and Mg amounts to 0.2 to 0.5.

6. Die-casting alloy according to any one of claims 1 to 5, characterized in that the die-casting alloy contains 9.5 to 11.5 wt.-% silicon (Si).

7. Die-casting alloy according to any one of claims 1 to 6, characterized in that the die-casting alloy contains 0.35 to 0.6 wt.-% iron (Fe).

8. Die-casting alloy according to any one of claims 1 to 7, characterized in that the die-casting alloy contains 0.3 to 0.75 wt.-% manganese (Mn).

9. Die-casting alloy according to any one of claims 1 to 8, characterized in that the die-casting alloy contains 0.1 to 0.4 wt.-% copper (Cu).

10. Die-casting alloy according to any one of claims 1 to 9, characterized in that the die-casting alloy contains 0.24 to 0.5 wt.-% magnesium (Mg).

11. Die-casting alloy according to any one of claims 1 to 10, characterized in that the die-casting alloy contains 0.40 to 1.0 wt.-% zinc (Zn).