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(54) Titre : ALLIAGE D'ALMINIUM
(54) Title: ALUMINUM ALLOY

(57) **Abrégé/Abstract:**

Aluminum alloy having the following composition: 0.2 to 1.8 wt% of Si, 0.2 to 1.8 wt% of Mg, 0.3 to 2.5 wt% of Mn, 0.2 to 1.5 wt% of Fe, 0.05 to 0.75 wt% of Zr, 0.03 to 0.18 wt% of Ti, optionally one or more of the following elements: max. 0.1 wt% of Cr, max. 0.05 wt% of Cu, 0.2 to 1.8 wt% of Zn, 0.02 to 0.5 wt% of Er; and optionally 0.01 to 0.2 wt% of a Ti- and B- containing grain refining agent; and, as the remainder, aluminum and unavoidable impurities. The alloy is suitable for components having elevated thermal stability, especially for production of components for the automobile industry, by means of extrusion, forging or casting in permanent forms.

ABSTRACT

An aluminum alloy having the following composition:
0.2 to 1.8 wt% of Si
5 0.2 to 1.8 wt% of Mg
0.3 to 2.5 wt% of Mn
0.2 to 1.5 wt% of Fe
0.05 to 0.75 wt% of Zr
0.03 to 0.18 wt% of Ti,
10 optionally one or more of the following elements:
max. 0.1 wt% of Cr,
max. 0.05 wt% of Cu,
0.2 to 1.8 wt% of Zn
0.02 to 0.5 wt% of Er;
15 and optionally 0.01 to 0.2 wt% of a grain refiner contain-
ing Ti and B;
the balance being aluminum and inevitable impurities.

The alloy is suitable for components having elevated heat
20 stability, especially for the production of components for
the automobile industry, by means of extrusion, forging or
casting in permanent molds.

Aluminum Alloy

The invention relates to an aluminum alloy for components with increased heat stability. The components made from the alloy are characterized by a high strength and high hardness after exposure to high heat. The inventive aluminum alloy is particularly suitable for manufacturing components of the aforementioned type by extrusion, forging, or casting in permanent molds, as well as for further processing of the components thus prepared by means of thermal joining methods. The invention further relates to components which are produced by means of said alloy, and to the use of this aluminum alloy for the production of components, in particular of components for the automotive industry.

15

Extrusion and mold casting are two of the most economical methods of forming aluminum alloys.

In extrusion, the design options are influenced and limited mainly by the type of alloy, the available process forces and the pressing direction. Another important parameter in forming by means of extrusion is the pressing temperature, the height of which is limited by the particular alloy composition, in particular by its resistance to heat application. Since there may occur local heating of the alloy during the forming process, partial melting may occur, especially in the area of the die inlet edges, which affects the mechanical properties of the extruded product.

In high-pressure die casting, the design limits are influenced mainly by the aspired simplest possible component geometry, since the method needs to be realized without the use of insertable cores.

The quality of the extruded part depends not only on the machine setting and tool design (die geometry), but largely on the selected alloy system. Particularly, AlMn(Cu) and AlMgSi alloy systems are widely used for extruded products (F. OSTERMANN: "Anwendungstechnologie Aluminium", 3rd Edition, pp 456-457, Berlin 2014). In the permanent mold processes, in particular in die casting, too, the chemical composition and microstructure play a crucial role for the later component properties relevant in terms of application technologically.

In forming by forging, too, a temperature increase may occur due to the deformation energy - especially at excessively high forming rates. In that case, local overheating may occur in the workpiece, which adversely affects the microstructure and the mechanical properties. With this forming process, too, the influence of alloy composition is essential.

Even when designing forgings, process-related design rules apply which limit the design options.

As described above, there are limits to the freedom of design in the above-mentioned forming methods (extrusion, mold casting, forging), which may be due to technological or economic reasons.

However, in particular in the automotive industry, increasingly complex components and component groups are being used which cannot be produced, or cannot be economically produced, by forming processes such as extrusion or mold casting.

Through the further development of suitable joining methods, especially welding or soldering/brazing, the applica-

tions for components made of aluminum alloys have greatly expanded as more complex components and component groups can be produced in this way.

5 Since thermal joining processes such as welding or soldering/brazing are usually employed in this connection, the reliability of the material and its stability under the thermal stress conditions occurring in these thermal joining processes are essential. The resistance of the material
10 to short-term thermal stress is important both in the case of accidental heating and in the case of an intended heating of a structure, such as in soldering/brazing or welding.

15 In general, the development of aluminum alloys having a marked high-temperature strength at high processing and operating temperatures for use in sophisticated components has been increasingly paid attention to in the past. Especially in the automotive industry there is a demand for materials stability, particularly in terms of strength and
20 hardness, after processing by methods involving exposure to the highest temperatures possible.

In this context, there is an increasing demand for aluminum
25 alloys that are suitable for components which require no further heat treatment after passing through the production process in order to achieve the desired mechanical properties.

30 An increased resistance to thermal stress is of the utmost importance also because of the ever increasing operating temperatures, for instance in engine components such as pistons. For this area of application, too, favorable

strength characteristics at elevated temperatures are being demanded, in addition to other required properties such as high wear resistance, low density, low thermal expansion and good castability. These requirements can hitherto only
5 be met with casting alloys with relatively high Si contents and admixtures of Cu. However, such alloys are hardly suitable for pressure die casting processes due to their tendency to form inclusions of air.

10 The term high-temperature strength is generally understood to mean the strength of the material at elevated temperatures. The highest values in terms of high-temperature strength are exhibited, inter alia, by the alloys of the 2xxx type (AlCu). High-temperature strength is achieved,
15 among other things, by increased amounts of Si, Cu, Ni or Fe, whereby, however, a deterioration of the mechanical properties (e.g. fracture toughness) is caused (F. OSTERMANN, loc. cit., pp 300-303).

20 At higher temperatures, there may occur not only an irreversible change in the microstructure and thus an irreversible reduction in strength, but also creep processes, wherein the material or component is slowly plastically deformed. Aluminum materials with favorable creep properties
25 are among the alloys of the 3xxx, 5xxx and 6xxx alloy systems (F. OSTERMANN: "Anwendungstechnologie Aluminium", 3rd edition, pp 300-304, Berlin 2014). For joining techniques such as welding or soldering/brazing, aluminum alloys of the type 4xxx are normally used.

30

Usually, the required mechanical properties, especially a high hardness, are achieved by addition of copper or zinc to the alloys. In addition, these alloys are subjected to a

heat treatment to achieve an improvement in mechanical properties due to the hardening effects. Here, metastable phases are formed to counteract dislocation movements upon application of force. Alternatively, Al-Mn alloys are
5 used.

A prerequisite for the solderability/brazeability of an alloy is that the solidus temperature of the material is above the liquidus temperature of the solder. In brazing,
10 the working temperature is generally 440 to 600 °C; in soldering, the working temperature is below 440 °C.

The temperature profile of the brazing process significantly affects the mechanical properties. Where temperatures
15 near the solidus are used, this leads to a softening of the material. A gain in strength can only be achieved by subsequent natural or artificial age-hardening with rapid cooling of the structure.

20 The number of brazeable aluminum alloys is very limited. This is a result of the above-mentioned condition that the solidus temperature of the material must be above the liquidus temperature of the brazing solder. Prevalent Al-Mn alloys are less susceptible to the effects of heat, but at
25 processing temperatures near solidus point they also exhibit deficits in hardness stability.

Furthermore, aluminum alloys for high temperature applications are known which contain additions of alloying elements from the group of rare earth metals (e.g. Sc, Er).
30 These rare earth metals form dispersoids in the aluminum matrix (e.g. of the Al₃Er type), which is meant to improve the mechanical properties at elevated service temperatures.

Such an alloy is known from EP 2 110 452 A1, this alloy having a high Cu content (1.0 to 8.0 wt%) but containing no Zn.

5 In view of the above-described requirements, the object of the present invention was to provide an aluminum alloy which is suitable for extrusion, forging and casting in permanent molds (in particular, high-pressure die casting) and which is readily castable and has a high hardness in
10 the as-cast state and during brief application of high heat. In addition, the alloy is to have good joining properties, in particular good brazeability, and high corrosion resistance. Furthermore, the alloy is to be suitable for the production of components for the automotive industry,
15 in particular components with increased high-temperature strength.

These objects are achieved with an aluminum alloy according to the main claim and by the embodiments specified in the
20 dependent claims, as well as by the components which are manufactured using the aluminum alloy of the invention and which are optionally further processed by means of joining processes, in particular thermal joining processes.

25 Using the inventive alloy composition, it is possible to achieve a high heat stability not only in extruded sections, but also in forgings and pressure die castings in the as-fabricated or as-cast condition, at good hardness values. The alloy is therefore especially suitable for pro-
30 ducing temperature-stressed parts for the automotive industry and/or for further processing by means of joining methods, in particular thermal joining processes such as brazing or welding. (Due to the increased heat stability of the

alloy, extrusion processes or other forming processes can be carried out at a higher process speed or at higher pressures, without local overheating occurring in the work-piece.)

5

The inventive alloy has the following composition:

0.2 to 1.8 wt% Si

0.2 to 1.8 wt% Mg

0.3 to 2.5 wt% Mn

10

0.2 to 1.5 wt% Fe

0.05 to 0.75 wt% Zr

0.03 to 0.18 wt% Ti.

In addition, the alloy may optionally also contain one or
15 more of the following elements in the proportions indicated below:

max. 0.1 wt% Cr

max. 0.05 wt% Cu

0.2 to 1.8 wt% Zn

20

0.02 to 0.5 wt% Er.

Furthermore, the alloy may optionally contain a Ti and B-containing grain refiner in an amount of 0.01 to 0.2 wt%. The specified composition of the alloy remains unaffected.
25 The grain refining agent is preferably added when preparing the alloy in the form of an aluminum master alloy containing the components mentioned.

The balance consists of aluminum and unavoidable impurities.
30 ties. The proportion of these impurities is preferably max. 0.05 wt% (individually) or max. 0.15 wt% (in total).

Surprisingly, it has been found that the limitation of the Cu content to a maximum of 0.05 wt% prevents the solidus point of the alloy from falling below 610 °C. Preferably, the Cu content is limited to a maximum of 0.03 wt%.

5

Furthermore, it was found that by adjusting the Mn content in the range of 0.3 to 2.5 wt%, preferably in the range of 0.8 to 1.5 wt% Mn, more preferably 1.2 to 1.5 wt% Mn, a high dimensional strength at elevated temperatures can be secured, so that during demolding very little or no warpage is to be expected. Furthermore, in the case of production by means of casting methods, especially pressure die casting, the Mn contents employed in accordance with the present invention prevent any sticking in the mold and ensure demoldability.

10
15

Further, it has been found, surprisingly, that by setting the iron/manganese ratio (based on percentage by weight) to the range of 0.5 to 0.7, in particular to the range of 0.6 to 0.7, improvement of the castability of the alloy is effected. It is particularly advantageous if the Fe/Mn ratio is 2:3 (= 0.67).

20

The preferred silicon content is 0.6 to 0.8 wt%, in particular 0.7 wt%. With respect to the Si content, it has also been found that an adjustment of the Si/Mg ratio in the range of 0.9 to 1.1 has a favorable effect on the hardness of the alloy and on its castability. For optimum hardness and castability, a Si/Mg ratio of 1:1 should preferably be maintained.

25
30

The preferred zirconium content is 0.08 to 0.35 wt%, in particular 0.1 to 0.3 wt%. With respect to the Zr content,

it was also found that the heat stability and castability of the alloy can be further increased if the Ti/Zr ratio is in the range of 0.15 to 1, preferably 1:4 (= 0.25).

5 The Fe content is 0.2 to 1.5 wt%, preferably 0.2 to 1.0 wt%, in particular 0.2 to 0.8 wt%. The Fe content is preferably adjusted depending on the Fe content, as explained above (Fe/Mn ratio).

10 The Mg content is in the range from 0.2 to 1.8 wt% Mg, preferably 0.2 to 1.2 wt%, in particular 0.2 to 0.9 wt%, and is more preferably 0.7 wt%.
The Mg content is preferably set depending on the Si content, as discussed above (Si/Mg ratio).

15 The Ti content is in the range of 0.03 to 0.18 wt%, preferably in the range of 0.05 to 0.1 wt%. The Ti content is preferably set depending on the Zr content, as explained above (Ti/Zr ratio).

20 Further, it has been found, surprisingly, that by the addition of erbium (Er), the heat stability of the alloy can be further increased. According to a preferred embodiment, the inventive alloy therefore contains erbium as a further alloying element. The desired effect is achieved by adding
25 0.02 to 0.5 wt% Er. Preferably, this proportion is in the range of 0.02 to 0.3 wt% Er.

30 Furthermore, it has surprisingly been found that by the addition of zinc (Zn), the heat stability of the alloy can be further increased. According to a preferred embodiment, the alloy of the invention thus contains zinc as a further alloying element. The optional Zn content is in the range of

0.2 to 1.8 wt% of Zn; it is preferably 0.4 to 0.8 wt%, in particular 0.5 to 0.7 wt%. According to further embodiments, the Zn content is in the range of 0.4 to 1.2 wt%, preferably from 0.6 to 1.2 wt%, in particular 1 wt%.

5

Furthermore, it was surprisingly found that the alloying elements Zn and Er, when used in combination, allow a further increase in heat stability. In particular by adding, in combination, 0.02 wt% to 0.5 wt% Er, and 0.2 to 1.8 wt% Zn, preferably 0.4 to 0.8 wt% Zn, such an increase can be achieved.

15 Preferably, the inventive alloy is subjected to a grain refinement wherein a Ti and B-containing grain refiner is used. The proportion of the grain refining agent in the inventive alloy is preferably 0.5 to 2 kg/t, more preferably 1.5 kg/t.

20 Preferably, an aluminum master alloy which contains Ti and B (balance: aluminum) and which during the production of the alloy is added in a proportion of preferably 0.5 to 2 kg/t, particularly preferably 1.5 kg/t, is used as a grain refiner. In such an Al master alloy, Ti and B are substantially contained in a crystalline or particulate form, which can serve as crystallization nuclei (e.g. TiB₂, Al₃Ti AlTi₅B₁, AlTi₆).

25 Preferably, the master alloy contains 2.7 to 3.2 wt% Ti, in particular 2.9 to 3.1 wt% Ti, and 0.6 to 1.1 wt% B, in particular 0.8 to 0.9 wt% B, in each case aluminum being the balance.

30

Furthermore, it is preferred that the weight ratio of Ti/B in the master alloy be 2.5 to 3.5, in particular 3:1 (= 3.0).

5 The aluminum alloy of the invention and the components produced therefrom are distinguished in that they have a Brinell hardness of at least 55 HBW5/250, preferably at least 65 HBW5/250, more preferably at least 80 HBW5/250.

10 The aluminum alloy of the invention and the components made therefrom are further distinguished by a solidus temperature of ≥ 610 °C, in particular ≥ 630 °C.

Depending on the application or requirement profile, the
15 inventive alloy can optionally be subjected to a heat treatment. This is preferably carried out for a time period of 2 to 42 hours, in particular 6 to 24 hours, at a temperature in the range of 325 to 425 °C, in particular 350 to 400 °C. This is followed by air cooling, or the heat-
20 treated alloy is quenched in a suitable gaseous (e.g., air or inert gas) or liquid medium (e.g., water or oil). The preferred heat treatment is carried out at 6-24 h and 350-400 °C, followed by air cooling.

25 The inventive alloy can be used for the production of components for different applications, preferably for applications in the automotive industry. The inventive alloy, in particular the heat-treated alloy (see above), is suitable for the production of components that are subjected to high
30 operating temperatures - e.g. up to 250 °C or up to 300 °C (e.g., engine components or gearbox components, such as pistons, cylinder heads, engine blocks, gearbox housings, heat exchanger).

Furthermore, the alloy of the invention is especially suitable for components which are further processed by means of thermal joining methods such as soldering/brazing (in particular, brazing) or welding. The inventive alloy is suitable for the soldering/brazing of aluminum components using flux, for example in the automotive industry and in HVAC technology, as well as for processes in soldering/brazing furnaces; especially for the manufacture of heat exchangers.

The invention thus extends to components that are prepared from an alloy - defined in more detail above. Preferably, the components are manufactured by casting in permanent molds, in particular by high-pressure die casting, or by extruding, or by forging. If necessary, the components can be further processed by means of other methods, in particular thermal joining methods (e.g., soldering/brazing, welding), or by forging, to obtain complex assemblies or components having complex geometries.

In general, the heat resistance of components made from the alloy of the present invention can, if desired, be further increased by subjecting the components to artificial ageing. In addition, an increase in the Brinell hardness can be achieved by such a heat treatment.

Surprisingly, it has been found that the high hardness (typically in the range of 50 to 70 HBW 5/250) present in the components produced with the inventive alloy in the condition as manufactured, can be increased even further by performing a heat treatment at 150 to 240 °C, preferably 180 to 220 °C, particularly preferably at 200 °C, for a pe-

riod of 4 h to 72 h, preferably 8 to 24 h, more preferably 8 to 12 h. After such heat treatment, the components have an increased Brinell value (HBW5/250) which typically corresponds to 1.1 to 1.5 times the initial value (prior to heat treatment). It is possible to increase hardness even further.

By performing a heat treatment as described above, components can be obtained which have a Brinell hardness (HBW5/250) of at least 70, preferably at least 80. Preferably, the components thus prepared have a Brinell hardness in the range of 70 to 120, in particular in the range of 75 to 95.

The alloys of the invention and the components produced therefrom are distinguished by a high heat stability under exposure to high heat, even over prolonged periods. As a result, the mechanical properties, especially hardness, are largely stable under such temperature conditions.

Under the influence of elevated temperatures, the components produced from the alloy of the invention generally exhibit the behavior described below in terms of temperature-dependent change in hardness (Brinell hardness):

- Heat exposure of the components to 150 to 240 °C, preferably 180 to 220 °C, particularly preferably 200 °C, for a period of 4 h to 72 h, preferably 8 to 24 h, more preferably 8 to 12 h, generally causes an increase in hardness. Due to this increase, the components have a Brinell value which corresponds to at least 1.1 to 1.5 times the initial Brinell value (HBW5/250). Even a prolonged heat treatment (e.g. more than 3 d, up to 30 d,

or even longer), as may occur for example during the use or under the service conditions of the components, has no adverse effects on the hardness or other mechanical properties of the components.

5

- If the heat exposure is carried out for a prolonged period (>3 d, especially 4 d, or even longer, such as 30 d) at the above indicated temperatures, the components thereafter exhibit a Brinell hardness corresponding to at least 1 to 1.3 times the initial Brinell value (HBW5/250). Preferably, even on prolonged application of heat (3 d or longer, in particular 4 d or more, e.g. 30 d) at the temperatures indicated above, no deterioration of hardness occurs. The initially present hardness properties are, at least, substantially maintained unless - as described - an increase in hardness is achieved.

- Heat exposure of the components to 260 to 350 °C, preferably 280 to 320 °C, particularly preferably 300 °C, for a period of 4 h to 72 h, preferably 8 to 24 h, more preferably 8 to 12 h, will result in a slight decrease in hardness only. In general, after such a heat treatment the Brinell hardness will still amount to 80-95% of the initial value (that is, based on the as-fabricated condition). Preferably, even on prolonged application of heat (3 d or more, in particular 4 d or more, e.g. up to 30 d) at the temperatures indicated above, no further change in the Brinell hardness occurs (that is, it remains substantially constant at about 80-95% of the initial value).

Another important and advantageous property of the alloy of the invention is that the components thus produced can be temporarily exposed to a temperature that is close to the solidus point, without thereby causing a substantial deterioration of the hardness or other mechanical properties. This heat stability is of practical importance since components are exposed to such a thermal load when they are further processed, for example, by means of thermal joining methods (in particular, brazing or welding).

10

The components produced using the inventive alloy can briefly (≤ 30 min, preferably ≤ 20 min, especially ≤ 15 min) be subjected to a temperature of 400 to 650 °C, preferably 400 to 620 °C, especially 400 to 610 °C, without thereby causing a relevant deterioration of their mechanical properties, particularly their hardness. After exposure to heat as indicated above, only a slight decrease in hardness is observed. In general, after such a brief exposure to heat, the Brinell hardness still amounts to 70-95% of the initial value (as-prepared condition).

20

The alloy of the invention and the components made therefrom thus fulfill the aforementioned requirements, particularly with regard to heat stability on exposure to high heat.

25

The inventive aluminum alloy is above all suitable for the manufacture of components for the automotive industry by pressure die casting, forging or extrusion, wherein said components can optionally be further processed by joining processes, in particular by means of thermal joining processes.

30

The inventive aluminum alloy can preferably be used for the production of components which, during their manufacture, their further processing or in subsequent use, are subject to increased requirements in terms of temperature, such as
5 engine or gearbox components (e.g. pistons, cylinder heads, engine blocks, gearbox housings, etc.) heat exchangers, as well as chassis components and body components.

The inventive aluminum alloy can be prepared by methods
10 known to those skilled in the art, typically by preparing a melt having a composition corresponding to the above-mentioned alloy composition of the invention. The alloying elements Ti and B are preferably added in the form of a master alloy during the production of the alloy, as ex-
15 plained above.

The alloy of the invention is preferably prepared using the vertical continuous casting method. By means of a prior gas treatment of the melt with inert gases, sufficient melt
20 quality is ensured and a hydrogen-poor cast product is produced; this is also an important prerequisite for achieving a high hardness stability on exposure to heat. Methods for treating metal melts with inert gases are known in the art.

25 According to a preferred embodiment, the alloy, after its preparation, is subjected to an optional heat treatment. This heat treatment is preferably carried out for a period of 2 to 42 hours, in particular 6 to 24 hours, at a temperature in the range of 325 to 425 °C, in particular 350 to
30 400 °C. This is followed by air cooling, or the heat-treated alloy is quenched in a suitable gaseous (e.g., air or inert gas) or liquid medium (e.g. water or oil). The

preferred heat treatment is carried out for 6 to 24 h and at 350-400 °C and is followed by air cooling.

Using the alloy of the invention, components can also be fabricated by known methods, preferably by extrusion, casting in permanent molds (in particular, die-casting) and/or forging. Optionally, the components can be subjected to further processing by means of joining methods (in particular, brazing or welding) or by means of forming processes.

10

According to a preferred embodiment, the components produced from an alloy of the present invention are subjected to an optional heat treatment (artificial aging) for the purpose of increasing their hardness. This heat treatment is performed at 150 to 240 °C, preferably 180 to 220 °C, particularly preferably at 200 °C, during a period of 4 h to 72 h, preferably 8 to 24 h, more preferably 8 to 12 h.

15

Examples

20

As a starting point or comparative alloy, an Al-Mn alloy based on EN AW-3103 which is known under the trade name "Aluman 16" (AlMn1,6; manufactured by Aluminium Rheinfelden GmbH) was used. This alloy can be brazed due to its high solidification point, and it is suitable for the die casting process. The alloy is used in the manufacture of coolers and in the food industry.

25

The composition of this alloy is given in Table 1 (below) (first row, "V").

30

Due to its relatively high Mn and Fe contents, this alloy is characterized by good heat stability at elevated temper-

atures. However, with the above-described new areas of application (particularly for applications in the automotive industry) this alloy has reached its limits. In particular, the hardness is no longer sufficient to meet the required component properties. Here, it was possible to achieve a significant improvement by using the alloy described in the present application, as is shown by the test results given in Tables 2, 3 and 4 shown below.

10 **Table 1: Alloy Compositions**

| | Si | Mg | Mn | Fe | Zn | Zr | Ti | Cr | Cu | Er | Solidus [°C] |
|-----|------|------|-----|-----|-----|-----|------|------|------|------|--------------|
| V | 0.15 | 0.05 | 1.5 | 0.9 | 0.1 | - | 0.15 | - | 0.03 | - | 650 |
| L1 | 0.7 | 0.7 | 1.5 | 0.8 | - | 0.1 | 0.1 | 0.06 | - | - | 635 |
| L2 | 0.7 | 0.7 | 1.2 | 0.8 | - | 0.2 | 0.05 | 0.06 | - | - | 630 |
| L3 | 0.7 | 0.7 | 1.2 | 0.8 | - | 0.3 | 0.05 | 0.06 | - | - | 630 |
| L5 | 0.7 | 0.7 | 1.2 | 0.8 | - | 0.3 | 0.05 | 0.06 | - | 0.05 | 630 |
| L6 | 0.7 | 0.7 | 1.2 | 0.8 | 0.8 | 0.3 | 0.05 | 0.06 | - | - | 620 |
| L7 | 0.7 | 0.7 | 1.2 | 0.8 | 0.8 | 0.3 | 0.05 | 0.06 | 0.03 | - | 615 |
| L4 | 0.7 | 0.7 | 1.2 | 0.8 | 0.6 | 0.3 | 0.08 | 0.06 | - | 0.1 | 625 |
| L8* | 0.7 | 0.7 | 1.2 | 0.8 | 0.6 | 0.3 | 0.08 | 0.06 | - | 0.1 | 625 |

* Heat-treated according to claim 18

All values in wt%; balance: Al and unavoidable impurities. The rows designated by L1, L2, L3, L4, L5, L6 and L7 relate to alloy variants according to the present invention. L8 corresponds to L7 with additional heat treatment according to claim 18, and likewise constitutes an alloy of the invention.

20

Seven alloys, L1, L2, L3, L4, L5, L6 and L7 of the present invention, whose composition is given in Table 1, were prepared by melting. L8 corresponds to L7 with additional heat treatment according to claim 18. As a reference, a comparative alloy V ("Aluman-16", see above), the composition of which is also shown in Tab. 1, was smelted. Cylindrical test bodies (\varnothing 40 mm; height 30 mm) were cast from all eight alloys.

10 To test the influence of temperature on the change in hardness, the test specimens cast from the eight alloys were subjected to different heat applications.

The tests were performed at three temperatures during periods of different length. The results are given in Tables 2, 3 and 4 below.

15 Long-term tests were performed at 200 °C (Tab. 2) and 300 °C (Tab. 3), in each case for a period of 10 h and 100 h.

20 Furthermore, a short-term test was performed at 600 °C, for a duration of 900 s (15 min) (Tab. 4) in order to simulate the thermal load and the behavior of the alloys in thermal joining processes.

25 After the heat treatment, the test specimens treated under the specified temperature conditions were cooled to room temperature (ca. 25 °C.) in air, and then subjected to a Brinell hardness test (HBW5/250; tungsten carbide hard metal-test ball; ball diameter 5 mm). The arithmetic mean of the measured hardness values is listed in Tables 2, 3 and 4.

30 The results show that all the aluminum alloys of the invention (L1 to L8) regardless of the duration of the exposure

to heat have a higher hardness than the comparative alloy V.

5 It has been found that, already in the as-cast condition (that is, before the test), the inventive alloy variants (L1 to L8) exhibit a markedly greater hardness compared to the comparative alloy V. In the case of the heat treatment at 200 °C (10 h) it was even possible to increase hardness even further (see Tab. 2).

10

All other tests show that the alloy variants of the present invention (L1 to L8) are superior to the comparative alloy in terms of hardness values. It is true that at higher temperatures or with longer duration of the test a decrease in
15 hardness, as compared to the as-cast state, is observed (see Tab. 3 and 4), but the hardness values thus achieved are still above the hardness values of the comparative alloy.

20 Even the short-term test conducted at 600 °C shows a clear result. The measured hardness values of the inventive aluminum alloys L1 to L8 exceed the hardness value of the comparative alloy V by more than 10 Brinell hardness units.

Table 2: Hardness comparison (HBW5/250) at 200 °C

| | Prior to testing | 10 h | 100 h |
|----|------------------|------|-------|
| V | 42 | 43 | 45 |
| L1 | 72 | 85 | 74 |
| L2 | 69 | 80 | 72 |
| L3 | 57 | 83 | 73 |
| L5 | 62 | 83 | 74 |
| L6 | 65 | 85 | 72 |
| L7 | 65 | 83 | 72 |
| L4 | 69 | 81 | 74 |
| L8 | 72 | 81 | 75 |

Table 3: Hardness comparison (HBW5/250) at 300 °C

| | Prior to testing | 10 h | 100 h |
|----|------------------|------|-------|
| V | 42 | 43 | 43 |
| L1 | 72 | 58 | 58 |
| L2 | 69 | 60 | 55 |
| L3 | 57 | 55 | 57 |
| L5 | 62 | 58 | 58 |
| L6 | 65 | 56 | 55 |
| L7 | 65 | 56 | 55 |
| L4 | 69 | 60 | 58 |
| L8 | 72 | 62 | 60 |

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Table 4: Hardness comparison (HBW5/250) at 600 °C

| | Prior to testing | 900 s |
|----|------------------|-------|
| V | 42 | 40 |
| L1 | 72 | 52 |
| L2 | 69 | 54 |
| L3 | 57 | 55 |
| L5 | 62 | 56 |
| L6 | 65 | 54 |
| L7 | 65 | 51 |
| L4 | 69 | 57 |
| L8 | 72 | 60 |

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Claims

1. An aluminum alloy for components having increased heat stability, particularly for the production of such components by means of extrusion, forging or casting in permanent molds, the alloy having the following composition:
- 0.2 to 1.8 wt% of Si
 - 0.2 to 1.8 wt% of Mg
 - 0.8 to 2.5 wt% of Mn
 - 10 0.2 to 1.5 wt% of Fe
 - 0.05 to 0.75 wt% of Zr
 - 0.03 to 0.18 wt% of Ti,
- optionally one or more of the following elements:
- max. 0.1 wt% of Cr,
 - 15 max. 0.05 wt% of Cu,
 - 0.2 to 1.8 wt% of Zn
 - 0.02 to 0.5 wt% of Er;
- and optionally 0.01 to 0.2 wt% of a grain refiner containing Ti and B;
- 20 the balance being aluminum and inevitable impurities.
2. The aluminum alloy according to claim 1, characterized in that the Mn content is 0.8 to 1.5 wt%, preferably 1.2 to 1.5 wt%.
- 25
3. The aluminum alloy according to claim 1 or 2, characterized in that the ratio Fe/Mn is in the range of 0.5 to 0.7, preferably 2:3.
- 30 4. The aluminum alloy according to any one of the preceding claims, characterized in that the Si content is 0.6 to 0.8 wt%, preferably 0.7 wt%.

5. The aluminum alloy according to any one of the preceding claims, characterized in that the ratio Mg/Si is in the range of 0.9 to 1.1, preferably 1:1.
- 5 6. The aluminum alloy according to any one of the preceding claims, characterized in that the Zr content is from 0.08 to 0.35 wt%, preferably 0.1 to 0.3 wt%.
7. The aluminum alloy according to any one of the preceding
10 ing claims, characterized in that the ratio Ti/Zr is in the range of 0.15 to 1, preferably 1:4.
8. The aluminum alloy according to any one of the preceding
15 amount not exceeding 0.05 wt%, preferably not exceeding 0.03 wt%.
9. The aluminum alloy according to any one of the preceding
20 amount not exceeding 0.1 wt%, preferably not exceeding 0.08 wt%.
10. The aluminum alloy according to any one of the preceding
25 0.5 wt% Er, preferably 0.02 to 0.3 wt% Er.
11. The aluminum alloy according to any one of the preceding
30 ing claims, characterized in that the Zn content is 0.4 to 0.8 wt%, preferably 0.5 to 0.7 wt%.
12. The aluminum alloy according to any one of claims 1 to 10, characterized in that the Zn-content is 0.4 to 1.2 wt%, preferably 0.6 to 1.2 wt%, particularly 1 wt%.

13. The aluminum alloy according to any one of the preceding claims, characterized in that it has a Brinell hardness (HBW5/250) of at least 55, preferably at least 65, more preferably at least 80.

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14. The aluminum alloy according to any one of the preceding claims, characterized in that its solidus temperature is ≥ 610 °C.

10 15. The aluminum alloy according to any one of the preceding claims, characterized in that it was heat-treated for 2 to 42 h, preferably 6 to 24 h, at 325 to 425 °C, preferably at 350 to 400 °C, followed by cooling in a gaseous or liquid medium.

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16. A component, in particular for the automotive industry, made of an alloy according to any one of the preceding claims.

20 17. The component according to claim 16, characterized in that it is produced by casting in permanent molds, in particular by pressure die casting, or by forging, or by extrusion.

25 18. The component according to claim 16 or 17, characterized in that it is subjected to a heat treatment for 4 h to 72 h, preferably for 8 to 24 h, at 150 to 250 °C, preferably at 180 to 220 °C.

30 19. The component according to claim 18, characterized in that it has a Brinell hardness (HBW5/250) in the range of 70 to 120, in particular in the range of 75 to 95.

20. The component according to any one of claims 16 to 19, characterized in that it has been further processed by means of one or more thermal joining processes, preferably by means of soldering/brazing or welding.

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21. Use of an aluminum alloy according to any one of claims 1 to 15 for the manufacture of components for the automotive industry by pressure die casting, forging or extrusion, wherein the components are optionally further processed by joining processes, in particular by means of thermal joining processes.

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