Ductile Aluminum Alloys for Automotive Structural Applications

RHEINFELDEN ALLOYS
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“Progress by tradition”

ALUMINIUM RHEINFELDEN Group: This history of aluminum in Germany started at Rheinfelden. In 1898 Europe’s first river power station brought about the establishment of the first aluminum 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 independent GmbH & Co. KGs.

www.alurheinfelden.com

Our policy

Our 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 aluminum is on the forefront of our new developments in materials.

It is RHEINFELDEN ALLOYS philosophy to fulfill 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 ALLOYS GmbH & Co. KG: Products of RHEINFELDEN ALLOYS can be found wherever steel designs or iron casts can be replaced by light aluminum 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

Panoramic view of the entire RHEINFELDEN complex
R&D and Customer Support

When RHEINFELDEN ALLOYS develop new materials we always aim to achieve efficient and specific use of aluminum cast. Through the use of materials, tailored and refined to increase performance, RHEINFELDEN ALLOYS is constantly striving to help reduce vehicle weight and therefore cut emissions. We run development projects with the goal to optimise the mechanical and cast properties of our aluminum HPDC alloys. Our recent developed alloys are Silafont-38, Magsimal-plus and Castaduct-42.

RHEINFELDEN Customer Support and RHEINFELDEN TechCenter

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. 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 aluminum cast, the design of casts and the choice of alloy. Use our experience for your success as RHEINFELDEN ALLOYS customer.

RHEINFELDEN alloys globally

Our development of special HPDC alloys results to patents for Castasil-21, Castasil-37 and pending patents in 2017 for Castaduct-42, Magsimal-plus and Silafont-38. Our license partners produce these alloys globally, especially DUBAL in Dubai, NIKKEI NMA in North America and also in China.

In this cooperation all here described alloys are available globally. Please ask for a possibility of local production by our partners.
Aluminum 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’ new alloys, which are used in the automotive industry either for structural and chassis parts, for e-mobility application and their high demand for lightweight or either for thermal conducting but light parts.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Chemical denomination</th>
<th>Structural application</th>
<th>Electrical application</th>
<th>HPDC castability</th>
<th>Frangibility</th>
<th>Electrical conductivity</th>
<th>Suitable for technical anodising</th>
<th>Strength in as-cast state</th>
<th>Elongation</th>
<th>Hardness</th>
<th>Corrosion resistance</th>
<th>Thin wall application</th>
<th>Impact toughness / ductility</th>
<th>Weldability</th>
<th>Machinability at F</th>
<th>Machinability following T6</th>
<th>High temperature application</th>
<th>Stable mechanical properties after long-time heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castaduct-42</td>
<td>AlMg4Fe2</td>
<td>•</td>
<td>•</td>
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</tr>
<tr>
<td>Silafont-38</td>
<td>AlSi9MnMgZn</td>
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<td>Castaman-35</td>
<td>AlSi10MnMg</td>
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<td>Castasil-37</td>
<td>AlSi9MnMoZr</td>
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<tr>
<td>Castasil-21</td>
<td>AlSi9Sr-E</td>
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<tr>
<td>Magsimal-59</td>
<td>AlMg5Si2Mn</td>
<td>•</td>
<td>•</td>
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<td>•</td>
<td>•</td>
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<tr>
<td>Magsimal-plus</td>
<td>AlMg5Si2MnZr</td>
<td>•</td>
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<td>•</td>
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<td>—</td>
</tr>
</tbody>
</table>

- excellent
- very good
- good
- all right
- 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 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 thermal conductivity.
Nature’s equivalent: the vine shoot which turns towards the sun, flexible, elastic and yet incredibly tough and strong.  > page 8–11

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 12–15

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 16–17

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 18–19
Recently developed from RHEINFELDEN ALLOYS Tech-Center this new alloy family AlMgFe astonished the industry. Highest elongation in the cast together with a yield strength typically found after heat treatment T7 can be achieved in the as cast state. And the castability enables large and thin wall HPDC casts, like the car builders ask for. And joining techniques of different kind are possible.

Castaduct-42 has no hardening effect, that means no effect due heat influence, even long or short time exposure. In this Castaduct-42 can be used for battery housings, electronic covers or shelter housings too.

The plain alloy composition is basically a fine AlFe eutectic one with Mg, but special alloy additions in a controlled small composition range helps the die caster to produce constantly. Castaduct-42 can be easily handled with well-designed casts following the lightweight design rules. Typically there is no excellent sticking to the die due to the high Fe content. But the higher shrinkage ask for a higher inclination, best 1.5°.

The corrosion resistance is excellent good, in addition this silicon-free alloy is suitable also for electrostatic powder coating or anodizing, maybe for isolating or decorative applications too.

**KEY FIGURES of Cc-42**

- suitable for lightweight design
- highest deformability in as cast state
- excellent corrosion resistance
- suitable for all joining techniques in car design
Castaduct®-42 [AlMg4Fe2]

Areas of use
Large and thin-walled structural casts; connection nodes for space frame designs; battery housings, electronic covers or shelter housings; thin-walled body parts; for architecture, cars, lighting, aircraft, domestic appliances, air conditioning, automotive engineering, foodstuffs industry, mechanical engineering, shipbuilding, defense engineering. Replaces typical AlSi10MnMg high pressure die casts with O/T4/T7 treatment, but also Magnesium-based HPDC.

Distinguishing characteristics
High pressure die casting alloy with very good casting properties, even with 6 mm thick-walled designs. Best in class corrosion resistance to weathering and salt water. Ideal for adhesive bonding in car design. Best anodizing capabilities, including decorative anodizing.

Chemical composition of Cc-42 in the ingot [% 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>
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<tbody>
<tr>
<td>min.</td>
<td>1.5</td>
<td>4.1</td>
<td>0.2</td>
<td>0.15</td>
<td>4.1</td>
<td>0.3</td>
<td>0.2</td>
<td>Be</td>
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<tr>
<td>max.</td>
<td>0.2</td>
<td>1.7</td>
<td>0.2</td>
<td>0.15</td>
<td>4.5</td>
<td>0.3</td>
<td>0.2</td>
<td>Be</td>
</tr>
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</table>

Mechanical properties

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>Wall thickness [mm]</th>
<th>YTS $R_{0.2}$ [MPa]</th>
<th>UTS $R_m$ [MPa]</th>
<th>Elongation E [%]</th>
<th>Brinell hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>2 – 3</td>
<td>125 – 135</td>
<td>245 – 265</td>
<td>11 – 15</td>
<td>65 – 75</td>
</tr>
<tr>
<td>F</td>
<td>3 – 4</td>
<td>120 – 130</td>
<td>245 – 265</td>
<td>12 – 16</td>
<td>65 – 75</td>
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Physical data

<table>
<thead>
<tr>
<th>Density [kg/dm³]</th>
<th>Coefficient of thermal expansion [1/K x 10⁻⁶]</th>
<th>Thermal Conductivity [W/(K x cm)]</th>
<th>Electrical Conductivity [% IACS]</th>
<th>Shrinkage [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.67</td>
<td>24</td>
<td>1.1</td>
<td>26.0 – 29.5</td>
<td>0.6 – 0.9</td>
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</tbody>
</table>

Stress-strain curve for Castaduct-42, AlMg4Fe2 in the as-cast state (F)

Bending test diagram for Castaduct-42, AlMg4Fe2 in the as-cast state (F)
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
- suitable for adhesive bonding applications

**Key Figures of Ci-37**

- suitable for different wall thicknesses
- highest fatigue strength compared to AlSi-alloys
- very good corrosion resistance
- no aging, best dimensional stability in as cast
- suitable for adhesive bonding applications
Castasil®-37 [AlSi9MnMoZr]

Areas of use
Connection nodes for space frame designs; thin-walled body parts; architecture, cars, lighting, aircraft, domestic appliances, air conditioning, automotive engineering, foodstuffs industry, mechanical engineering, shipbuilding, defence engineering; replaces high pressure die castings with T7 or T6 with air quenching.

Distinguishing characteristics
High pressure die casting alloy with excellent castability. Very high elongation in as-cast state as a result of which it can be used in more ways when in as-cast state. Further increase in ductility thanks to single-stage heat treatment. No distortion or blisters from solution heat treatment, very good corrosion resistance, no long-term ageing due to heat, good machinability, ideal for riveting and adhesive bonding in automotive engineering.

Chemical composition of CI-37 in the ingot [% 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>Mo</th>
<th>Zr</th>
<th>Tr</th>
<th>Sr</th>
<th>others</th>
</tr>
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<tr>
<td>min.</td>
<td>8.5</td>
<td>0.35</td>
<td>0.1</td>
<td>0.1</td>
<td>0.006</td>
<td></td>
<td></td>
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<tr>
<td>max.</td>
<td>10.5</td>
<td>0.15</td>
<td>0.05</td>
<td>0.06</td>
<td>0.3</td>
<td>0.15</td>
<td>0.025</td>
<td>0.10</td>
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Mechanical properties

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<thead>
<tr>
<th>Wall thickness [mm]</th>
<th>YTS R_p,2 [MPa]</th>
<th>UTS R_m [MPa]</th>
<th>Elongation E [%]</th>
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</thead>
<tbody>
<tr>
<td>2 – 3</td>
<td>120 – 150</td>
<td>260 – 300</td>
<td>10 – 14</td>
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<tr>
<td>3 – 5</td>
<td>100 – 130</td>
<td>230 – 280</td>
<td>10 – 14</td>
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<tr>
<td>5 – 7</td>
<td>80 – 110</td>
<td>200 – 250</td>
<td>10 – 14</td>
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Physical data

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<tr>
<td>2.69</td>
<td>21</td>
<td>1.3</td>
<td>31.0 – 38.0</td>
<td>0.4 – 0.6</td>
</tr>
</tbody>
</table>

Wöhler’s diagram for Castasil-37
Stress ratio r = -1
4 mm wall thickness, form factor K_t = 1.2
5%, 50%, 95% fracture probability

Stress-strain curve for Castasil-37, AlSi9MnMoZr, in the as-cast state (F)

Wöhler’s diagram for Castasil-37, AlSi9MnMoZr, in the as-cast state (F)
Castasil®-21 (Ci-21)
Large areas, high dimensional stability, fantastic to cast

Castasil-21 is a HPDC alloy developed by RHEINFELDEN ALLOYS for casts with outstanding requirements in terms of electrical or thermal conductivity. Aluminum 99,7 for rotors has indeed higher electrical conductivity, but in praxis 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%) compared with usual HPDC aluminum alloys and still around 10% higher than with Silafont-36.

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 compared to Al for rotors
- excellent machinability
- flangeable or deformable to fix parts together
- suitable for adhesive bonding applications
- electrical conductivity comes up to 48.5% IACS, to substitute Cu in the idea of light weight design or Al99,7 in rotors

KEY FIGURES of Ci-21
- well usable for thin wall fins
- very good corrosion resistance to weathering
- good mechanical strength; excellent machinability
- electrical conductivity comes up to 48.5% IACS, to substitute Cu in the idea of light weight design or Al99,7 in rotors
Castasil®-21 [AlSi9Sr-E]

Areas of use
Also for all kind of castings with requirements in terms of high thermal or electrical conductivity. Conductor plate for electronics, automotive and mechanical engineering, LED-lighting, air cooling, electronic boxes or covers, E-mobil applications, inclusive electric engines.

Distinguishing characteristics
High pressure die casting alloy with high casting ability, optimized for high thermal or electrical conductivity. A casting treatment O gives highest conductivity compared with other AlSi-die casting alloys. Flangeable, very good corrosion resistance to weathering.

Chemical composition of Ci-21 in the ingot [% 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>0.5</td>
<td></td>
<td>0.01</td>
<td>0.03</td>
<td>0.07</td>
<td>0.01</td>
<td>0.03</td>
<td>0.10</td>
</tr>
<tr>
<td>max.</td>
<td>9.0</td>
<td>0.7</td>
<td>0.02</td>
<td>0.01</td>
<td>0.03</td>
<td>0.07</td>
<td>0.01</td>
<td>0.03</td>
<td>0.10</td>
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Mechanical properties

<table>
<thead>
<tr>
<th>Temper</th>
<th>YTS (R_{0.2}) [MPa]</th>
<th>UTS (R_m) [MPa]</th>
<th>Elongation (E) [%]</th>
<th>Brinell hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>90 – 100</td>
<td>200 – 230</td>
<td>6 – 9</td>
<td>55 – 65</td>
</tr>
<tr>
<td>O</td>
<td>80 – 90</td>
<td>170 – 190</td>
<td>9 – 14</td>
<td>45 – 55</td>
</tr>
</tbody>
</table>

Physical data

<table>
<thead>
<tr>
<th>Density ([\text{kg/dm}^3])</th>
<th>Coefficient of thermal expansion ([1/\text{K} \times 10^{-6}])</th>
<th>Thermal Conductivity ([\text{W/(K} \times \text{cm}])</th>
<th>Electrical Conductivity ([% \text{IACS}])</th>
<th>Shrinkage [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.65</td>
<td>21</td>
<td>1.7</td>
<td>43.5 – 48.5</td>
<td>0.4 – 0.6</td>
</tr>
</tbody>
</table>

Electrical conductivity of Castasil-21, AlSi9Sr-E, through heat treatment of the HPDC.
Magsimal®-59 (Ma-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. High 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.

The properties of Magsimal-59 depend on the wall thickness and on cooling method after HPDC. A one step heat treatment is suggested to compensate these differences and to result in up to 30% higher YTS. Air quenching would be the best, due it excludes distortions and results in high rigidity.

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
• excellent suitable for adhesive bonding applications
• very high fatigue strength
• excellent corrosion behavior
• suitable for self-piercing riveting

KEY FIGURES of Ma-59
• high yield strength in conjunction with high ductility
• very high energy absorption capacity
• excellent fatigue strength even with sea water contact
• excellent corrosion behavior
Magsimal®-59 [AlMg5Si2Mn]

Areas of use
Architecture, cars, aircraft, domestic appliances, air conditioning, automotive engineering, foodstuffs industry, mechanical engineering, optics and furniture, shipbuilding, chemical industry.

Distinguishing characteristics
High pressure die casting alloy with excellent mechanical and dynamic properties with thin walls.
Very good weldability, suited to self-piercing riveting. Excellent corrosion resistance, excellent mechanical polishability and good machinability, ideal adhesive bonding in car body design.

Chemical composition of Ma-59 in the ingot [% 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>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>0.5</td>
<td>5.0</td>
<td>0.07</td>
<td>0.2</td>
<td>0.04</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>0.20</td>
<td>0.2</td>
<td>0.04</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Mechanical properties

<table>
<thead>
<tr>
<th>Wall thickness [mm]</th>
<th>YTS $R_{p0.2}$ [MPa]</th>
<th>UTS $R_m$ [MPa]</th>
<th>Elongation E [%]</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 data

<table>
<thead>
<tr>
<th>Density [kg/dm³]</th>
<th>Coefficient of thermal expansion [1/K × 10⁻⁵]</th>
<th>Thermal Conductivity [W/(K × cm)]</th>
<th>Electrical Conductivity [% IACS]</th>
<th>Shrinkage [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.63</td>
<td>24</td>
<td>1.1</td>
<td>24.0 – 27.5</td>
<td>0.6 – 1.1</td>
</tr>
</tbody>
</table>

Stress-strain curve for Magsimal-59, AlMg5Si2Mn, in the as-cast state.
Wall thickness of samples: 3 mm

Wöhler’s curve for Magsimal-59, AlMg5Si2Mn, in the as-cast state
Stress ratio $r = -1$
Wall thickness 4 mm
5%, 50%, 95% fracture probability
Temper F
YTS = 178 MPa
UTS = 313 MPa
E = 20.6%
Magsimal®-plus (Ma-plus)

Of filigree lightness, but extremely resilient

The Magsimal-plus, AlMg6Si2MnZr with an additional yield tensile strength on top to the previous Magsimal-59 was developed in the RHEINFELDEN ALLOYS TechCenter. Our aim is to get 10% more YTS, which means 20 MPa more and may result in less wall thickness respective less weight of the cast. Compared to AlSi10MnMg this may be even 40% advantage in strength. With this strength even steel sheet parts maybe substituted with a cast and its advantages for high functional integral design, ready in the as cast state.

Besides a higher content of the well-known alloying elements there is Zr and Mo in the alloy too. The microstructure is still very fine and results in the same level of elongation. Despite the high Mg content of Magsimal-plus extraordinary good corrosion behavior is recognized in our tests. The properties of Magsimal-plus depend on the wall thickness and on cooling method after HPDC. A 250 °C heat treatment is suggested to compensate these differences, due natural hardening takes 4–6 weeks. Air quenching would be the best, due it excludes distortions and results in high rigidity.

Magsimal-plus is the ultrahigh-strength AlMg die-casting alloy for high-tech lightweight construction in the vehicle structure.

- application in as cast state for die casting of 2–6 mm wall thickness
- natural hard alloy with hardening effect
- excellent corrosion resistance against salt water
- very high dynamic fatigue strength

KEY FIGURES of Ma-plus

- excellent yield strength in conjunction with high ductility
- no further aging effects after short term T5 treatment, e.g. paint bake cycle after powder coating
- very high energy absorption capacity
- excellent corrosion behavior
- well suitable for self-piercing riveting

Example of use
Magsimal®-plus [AlMg6Si2MnZr]

Areas of use
Architecture, automotive or trucks, aircraft, domestic appliances, air conditioning, automotive engineering, mechanical engineering, shipbuilding, chemical industry

Distinguishing characteristics
High pressure die casting alloy with excellent mechanical and dynamic properties with thin walls. Very good weldability, suited to self-piercing riveting. Excellent corrosion resistance, excellent mechanical polishability and good machinability, ideal for adhesive bonding in contact to glass or in car body design.

Chemical composition of Ma-plus in the ingot [% 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>Zr</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td>min.</td>
<td>2.1</td>
<td>0.5</td>
<td>6.0</td>
<td>0.1</td>
<td>6.4</td>
<td>0.07</td>
<td>0.05</td>
<td>0.3</td>
<td>Mo; Be</td>
</tr>
<tr>
<td>max.</td>
<td>2.6</td>
<td>0.15</td>
<td>0.05</td>
<td>0.8</td>
<td>6.4</td>
<td>0.07</td>
<td>0.05</td>
<td>0.3</td>
<td>Mo; Be</td>
</tr>
</tbody>
</table>

Mechanical properties with 3 mm wall thickness

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>YTS $R_{0.2}$ [MPa]</th>
<th>UTS $R_m$ [MPa]</th>
<th>Elongation $E$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>200 – 220</td>
<td>340 – 360</td>
<td>9 – 12</td>
</tr>
<tr>
<td>T5</td>
<td>230 – 250</td>
<td>350 – 380</td>
<td>8 – 12</td>
</tr>
</tbody>
</table>

Physical data

<table>
<thead>
<tr>
<th>Density [kg/dm³]</th>
<th>Coefficient of thermal expansion [1/K x 10^-6]</th>
<th>Thermal Conductivity [W/(K x cm)]</th>
<th>Electrical Conductivity [% IACS]</th>
<th>Shrinkage [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.63</td>
<td>24</td>
<td>1.1</td>
<td>22.0 – 27.5</td>
<td>0.6 – 1.1</td>
</tr>
</tbody>
</table>

Stress-strain curve for Magsimal-plus, AlMg6Si2MnZr in the as-cast state (F) and temper T5.
The HPDC alloy Silafont-38 was developed by RHEINFELDEN ALLOYS to further increase yield strength compared to Silafont-36 without significant change in ductility.

Several hardening elements are alloyed in defined ranges in the Silafont-38. That's the cause why the advantage is with a T6 heat treatment. The first step – solutionizing – is still necessary, but the cooling may differ.

Even with an air quenching to lower distortion the complex alloyed Silafont-38 reaches 180 MPa yield strength after artificial aging.

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 therefore 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:
- 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 aluminum profile – cast designs
- suitable for self-piercing riveting

KEY FIGURES of Sf-38
- no sticking to the die; the low-iron Silafont-38 is therefore multi element alloyed
- very high YTS in conjunction with T6 including air quenching
- good corrosion resistance due to specially balanced composition
- excellent weldability for wrought aluminum profile – cast designs
- suitable for self-piercing riveting
**Silafont®-38 [AlSi9MnMgZn]**

**Areas of use**
Light-weight car body structures for vehicles, gearboxes, battery housings mechanical engineering.

**Distinguishing characteristics**
Casting alloy with very high mechanical properties after T6 treatment including an air queching for reduced distortion.
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, combined with the advantages of high functional integral designs.

**Chemical composition of Sf-38 in the ingot [% 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>Zr</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td>min.</td>
<td>8.5</td>
<td>0.1</td>
<td>0.4</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>max.</td>
<td>10.0</td>
<td>0.15</td>
<td>0.4</td>
<td>0.8</td>
<td>0.4</td>
<td>0.3</td>
<td>0.15</td>
<td>0.3</td>
<td>Mo; Sr</td>
</tr>
</tbody>
</table>

**Mechanical properties**

<table>
<thead>
<tr>
<th>Casting method</th>
<th>Treatment state</th>
<th>Quenching cooling</th>
<th>YTS $R_{0.2}$ [MPa]</th>
<th>UTS $R_{m}$ [MPa]</th>
<th>Elongation E [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPDC</td>
<td>F</td>
<td></td>
<td>140 – 160</td>
<td>270 – 300</td>
<td>4 – 7</td>
</tr>
<tr>
<td>HPDC</td>
<td>T6</td>
<td>Water</td>
<td>230 – 270</td>
<td>300 – 340</td>
<td>6 – 9</td>
</tr>
<tr>
<td>HPDC</td>
<td>T6</td>
<td>Air</td>
<td>180 – 200</td>
<td>250 – 280</td>
<td>8 – 10</td>
</tr>
</tbody>
</table>

**Physical data**

<table>
<thead>
<tr>
<th>Density [kg/dm³]</th>
<th>Coefficient of thermal expansion [1/K × 10⁻⁶]</th>
<th>Thermal Conductivity [W/(K × cm)]</th>
<th>Electrical Conductivity [% IACS]</th>
<th>Shrinkage [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.67</td>
<td>21</td>
<td>1.5</td>
<td>36.0 – 38.0</td>
<td>0.4 – 0.6</td>
</tr>
</tbody>
</table>

Stress-strain curve for Silafont-38, AlSi9MnMgZr, in the as-cast state. Wall thickness of samples: 3 mm
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.

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:

• good corrosion resistance
• high fatigue strength
• excellent weldability, also for aluminum profile – cast designs
• suitable for self-piercing riveting and similar joining processes
• suitable for adhesive bonding applications

KEY FIGURES of Cm-35

• yield strength and elongation adjustable through Mg and heat treatment
• excellent castability
• as AlSi alloy very high fatigue strength
• good corrosion resistance
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, good corrosion resistance to weathering and water.

Chemical composition of Cm-35 in the ingot (% 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>0.03</td>
<td>0.5</td>
<td>0.2</td>
<td>0.1</td>
<td>0.15</td>
<td>Sr</td>
</tr>
<tr>
<td>max.</td>
<td>11.0</td>
<td>0.2</td>
<td>0.8</td>
<td>0.5</td>
<td>0.1</td>
<td>0.15</td>
<td>Sr</td>
<td></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 E [%]</th>
<th>Brinell hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPDC</td>
<td>F</td>
<td>120 – 150</td>
<td>200 – 290</td>
<td>4 – 9</td>
<td>75 – 90</td>
</tr>
<tr>
<td>HPDC</td>
<td>T7</td>
<td>110 – 150</td>
<td>190 – 230</td>
<td>8 – 13</td>
<td>60 – 75</td>
</tr>
</tbody>
</table>

Physical data

<table>
<thead>
<tr>
<th>Density [kg/dm³]</th>
<th>Coefficient of thermal expansion [1/K × 10⁻⁶]</th>
<th>Thermal Conductivity [W/(K × cm)]</th>
<th>Electrical Conductivity [% IACS]</th>
<th>Shrinkage [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.68</td>
<td>21</td>
<td>1.4</td>
<td>36.0 – 45.0</td>
<td>0.4 – 0.6</td>
</tr>
</tbody>
</table>

Stress-strain curve for Castaman-35, AlSi10MnMg in the T7 state with air quenching

The required ductility and strength especially of this AlSiMg-pressure die casting alloy can 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 Castaman-35:

- 0.15 – 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 casts with air quenching after solutionizing (temper T6 or T7); also for T5 treatment.
- 0.35 – 0.45 % Mg for designs focused on strength in as-cast state or after O or T6
Profile of the alloys for the die casters

Get the spirit of RHEINFELDEN

Castaduct®-42 [AlMg4Fe2]
- usage in the as-cast state especially for large and thin wall HPDC
- low melt oxidation due to special alloy addition
- smart alloy composition with an AlFe eutectic
- easy handling
- no sticking to the die due to high Fe content
- higher shrinkage due Si is < 0.20%
- highest elongation even at room temperature
- excellent corrosion resistance
- long term stability

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>Wall thickness [mm]</th>
<th>YTS [MPa]</th>
<th>UTS [MPa]</th>
<th>E [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>2 – 3</td>
<td>125 – 135</td>
<td>245 – 265</td>
<td>11 – 15</td>
</tr>
<tr>
<td>F</td>
<td>3 – 4</td>
<td>120 – 130</td>
<td>245 – 265</td>
<td>12 – 16</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 due to defined alloying elements
- very good corrosion resistance
- suitable for self-piercing riveting

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>Wall thickness [mm]</th>
<th>YTS [MPa]</th>
<th>UTS [MPa]</th>
<th>E [%]</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®-21 [AlSi9Sr-E]
- highest thermal 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, compared to Al for rotors
- suitable for flanging, clinching or self-piercing, especially in temper O

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>YTS [MPa]</th>
<th>UTS [MPa]</th>
<th>E [%]</th>
<th>Conductivity [IACS %]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>90 – 100</td>
<td>200 – 230</td>
<td>6 – 9</td>
<td>&lt; 43.5</td>
</tr>
<tr>
<td>O</td>
<td>80 – 90</td>
<td>170 – 190</td>
<td>9 – 14</td>
<td>&lt; 48.5</td>
</tr>
</tbody>
</table>
Magsimal®-59 [AlMg5Si2Mn]
• usage in the as-cast state for HPDC with 2 to 6 mm wall thickness
• low melt oxidation due to patented alloy addition
• high-tech alloy
• low sticking to the die

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>Wall thickness [mm]</th>
<th>YTS [MPa]</th>
<th>UTS [MPa]</th>
<th>E [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>2 – 4</td>
<td>160 – 220</td>
<td>310 – 340</td>
<td>12 – 18</td>
</tr>
<tr>
<td>F</td>
<td>4 – 6</td>
<td>140 – 170</td>
<td>250 – 320</td>
<td>9 – 14</td>
</tr>
</tbody>
</table>

Magsimal®-plus [AlMg6Si2MnZr]
• best in class YTS and still 8% E in as-cast state for HPDC with 2 to 6 mm wall thickness
• low melt oxidation due to patented alloy addition
• high-tech alloy
• different alloying elements to control

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>Wall thickness [mm]</th>
<th>YTS [MPa]</th>
<th>UTS [MPa]</th>
<th>E [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>2 – 4</td>
<td>190 – 230</td>
<td>310 – 355</td>
<td>8 – 13</td>
</tr>
</tbody>
</table>

Silafont®-38 [AlSi9MnMgZn]
• applicable to thinnest wall designs and complex designs
• air quenching after solutionizing reduce distortion of the casts
• alloying elements enables highest strength and good crash properties
• good corrosion resistance due to exact alloy limits
• high fatigue properties
• excellent weldability and machinability
• suitable for self-piercing riveting

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>YTS [MPa]</th>
<th>UTS [MPa]</th>
<th>E [%]</th>
<th>Hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>water-T6</td>
<td>230 – 270</td>
<td>300 – 340</td>
<td>6 – 9</td>
<td>90 – 115</td>
</tr>
<tr>
<td>air-T6</td>
<td>180 – 200</td>
<td>250 – 280</td>
<td>8 – 10</td>
<td>80 – 110</td>
</tr>
</tbody>
</table>

Castaman®-35 [AlSi10MnMg]
• outstanding castability, even for huge die cast designs
• magnesium content adjustable to a wide range of requirements
• good die cast ejectability
• heat treatment T6 enables wide range of mechanical properties
• good corrosion resistance with high fatigue properties
• excellent weldability and machinability
• suitable to fit by flanging or self-piercing riveting

<table>
<thead>
<tr>
<th>Treatment state</th>
<th>YTS [MPa]</th>
<th>UTS [MPa]</th>
<th>E [%]</th>
<th>Hardness [HBW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>120 – 150</td>
<td>200 – 290</td>
<td>4 – 9</td>
<td>75 – 90</td>
</tr>
<tr>
<td>T7</td>
<td>110 – 150</td>
<td>190 – 230</td>
<td>8 – 13</td>
<td>60 – 75</td>
</tr>
</tbody>
</table>
The mechanical properties are based on in-house measurements of our alloys, machined from HPDC. The ranges of mechanical properties stated indicate the performance of the alloys and the amount of scatter depending on material and process variation. 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.

**Surface coating techniques for die casts**

Maximum surface condition requirements are defined for pressure die castings which are to be coated or anodized. 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 or anodizing:

- Pressure die cast design and process
- Die design and metal flow
- Handling and machining

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

**Influence from the cast 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 (KTL).

**Influence from the die design**

At least 1% inclination for the AlSi-alloys and at least 1.5% for the AlMg-based alloys should be assumed. Hot cracks may appear in thermally loaded areas of the cast with older dies. These die crack marks and other burrs 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.

**Influence from the HPDC process**

Die release agents, preferably water based, are used for smooth and easy 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. The ingate should not be in the visible area of the cast as far as possible. These lubricants also cause adhesion losses for coatings. Therefore a very economical use of these lubricants is recommended for casts to be coated.
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.

Heat treatments at solutionizing temperatures above 450 °C, such as T4, T6 and T7 for AlSi10MnMg, produce highly oxidised surfaces which must be considered during surface pre-treatment.

Ceramic media, such as corundum in particular, are very suitable blasting media. Glass beads or aluminum granules cause 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.

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

It is necessary to clean chemically the work piece prior to blasting as residues from lubricant or crack testing agents can be hammered 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. Keep this in mind especially for parts in the as cast state.

Alkaline pickling processes for targeted roughening of the surface are not recommended for the surface treatment of AlSiMg-pressure die castings. The high silicon content cause dark, insoluble residues during alkaline pickling. Subsequent acid pickling is then unavoidable for removing this “pickling deposit”. Our AlMg alloys don’t show such effect. To optimize the paint adhesion with the AlSi-alloys we suggest a chromate pre-treatment.

Effect of baking temperatures

Electrostatically adhering powder particles should be sintered together on HPDC at target temperatures of 120 to maximum 200 °C. A change occurs in the mechanical properties of AlSi10MnMg during the coating process starting from 150 °C after 1 hour; with Magsimal-alloys this happens only above 180 °C. Furthermore mechanical properties of Magsimal-59 and Magsimal-plus gets stable after paint bake cycle treatment with temperature above 180 °C.

Castasil-37, Castaduct-42 and Castasil-21 shows no changes.

Joining techniques for die casts

Adhesive bonding

Magsimal-59, Magsimal-plus, Castasil-37 and Castaduct-42 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 assembling with adhesive bonding. Additionally there is no longtime influence through our alloys, due low Cu and Zn content.

Flanging

AlSi10MnMg with a magnesium content of approx. 0.16% can be used particularly for flanging technology. The designer can thus join the aluminum pressure die casts 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). 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 and Castaduct-42.
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 265 MPa and 14% elongation. A further improvement in deformability is achieved in temper O.

Ask for our experience in self-piercing riveting with our other alloys for structural design demands.

Welding

All here mentioned HPDC alloys are suitable for friction stir welding and other pressure welding methods.

The suitability of HPDC for fusion welding is highly dependent on the high pressure die casting processes. There is no tendency for hot tearing with these die cast alloys. Alloys, melting and 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 preferable they should also be close to the ingate, due cast quality generally is there higher.

High pressure die castings made from Castaman-35, Silafont-38 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 AlMg-based alloys, like Magsimal-59, Magsimal-plus and Castaduct-42 have a higher shrinkage rate and force than AlSi high pressure die casting alloys. Mould release agents recently developed for work with alloy family 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, Magsimal-plus and Castaduct-42 are undertaken with the addition material AlMg4.5MnZr using the TIG method. Unlike the case with elongation, the mechanical properties in the heat influence zone are hardly affected. If the welding addition material AlSi5 is used, the elongation values fall yet further.

<table>
<thead>
<tr>
<th>Wall thickness (mm)</th>
<th>$R_{90} \text{ [MPa]}$</th>
<th>$R_m \text{ [MPa]}$</th>
<th>$\Delta %$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ma-59 not welded</td>
<td>165</td>
<td>287</td>
<td>17</td>
</tr>
<tr>
<td>Ma-59 welded</td>
<td>148</td>
<td>246</td>
<td>6</td>
</tr>
</tbody>
</table>

Spot and laser beam welding keep their particularities regarding Al products.

Patented by RHEINFELDEN ALLOYS are the alloys Magsimal-59, Castasil-37 and Castasil-21. Magsimal-plus, Silafont-38 and Castaduct-42 are in status patent pending.

We would like to thank all our business partners who have provided castings or photographs for this publication and AUDI AG for the ASF picture on the front side.

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