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“Progress by tradition”

ALUMINIUM RHEINFELDEN group: This history of aluminium in Germany started at Rheinfelden. In 1898 Europe’s first river power station brought about the establishment of the first aluminium smelter in Germany, at Rheinfelden, Baden. The company has always operated in three business segments and in October 2008 restructuring turned ALUMINIUM RHEINFELDEN GmbH into a holding company and the former ALLOYS, SEMIS and CARBON divisions became independent GmbH & Co. KGs.

www.rheinfelden-group.eu

RHEINFELDEN ALLOYS GmbH & Co. KG: Products of RHEINFELDEN ALLOYS can be found wherever steel designs or iron casts can be replaced by light aluminium casts. RHEINFELDEN ALLOYS is a powerful partner, especially to the automotive and mechanical engineering sectors in providing alloys designed to the process and cast part based on the customer’s particular needs.

www.rheinfelden-alloys.eu · Tel. +49 7623 93 490

RHEINFELDEN SEMIS GmbH & Co. KG
www.rheinfelden-semis.eu

RHEINFELDEN CARBON GmbH & Co. KG
www.rheinfelden-carbon.eu

Our policy

Our RHEINFELDEN ALLOYS GmbH & Co. KG innovative character is what allows us to adapt rapidly to fast changing market needs. The agility of a private family owned operated company, the central geographic location in the European cast metal market, the know-how and experience of our team, are factors making a difference for Customers looking for reliable tradition and modern innovation. Efficient and effective use of cast aluminium is on the forefront of our new developments in materials.

It is RHEINFELDEN ALLOYS philosophy to fulfill also the newest requested standards of quality, either ISO or VDA. Please ask for our actual certificates or have a look at our homepage.

We offer customized alloys and new solutions for high performance materials and light weight components with focus on low carbon footprint products. Everywhere where steel construction, cast iron or composites can be replaced by light-weight cast aluminum, we’re at work!
RHEINFELDEN FAST ALLOYS

Ordered today
Produced tomorrow
Ready for shipment one day later

Seven good reasons for RHEINFELDEN FAST ALLOYS

• No storage costs
• No finance costs
• No LME speculation
• No supply bottleneck
• Flexibility for your production
• Contemporary reaction to market change
• Higher flexibility close to your customer’s request
Forms of delivery

**RHEINFELDEN-Ingot**: Since the new RHEINFELDEN Production System came on line, all our materials have been supplied in the form of RHEINFELDEN ingots. This ingot form is replacing the HSG ingot yet retains all the advantages of the old form of delivery.

**Liquid metal**: If you want us to deliver metal to go straight into production, we can also supply liquid metal.

**Chemical analysis**: The delivery slip contains the average actual batch analysis.

**Stack labelling**: Each stack features an information box containing the brand name and/or alloy group name, internal material number, stack weight and on request a colour marking. The batch number consists of the year in the sequential production number and the number in the sequenze. Machine-readable bar codes can be printed in this box.

<table>
<thead>
<tr>
<th>Ingot</th>
<th>Stack of 13 layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>Stack weight</td>
</tr>
<tr>
<td>6 – 8 kg</td>
<td>760 kg</td>
</tr>
<tr>
<td>Surface</td>
<td>Stack surface</td>
</tr>
<tr>
<td>716 × 108 mm</td>
<td>716 × 716 mm</td>
</tr>
<tr>
<td>Height</td>
<td>Stack height</td>
</tr>
<tr>
<td>bis 52 mm</td>
<td>780 mm</td>
</tr>
</tbody>
</table>

The stack of RHEINFELDEN ALLOYS is built with 95 single ingots including the 4 base ingots; here the highest stack with 13 layers of ingots.
Customer support and research and development

When RHEINFELDEN ALLOYS develop new materials we always aim to achieve efficient and
specific use of aluminium cast. Through the use of materials tailored and refined to increase perfor-
mane, RHEINFELDEN ALLOYS is constantly striving to help reduce vehicle weight and therefore
cut fuel consumption and CO₂-emissions.

Every product and every customer has individual requirements of the material. The Customer
Support team at RHEINFELDEN ALLOYS has the job of anticipating these needs and producing
tailored materials, fitting the casts and your requirements.

RHEINFELDEN Customer Support
Please contact our customer support team and use our TechCenter installations at RHEINFELDEN
ALLOYS also for your foundry concerns. We can advise on the use of aluminium cast, the design of
casts and the choice of alloy. Use our experience for your success.

RHEINFELDEN technical center
Time is increasingly of the essence when our customers experience casting technology problems.
It is therefore crucial that we have the facilities to allow us to quickly solve problems through
experimentation and immediately incorporate new findings into production. This technical support,
renowned throughout the industry, is available exclusively to RHEINFELDEN ALLOYS customers.

Goals of research and development
The technical center assists the customer support team and runs development projects with the
following goals:
• To optimise the mechanical and cast properties of our aluminium cast alloys
• To develop alloys under consideration of the appropriate casting method
• To collaborate with designers on use of our cast alloy most suited to their applications,
  including testing mechanical properties

RHEINFELDEN sales service
The portfolio of RHEINFELDEN ALLOYS sales department is always adjusted to the request of
our customer. RHEINFELDEN ALLOYS has the possibility to offer different commercial strategies.

RHEINFELDEN Internet portal www.rheinfelden-alloys.eu

We at RHEINFELDEN ALLOYS development use also phase
simulation software for calculations and optimization of our
wide range of cast alloys. Highlighted is here the solidification and
phase growing simulation of Magsimal-59.
Aluminium casting alloys by RHEINFELDEN ALLOYS

Get the spirit of RHEINFELDEN

Quick finder for selecting the right alloy

The following table provides an overview of RHEINFELDEN ALLOYS, which are used in the car building industry either for structural and chassis parts or either for heat conducting parts. Further on table presents some details of the alloy properties.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Chemical denomination</th>
<th>Sand casting</th>
<th>Gravity die</th>
<th>HPDC</th>
<th>Frangibility</th>
<th>Electrical conductivity</th>
<th>Suitable for technical anodising</th>
<th>Suitable for punch riveting</th>
<th>Strength in as-cast state</th>
<th>Elongation</th>
<th>Hardness</th>
<th>Corrosion resistance for constructions with thin walls</th>
<th>Impact toughness</th>
<th>Machinability at F</th>
<th>Mechanical properties at elevated temperatures (200°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anticorodal-70</td>
<td>AlSi7Mg0.3</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
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<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Silafont-36</td>
<td>AlSi10MnMg</td>
<td>−</td>
<td>−</td>
<td>−</td>
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<td>−</td>
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</tr>
<tr>
<td>Silafont-38</td>
<td>AlSi10MnMgZn</td>
<td>−</td>
<td>−</td>
<td>−</td>
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<td>−</td>
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<tr>
<td>Silafont-09</td>
<td>AlSi9</td>
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<tr>
<td>Castasil-37</td>
<td>AlSi9MnMoZr</td>
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<td>Unifont-94</td>
<td>AlZn10Si8Mg</td>
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<td>Castadur-30</td>
<td>AlZn3Mg3Cr</td>
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<tr>
<td>Magsimal-59</td>
<td>AlMg5Si2Mn</td>
<td>−</td>
<td>−</td>
<td>−</td>
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<td>−</td>
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<td>Alufont-52</td>
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<tr>
<td>Thermodur-72</td>
<td>AlMg7Si3Mn</td>
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<td>Thermodur-73</td>
<td>AlSi10Cu2Mg2</td>
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<tr>
<td>Anticorodal-71</td>
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</tr>
<tr>
<td>Rotoren-Al 99.7</td>
<td>Al99.7E</td>
<td>−</td>
<td>−</td>
<td>−</td>
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<td>Castasil-21</td>
<td>AlSi9Sr</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
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</tr>
</tbody>
</table>

- excellent
- very good
- good
- OK
- poor
- not applicable
**Castasil® – large surface, high dimensional stability, fantastic to cast**

An alloy, produced for large high pressure die cast structural parts in the automotive construction industry. In the meantime several OEMs recognised the advantages of these alloys for car structural or electrical applications: high dimensional stability, can be used without heat treatment, shape well and easy to weld, or by Castasil-21 with highest electrical or heat conductivity.

Nature’s equivalent: the vine branch which turns towards the sun, flexible, elastic and yet incredibly tough and strong.  > page 11

---

**Silafont® – an infinite wealth of properties**

A family of materials which can be adapted to the part specifications and to the customer’s individual production process with ultimate precision. Can be processed using any casting procedure, outstanding flow properties, can be modified with sodium or strontium to further enhance properties. Silafont is for complex, delicate components which have to satisfy precisely defined requirements and, if they feature the right components, make maximum production efficiency possible.

Silafont emulates flowing water, that flows around every stone and fills every cavity.  > page 25

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**Castaman® – Reducing the Carbon-Footprint**

An alloy family, that uses the possibilities of recycling, for a desired high sustainability – represented in carbon footprint counter.

Nature’s role model: the lupine, growing from the humus of last year’s crop.  > page 39

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**Thermodur® – a glimpse into the future**

A new material that withstands high temperatures like never before, allowing to play a key role in increased efficiency in combustion engines: increased output, lower fuel consumption, greater durability and lower CO₂ emissions.

This alloy simulates the spider’s silk: outstanding mechanical properties, maximum strength, stable, resilient and incredibly light.  > page 41

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**Magsimal® – of filigree lightness, but extremely resilient**

An alloy for delicate parts which need to retain their strength and precise form over a long period. Good weldability, high resilience, can be used in virtually any application.

Supreme corrosion resistance, even to salt water.

Parts which simulate the structure of the wings of a dragonfly: wafer thin, elastic and yet offering incredible strength and resilience, they enable this dainty insect to fly distances that never cease to amaze.  > page 43
Profile of the alloys for the die casters

**Silafont®-36 [AlSi10MnMg]**
- excellent castability
- applicable to thinnest wall designs
- magnesium content adjustable to a wide range of requirements
- good die cast ejectability
- heat treatable to highest elongation and ductility
- very high corrosion resistance

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>( R_{p0.2} ) [MPa]</th>
<th>( R_m ) [MPa]</th>
<th>A [%]</th>
<th>Hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>120 – 150</td>
<td>250 – 290</td>
<td>5 – 11</td>
<td>75 – 95</td>
</tr>
<tr>
<td>T7</td>
<td>120 – 170</td>
<td>200 – 240</td>
<td>15 – 20</td>
<td>60 – 75</td>
</tr>
</tbody>
</table>

**Silafont®-38 [AlSi9MnMgZn]**
- applicable to thinnest wall designs and complex designs
- an air cooling after solutionizing reduce casting distorsion
- alloying elements enables highest strength and good crash properties
- very high corrosion resistance due to exact alloy limits
- high fatigue properties
- excellent weldability and machinability
- suitable for self piercing

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>( R_{p0.2} ) [MPa]</th>
<th>( R_m ) [MPa]</th>
<th>A [%]</th>
<th>Hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>water-T6</td>
<td>230 – 270</td>
<td>300 – 345</td>
<td>6 – 9</td>
<td>90 – 115</td>
</tr>
<tr>
<td>air-T6</td>
<td>180 – 200</td>
<td>250 – 275</td>
<td>8 – 10</td>
<td>80 – 110</td>
</tr>
</tbody>
</table>

**Castasil®-21 [AlSi9Sr]**
- highest heat and electrical conductivity compared to AlSi die casting alloys due to low disturbing impurities
- thin wall design possible
- good die cast ejectability
- long-term stability after temper O
- high yield strength and elongation in the as-cast state or after temper O
- suitable for flanging, clinching or self piercing, especially in temper O

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>( R_{p0.2} ) [MPa]</th>
<th>( R_m ) [MPa]</th>
<th>A [%]</th>
<th>Conductibility [MS/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>90 – 100</td>
<td>200 – 230</td>
<td>6 – 9</td>
<td>23 – 25</td>
</tr>
</tbody>
</table>

**Castasil®-37 [AlSi9MnMoZr]**
- no heat treatment needed to reach high elongation
- good die cast ejectability; usable even for thinnest wall thicknesses
- long-term stability
- high yield strength and excellent elongation in the as-cast state
- very good corrosion resistance
- high fatigue stress resistance; highest compared to AlSi-alloys
- excellent weldability; Suitable for flanging, clinching or self piercing

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>Wall thickness [mm]</th>
<th>( R_{p0.2} ) [MPa]</th>
<th>( R_m ) [MPa]</th>
<th>A [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>2 – 3</td>
<td>120 – 150</td>
<td>260 – 300</td>
<td>10 – 14</td>
</tr>
<tr>
<td>F</td>
<td>3 – 5</td>
<td>100 – 130</td>
<td>230 – 280</td>
<td>10 – 14</td>
</tr>
</tbody>
</table>

**Castasil®-37 [AlSi9MnMoZr]**
- highest heat and electrical conductivity compared to AlSi die casting alloys due to low disturbing impurities
- thin wall design possible
- good die cast ejectability
- long-term stability after temper O
- high yield strength and elongation in the as-cast state or after temper O
- suitable for flanging, clinching or self piercing, especially in temper O

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>( R_{p0.2} ) [MPa]</th>
<th>( R_m ) [MPa]</th>
<th>A [%]</th>
<th>Conductibility [MS/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>90 – 100</td>
<td>200 – 230</td>
<td>6 – 9</td>
<td>23 – 25</td>
</tr>
</tbody>
</table>
**Castaman®-35 [AlSi10MnMg]**
- Outstanding castability, even for bigger die casting designs
- Magnesium content adjustable to a wide range of requirements
- Good die cast ejectability
- Heat treatment T6 enables wide range of mechanical properties
- Very high corrosion resistance with high fatigue properties
- Excellent weldability and machinability
- Suitable for flanging, clinching or self piercing

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>$R_{p0.2}$ [MPa]</th>
<th>$R_m$ [MPa]</th>
<th>$A$ [%]</th>
<th>Hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>120 – 150</td>
<td>200 – 270</td>
<td>4 – 9</td>
<td>75 – 90</td>
</tr>
<tr>
<td>T6</td>
<td>180 – 280</td>
<td>250 – 340</td>
<td>6 – 12</td>
<td>80 – 110</td>
</tr>
</tbody>
</table>

**Thermodur®-72 [AlMg7Si3Mn]**
- Usage in the as-cast state also for thick wall HPDC
- Low melt oxidation due to patented alloy addition
- No sticking to the die
- Higher shrinkage in comparison to AlSi-alloys
- High elongation even at room temperature
- High temperature strength, especially at $> 225^\circ$C
- Very high corrosion resistance

<table>
<thead>
<tr>
<th>Ageing</th>
<th>$R_{p0.2}$ [MPa]</th>
<th>$R_m$ [MPa]</th>
<th>$A$ [%]</th>
<th>Hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td>190 – 200</td>
<td>350 – 380</td>
<td>7 – 10</td>
<td>80 – 100</td>
</tr>
<tr>
<td>225°C/500 h</td>
<td>150 – 175</td>
<td>180 – 205</td>
<td>$&lt; 20$</td>
<td></td>
</tr>
</tbody>
</table>

**Thermodur®-73 [AlSi11Cu2Ni2Mg2Mn]**
- Excellent castability, also for thick wall HPDC
- Reducing distortion is possible due to stabilising T5
- High corrosion resistance due to exact alloy limits
- High fatigue strength due to low iron content
- Excellent machinability
- Very high hardness
- High temperature strength

<table>
<thead>
<tr>
<th>Ageing</th>
<th>$R_{p0.2}$ [MPa]</th>
<th>$R_m$ [MPa]</th>
<th>$A$ [%]</th>
<th>Hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>150°C/500 h</td>
<td>280 – 310</td>
<td>330 – 355</td>
<td>$&lt; 1$</td>
<td>130 – 150</td>
</tr>
<tr>
<td>225°C/500 h</td>
<td>130 – 155</td>
<td>250 – 280</td>
<td>1 – 2</td>
<td></td>
</tr>
</tbody>
</table>

**Magsimal®-59 [AlMg5Si2Mn]**
- Usage in the as-cast state for HPDC with 2 to 8 mm wall thickness
- Low melt oxidation due to patented alloy addition
- No sticking to the die
- Higher shrinkage in comparison to AlSi-alloys
- Very high corrosion resistance, no stress corrosion
- Very high fatigue strength
- Excellent weldability, suitable for flanging, clinching and self piercing

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>Wall thickness [mm]</th>
<th>$R_{p0.2}$ [MPa]</th>
<th>$R_m$ [MPa]</th>
<th>$A$ [%]</th>
</tr>
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<tbody>
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Publications


Catalogues

Primary aluminium casting alloys  Manual
Primary aluminium casting alloys  Leporello

Manuals and processing data sheets

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<td>Aluminium for rotors</td>
<td>Al99.7-E</td>
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Reports based on real-life use and on the development of aluminium

Producing Low-iron Ductile Aluminium Die Casting in Silaforent-36  630
Experiences of series production of high pressure die cast steering wheel frames in Magsimal-59  632
Melt testing in the aluminium foundry with a focus on quality  623
The possibilities of aluminium high pressure die casting – using this technology close to the limits; Sf-36 und Ma-59  635
Potentials of aluminium pressure die casting – application of this technology close to the limits; Sf-36 and Ma-59  636
31 reasons for using aluminium casting  629
Ductile high pressure die casting alloy with low iron content; Silaforent-36  803
Recently developed high pressure die casting alloy with outstanding mechanical properties when cast; Magsimal-59  804
Non-ageing ductile high pressure die casting alloy for automotive construction; Castasil-37  806
Development by RHEINFELDEN ALLOYS Castasil-37 shows good mechanical properties, especially elongation, which are superior to those of conventional AlSi-type alloys. Outstanding castability and weldability enable the casting of complex designs. Self-piercing riveting trials in the as-cast state led for example to good results.

The properties are mainly influenced by alloying with silicon, manganese, molybdenum and strontium. A low magnesium content is essential for the excellent stability of long-term stability of mechanical properties.

Specially chosen chemical composition enables the following casting properties:
- excellent castability
- suitable for minimum wall thicknesses
- no sticking to the die

With increasing number of applications, mainly in car manufacturing, other properties of Castasil-37 became also important:
- high fatigue strength
- very good corrosion resistance
- excellent weldability
- excellent machinability
- suitable for self-piercing riveting and clinching
- suitable for glueing connections in car design
Castasil®-37 – Properties at a glance

Chemical composition of Castasil-37, AlSi9MnMoZr

<table>
<thead>
<tr>
<th></th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
<th>Mo</th>
<th>Zr</th>
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<th>Sr</th>
<th>others</th>
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<tr>
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<td>8.5</td>
<td>0.35</td>
<td>0.05</td>
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Mechanical properties

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<th>Wall thickness [mm]</th>
<th>YTS $R_{p0.2}$ [MPa]</th>
<th>UTS $R_m$ [MPa]</th>
<th>Elongation A [%]</th>
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<td>260 – 300</td>
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<td>3 – 5</td>
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<td>5 – 7</td>
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Physical composition

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<th>Unit</th>
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<tr>
<td>Solidification range</td>
<td>595 – 550 °C</td>
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<tr>
<td>Density</td>
<td>2.69 kg/dm$^3$</td>
<td>20 °C</td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>68 – 75 GPa</td>
<td>20 °C</td>
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<tr>
<td>Linear thermal expansion coefficient</td>
<td>21 $1/K \times 10^{-6}$</td>
<td>20 – 200 °C</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>1.3 W/(K × cm)</td>
<td>20 – 200 °C</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>18 – 22 MS/m or m/(Ω × mm$^2$)</td>
<td>20 °C</td>
</tr>
<tr>
<td>Fatigue strength ($r = -1$); as-cast state (F); form factor $K_t = 1.2$</td>
<td>86 MPa</td>
<td>$10^6$ cycles</td>
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Note chapter “Technical Information”!

Processing properties compared to standard pressure die casting alloys

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<tr>
<th>Alloy type</th>
<th>Castasil-37</th>
<th>Silafont-36</th>
<th>AlSi9Cu3(Fe)</th>
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<tr>
<td>Stability of mechanical properties</td>
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<td>medium</td>
<td>good</td>
</tr>
<tr>
<td>Hot crack tendency</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Sticking tendency</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Die life</td>
<td>&gt; 80%</td>
<td>&gt; 80%</td>
<td>100%</td>
</tr>
<tr>
<td>Linear shrinkage</td>
<td>0.4 – 0.6%</td>
<td>0.4 – 0.6%</td>
<td>0.4 – 0.6%</td>
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</tbody>
</table>
Longitudinal carrier / Audi A8
Castasil-37; as-cast
1400 × 600 × 300 mm; weight: 10 kg

The extraordinary properties of Castasil-37 in the as-cast state result together with a well running HPDC process to the recommended high strength (YTS > 120 MPa) and very high ductility (elongation > 10%).

From one side these casted structural nodes reduced the BIW weight by 200 kg. On the other side they are reducing the "Carbon footprint" even during production by energy low casting process and further on during the long-term usage of the car.

Suspension-strut dome
Castasil-37; as-cast
Wall thickness 5 mm
430 × 330 × 340 mm; weight: 4.4 kg

More and more cars are designed with compact suspension strut domes, produced in HPDC with vacuum application. The showed suspension strut dome in Castasil-37 has several integrated design elements and is used in the front BIW without any additional heat treatment like T6/T7. This is substituting a complex multi-part sheet design.

These die casted suspension strut domes have good weldability, rivet deformability and are easy to glue. In addition they have high dynamic strength and reduce weight and production cost due to lower connecting areas and stiffer BIW structure.
Castasil®-37 [AlSi9MnMoZr]

Cover for switching electronics
Castasil-37; as-cast
365 × 270 × 45–65 mm; weight: 0.69–1.5 kg

A-pillar car / Audi
Castasil-37; as-cast; weldable
815 × 575 × 190 mm; weight: 6 kg

As part of the structural design for cars this part is responsible for crash safety a lot and has to implement or carry several other elements. Also parts of the car electronic are mounted, by using the quite high heat transfer of this Castasil-37 cast.

Crosswise reinforcement/sports car
Castasil-37; as-cast
370 × 70 × 60 mm; weight: 0.18 kg

Internal door parts for a sports car
Castasil-37; as-cast
620 × 340 × 170 mm; weight: 1.2 kg
700 × 340 × 170 mm; weight: 2.1 kg
Castasil®-37 [AlSi9MnMoZr]

Rear connecting nodes of aluminium body / Lamborghini
Castasil-37; as-cast; weldable
320 × 210 × 200 mm; weight: 2.0 kg

Convertible soft-top lever / VW
Castasil-37; as-cast
510 × 100 × 80 mm; weight: 0.56 kg

Upper safety housing for high voltage plug connectors
Castasil-37; as-cast
210 × 330 × 140 mm; weight: 1.5 kg

In hybrid or electric cars the power electronic has to be sheltered separately and is covered with a crash safe housing to avoid unexpected contact. Additionally there is a die casted cover to avoid plug-off without intention during a service run.

Reinforcement for convertible soft-top
Castasil-37; as-cast; weldable
260 × 220 × 60 mm; weight: 0.6 kg

In the event of a crash the hinged levers of the folding top are particularly close to the passengers in the vehicles and are therefore subject to especially high ductility requirements. These components must be prevented from breaking off. Castasil-37 fulfils the particular requirements of this folding top lever.
Castasil®-37 – Chemical composition

Table 1 shows the typical chemical composition. The silicon content of 8.5 to 10.5% enables good castability and outstanding die filling capabilities. This is important for casting large components and for filling complex designed structures. Silicon growth during solidification leads to less shrinkage and hot crack tendency of the alloy compared to other alloy systems.

Strontium modifies the eutectic silicon, which is very important for ductility. The addition of strontium changes the morphology of the silicon from lamellar or plate-like into a sponge-like coral one. As strontium promotes hydrogen absorption, an effective degassing of the melt with a rotating impeller is necessary. This keeps the hydrogen content low and thus reduces porosity and improves weldability. High elongation essentially results from the high cooling rate of the pressure die casting process, the modification with strontium and the very finely distributed eutectic. These raise the elongation values up to more than 12%.

The difference between a very fine Castasil-37 eutectic and a modified, but coarser Silafont-36 eutectic is shown in figure 1 respectively figure 4 on page 32. The microstructures are taken from 3 or 4 mm thick die cast sample plates.

An iron content below 0.15% minimizes the formation of AlFeSi-phases, which have a needlelike shape in the microstructure. Due to their shape, these phases significantly influence the strength, elongation and fatigue strength and promote crack formation under load. Manganese is used instead of iron to avoid sticking to the die. Manganese forms Al$_2$Mn$_3$Si$_2$-phases, which can be seen as globulitic particles in the microstructure, see figure 1a.

Magnesium is kept very low as it determines long-term ageing behaviour.

<table>
<thead>
<tr>
<th>%</th>
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<th>Cu</th>
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<th>Zn</th>
<th>Mo</th>
<th>Zr</th>
<th>Ti</th>
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<tr>
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Tab. 1: Chemical composition of Castasil-37, AlSi9MnMoZr in the ingot (weight in %)

![Microstructure of Castasil-37, AlSi9MnMoZr, in the as-cast state, 3 mm sample plate](image1.png)

![Yield strength depending on the magnesium content in temper F, after 1000 h at 120°C and after 3 h at 180°C. Sample plate: 220 × 60 × 3 mm](image2.png)
**Effect of magnesium on ageing behaviour**

Figure 2 gives an overview of the properties of Castasil-37 in the as-cast state, after 3 hours at 180 °C and after ageing at 120 °C for 1000 hours (almost 6 weeks). The material properties change during the course of time, whereby the effect of the magnesium on ageing behaviour becomes obvious. Artificial ageing is necessary in order to avoid this natural ageing or to minimize its effect. The following trials should indicate with which magnesium contents no ageing occurs and how the mechanical properties are influenced.

Table 3 shows the chemical analyses of the tested variants. Magnesium was added in quantities between 0.003 % and 0.1 %. The manganese content was maintained at an optimum level of 0.6% and strontium at 120 ppm for a good modification of the eutectic silicon. Sample plates 220 × 60 × 3 mm were cast in a single-cavity die in order to determine the mechanical properties. The test samples were cast on a 400 t Bühler B machine with a forced venting system. The melt was cleaned and degassed by means of a rotating impeller and the density was checked by means of a low-pressure density sample. A density index between 3% and 5% was established prior to degassing, thereafter below 2%.

Samples were artificially aged at 120 °C for 1000 hours to simulate long-term ageing in the as-cast state.

Figure 2 shows the impact of magnesium content on the yield strength in temper F (as-cast state), O (180 °C/3 h) and O (120 °C/1000 h). If the samples are left at room temperature in the as-cast state, the yield point remains approximately at the same level with different magnesium contents. However, with increased temperature the material properties change perceptibly with increasing magnesium content. Ageing starts from a magnesium content between 0.04 % and 0.08 %. 0.06 % can be assumed as the limit value. No significant dependence on the magnesium content was established with regard to ultimate tensile strength and elongation. Elongation values between 10 % and 12 % were established in all tempers, which is rather high for an AlSi alloy without deep changes of the microstructure.

The mechanical properties of Castasil-37 depend to a slight extent on the wall thickness and therefore on the solidification conditions. The elongation values are impressive: 11.6% with 2 mm wall thickness and even 14% with wall thickness between 3 and 6 mm.

Yield strength and ultimate tensile strength react as known to thicker walls and therefore longer solidification times.

Castasil-37 reached on our flat tensile samples a yield strength of 139 MPa with 2 mm wall thickness, falling down to 95 MPa with 6 mm-thick samples (fig. 3). The yield strength is therefore almost two times higher than the one of other magnesium-free AlSi-pressure die casting alloys. At the same time elongation remains steadily above 12%, which reveals very important for modern applications in crashrelevant bodywork manufacturing.

<table>
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<tr>
<th>No.</th>
<th>Si</th>
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<th>Mg</th>
<th>Zn</th>
<th>Ti</th>
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<td>5</td>
<td>10.3</td>
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<td>0.61</td>
<td>0.102</td>
<td>0.005</td>
<td>0.08</td>
<td>0.0120</td>
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</table>

Tab. 2: Chemical compositions of trial series with different magnesium content in weight %
Castasil®-37 – Mechanical properties

The extremely regular stress-strain curve in figure 4 results from a finely modified microstructure with no strengthening effect of magnesium in solid solution.

One of the advantages of Castasil-37 are good mechanical properties in the as-cast state in order to save the time and costs of heat treatments with solutionizing, which produces component distortion and needs an additional straightening process.

Heat treatment

Castasil-37 can be annealed to temper O (without solutionizing) in order to further increase its elongation. Figure 5 indicates the mechanical properties for annealed states over different periods. The yield point of 114 MPa in the as-cast state gradually falls to 93 MPa after 90 minutes at an annealing temperature of 350°C. The ultimate tensile strength behaves in a similar way. Yield strength and ultimate tensile strength can be assumed to be stable from a technical point of view! Elongation, on the other hand, increases continuously from 14% to 16.5% after 90 minutes. This means that elongation can be increased in Castasil-37 by a single-step annealing to temper O.

Fatigue strength

In addition to the properties under static load, the designer needs information on the dynamic load-bearing capacity of a material. Samples were taken from temper F die cast plates with 4 mm wall thickness in order to determine the fatigue limit under alternating loads. The sample geometry has a decisive influence on the number of load alternations achieved. Form factor $K_t = 1.2$ was selected in this case. The results of the fatigue test are shown in figure 6. The progress of the curves in figure 6 is determined according to the common assessment method of 2007. Wöhler curves show the fatigue strength under alternating load with 5%, 50% and 95% fracture probability. Castasil-37 endures one million loads alternations to an amplitude of 86 MPa (5% fracture probability) and the same number of cycles to an amplitude of 103 MPa with 50% fracture probability. This equals 39% of the static notch-ultimate tensile strength in relation to the sample shape used. Experience shows that cast samples of conventional aluminium alloys in the heat-treated state only achieve a far lower value.

High speed test for deformability

There is a difference in material performance either measuring the tension test at high speed or with normal low speed with 0.02 mm/s. Therefor a tension test was run with 6 m/s similar to the crash test velocity.

With Castasil-37 we measured a high positive effect for the yield strength of 35–40%, like demonstrated in fig. 7.

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Fig. 3: Mechanical properties of Castasil-37, AlSi9MnMoZr, in the as-cast state (F), depending on the wall thickness

Fig. 4: Stress-strain curve for Castasil-37, AlSi9MnMoZr, in the as-cast state (F)
Melting
Castasil-37 ingots can generally be processed into pressure die castings in the foundry without special treatment. However, in order to produce casts of high consistent quality, following points must be noted.

The good properties of Castasil-37 are based essentially on the production of this alloy from very pure electrolytic metal. Metallic impurities in the melt like magnesium, iron zinc and copper should be avoided. Rapid melting is important in order to avoid strong oxidation of the melt and the formation of segregations. Oxides have a negative impact on the casting behaviour and on the properties of the cast to a large extent. Melt cleaning, preferably with an impeller, is necessary in order to avoid this with Castasil-37. This cleaning of oxides and dissolved hydrogen should be carried out in the melting furnace as far as possible, otherwise a low-turbulence metal pouring is necessary in each step of the process.

The strontium loss must be kept at a minimum in order to maintain good mechanical and technical properties. A strontium loss of 0.004 % can normally be expected per melting procedure. In practice, a minimum content of 60 ppm and an upper limit of 250 ppm strontium in the melting furnace have proved to be successful for a good strontium modification. Higher strontium contents may possibly lead to increased hydrogen absorption in the melt, which should however be avoided for weldable casts. A reduction in elongation can be expected with lower contents of strontium.

The melt temperature should not exceed 780 °C. Otherwise, increased strontium loss and increased oxide formation are to be expected. A casting temperature of 680 to 720 °C is recommended. The casting temperature depends on the shape, flow distance and wall thickness of the casts but also on the dosing system from the melting furnace and on the eventual presence of a shot sleeve heating device.

Casting
Common guidelines apply to the configuration and design of pressure die castings with regard to wall thicknesses, avoidance of material accumulations, radii of edges, corners and transition points, chamfers and undercuts. Some points are specified below:
A linear shrinkage of 0.4 – 0.6 % is assumed for pressure die casting dies designed for this AlSi-alloy with 9 % silicon.
Castasil®-37 – Application

The shrinkage depends locally on the die configuration, e. g. when casts have varying rib patterns. Good ejection behaviour enables draft angles starting from 1.0 °C. Lower draft angles shall be defined with the die designer.

Conventional die-release agents and their mix ratios can be used. The release agent quantity and its application must be adapted to special cast requirements such as those of welded structural parts, parts assembled by flanging or with a top-quality painting.

Pre-solidification
Deformation-intensive casts react sensitively to internal notches. Pre-solidifications from the shot sleeve form defects such as those shown in Figure 8a and thereby reduce the achievable deformation. Pre-solidifications can be metallographically detected on the basis of the different solidification microstructure as shown on an etched sample in Figure 8b. Investigations with a thermoregulated shot sleeve on a 400 t pressure die casting machine have demonstrated that pre-solidifications no longer occur in test plates starting from a sleeve temperature over 190 °C. The lower the filling level of the chamber, the higher this temperature should be.

Joining technology
Also in chapter "Joining techniques for die casting" there are details described for welding, riveting with glueing and flanging of Castasil-37 casts.

Applications
Castasil-37 was developed for pressure die castings requiring high elongation and a specific yield strength in the as-cast state. These are, for example, structural components such as nodes for SpaceFrame designs or pillars for car bodies. Today the majority of these components are manufactured in AlSi-alloys and costintensively heat treated in order to obtain the required properties. Thin-walled components may distort during heat treatment with solutionizing, calling for an additional process step to straighten the component.

Castasil-37 with a yield strength of at least 120 MPa and elongation of more than 12% provides in the as-cast state mechanical properties which are adequate for many structural components in cars. Elongation can be further increased with single-step annealing at 350 °C for 30 to 90 minutes. In addition to the good properties in the as-cast state, Castasil-37 is resistant to long-term ageing thanks to the absence of magnesium. Long-term trials at high temperatures (120 °C/1000 h) have shown that mechanical properties remain at least at the high level of the as-cast state.

Bibliography

Castasil-21 is a HPDC alloy developed by RHEINFELDEN ALLOYS for casts with outstanding requirements in terms of electrical or thermal conductivity. Aluminium 99.7 for rotors has indeed higher electrical conductivity, but in practice you need lower contraction for huge casts, like with an alloy with more than 8% silicon.

The application of Castasil-21 may help to lower the weight of HPDC, especially for the light weight design of cars with their additional casts like battery housing, conductor plate for electronics, LED-lighting, but also for general purposes of heating and cooling.

Chemical composition was optimized in order to have high conductivity (up to 30%) compare with usual HPDC aluminium alloys.

The specially chosen chemical composition results in following casting properties:

- excellent casting ability with good ejectability
- well usable for thin wall fins

More and more applications either in car design or in telecommunication area need also following properties:

- very good corrosion resistance to weather
- good mechanical strength; excellent machinability
- flangeable or deformable to fix parts together
- suitable for glueing connections in car design
- electrical conductivity comes up to 45% IACS, to substitute Cu in the idea of light weight design or Al99.7 in rotors
Castasil®-21 – Properties at a glance

Chemical composition of Castasil-21, AlSi9Sr

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<th>Si</th>
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Mechanical properties

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<tr>
<th>Temper</th>
<th>YTS $R_{p0.2}$ [MPa]</th>
<th>UTS $R_m$ [MPa]</th>
<th>Elongation $A$ [%]</th>
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<td>F</td>
<td>90–100</td>
<td>200–230</td>
<td>6–9</td>
</tr>
<tr>
<td>O</td>
<td>80–90</td>
<td>170–190</td>
<td>9–14</td>
</tr>
</tbody>
</table>

Physical composition

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Validity range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solidification range</td>
<td>°C</td>
<td>595–550</td>
</tr>
<tr>
<td>Density</td>
<td>kg/dm³</td>
<td>20 °C</td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>GPa</td>
<td>20 °C</td>
</tr>
<tr>
<td>Linear thermal expansion coefficient</td>
<td>$1/K \times 10^{-6}$</td>
<td>20–200 °C</td>
</tr>
<tr>
<td>Thermal conductivity temper O</td>
<td>$W/(K \times cm)$</td>
<td>20–200 °C</td>
</tr>
<tr>
<td>Electrical conductivity temper F</td>
<td>MS/m or m/(Ω × mm²)</td>
<td>20 °C</td>
</tr>
<tr>
<td>Electrical conductivity temper O</td>
<td>MS/m or m/(Ω × mm²)</td>
<td>20 °C</td>
</tr>
</tbody>
</table>

Processing properties compared to standard pressure die casting alloys

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>Castasil-21</th>
<th>Silafont-36</th>
<th>Rotoren-Al 99.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability of mechanical properties</td>
<td>very good</td>
<td>medium</td>
<td>very good</td>
</tr>
<tr>
<td>Hot crack tendency</td>
<td>very low</td>
<td>very low</td>
<td>high</td>
</tr>
<tr>
<td>Sticking tendency</td>
<td>low</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Die life</td>
<td>100%</td>
<td>100%</td>
<td>80%</td>
</tr>
<tr>
<td>Linear shrinkage</td>
<td>0.4–0.6%</td>
<td>0.4–0.6%</td>
<td>0.8–1.2%</td>
</tr>
</tbody>
</table>

Note chapter “Technical Information”!
This cast with fixed electrical device has to diffuse the hot spot of heat through the massive plate and the casted fins and should lower the maximum temperature ever. Higher heat conductivity of the alloy results directly in lower temperature. It is not necessary to design longer fins or add forced air ventilation.
Chemical composition

Table 1 shows the Castasil-21 composition with a silicon content of 8 to 9%. Thus, the processing temperature is 680 – 750 °C, an area with typical thermal shock wear of die chamber and cavity. Strontium causes a further lowering of the eutectic point, that is the melting temperature, of about 6 – 8 °C. In die casting alloys Strontium reduces the affinity of the melt to the die mold, i.e. the tendency to stick on, although Castasil-21 is already alloyed with an Fe content from 0.5 to 0.7%.

As an impurity in this conductive alloy are magnesium and zinc contents of more than 0.08% and a copper content more than 0.02%. While forming the conductivity disturbing solid solution phases these elements are already at lower levels, but this is negligible compared to the effects from the die casting process (Fig. 1). Not so with the manganese and titanium content. Here a value of only 0.01% should not be exceeded in order to keep the conductivity high. Because Castasil-21 is produced with primary aluminum as base, further accompanying elements are also kept very low.

Electrical conductivity

But more important is the modification of the silicon crystal during solidification. The strontium addition causes a coralline solidification structure of the Si crystal in the eutectic, the so called modification. The relevant Castasil-21 advantage of this modification is the higher conductivity of plus 2 – 4 MS/m.

Heat treatment

The processing in the die casting is characterized by a very rapid solidification. Although this achieves higher strength and hardness, this microstructure is negative for achieving high conductivity! Castings out of Castasil-21 can even further be increased in their conductivity by one-stage heat treatment, whereby the internal stress of the cast structure is equalized than. In the as-cast state a die cast with 6 mm wall thickness may reach even 25 MS/m.

A heat treatment of 350 °C for 2 h or 250 °C for 3 h provides superior conductivity of around 28 MS/m (Fig. 2). In this state, the die casts have 83% of the conductivity of Al99.7. Upon the cooling of the components after the stress-relieving may only slowly air cooling to be made.

Handling instructions

Cleaning and processing the melt should result in a low achieved oxide impurity. A strontium content of 100 to 350 ppm ensures the modification. Ingate design and die cast parameters must be optimized to result in a solid structure without pores, due to these technically disturb the conductivity. Handling instructions for melt preparation on page 56.
The pressure die casting alloy Silafont-36 was developed by Rheinfelden Alloys in order to obtain maximum elongation after heat treatment with average strength values compared to standard pressure die casting alloys. Mechanical properties at Silafont-36 can be further improved by various heat treatments. Silafont-36 can thus achieve elongation values over 15% or yield strength values around 260 MPa.

Besides these particular good mechanical properties, Silafont-36 has also following properties required for the pressure die casting process:

• excellent die cast castability
• no sticking to the die
• excellent machinability

In more and more applications, mainly in car manufacturing, other properties of Silafont-36 are of increasing importance:

• very good corrosion resistance
• high fatigue strength
• excellent weldability for aluminium profil-cast designs
• suitable for self-piercing riveting and similar joining processes
• suitable for glueing connections in car design
Physical composition

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Validity range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solidification range</td>
<td>°C</td>
<td>590 – 550</td>
</tr>
<tr>
<td>Density</td>
<td>kg / dm³</td>
<td>20 °C</td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>GPa</td>
<td>74 – 83</td>
</tr>
<tr>
<td>Linear thermal expansion coefficient</td>
<td>1/K x 10⁻⁶</td>
<td>20 – 200 °C</td>
</tr>
<tr>
<td>Thermal conductivity temper O</td>
<td>W / (K x cm)</td>
<td>20 – 200 °C</td>
</tr>
<tr>
<td>Electrical conductivity temper F</td>
<td>MS/m or m/(Ω x mm²)</td>
<td>20°C</td>
</tr>
<tr>
<td>Fatigue strength (r = -1) in the as-cast state (F)</td>
<td>MPa</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>50 x 10⁶ cycles</td>
<td></td>
</tr>
</tbody>
</table>

Note chapter “Technical Information”!

Processing properties compared to standard pressure die casting alloys

<table>
<thead>
<tr>
<th></th>
<th>Silafont-36</th>
<th>AlSi10Mg(Fe)</th>
<th>AlSi9Cu3(Fe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat treatment for property improvement</td>
<td>very good</td>
<td>good</td>
<td>medium</td>
</tr>
<tr>
<td>Hot crack tendency</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Sticking tendency</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Joining potential</td>
<td>high</td>
<td>medium</td>
<td>low</td>
</tr>
<tr>
<td>Die life</td>
<td>&gt; 80%</td>
<td>&gt; 80%</td>
<td>100%</td>
</tr>
<tr>
<td>Linear shrinkage</td>
<td>0.4 – 0.6%</td>
<td>0.4 – 0.6%</td>
<td>0.4 – 0.6%</td>
</tr>
</tbody>
</table>
Cross member / Porsche Cayman
Silafont-36; temper T6
610 × 830 × 60 mm; weight: 6.5 kg

Cross member off-road vehicle
Silafont-36; as-cast
1020 × 690 × 280 mm; weight: 10.3 kg

Cross member / Fiat
Silafont-36; temper T5
450 × 930 × 230 mm; weight: 10.7 kg

Suspension strut dome
Silafont-36; as-cast
420 × 390 × 330 mm; weight: 4.3 kg

To cast a suspension dome reduce the overall production effort a lot in comparison to a sheet design, and give an weight reduction advantage too. In addition the Silafont-36 with Mg 0.25 – 0.35% is easy to cast worldwide even with some integrated design elements.
Silafont®-36 [AlSi10MnMg]

Engine Cradle / Daimler
Silafont-36; temper O
920 × 580 × 170 mm; weight: 10.0 kg
This pressure die casting replaces a heavier, painted sheetsteel welded structure. As a cast part, it integrates further functions at the same time. The high deformation capability of this Silafont-36 pressure die casting was achieved by heat treatment in Temper O. This engine cradle was-cast in a die-cavity provided with a forced venting system in order to obtain high product safety.

Frontplate, front bumper bar
Silafont-36; temper T7
195 × 145 × 55 mm; weight: 0.75 kg

Truck cab tilting joint / Lkw Renault
Silafont-36; temper T5
560 × 460 × 250 mm; weight: 9.5 kg
This 9.5 kg-pressure die cast replaces a heat-treated gravity cast. This Silafont-36 component supports the driver’s cab and locks the forward tilted driver’s cab when the engine compartment is open.

Foot board for truck bumper, electron beam welded
Silafont-36; as-cast
190 × 640 × 110 mm; weight 2.8 kg
Extraordinary safety requirements and a life time over 20 years in public cars can be fulfilled with this two casts design. The single casts are produced in Silafont-36 with 0.35% Mg and welded together in the as-cast state. Electron beam welding without any added material enables a distortion free but heavy-loadable design in best surface shape.
Silafont®-36 [AlSi10MnMg]

Front section frame / BMW 3 Series Cabrio
Silafont-36; as-cast
1250 × 350 × 250 mm; weight: 4.5 kg
As this cast is the top part of the car front section, it must absorb as much kinetic energy as possible through deformation. The torsional rigidity of the component gives an additional advantage during mounting into the convertible car. This was made possible thanks to a strong rib pattern design on the component underside and by the material Silafont-36 with 0.24% magnesium.

Steering column / Daimler
Silafont-36; as-cast
450 × 70 × 90 mm; weight: 0.96 kg
Filigree guide surfaces to be cast with high dimensional accuracy, deformation without fracture edges in the event of a crash and maximum rip-out resistance strength in the ignition lock area are the decisive requirements for Silafont-36 with a magnesium content around 0.24%.

Tailgate frame / BMW
Silafont-36; temper F
510 × 1130 × 320 mm; weight: 3.3 kg

Frame side rail, rear node / Alfa Giulia
Silafont-36; temper T5
210 × 550 × 340 mm; weight: 4.8 kg

Housing for rollover bar mechanism / Opel
Silafont-36; as-cast, crimped pipe
45 × 250 × 40 mm; weight: 0.37 kg
Integrated into the driver’s seat this mechanism device has to push out and to fix the roll over safety bar in case of a crash. A flangable edge of the pipe with the SRS explosive and the high stability of the light weight cast are the advantages of Silafont-36 with 0.20% Mg.
Silafont®-36 – Chemical composition

Chemical composition of Silafont-36, AlSi10MnMg

<table>
<thead>
<tr>
<th>[%]</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
<th>Ti</th>
<th>Sr</th>
<th>P</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td>min.</td>
<td>9.5</td>
<td>0.5</td>
<td>0.1</td>
<td>0.04</td>
<td>0.010</td>
<td>0.04</td>
<td>0.015</td>
<td>0.025</td>
<td>0.001</td>
<td>0.10</td>
</tr>
<tr>
<td>max.</td>
<td>11.5</td>
<td>0.15</td>
<td>0.03</td>
<td>0.8</td>
<td>0.5</td>
<td>0.07</td>
<td>0.15</td>
<td>0.010</td>
<td>0.025</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Tab. 1: Chemical composition of Silafont-36, AlSi10MnMg in the ingot (weight in %)

Silafont-36 is a pressure die casting AlSi9MgMn-type alloy with strontium, which is produced on the basis of aluminium metal with 99.8% purity. The alloy constituent elements (tab.1) with narrow tolerances produce constant good cast quality. Strontium is included for modification, i.e. for the modification of the eutectic silicon.

The magnesium content is further adjusted according to the various applications. The cast composition can have a higher limit for iron, copper and zinc. This results from the conditions in the pressure die casting foundry, but is determined by the requirements on the component.

A silicon content of around 10.5% enables an excellent die filling capability, and therefore an excellent castability.

In order to ensure that the silicon phase is already finely distributed in the as-cast state, the aluminium-silicon eutectic is modified by the addition of strontium. This leads to high elongation values in the as-cast state and also helps the spheroidisation of silicon in case of following heat treatments.

As high deformation values are required, the iron content was kept as low as possible in order to keep the share of the plate-type AlFeSi-phases occurring in the structure as low as possible. These phases are the essential cause of low strength and elongation values, as they act as the starting point for crack formation by reason of their morphology in case of a deformation and especially in presence of dynamic loads.

The manganese content was increased to approximately 0.65% in order to reduce the sticking tendency and to increase the form strength of the casts.

Manganese has the same effect as iron with regarding the reduction of the sticking tendency to the die. However, in contrast to iron, the precipitations occurring during solidification are globulitic and not acicular.

Variation of magnesium
The required ductility and strength especially of this AlSiMg-pressure die casting alloy can actually be adjusted with the most appropriate magnesium content to meet the component requirements, particularly if the casts are to be heat treated. Five alloy variants emerged for Silafont-36 with these focus:

0.13 – 0.19% Mg for crash-relevant components and flanging technology.
0.18 – 0.28% Mg for rigid and even crash safety components in presence of fatigue loads.
0.24 – 0.35% Mg for components with high operating strength against impact stress.
0.28 – 0.35% Mg for heat-treated components with air quenching after solutionizing.
0.35 – 0.45% Mg For designs focused on strength in as-cast state or after O, T4 or T6

Effect of manganese
From the literature it is well known that manganese should reduce elongation in an AlSiMg-alloy, when its content exceeds 0.2%. For this reason manganese is not recommended as an addition to pressure die casting alloys as a substitute for or in combination with iron. A series of tests was carried out with manganese contents ranging between 0.04% and 1.2% in order to better understand its effect on properties. At the same time, the iron content was kept below 0.15%. The magnesium content was on average 0.19%. The strontium content was between 130 and 170 ppm in order to guarantee a good eutectic modification.
The test samples were cast on a 400 t Bühler B Machine with a forced venting system. A four-cavity die was used with standard machine conditions, i.e. melt temperature at 710 to 720°C, melt density index < 1% (80 mbar low pressure density test), die temperature 200°C on both die halves, die lubricant dilution 1:180, gate speed 30 to 40 m/s. The test bars had a cross-section of 3 × 10 mm in the gauge length according to DIN 50 125 Form E. The tensile tests were carried out two days after casting in order to ensure that the samples were in a stable condition. The tensile tests were carried out in as-cast state (temper F) and in temper T6 under the following conditions:

- Solutionizing at 520°C for 1 hour, quenching in water and artificial ageing at 160°C for 6 hours. It was stated that in the absence of manganese, the tendency of sticking to the die was very pronounced, even if it was a simple die design. The sticking tendency decreased with an increasing manganese content and the required behaviour became apparent above content of 0.4%. In the as-cast state it can be seen that there is only a slight difference in ultimate tensile and yield strength with varying manganese content as shown in figure 1a.

The same progression can be observed in temper T6 (Fig. 1b). Only samples without manganese manifest different behaviour. This might be caused by the strong sticking tendency as described above. The components showed surface cracks and the heat treatment may have caused surface damages leading to poor results. The elongation, as seen in fig. 1c, shows a different progression in both conditions. In both cases, elongation is low without manganese by reason of the strong sticking tendency. In the as-cast state, elongation increases steadily up to a manganese content of 0.4%. It is still above 8% even with high manganese contents. The optimum manganese content for maximum elongation values in the as-cast state is between 0.5% and 0.8%.

Elongation in temper T6 behaves differently. The highest value was recorded with 0.2% manganese. Elongation is approximately at a level between 12% and 14% with 0.4% to 1.0% manganese. On the other hand, the optimum range for a stable condition is between 0.5% and 0.8% manganese.

The different elongation values depending on the manganese content may be caused by the T6 heat-treatment. During solutionizing the intermetallic manganese phases tend to assume a globulitic form. Surrounded by a ductile matrix, these globulitic particles might increase elongation in comparison to the as-cast state.
The microstructures (figures 3, 4 and 5) are taken from pressure die cast plates with dimensions 220 × 60 × 4 mm (fig. 2).

The eutectic aluminium-silicon matrix is almost globulitically modified alongside the clearly recognizable bright α-aluminium dendrites. Al12Mn3Si2-phases also appear in the eutectic as bright-gray phases in its globulitic shape.

At higher magnesium contents the Mg2Si-intermetallic phase is still present, light optically hardly perceptible.

The rapid cooling rate in pressure die casting is by itself not enough to produce a sufficiently fine cast microstructure and therefore the required high elongation values. Only the modification with strontium produces a sufficiently fine eutectic casting microstructure. Fig. 5 shows the structure of a sample which was produced from the same alloy type however without modification.

A comparison with fig. 4 clearly shows that the eutectic silicon is considerably finer thanks to modification. The achievable elongation to fracture increases from 5% to 10%. This effect is also visible with a solutionizing. Figures 6 and 7 show the structure of a 6 mm pressure die casting sample after solutionizing for 3 hours at 490 °C. The silicon has coarsened somewhat but is still globulitically modified. Further trials showed that the spheroidization of the eutectic silicon is achieved already at 350 °C.
**Effect of magnesium content on mechanical properties in the as-cast state**

The extraordinarily high elongation amongst AlSiMg-alloys is the distinguishing characteristic of Silafont-36. Figure 8 shows the stress-strain curve for Silafont-36 in the as-cast state.

The curves for T5 (artificially aged) and T7 (overaged) tempers, are also reported.

Yield strength rises with increasing magnesium content, whereas elongation decreases. If high yield strength is required, the magnesium content should therefore be set in the upper range of the alloy standards, i.e. at 0.3–0.4%. If higher elongation is required and yield strength does not play a significant role, a low magnesium content of 0.15% is preferred.

Table 2 is a summary of mechanical properties for various magnesium contents. The corresponding trials were conducted with casts which were produced in accordance with the parameters in table 3.

Elongation drops from 11.2 to 5.8% with increasing magnesium contents, while yield strength increases from 117 to 146 MPa. Ultimate tensile strength is also increased from 250 to 286 MPa by increasing magnesium contents.

Therefore, in the as-cast state a wide range of mechanical properties can be fulfilled. Magnesium contents above 0.5% produce no further increase in yield strength, as excess magnesium precipitates as the Mg$_2$Si-phase and no longer contributes to the hardening of the aluminium solid solution.
Silafont®-36 – Mechanical properties

Effect of heat treatment on mechanical properties

The mechanical properties of Silafont-36 can be targeted by means of specific heat treatment, as well as with varying magnesium contents.

There are two completely different possibilities in the event of heat treatment: with or without solutionizing.

The following heat treatments can be carried out with Silafont-36 without solutionizing:

- O: Annealed at low temperature
- T5: Quenched directly after removal from the die and artificially aged

The desired spheroidisation of the eutectic silicon requires the following heat treatments with solutionizing:

- T4: Solutionized, quenched, naturally aged for more than 6 days
- T6: Solutionized, quenched and artificially aged
- T7: Solutionized, quenched and overaged

Heat treatments without solutionizing

Temper O

An increase in yield strength or elongation can be achieved to a slight extent with this heat treatment without risk of casting distortion. Two different variants for this temper are actually defined:

- O(I): annealed at lower temperature (320°C/30–60 min.)
- O(II): annealed at higher temperature (380°C/30–60 min.)

An increase in yield strength to 140–160 MPa with 8–12% elongation is achievable on thin samples with up to 3 mm wall thickness and magnesium contents of 0.2% in temper O(I). Identical samples in temper O(II) achieve elongation of 12–16% with yield strength of 100–130 MPa.

Temper T5

The mechanical properties of Silafont-36 T5 are given in tables 4 and 5 for two different magnesium contents of the various casts. Thanks to the T5 heat treatment, yield strength can be increased by almost 100 MPa compared to the as-cast state.

It is particularly interesting to note that elongation does not decrease, but remains between 5 and 9%. The highest increases in yield strength are achieved with Silafont-36 with over 0.30% magnesium, if there are at least 10 hours storage time between casting and ageing, as visible in table 5.

---

**Tab. 3: Mechanical properties in temper T5, 0.30% magnesium content; test plate 4 mm**

<table>
<thead>
<tr>
<th>Ageing temperature [°C]</th>
<th>Ageing time [h]</th>
<th>R$_{p0.2}$ [MPa]</th>
<th>R$_m$ [MPa]</th>
<th>A [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>170</td>
<td>1.0</td>
<td>157</td>
<td>291</td>
<td>7.1</td>
</tr>
<tr>
<td>170</td>
<td>2.0</td>
<td>169</td>
<td>292</td>
<td>5.0</td>
</tr>
<tr>
<td>170</td>
<td>3.0</td>
<td>185</td>
<td>302</td>
<td>6.0</td>
</tr>
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<td>170</td>
<td>4.0</td>
<td>188</td>
<td>305</td>
<td>8.5</td>
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<tr>
<td>170</td>
<td>5.0</td>
<td>197</td>
<td>309</td>
<td>7.1</td>
</tr>
<tr>
<td>170</td>
<td>6.0</td>
<td>195</td>
<td>309</td>
<td>8.5</td>
</tr>
<tr>
<td>170</td>
<td>8.0</td>
<td>201</td>
<td>313</td>
<td>8.9</td>
</tr>
<tr>
<td>200</td>
<td>0.5</td>
<td>211</td>
<td>316</td>
<td>8.4</td>
</tr>
<tr>
<td>200</td>
<td>1.0</td>
<td>212</td>
<td>314</td>
<td>7.9</td>
</tr>
</tbody>
</table>

**Tab. 4: Mechanical properties in temper T5, 0.33% magnesium content; test plate head cover 3.8 mm**

<table>
<thead>
<tr>
<th>Ageing temperature [°C]</th>
<th>Ageing time [h]</th>
<th>R$_{p0.2}$ [MPa]</th>
<th>R$_m$ [MPa]</th>
<th>A [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>170</td>
<td>3.0</td>
<td>193</td>
<td>290</td>
<td>4.5</td>
</tr>
<tr>
<td>170</td>
<td>4.0</td>
<td>199</td>
<td>295</td>
<td>4.8</td>
</tr>
<tr>
<td>170</td>
<td>6.0</td>
<td>206</td>
<td>300</td>
<td>5.0</td>
</tr>
<tr>
<td>200</td>
<td>0.5</td>
<td>193</td>
<td>290</td>
<td>5.7</td>
</tr>
<tr>
<td>200</td>
<td>1.0</td>
<td>200</td>
<td>297</td>
<td>5.6</td>
</tr>
<tr>
<td>220</td>
<td>0.5</td>
<td>199</td>
<td>293</td>
<td>5.8</td>
</tr>
<tr>
<td>250</td>
<td>0.5</td>
<td>180</td>
<td>268</td>
<td>3.5</td>
</tr>
</tbody>
</table>

**Tab. 5: Mechanical properties in temper T5 with different storage times prior to ageing at 200°C for 1 hour, test plate 4 mm, 0.32% magnesium content**

<table>
<thead>
<tr>
<th>Interim storage time [h]</th>
<th>R$_{p0.2}$ [MPa]</th>
<th>R$_m$ [MPa]</th>
<th>A [%]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>207</td>
<td>307</td>
<td>6.9</td>
</tr>
<tr>
<td>10</td>
<td>233</td>
<td>324</td>
<td>6.6</td>
</tr>
<tr>
<td>72 h or 3 days</td>
<td>232</td>
<td>324</td>
<td>6.8</td>
</tr>
</tbody>
</table>
**Heat treatments with solutionizing**

**Temper T4**
Table 7 lists the mechanical properties after solutionizing (490°C/3 h) with subsequent quenching in water. The spheroidisation of the silicon and the other intermetallic phases achieved in this way produce an increase in elongation to 15% and more, depending on magnesium content.

Yield strength increases to 141 MPa from 94 MPa of the as-cast state. The ultimate tensile strength range of 206 to 259 MPa is somewhat lower than in the as-cast state.

**Temper T6**
Temper T6 produces maximum strength. For this purpose a magnesium content above 0.3% in the pressure die casting should be aimed at, in order to exploit the hardening potential of the alloy. Elongation settles to lower values. Figure 9 shows graphically the mechanical properties over the ageing time for a magnesium content of 0.3%. The point of maximum strength is at a yield strength of 240 MPa and ultimate tensile strength of 310 MPa, however with an elongation of 7.1%.

Single trials with higher magnesium contents have demonstrated that yield strength can be increased to over 280 MPa, whereby elongation is still above 3% nevertheless.

**Temper T7**
The curve progression in figure 9 indicates that elongation again increases with increasing ageing time, i.e. in an increasingly overaged state. Trials with real casts have shown that with targeted heat treatments, elongations up to 20% can be achieved; yield strength then reaches values of 120–130 MPa.

**Air quenching**
Quenching with air instead of water is carried out after the solutionizing in order to minimize the distortion of pressure die castings. Yield strength of over 120 MPa can only be achieved with a magnesium content of 0.3%, if a subsequent ageing for 2 hours at a temperature of 170°C is performed.

**Overview of mechanical properties**
The figure on page 26 provides an overview of the ranges of mechanical properties which can be achieved with the various heat treatments.

It should be taken into account that the magnesium content must be tuned according to the required property profile. Higher elongation values are linked to lower values for yield strength and vice versa.

<table>
<thead>
<tr>
<th>Mg-content [%]</th>
<th>(R_{p0.2}) [MPa]</th>
<th>(R_m) [MPa]</th>
<th>(A) [%]</th>
<th>Casting description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15</td>
<td>94</td>
<td>206</td>
<td>20.6</td>
<td>Rear side members 2.5 mm</td>
</tr>
<tr>
<td>0.20</td>
<td>107</td>
<td>223</td>
<td>20.4</td>
<td>Rear side members 2.5 mm</td>
</tr>
<tr>
<td>0.25</td>
<td>119</td>
<td>229</td>
<td>17.3</td>
<td>Rear side members 2.5 mm</td>
</tr>
<tr>
<td>0.28</td>
<td>121</td>
<td>242</td>
<td>16.7</td>
<td>Rear side members 2.5 mm</td>
</tr>
<tr>
<td>0.42</td>
<td>141</td>
<td>259</td>
<td>15.0</td>
<td>Test plate 4 mm</td>
</tr>
</tbody>
</table>

Tab. 6 Mechanical properties of Silafont-36, AlSi10MnMg, in temper T4 depending on magnesium content

![Fig. 9: Mechanical properties of Silafont-36, AlSi10MnMg, with a magnesium content of 0.3% as a function of the ageing time (solutionizing at 490°C for 3 hours, quenching in water and ageing at 170°C)](image-url)
Fatigue strength

Fatigue strengths for pressure die cast plates with 4 mm wall thickness are shown in Figure 11 in the as-cast state according to Wöhler’s curves. The trials were conducted on a high frequency pulse generator with a frequency of around 117 Hz. The stress ratio was \( r = -1 \) on a normal sample geometry. Figure 11 shows that the fatigue strength reaches 89 MPa under these test conditions; this equals approximately 66% of the yield strength.

Corrosion behaviour

The corrosion behaviour can be compared to an aluminium-silicon primary alloy. Silafont-36 is not susceptible to corrosion and does not manifest any tendency to stress corrosion cracking. As visible in the application examples, the alloy is used, among other things, for uncoated bodywork and car chassis components.

Melting and Casting

The detailed description on page 19 is also usable for handling Silafont-36. But the strontium content should be leveled higher than 80 ppm to assure a fine modified AlSi eutectic with high elongation. Handling instructions for melt preparation is on page 57.

Prototypes

Dimensionally identical prototypes of high pressure die castings in Silafont-36 can be produced with the same alloy in sand casting, or even better in low-pressure sand casting. The mechanical properties, particularly elongation, are lower due to a lower cooling rate. The strontium content and the heat treatment parameters have to be adapted when using Silafont-36 for sand casting prototypes. The mechanical properties achieved in this way are indicated in Table 8 for various heat treatments on Silafont-36 with 0.29% magnesium.

Some sand prototype casts can more than double the achievable elongation by the application of chills. Only with this solution and an additional T4 heat treatment will the sand prototype partially correspond with regard to its mechanical properties to the following pressure die casting in the as-cast state.

<table>
<thead>
<tr>
<th>Heat treatment</th>
<th>( R_{0.2} ) [MPa]</th>
<th>( R_m ) [MPa]</th>
<th>A [%]</th>
<th>HB</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>96</td>
<td>175</td>
<td>2</td>
<td>61</td>
</tr>
<tr>
<td>T4</td>
<td>133</td>
<td>229</td>
<td>4</td>
<td>77</td>
</tr>
<tr>
<td>T6</td>
<td>250</td>
<td>299</td>
<td>1</td>
<td>109</td>
</tr>
<tr>
<td>T7</td>
<td>222</td>
<td>260</td>
<td>1</td>
<td>90</td>
</tr>
</tbody>
</table>

Tab. 7: Mechanical properties in different heat treatment states of sand casting prototypes in Silafont-36, AlSi10MnMg, with 0.29% magnesium

Bibliography

The HPDC alloy Silafont-38 was developed by RHEINFELDEN ALLOYS to further increase yield strength in comparison to Silafont-36 without significant change in ductility.

Even with an air cooling to lower distortion the complex alloyed Silafont-38 reaches 180 MPa yield strength.

Besides these moderate cooling rates it is possible to cool down with water after the solutionizing treatment to achieve highest strength.

Additionally Silafont-38 has also following properties required for the pressure die casting process:

- excellent castability even with varying wall thicknesses
- no sticking to the die; the low-iron Silafont-38 is there for alloyed with manganese and strontium
- excellent machinability

In more and more applications, mainly in car manufacturing, other properties of Silafont-36 are of increasing importance:

- very good corrosion resistance due to specially balanced composition
- high fatigue strength and crash performance due to reduced effect of disturbing Fe and Si phases
- excellent weldability for aluminium profil-cast designs
- suitable for self-piercing riveting
Areas of use
Weight reduced car body structures for vehicles, mechanical engineering

Distinguishing charcteristics
Casting alloy with very high mechanical properties after T6 treatment including a air queching for reduced distorsion. Very high yield strenght combined with high values of elongation for crash relevant structural die castings.
Silafont-38 substitutes sheet designs in vehicle design and offers high cost and weight reduction.

Alloy denomination
Chemical denomination: AlSi9MnMgZn

Chemical composition [% of mass]

<table>
<thead>
<tr>
<th></th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
<th>Ti</th>
<th>Sr</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td>min.</td>
<td>8.0</td>
<td>0.1</td>
<td>0.5</td>
<td>0.1</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td>0.010</td>
</tr>
<tr>
<td>max.</td>
<td>10.0</td>
<td>0.15</td>
<td>0.4</td>
<td>0.8</td>
<td>0.5</td>
<td>0.4</td>
<td>0.15</td>
<td>0.02</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Mechanical properties

<table>
<thead>
<tr>
<th>Casting method</th>
<th>Treatment state</th>
<th>Quenching cooling</th>
<th>YTS Rp0.2 (MPa)</th>
<th>UTS Rm (MPa)</th>
<th>Elongation A [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPDC</td>
<td>F</td>
<td></td>
<td>140 – 160</td>
<td>270 – 300</td>
<td>3 – 7</td>
</tr>
<tr>
<td>HPDC</td>
<td>T6</td>
<td>Water</td>
<td>230 – 270</td>
<td>300 – 345</td>
<td>6 – 9</td>
</tr>
<tr>
<td>HPDC</td>
<td>T6</td>
<td>Air</td>
<td>180 – 200</td>
<td>250 – 275</td>
<td>8 – 10</td>
</tr>
</tbody>
</table>

Note chapter “Technical Information”!

Processing properties compared to standard pressure die casting alloys

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>Silafont-38</th>
<th>Silafont-36</th>
<th>Silafont-09</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sticking tendency</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Die life</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Linear shrinkage</td>
<td>0.4 – 0.6%</td>
<td>0.4 – 0.6%</td>
<td>0.4 – 0.6%</td>
</tr>
</tbody>
</table>

Temper F
- Rp0.2 = 147 MPa
- Rm = 290 MPa
- A = 5.5%

Temper T6 Water
- Rp0.2 = 272 MPa
- Rm = 344 MPa
- A = 6%

Temper T6 Air
- Rp0.2 = 185 MPa
- Rm = 278 MPa
- A = 10%
The HPDC alloy Castaman-35 was developed by RHEINFELDEN ALLOYS to allow the use of high quality recycling material.

The same strength values and a similarly high elongation compared to primary aluminum die casting alloy Silafont-36 could be reached, despite the increasing iron content.

The designer has in addition the possibility to arise strength by two step heat treatment, solutionizing included. Castaman-35 in 3 mm thickness can archive 8 % elongation and 260 MPa yield strength by this.

Besides these particular mechanical properties, Castaman-35 has also following properties required for the pressure die casting process:
• excellent castability
• no sticking to the die
• excellent machinability

In more and more applications, mainly in car manufacturing, other properties of Castaman-35 are of increasing importance:
• very high corrosion resistance
• high fatigue strength
• excellent weldability, also for aluminium profil-cast designs
• suitable for self-piercing riveting and similar joining processes, glueing connections
• suitable for glueing connections in car design
Castaman®-35 [AlSi10MnMg]

Areas of use
Large and huge structural car body cast, lighting, automotive engineering, mechanical engineering

Distinguishing characteristics
High pressure die casting alloy with very good casting properties, even with thick-walled designs.
Very good corrosion resistance to weathering and water.

Alloy denomination
Chemical denomination: AlSi10MnMg   Numerical denomination: 43 500

Chemical composition [% of mass]

<table>
<thead>
<tr>
<th></th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
<th>Ti</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td>min.</td>
<td>9.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>max.</td>
<td>11.0</td>
<td>0.2</td>
<td>0.03</td>
<td>0.8</td>
<td>0.5</td>
<td>0.1</td>
<td>0.15</td>
<td>Sr</td>
</tr>
</tbody>
</table>

Mechanical properties

<table>
<thead>
<tr>
<th>Casting method</th>
<th>Treatment state</th>
<th>YTS $R_{P0.2}$ [MPa]</th>
<th>UTS $R_m$ [MPa]</th>
<th>Elongation A [%]</th>
<th>Brinell hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPDC</td>
<td>T6</td>
<td>180–280</td>
<td>250–340</td>
<td>6–12</td>
<td>80–110</td>
</tr>
</tbody>
</table>

Processing properties compared to standard pressure die casting alloys

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>Castaman-35</th>
<th>Silafont-36</th>
<th>Silafont-09</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sticking tendency</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Die life</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Linear shrinkage</td>
<td>0.4–0.6%</td>
<td>0.4–0.6%</td>
<td>0.4–0.6%</td>
</tr>
</tbody>
</table>

Note chapter “Technical Information”!

Temper T6

$R_{P0.2} = 178$ MPa
$R_m = 254$ MPa
$A = 8.5\%$
Thermodur®-72 / -73

A glimpse into the future

RHEINFELDEN ALLOYS developed this heat-resistant die cast alloy on the base of AlMg alloys for the production of casts in the engine compartment such as crank case and a number of other – the engine block near – assemblies. Beside this Thermodur-72 can be used for particularly high-strength components in addition to Magsimal-59 or instead Peraluman-90, AlMg9 as a particularly corrosion-resistant die cast alloy.

Thermodur-72 has following properties:
• well usable for AlMg die cast with thick walls
• low oxidation of the melt due to patented alloying elements
• with high temparature higher strength than with AlSi-alloys

RHEINFELDEN ALLOYS has developed on the base of the piston alloy Silafont-70 a heat-resistant die cast alloy. The structure posess no primary silicon and is modified with strontium. The high alloy contents of Cu and Ni allow the heat resistance of the alloy.

Excellent casting characteristics and a very good ma-chinability allow the various component designs, such as reduced-weight engine blocks or as thick walled fan hub.

Thermodur-73 has following properties:
• easy handling in the die cast flor shop
• low shrinkage behavior enables even bigger iron inserts
• very high pressure toughness
**Thermodur®-72 [AlMg7Si3Mn]**

**Areas of use**
Manufacture of engines, crankcases, engine components, turbo charge housing

**Distinguishing characteristics**
High pressure die casting alloy for the manufacture of engines for parts that require very good mechanical properties at elevated temperatures and high corrosion resistance.

**Chemical composition [% of mass]**

<table>
<thead>
<tr>
<th></th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
<th>Ti</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td>min.</td>
<td>2.8</td>
<td>0.15</td>
<td>0.03</td>
<td>0.5</td>
<td>7.0</td>
<td>0.07</td>
<td>0.15</td>
<td>0.004 Be</td>
</tr>
<tr>
<td>max.</td>
<td>3.2</td>
<td>0.15</td>
<td>0.03</td>
<td>0.8</td>
<td>8.8</td>
<td>0.07</td>
<td>0.15</td>
<td>0.004 Be</td>
</tr>
</tbody>
</table>

**Mechanical properties**
Tested at temperature indicated

<table>
<thead>
<tr>
<th>Ageing temperature</th>
<th>Ageing time</th>
<th>YTS $R_{p0.2}$ [MPa]</th>
<th>UTS $R_m$ [MPa]</th>
<th>Elongation A [%]</th>
<th>Brinell hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td></td>
<td>190 – 220</td>
<td>350 – 380</td>
<td>7 – 10</td>
<td>80 – 100</td>
</tr>
<tr>
<td>150°C</td>
<td>500 h</td>
<td>220 – 245</td>
<td>260 – 290</td>
<td>&gt; 15</td>
<td></td>
</tr>
<tr>
<td>225°C</td>
<td>500 h</td>
<td>150 – 175</td>
<td>180 – 205</td>
<td>&gt; 20</td>
<td></td>
</tr>
</tbody>
</table>

**Thermodur®-73 [AlSi11Cu2Ni2Mg2Mn]**

**Areas of use**
Cars, manufacture of engines, fan design

**Distinguishing characteristics**
Very good hardness and high strength in as-cast state, very good mechanical properties at elevated temperatures. Good castability in sand, chill and high pressure die casting. Excellent weldability and machinability.

**Chemical composition [% of mass]**

<table>
<thead>
<tr>
<th></th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
<th>Ti</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td>min.</td>
<td>10.0</td>
<td>0.15</td>
<td>1.8</td>
<td>0.4</td>
<td>1.8</td>
<td>0.10</td>
<td>0.10</td>
<td>1.8–2.3 Ni; Sr</td>
</tr>
<tr>
<td>max.</td>
<td>11.8</td>
<td>0.15</td>
<td>2.3</td>
<td>0.4</td>
<td>2.3</td>
<td>0.10</td>
<td>0.10</td>
<td>1.8–2.3 Ni; Sr</td>
</tr>
</tbody>
</table>

**Mechanical properties**
Tested at temperature indicated

<table>
<thead>
<tr>
<th>Ageing temperature</th>
<th>Ageing time</th>
<th>YTS $R_{p0.2}$ [MPa]</th>
<th>UTS $R_m$ [MPa]</th>
<th>Elongation A [%]</th>
<th>Brinell hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td></td>
<td>270 – 300</td>
<td>300 – 320</td>
<td>&lt; 1</td>
<td>130 – 150</td>
</tr>
<tr>
<td>150°C</td>
<td>500 h</td>
<td>280 – 310</td>
<td>330 – 355</td>
<td>&lt; 1</td>
<td></td>
</tr>
<tr>
<td>225°C</td>
<td>500 h</td>
<td>130 – 155</td>
<td>250 – 280</td>
<td>1 – 2</td>
<td></td>
</tr>
</tbody>
</table>

Note chapter “Technical Information”!
Magsimal®-59
Of filigree lightness, but extremely resilient

Magsimal-59 developed by RHEINFELDEN ALLOYS is a widely used HPDC alloy for automotive applications. This alloy type has excellent properties in the as-cast state, i.e. high yield strength in conjunction with high ductility. Energy absorption capacity, e.g. in the event of a crash. The fatigue strength is also higher than for conventional pressure die cast alloys.

Most applications are therefore safety components with high performance requirements e.g. safety-belt pretensioners, steering wheel frames, crossbeams, motorbike wheel rims, control arm, suspension-strut brackets and other flap or chassis components.

While the properties of Magsimal 59 depend on the wall thickness, a special heat treatment is suggested to compensate the difference and to enable either high cast rigidity or high ductility. This heat treatment do not require the water quenching, and the aging is performed below the blister formation temperature. Air cooling is also possible to exclude distortions.

The alloy Magsimal-59 is produced on a primary metal basis and therefore manifests high analytical purity. This produces as a consequence outstanding mechanical strength and an excellent corrosion behavior.

Specially chosen chemical composition enables the following casting properties:
• very good castability
• suitable for minimum wall thicknesses
• low sticking to the die
• excellent properties in the as-cast state

With increasing number of applications, mainly in car manufacturing, other properties of Magsimal-59 became also important:
• high yield strength in conjunction with high ductility
• very high energy absorption capacity
• very high fatigue strength
• excellent corrosion behavior
• suitable for self-piercing riveting
• excellent suitable for glueing connections in car design
Magsimal®-59 – Properties at a glance

Chemical composition of Magsimal-59, AlMg5Si2Mn

<table>
<thead>
<tr>
<th>[%]</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
<th>Ti</th>
<th>Be</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td>min.</td>
<td>1.8</td>
<td>0.5</td>
<td>0.03</td>
<td>5.0</td>
<td></td>
<td>0.07</td>
<td>0.2</td>
<td>0.004</td>
<td>0.2</td>
</tr>
<tr>
<td>max.</td>
<td>2.6</td>
<td>0.2</td>
<td></td>
<td>0.8</td>
<td>6.0</td>
<td></td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mechanical properties in the as-cast state depending on wall thickness of test samples

<table>
<thead>
<tr>
<th>Wall thickness [mm]</th>
<th>YTS $R_{p0.2}$ [MPa]</th>
<th>UTS $R_m$ [MPa]</th>
<th>Elongation $A$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2</td>
<td>&gt; 220</td>
<td>&gt; 300</td>
<td>10 – 15</td>
</tr>
<tr>
<td>2 – 4</td>
<td>160 – 220</td>
<td>310 – 340</td>
<td>12 – 18</td>
</tr>
<tr>
<td>4 – 6</td>
<td>140 – 170</td>
<td>250 – 320</td>
<td>9 – 14</td>
</tr>
<tr>
<td>6 – 12</td>
<td>120 – 145</td>
<td>220 – 260</td>
<td>8 – 12</td>
</tr>
</tbody>
</table>

Physical properties in the as-cast state

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Validity range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solidification range</td>
<td>618 – 580</td>
<td>°C</td>
</tr>
<tr>
<td>Density</td>
<td>2.65</td>
<td>kg/dm³</td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>68 – 75</td>
<td>GPa</td>
</tr>
<tr>
<td>Linear thermal expansion coeff.</td>
<td>24</td>
<td>$1/K \times 10^6$</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>1.1</td>
<td>W/(K × cm)</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>14 – 16</td>
<td>MS/m oder m/(Ω × mm²)</td>
</tr>
<tr>
<td>Fatigue strength ($r = -1$)</td>
<td>100</td>
<td>MPa</td>
</tr>
</tbody>
</table>

Processing properties compared to standard pressure die casting alloys

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>Magsimal-59</th>
<th>AlMg3Mn</th>
<th>AlSi10Mg(Fe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat treatment</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Hot crack tendency</td>
<td>low</td>
<td>high</td>
<td>no</td>
</tr>
<tr>
<td>Sticking tendency</td>
<td>low</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Tendency to increased dross formation</td>
<td>medium</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Die life</td>
<td>&gt; 90 %</td>
<td>&gt; 70 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Linear shrinkage</td>
<td>0.6 – 1.1 %</td>
<td>0.9 – 1.3 %</td>
<td>0.4 – 0.6 %</td>
</tr>
</tbody>
</table>

Note chapter “Technical Information”!
Magsimal®-59 [AlMg5Si2Mn]

Door design for four-door sports car
Magsimal-59; as-cast
Wall thickness 2 mm
1140 × 690 × 155 mm; weight: 4.1 kg

Steering-wheel frame / VW New Beetle
Magsimal-59; as-cast
Ø 370 × 125 mm; weight: 0.85 kg

Cross member for off-roadcars / BMW
Magsimal-59; as-cast; weldable
770 × 460 × 200 mm; weight: 4.8 kg

Cross member for 4x4 SUV
Magsimal-59; as-cast
710 × 910 × 85 mm; weight: 7.6 kg

This crossbeam replaces a considerably heavier gravity casting variant made with a heat-treated AlSiMg-alloy. The lightweight construction with corresponding thin wall thickness of this die cast design is particularly economic, if no heat treatment with solutionizing is performed. Considerable component distortion would otherwise have to be rectified, which would again introduce stresses into the component.

Strut mounting for sports car
Magsimal-59; as-cast
Wall thickness 3 mm
590 × 450 × 340 mm; weight: 3.0 kg

Door design for off-road cars / BMW
Magsimal-59; as-cast; weldable
770 × 460 × 200 mm; weight: 4.8 kg

Cross member for 4x4 SUV
Magsimal-59; as-cast
710 × 910 × 85 mm; weight: 7.6 kg

This crossbeam replaces a considerably heavier gravity casting variant made with a heat-treated AlSiMg-alloy. The lightweight construction with corresponding thin wall thickness of this die cast design is particularly economic, if no heat treatment with solutionizing is performed. Considerable component distortion would otherwise have to be rectified, which would again introduce stresses into the component.
Front-wheel suspension strut / BMW 5er, 6er
Magsimal 59; as-cast
Wall thickness 2.5 mm
500 × 380 × 500 mm; weight: 2.3 kg

This component is subject to maximum dynamic loads in the aluminium front section of the BMW 5 and 6 Series. Different jointing technologies require maximum casting quality and extremely good material performance: modern self-piercing riveting joints with multi-layered sheet metal, under current welded joints, permanent glued joints, structural screw connections of the cross-brace. The thin component configuration with only 2.5 mm wall thickness complies with the material behaviour, which shows its best properties with these solidification conditions.

Node for window frame
Magsimal-59; as-cast; weldable
Up to 510 mm long; weight: 0.20 – 0.35 kg

Belt furling spindle / Saab, Daimler
Magsimal-59; as-cast
Wall thickness 1.0 – 5.0 mm
Ø 56 × 55 mm; weight: 0.066 kg

Internal door part for vehicle
Magsimal-59; as-cast; suited to welding
610 × 250 × 100 mm; weight: 1.0 kg

Suspension-strut bracket / Porsche Cayenne
Magsimal-59; as-cast
Wall thickness 6 mm
340 × 370 × 60 mm; weight: 0.9 kg

Magsimal®-59 [AlMg5Si2Mn]
Transmission crossrail / Porsche
Magsimal-59; as-cast
160 × 320 × 55 mm; weight: 0.34 kg

Rain sensor housing
Magsimal-59; as-cast
70 × 65 × 8 mm; weight: 0.013 kg

Gearbox crossbeam / Daimler
Magsimal-59; as-cast
Wall thickness 4 mm
610 × 210 × 75 mm; weight: 2.3 kg

Oilpans
Magsimal-59; as-cast
Weight: 3.0 – 4.2 kg

Oil pans for sports cars must have ductile floors in order to be able to reduce the eventual impact stresses, e.g. due to stones shooting up from the road or touching the ground without cracking.

A high degree of hardness in the screw-on flange must be guaranteed due to high surface pressure during assembly.

Base plate for convertible soft-top hinge
Magsimal-59; as-cast
Wall thickness 2 – 5 mm
600 × 350 × 280 mm; weight: 3.2 kg

Stabiliser rod bracket / BMW 5-er
Magsimal-59; as-cast
135 × 90 × 50 mm; weight: 0.18 kg

Magsimal®-59 [AlMg5Si2Mn]

Magsimal-alloy family guarantees an extraordinary high stiffness also on this 0.44 mm-thin housing. The long-term reliability of the glue jointing between glass and cast was decisive for the choice of Magsimal.
### Magsimal®-59 – Chemical composition

The table below gives the chemical composition of Magsimal-59. The magnesium/silicon ratio ensures good castability and good feeding during solidification. Excess magnesium promotes the formation of Mg₂Si compounds. This is important because for a good corrosion behaviour it must be ensured that no free silicon is available. Furthermore, excess magnesium ensures a high yield strength. Calcium and sodium must be kept to a minimum as these elements have a negative effect on casting behaviour, e.g. through an increased hot cracking tendency. Phosphorus must also be kept to a minimum as this element has a negative effect on the formation of the Al-Mg₂Si eutectic and therefore on the ductility.

AlMg-alloy melts with a magnesium content of > 2% have a tendency towards increased dross formation, if the melt remains in the furnace for a long time and the melting temperature is particularly high. A cauliflower-type dross is then produced which is difficult to remove. Therefore, beryllium is added into the alloy. This element increases the density of the oxide skin and therefore less aluminium and magnesium diffuse towards the outside and can oxidize there.

The thermal analysis of Magsimal-59 is shown in figure 1. The temperature curve was recorded with a Quick-Cup-crucible (in Croning sand). The liquidus temperature is approximately 618°C and the solidus temperature is approximately 594°C. A pronounced holding point can be detected at 592°C. The AlMg₂Si eutectic solidifies at this point. The structure of the pressure die casting, that means the presence of a very high cooling rate, results in a uniform α-phase. The bright particles in figure 2 are the Al₆Mn-phase. Manganese prevents sticking to the die.

### Table 1: Chemical composition of Magsimal-59, AlMg5Si2Mn in the ingot (weight in %)

<table>
<thead>
<tr>
<th></th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
<th>Ti</th>
<th>Be</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td>min.</td>
<td>1.8</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>5.0</td>
<td>0.07</td>
<td>0.20</td>
<td>0.004</td>
<td>0.2</td>
</tr>
<tr>
<td>max.</td>
<td>2.6</td>
<td>0.2</td>
<td>0.03</td>
<td>0.8</td>
<td>6.0</td>
<td>0.07</td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Fig. 1: Thermal analysis of Magsimal-59, AlMg5Si2Mn, in a Quick-Cup-Crucible*

The α-aluminium and Mg₂Si-eutectic is distributed around the α-dendrites. No coarse phases are to be seen in this image (see also front page of manual) and the eutectic is fine and spherical; therefore, this is a very ductile structure.

*Fig. 2: SEM-image of Magsimal-59, AlMg5Si2Mn, not etched*
Magsimal®-59 – Mechanical properties

**Mechanical properties in the as-cast state**

Brief details of a characteristic material property during static testing of AlMg alloys should be given at this point. Small “peaks” can be detected in the stress-strain curve during the tensile test. These are not incipient cracks in the material but in fact “strain-induced ageing”. This phenomenon occurs in the plastic area of the stress-strain curve, and, from an atomistic point of view, it is an interaction between solid solution atoms and migratory dislocations in the structure (Portevin-Chatelier effect), which causes a momentary low stress reduction in the stress-strain curve. Figure 3 shows a typical example of such behaviour.

The mechanical properties of Magsimal-59 are dependent on the wall thickness and thus on the solidification conditions.

Table 2 shows the mechanical property ranges. These mechanical properties were obtained from real casts and from separately cast sample bars and plates. It must be noted that the values can disperse within the cast and, as a rule, they are better in proximity to the gate rather than in remote or gate-opposite areas. This effect can be reduced by providing overflows.

Therefore, appropriate cut off areas of test samples from pressure die castings are critical and must be accurately defined between foundryman and designer in any case. Required mechanical properties and dimensions must be agreed.

![Stress-strain curve for Magsimal-59, AlMg5Si2Mn, in the as-cast state. Wall thickness of samples: 3 mm](image)

<table>
<thead>
<tr>
<th>Wall thickness [mm]</th>
<th>(R_{p0.2} ) [MPa]</th>
<th>(R_m ) [MPa]</th>
<th>(A ) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2</td>
<td>&gt; 220</td>
<td>&gt; 300</td>
<td>10 – 15</td>
</tr>
<tr>
<td>2 – 4</td>
<td>160 – 220</td>
<td>310 – 340</td>
<td>12 – 18</td>
</tr>
<tr>
<td>4 – 6</td>
<td>140 – 170</td>
<td>250 – 320</td>
<td>9 – 14</td>
</tr>
<tr>
<td>6 – 12</td>
<td>120 – 145</td>
<td>220 – 260</td>
<td>8 – 12</td>
</tr>
</tbody>
</table>

Tab. 2: Mechanical properties of Magsimal-59, AlMg5Si2Mn, in the as-cast state depending on wall thickness of separately cast test samples
Temper T5 and Temper O

Yield strength decreases more and more with increasing wall thicknesses and then values approaches to gravity permanent mould casting values. Now there are certainly applications, which fall partially into these thickness ranges, but where the required hardness values are no longer achieved by the casts. The strength properties can then be increased by a T5 treatment of the cast.

It has been proved that the cast must be quenched immediately after removal from the die so that the corresponding increase in strength can be achieved during hardening. Air cooling after removal from the die does not produce the desired effect. The change in mechanical properties is shown in figures 4. It can be concluded that a stable state is achieved after approximately 60 minutes ageing.

A yield strength of approximately 200 MPa can be achieved with 6 mm wall thickness. A higher yield strength is achieved with the 3 mm samples. However, the strength properties in this wall thickness are not very different for a T5 state. In contrast, elongation elongation is greatly dependent on wall thickness. After 60 minutes artificial ageing at 250°C the 3 mm samples still have approximately 10% elongation, whereas the 6 mm plates show a total elongation of approximately 4%. However, strength is normally more important than ductility in areas with high wall thickness, e.g. at screw-on points or in nodal areas.

This behaviour of the alloy in material accumulations or thick-walled areas can accordingly be defined as uncritical; however, it should be necessarily taken into account by the designer.

Age hardening provides a method of improving strength in areas with high wall thickness. If an ageing temperature of 350°C is selected, yield strength is reduced to 130 MPa to 150 MPa depending on the starting value and elongation is greatly increased. Higher ductility can be achieved if the values in the as-cast state should not be sufficient for the requirement profile.

Natural aging

Especially with thin-walled casts in Magsimal-59, AlMg5Si2Mn, water quenched after ejecting from the die an aging can be observed at room temperature. After 20 days the yield strength is 30 MPa higher with the water quenched casts, on the other hand with air-cooled are higher by only 5 MPa. However, the elongation hardly decreases. Figure 5 shows this at 3 mm die cast plates.
**Fatigue strength**

The fatigue strength is a significant criterion for the designer. It depends on the material, solidification conditions, casting defects and surface conditions of the cast. Therefore, the transferability of measurements is only possible to a limited extent. Figure 6 indicates the fatigue strength of Magsimal-59 with a stress ratio r of -1. This means that the average stress is zero. Measurement was carried out with 4 mm thick pressure die cast plates on a highfrequency pulse generator (approx. 110 Hz). The curves were determined for different fracture probabilities. As a rule the 5% fracture probability curve is always used for calculations. It is evident from the curves that the fatigue strength of Magsimal-59 is 100 MPa in the as-cast state.

**Corrosion resistance**

AlMg-alloys are usually very corrosion resistant and are therefore used in a salt-water atmosphere too. As this alloy type is also used for safety components, a test to determine the tendency towards stress cracking corrosion is unavoidable.

For this purpose, Magsimal-59 samples were loaded to the 75% of the yield strength by means of clamping and subjected to sea water immersion test in a 35 g/l-NaCl solution over a period of 30 days (ASTM G 47-90). The stress has not to be reduced after the test. A comparison of different materials with regard to fatigue behaviour without and in a corrosive atmosphere is shown in figure 7. It is evident that the alloy Magsimal-59 is superior under the influence of corrosion to the well-known alloy AlSi7Mg0.3 T6.
Melting
Magsimal-59 has a special long-term grain refinement particularly affecting the AlMg2Si-eutectic. The eutectic fineness degree determines the elongation and therefore the toughness of the cast (Fig. 8). A special melting process during alloy production greatly reduces the oxidation of the melt, which is a particular characteristic of the AlMg-alloys. The strong presence of oxides leads to a considerable reduction in elongation. With Magsimal-59 agglomerations of oxides rarely form on bath surfaces and on the furnace floor.

All these advantages can be maintained only if after a rapid melting of the ingots a deep melt cleaning by means of a gas-impeller is carried out and no melt process salts, grain-refining and modification agents, substances containing phosphorus, alkalis and alkaline earth, and other foreign metal or impurities are added to the melt. The AlMg2Si-eutectic is greatly affected and coarsened thereby (Fig. 9). The melt temperature, during melting, should not exceed 780 °C.

Furnaces, which keep the melt moving through heat convection, prevent segregation and the formation of a dross-cover due to melt oxidation reactions. This also applies to furnaces in which the bath stirring is carried out by means of rotors or circulating gas injection through the bottom of the furnace. Furnaces with over-head heating without bath circulation cause problems for AlMg-alloys especially during long holding times without refilling due to production breakdowns.

Melts of all aluminium alloys and also Magsimal-59 do not react with the refractory material, if this contains more than 85% aluminium oxide, Al2O3. New granulation mixes result in a particularly dense refractory material, in which infiltration and thus an undesired reaction is avoided.

The re-melting of ingots, returns, etc., does not pose a problem. However, it should be ensured that no mixing with other alloys can take place.

This can have a negative effect on the mechanical properties. Good melt cleaning by means of argon or nitrogen rotor degassing is absolutely essential when using returns, as oxide inclusions, oxide skins etc. must be removed. Otherwise a long-term melt pollution takes place, which results in a negative effect on the properties of cast components. The metal content of the drosses formed thereby can be reduced with particular melt process salts specially developed for Magsimal-59.

Casting
The eutectic temperature for Magsimal-59 and therefore the casting temperature is approx. 20 °C above the AlSi10Mg(Fe) one and must be taken into account in the die life calculation, if heat is dissipated mainly over the die surface by water spraying. Dies provided with cooling water systems through heat exchangers for heat dissipation have longer service lives. Despite greater shrinkage forces, the casts are easy to remove from the die because the high manganese content prevents sticking and increases the high temperature resistance and therefore the fatigue strength of the alloy. Nevertheless, the draft angles of the dies should be more than 1.5°.

The die release agent shall be applied with 30–50% higher concentration than normal for AlSi-alloys. Commercially available release agents can be used. Restrictions must be imposed for weldable pressure die castings. In this case the release agent must be used in accordance with the process.

Handling instructions for melt preparation is on page 60 and an eight-target-level diagram for HPDC requirements on page 64.

Fig. 8: Fine Al-Mg2Si-eutectic of Magsimal-59, AlMg5Si2Mn
Fig. 9: Coarse Al-Mg2Si-eutectic of Magsimal-59, AlMg5Si2Mn
Magsimal®-59 – Processing instructions/design guidelines

For the processing of AlMg-alloys newly developed mold release agents improve the castability, the lubrication during ejection and the weldability of die casts.

Surface treatment
Magsimal-59 can be painted or powdercoated and also polished or anodised. Polishing produces a typical light blue colour of the surface gloss. It should be noted that anodising produces a typical shade of grey due to the silicon content. Therefore, the application of a chromium coating or polishing is recommended for decorative purposes.

Design guidelines
The design of the ribs can be too thin, which produces a highly undesirable rigidity in the ribs themselves. Deformation then occurs only partially at the end" of the ribs, i.e. in the wall. 1 – 2 mm ribs are for example not recommended into a 6 mm wall-thick U-profile (Fig. 10).

Examples of good design using Magsimal-59:
• Eliminate nodal points so that sinks are not occurring on the opposite side of the wall. The high volume contraction causes on larger nodes these visible external sinks (Fig. 11).
• Material agglomerations on internal radii cause sinking points as mentioned above. A solution is given by "crow's feet" as shown in figure 12.

Center line shrinkage can become very long in unfavourable solidification conditions. However, as these shrinkages are located in the central position (neutral fibres), they do not have any evident effect on component strength. It is essential in this instance that the shrinkage does not have any contact with the open surface in the heavy-duty cast surface area.

Components for self-piercing riveting should not be thicker than 3 mm in order to guarantee the required component wall deformability.

Assistance on site
Our foundry engineers will be happy to discuss any queries with you regarding the technicalities of Magsimal-59.

Bibliography
Technical informations

This chapter is provided on how to work with our casting alloys in the melt process and how to gain optimum pouring results. In the various steps in the die cast process as possible grain refinement, strontium modification, quality of melt, heat treatment for HPDC, surface coating, and joining techniques for the HPDC is hereby received.

We consider this a very important part of the manual as it isn’t just the quality of casting alloy used which is key to successful applications, the right way of working before, during and after pouring is also of great importance. More questions will certainly arise during your work and as new developments enter the market. The RHEINFELDEN ALLOYS foundry specialists will happily answer these.

The mechanical properties are based on in-house measurements of our alloys and most exceed the values stipulated in the EN 1706 European standard.

The mechanical values were measured at tensile bars, machined from HPDC. The ranges of mechanical properties stated indicate the performance of the alloys and the amount of scatter depending on material and pouring. The respective maximum value is for the designer’s information. These values can also be reached in the cast or sub-areas with favorable casting conditions and corresponding casting technology work.

The HPDC alloys supplied by RHEINFELDEN ALLOYS have small and precisely defined analysis ranges in order to ensure good uniformity in the casting process and other properties.

Processing datasheets

RHEINFELDEN ALLOYS provides the following processing data sheets in order to detail how to work with the various alloys. If you use our casting alloys, please feel free to copy the following pages and use them in your company. They contain practical instructions and demonstrate the processes step by step.

Not all alloys are listed here, but the processing data sheet from within the corresponding alloy family can be used. The recommendations correspond to typical foundry circumstances. For example a crucible or shaft melting furnace is considered for melting down; the circumstances in a huge melting furnace may differ from the recommendations. Fine returns should also not be used for primary aluminium high pressure die casting alloys.

The volumes listed here are all percentages by weight, calculated for the charge weight. The temperatures quoted all relate to the temperature of melt, even for casting. The heat treatment recommendations apply for the standard process and may be varied, to minimise distortion for example.

If you have any questions relating to your specific alloy application and processing, please contact our foundry experts.
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Refining</td>
</tr>
<tr>
<td>2</td>
<td>Melting down the ingots</td>
</tr>
<tr>
<td>3</td>
<td>Salt treatment</td>
</tr>
<tr>
<td>4</td>
<td>Strontium burnout</td>
</tr>
<tr>
<td>5</td>
<td>Skimming</td>
</tr>
<tr>
<td>6</td>
<td>Temperature after melting down</td>
</tr>
</tbody>
</table>
| 7 | Degassing and refining the melts  | • In the transport crucible, better in casting or dosing furnace; effective refining and fastest method using quick-running rotor for gas feeding, 7–10 l/min argon or nitrogen, 6–10 min; during degassing in the transport crucible, cooling of 30–50 °C should be expected  
• Gas flushing lance with fine porous head, needs longer treatment times (cooling!)  
• Tablets for melt cleaning are inefficient |
| 8 | Skimming  | Required after degassing; the metal content of the skimmings may be reduced by adding melt fluxes during or after impeller treatment |
| 9 | Pouring temperature (approx. values)  | 680–720 °C depends on design, flow path and wall thickness of high pressure die casting, but also on the length and insulation of the flow channel from the dosing furnace and on use of shot sleeve heating. Temperature losses may cause initial solidification and should therefore be avoided |
| 10 | Mould temperature  | 250–350 °C, depending on cast and requirements of mechanical properties  
As a rule: the warmer the mould, the higher the elongation and the lower the strength. |
| 11 | Die chamber temperature  | Preheat the chamber electrical or with oil > 200 °C |
Castasil®-21 [AlSi9Sr]
Sequence of work when producing high pressure die castings from Castasil-21

1 Refining
Clean furnace, crucible, treatment and casting tools to avoid impurities from unwanted elements such as Cu, Zn and especially Mg!

2 Melting down the ingots
The melt should be quickly heated to above 670 °C to avoid segregations, e.g. of the solid solution containing Mn in the melt. The temperature of melt should not exceed 780 °C. An Sr melting loss should be expected when melting and keeping warm – the higher the temperature, the greater the loss. Sr melting loss should be expected in particular when melting down returns and degassing treatment is recommended to remove the H₂ and oxides. As the Sr content increases, so does the tendency for the melt to absorb hydrogen; this should not therefore exceed 350 ppm.

3 Salt treatment
Not needed when melting

4 Strontium burnout
Usually melting loss of 30–50 ppm per fusion; Sr should only be added if the Sr content of the melts is less than 60 ppm, add AlSr5 or AlSr10.
When fusing for the first time in a new crucible or in a crucible which has not yet been used for Sr-modified alloys, the Sr content falls sharply. Strontium will diffuse into the crucible; saturation is reached after the first fusion

5 Skimming
Needed after melting down; as well as their potential for danger, cold tools may result in molybdenum segregation

6 Temperature after melting down
After melting down maximum of 780 °C for holding temperature. Don’t keep the melt at temperature below 680 °C and steer melt if possible

7 Degassing and refining the melts
- In the transport crucible, better in casting or dosing furnace; effective refining and fastest method using quick-running rotor for gas feeding, 7–10 l/min argon or nitrogen, 6–10 min; during degassing in the transport crucible, cooling of 30–50 °C should be expected
- Gas flushing lance with fine porous head, needs longer treatment times (cooling!)
- Tablets for melt cleaning are less efficient

8 Skimming
Required after degassing; the metal content of the skimmings may be reduced by adding melt fluxes during or after impeller treatment

9 Pouring temperature (approx. values)
680–720 °C depends on design, flow path and wall thickness of high pressure die casting, but also on the length and insulation of the flow channel from the dosing furnace and on use of shot sleeve heating.
Temperature losses may cause initial solidification and should therefore be avoided

10 Mould and chamber temperature
250–350 °C, depending on cast and requirements of mechanical properties
As a rule: the warmer the mould, the higher the elongation and the lower the strength. Preheat the chamber electrical or with oil > 200 °C

11 Annealing to high conductivity by TS
250–350 °C/2–3 hours
The annealing and ageing times stated apply without a heating-up time
<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Melting down the ingots</td>
<td>As quickly as possible in efficient furnaces to keep magnesium melting loss, gas absorption and oxidation of melts low; replenish preheated ingots and returns in small volumes to avoid segregation and entrapped oxides; proportion of returns may extend to 50%</td>
</tr>
<tr>
<td>2</td>
<td>Salt treatment</td>
<td>Not needed when melting</td>
</tr>
<tr>
<td>3</td>
<td>Magnesium burnout</td>
<td>Normally a melting loss of 0.03% per fusion; compensation is only required if the magnesium content of the melts is outside tolerance, add magnesium master alloy or pure magnesium</td>
</tr>
<tr>
<td>4</td>
<td>Strontium burnout</td>
<td>Usually melting loss of 30–50 ppm per fusion; Sr should only be added if the Sr content of the melts is less than 80 ppm, add AlSr5 or AlSr10. When fusing for the first time in a new crucible or in a crucible which has not yet been used for Sr-modified alloys, the Sr content falls sharply. Strontium will diffuse into the crucible, saturation is reached after the first fusion</td>
</tr>
<tr>
<td>5</td>
<td>Skimming</td>
<td>Needed after melting down</td>
</tr>
<tr>
<td>6</td>
<td>Temperature</td>
<td>After melting down maximum of 780°C for holding temperature</td>
</tr>
<tr>
<td>7</td>
<td>Degassing and refining the melts</td>
<td>• In the transport crucible, better in a holding crucible or receptacle or in a dosing furnace with bottom blocks; effective refining and fastest method using quick-running rotor for gas feeding, 7–10 l/min argon or nitrogen, 6–10 min • Gas flushing lance with fine porous head, needs longer treatment times (cooling!) • Gas flushing tablets emitting nitrogen in the bell plunger procedure are not very suitable</td>
</tr>
<tr>
<td>8</td>
<td>Skimming</td>
<td>Required after melting down; the metal content of the skimmings may be reduced by adding melt fluxes within or after the impeller treatment</td>
</tr>
<tr>
<td>9</td>
<td>Pouring temperature (approx. values)</td>
<td>680–710°C – depends on design, flow path and wall thickness of high pressure die casting, but also on the length of the flow channel in the dosing furnace and possibly on chamber heating</td>
</tr>
<tr>
<td>10</td>
<td>Mould temperature</td>
<td>Die surface temperature 250–350°C</td>
</tr>
<tr>
<td>11</td>
<td>Ageing by T5</td>
<td>Water quenching immediately after the casting is taken out as high a temperature as possible (then age as 15)</td>
</tr>
<tr>
<td>12</td>
<td>Solution heat treatment</td>
<td>480–490°C / 2–3 hours; for special components: 400°C / 0.5 hours</td>
</tr>
<tr>
<td>13</td>
<td>Cooling after solution heat treatment</td>
<td>In water (10–60°C) without a delay wherever possible to &lt; 200°C; if cooling in the air, only a significantly lower yield tensile strength can be obtained</td>
</tr>
<tr>
<td>14</td>
<td>Delay time before artificial ageing</td>
<td>Only if dressing is needed, usually maximum of 12 hours</td>
</tr>
<tr>
<td>15</td>
<td>Full artificial ageing T6</td>
<td>155–170°C / 2–3 hours</td>
</tr>
<tr>
<td>16</td>
<td>Overageing T7</td>
<td>190–230°C / 2–3 hours</td>
</tr>
</tbody>
</table>

The annealing and ageing times stated apply without a heating-up time.
1 Melting down the ingots

As quickly as possible in efficient furnaces to keep magnesium melting loss, gas absorption and oxidation of melts low; replenish preheated ingots and returns in small volumes to avoid segregation and entrapped oxides; proportion of returns may extend to 50%

2 Salt treatment

Not needed when melting

3 Magnesium burnout

Normally a melting loss of 0.03% per fusion; compensation is only required if the magnesium content of the melts is outside tolerance, add magnesium master alloy or pure magnesium

4 Strontium burnout

Usually melting loss of 30–50 ppm per fusion; Sr should only be added if the Sr content of the melts is less than 80 ppm, add AlSr5 or AlSr10. When fusing for the first time in a new crucible or in a crucible which has not yet been used for Sr-modified alloys, the Sr content falls sharply. Strontium will diffuse into the crucible, saturation is reached after the first fusion

5 Skimming

Needed after melting down

6 Temperature

After melting down maximum of 780 °C for holding temperature

7 Degassing and refining the melts

• In the transport crucible, better in a holding crucible or receptacle or in a dosing furnace with bottom blocks; effective refining and fastest method using quick-running rotor for gas feeding, 7–10 l/min argon or nitrogen, 6–10 min
• Gas flushing lance with fine porous head, needs longer treatment times (cooling!)
• Gas flushing tablets emitting nitrogen in the bell plunger procedure are not very suitable

8 Skimming

Required after melting down; the metal content of the skimmings may be reduced by adding melt fluxes within or after the impeller treatment

9 Pouring temperature (approx. values)

680–710 °C – depends on design, flow path and wall thickness of high pressure die casting, but also on the length of the flow channel in the dosing furnace and possibly on chamber heating

10 Mould temperature

Die surface temperature 250–350 °C

11 Solution heat treatment

480–490 °C / 2–3 hours; for special components: 400 °C / 0.5 hours

12 Cooling with air

Immediate air cooling with a cooling rate of > 4 °C/s is only achieved with an intensive air stream (down to 200 °C) and results in lower distortion. If cooling in the air, only a significantly lower yield tensile strength can be obtained

13 Cooling with water

In water (10–60 °C) without a delay wherever possible

14 Delay time before artificial ageing

Only if dressing is needed, usually maximum of 12 hours

15 Full artificial ageing T6

155–170 °C / 2–3 hours

The annealing and ageing times stated apply without a heating-up time
1 Melting down the ingots
As quickly as possible in efficient furnaces to keep Mg melting loss, gas absorption and oxidation of melts low; replenish preheated ingots and returns in small volumes to avoid segregation; use refractory materials with a high clay content; avoid phosphorous and sodium absorption

2 Salt treatment
Prohibited to use usual salt! There is a risk of Na pick up

3 Magnesium burnout
Normally melting loss of 0.1% per fusion, correction not normally needed; if the Mg content is significantly below 7.0%, add pure magnesium of maximum 0.5%

4 Skimming
Needed after melting down

5 Temperature after melting down
Maximum of 780°C (check temperature!)

6 Temperature in holding furnace
Holding furnace temperature: 700–720°C
Do not allow to fall below 650°C and keep melt moving by means of:
• convection
• rotor (impeller)
• use bottom injection of N₂
• melt pouring
Do not use deep furnace with cover heating if melt is calm!

7 Degassing and refining the melts
• Effective refining and fastest method using quick-running rotor for gas feeding, 7–10 l/min argon or nitrogen, 6–10 min
• Gas flushing lance with fine porous head, needs longer treatment times (cooling!)
• Gas flushing tablets do not achieve the necessary effect!

8 Skimming
Careful skimming needed
Only totally Na-free salts may be used to reduce the metal content of skimmings!

9 Grain refining
Prohibited!

10 Modification
Prohibited! The elongation achievable would be reduced considerably

11 Pouring temperature (approx. values)
690–730°C, varies depending on design, size and wall thickness of high pressure die castings

12 Die temperature and die chamber temperature
Die surface temperature 250°C to 350 °C, depending on cast and requirements of mechanical properties
As a rule: the warmer the mould, the higher the elongation and the lower the strength.
Preheat the chamber electrical or with oil > 200°C

13 Quenching casts after removal from mould
Immediate quenching in water reduces the yield tensile strength and increases elongation

14 Heat treatment
Normally none

15 stress-relief annealing
Only in special cases for T5 and O; if necessary, age T5 at up to 250°C and for up to 90min, the yield tensile strength will increase and elongation decrease; if necessary, age O at between 320 °C and 380°C and for up to 90 min, the yield tensile strength will decrease and elongation increase
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Prohibited to use usual salt! There is a risk of Na pick up.

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Maximum of 780°C (check temperature!)

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Immediate quenching in water reduces the yield tensile strength and increases elongation

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Only in special cases for T5 and O; if necessary, age T5 at up to 250°C and for up to 90 min, the yield tensile strength will increase and elongation decrease; if necessary, age O at between 320°C and 380°C and for up to 90 min, the yield tensile strength will decrease and elongation increase.
Surface coating

For pressure die castings maximum surface condition requirements are defined for pressure die castings which are to be coated. This applies specifically to top-quality coatings which must meet maximum requirements, with regard to decorative appearance and resistance to corrosion for example in the automotive or aviation industry.

The following parameters have considerable influence on flawless coating:

- Pressure die casting design and process
- Die design
- Testing and machining

Here some design and processing tips are reported to help preventing detrimental influences on the coating.

Design

The cast design should have no sharp edges and small radii below 2 mm. "Thinning-out" causes running away of the coating film at the edges during baking with significantly lower coating thicknesses.

Undercuts and bores always present problem areas in the frequently applied electrostatic coating technology, which can only be covered evenly with electro-dip painting.

Die design

Sufficient die conicity must be taken into account at the die design, as too low draft angles in long designs can produce drawing grooves resulting in their turn in depressions in the coating.

At least 1% die inclination for Silafont-36 and Castasil-37 and at least 1,5% for Magsimal-59 should be assumed. Fine narrow burrs and flashes form on the die and core slide during ejection. Hot cracks can appear in thermally loaded areas of the cast with older dies. These burrs and the die crack marks must be removed as they cause "paint thinning" on their sharp edges. Deep die cavities without melt flow through possibility must be designed with overflows so that no air, release agent residues or any oxide skins are included in the cast during the die filling, which may cause blister formation during baking of the coating.

Pressure die casting process

Die release agents, preferably water based, are used for smooth removal of casts from the die. Some of these burn into the cast skin. Release agents containing silicon or graphite can thus cause considerable problems. The gate area is in some cases additionally greased in order to prevent soldering to the die due to increased thermal load. These lubricants also cause adhesion losses for coatings. Therefore a very economical use of these lubricants is recommended for casts to be coated.

Die-filling simulations may help to avoid high flow speeds, which lead to surface flaws in the cast with consequently uneven decorative coating.

The pressure die casting gate should not be in the visible area of the cast as far as possible. The die would be under greatest stress in this area and would undergo premature hot crack formations. In turn this would become visible as depressions in the cast and must be mechanically removed prior to any coating.

Fig. 1: Two die casts for rear swinging fork for motorbike; multi-pat welded structure in stiff design; powder coated
Surface coating

Crack testing
A penetration crack test is often carried out on Magsimal-59 pressure die casting alloys. Test agent residues on surface flaws or pores must be removed by intensive cleaning, e.g. using ultra sounds, otherwise there will be discolorations in the coatings or adhesion losses.

Heat treatment
Heat treatments at solutionizing temperatures above 480 °C, such as T4, T6 and T7 for Silafont-36, produce highly oxidised surfaces which must be considered during surface pre-treatment.

Machining
When using coolants for precision machining, it must be taken into account that they have to be completely removed immediately afterwards by degreasing. Coolants attacking aluminium must not be used. Material compatibility and removableness of coolants must determine their selection.

Machining allowances should be kept to an absolute minimum for pressure die castings in order to remove only a little of the fast solidified cast surface.

Surface pre-treatment
The mechanical effect of frequently applied vibratory grinding processes is often insufficient to reliably remove cast skins, so that a blasting process is recommended.

Ceramic media, such as corundum in particular, are very suitable blasting media. Glass beads or aluminium granules produce only slight material removal. Not suitable are metals and plastics, which cause painting adhesion losses due to the penetration of flakes into the workpiece surface. Residual iron particles also form nuclei for pitting corrosion.

It is necessary to degrease the work piece prior to blasting as lubricant residues can be driven into the workpiece surface by the blasting process. Large quantities of the die release agents and piston lubricants are particularly problematic as they cause burnt oil carbon residues on the cast.

Alkaline and acid pickling
Alkaline pickling processes for targeted roughening of the surface are not recommended for the surface treatment of AlSiMg-pressure die castings. The high silicon alloy contents cause dark, insoluble residues during alkaline pickling. Subsequent acid pickling is then unavoidable for removing this “pickling deposit”.

Effect of baking temperatures
Electrostatically adhering powder particles should be melt together and cross linked on pressure die castings at target temperatures of 120 to maximum 200 °C. A change occurs in the mechanical properties of Silafont-36 during the coating process starting from 150 °C; with Magsimal-59 this happens only above 180 °C; Castasil-37 shows no changes.

To optimize the paint adhesion with Silafont-36, Silafont-38 and Castaman-35 we suggest a chromate pre-treatment.

Glueing techniques for die castings
Glueing
Magsimal-59 and Castasil-37 are die casting alloys with the requested properties for structural application in the as-cast state. There is no dimensional correction needed due to the missing heat treatment. That gives high benefit to the assembling with glueing.

Joining techniques for die castings
Flanging
Silafont-36 with a magnesium content of approx. 0,16% can be used particularly for flanging technology. The designer can thus join the aluminium pressure die castings to other materials such as steel and plastic. This can be applied as fixing but also as structural joining technology with appropriate construction design (Fig. 1, page 63). The configuration of the flanging edge mostly requires an elongation of at least 8% on the pressure die cast material. Therefore high internal quality requirements are set on this area of the cast. As consequence, in this kind of applications the design of the die must guarantee good metal flow in the flanging edge, what has to be kept in mind especially with Magsimal-59.
Joining techniques for die castings

Self-piercing riveting

Joints, in which the cast is the lower layer in the riveting joint, have particularly high requirements concerning the absence of defects in the cast material. Figures 2a and 2b show the result of a self-piercing riveting trial in our laboratory. It should be noted that Castasil-37 can be self-piercing riveted in the as-cast state also under these severe design conditions, i.e. using a rivet die with flat geometry. The Castasil-37 batch used for this trial had a yield strength of 114 MPa, an ultimate tensile strength of 255 MPa and 14% elongation. A further improvement in deformability is achieved in temper O.

Welding

The suitability of high pressure die castings for welding is highly dependent on the melt and high pressure die casting process. Casting materials and melt and high pressure die casting methods which ensure low gas absorption and oxide impurity during high pressure die casting are needed.

The designer may place weld seams in zones with less loading, but, for a high pressure die casting, they should also be close to the ingate. Fig. 4 shows eight target levels of the high pressure die casting, the final one being a cast suitable for welding and heat treatment. The high pressure die casting methods and stages required for these are illustrated in terms of removing air, transport of melt and application of mould release agent.

High pressure die castings made from Silafont-36 and Castasil-37 are particularly well suited to welding, with both MIG and TIG standard methods. The AlSi5 or AlSi10 welding addition material is preferred for welded designs with AlMgSi0.5 wrought alloys. The weld seams and/or heat influence zones between components made from aluminium wrought alloys and high pressure die castings made from Silafont-36 and Castasil-37 withstand repeated loads perfectly if the cast edges feature a low number of pores and are virtually free of the oxide skin after any T7 heat treatment undertaken.

Fig. 3 states the mechanical values in the heat influence zone. Unlike elongation, the strength values in this zone are hardly influenced.

Magsimal-59 and Thermdur-72 have a higher shrinkage rate and force than AlSi high pressure die casting alloys. Mould release agents recently developed for work with this alloy improve both the ease of flow, i.e. ability to slide during ejection, and therefore the suitability of the high pressure die castings for welding.

Design welding with casts made from Magsimal-59 is undertaken with the AlMg4.5MnZr addition material using the TIG method or laser/electron beam welding method. Unlike the case with elongation, the mechanical properties in the heat influence zone are hardly affected. If the SG-AlSi5 welding addition material is used, the elongation values fall yet further.

All here mentioned HPDC alloys are suitable for friction stir welding or spot-welding.

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**Fig. 1:** Vibration damper housing made of Silafont-36, AlSi10MnMg, with structural flanging

**Fig. 2a:** Cross section of a self-piercing riveting trial, 5 mm semi-tubular rivet, 1.5 mm AlMg3 sheet metal, 4 mm Castasil-37 die cast plate in the as-cast state (F)

**Fig. 2b:** View from below

**Fig. 3:** Strength values of the heat influence zone of MIG welding with AlSi12 addition material
The following mechanical properties applicable to manual MIG welding with the AlMg4.5Mn addition material illustrate how the mechanical properties of Magsimal-59 in the heat influence zone are hardly affected compared with elongation.

### Eight Target levels for HPDC

Fig. 4 shows eight target levels of the high pressure die cast, the final one being a cast suitable for welding and heat treatment.

There are higher requirements for the production of crash relevant structural casts than for general purposes. Depending on your requested targets shows the eight-level-staircase the right alloy and for the main areas of HPDC some suggestions. We divide between dosing technique, air reduction in the cavity, melt handling and application of die release agent.

A requested high cast quality requires on the one hand the use of high-quality die-cast aluminum alloys, also with a metallurgically proper handling of the returns. On the other hand is the consistent application necessary by die cast fundamentals for technical cast design, such as gate design.
We would like to thank all our business partners who have provided castings or photographs for this publication.

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