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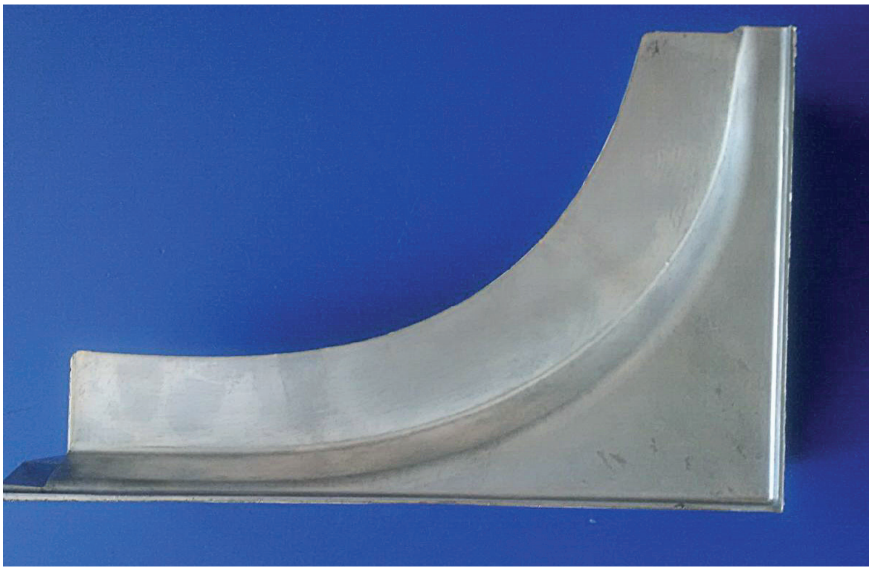
Practical application of high-strength alloy Silafont-38

The newly developed, high-strength alloy Silafont-38 was tested in a casting trial at the foundry G.A. Röders, Soltau, Germany. In a thin-section structural casting, the material properties were better than specified. Aspects examined in the context of the tests included the heat treatment practice, the metallurgical properties, riveting and welding behaviour as well as corrosion resistance of the alloy

In lightweight engineering of structural components the requirements on material properties are becoming increasingly more exacting. One objective is to achieve increasingly higher strengths in order to build structures of ever smaller section thicknesses. As a result of optimizations in the pressure die casting process and heat treatment practice, the potential of the standard alloy AlSi10MnMg has been continuously widened. By modifying the alloy and applying new heat treatment methods, it is possible to even further expand the applicability of this alloy.



Thin-walled structural component made of a high-strength Silafont-38 alloy tested at G. A. Röders in a practical casting test (Photos and Graphics: Rheinfelden Alloys)

The tested part

The tests were made on one of the structural parts, which the foundry G. A. Röders makes for Fastner Leichtmetalltechnik, Ilsfeld-Auenstein, Germany, and which is used in the Audi R8. **Figures 1**a and b show the approx. 300-mm-long component. It must meet the specifications applicable to crash-relevant components with section thicknesses of up to 2.0 mm. G.A. Röders produces this challenging casting in series using the alloy Silafont-36 (EN AC-AlSi10MnMg). In addition to the relevant material properties, the part must provide good weldability.

The alloy

When developing the alloy Silafont-38, special emphasis was placed on castability, which is more or less the same as that of Silafont-36. The contained zinc improves mold filling performance. The addition of iron and manganese reduces stickiness. Casting trials have confirmed the good casting properties of Silafont-38. Due to the alloy's good flowability, there was a slight tendency towards greater flash formation. However, the results of X-ray examinations and blister tests were just as good as those obtained from Silafont-36. The increase in strength after a heat treatment is predominantly due to a magnesium-copper ratio, which suppresses the development of corrosive phases. High-melting-point phases promote the formation of ultrafine eutectic structures.

Heat treatment

In its technology centre, the foundry Rheinfelden Alloys, located in southern Germany, casts different plates and a case with fins as test pieces. A comparison was made between material properties achievable in test plates of 3 mm thickness and in structural castings with extensive surface areas. While the similarities in mold filling of such plates and of large, high-quality structural parts were greater than expected, there were great differences in the quenching rates of the castings after removal from the molds and after the heat treatment. Small plates can be quenched at distinctly higher rates, with a corresponding effect on the material properties. For this reason, the heat treatment was modified such that the quenching conditions were very much like those

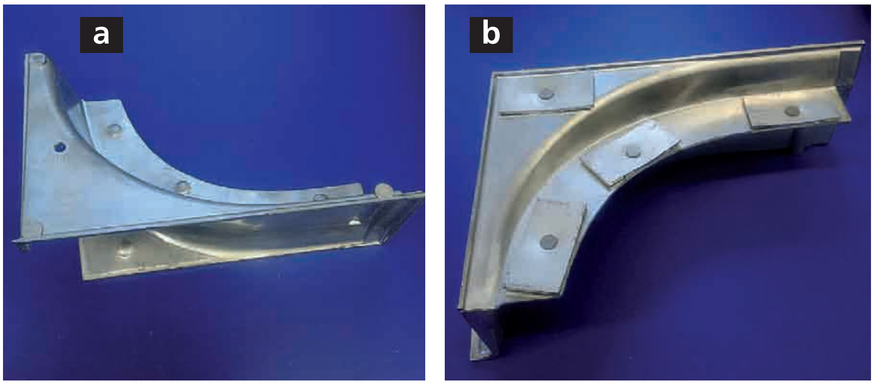


Figure 1: Front (a) and back (b) of the component joined by rivets

found in industrial manufacturing processes. Within the context of this simple modification, the maximum quenching rate was set at 3 °C/s. **Figure 2** shows the temperature curves of 3-mm plates under different quenching conditions. The measured material values correspond largely to those measured in standardized, industrial production processes. Aluminium heat treatment specialists Belte AG, Delbrück, Germany, applied High Speed Air Quenching (HISAQ) and an Aluquench treatment. The HISAQ temperature curve, which was measured by a trailing element, is shown in figure 2. The Aluquench method uses a polymer as quenching medium. The corresponding temperature curve runs very close to that of water quenching. This method achieved very good material values.

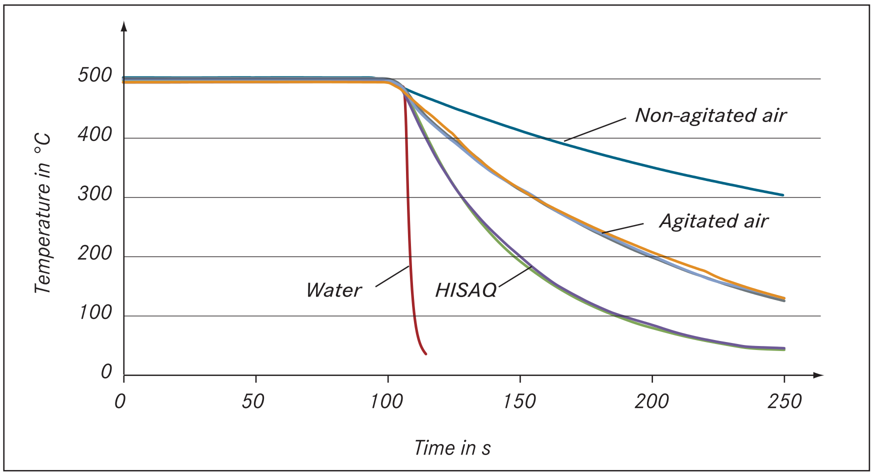


Figure 2: Quenching tests

Material specifications

The target was to achieve a yield strength of 180 N/mm² and an elongation at fracture of at least 8 %. With the casting technology developed at the G.A. Röders foundry, the material values were even better than specified (**Figure 3**). Plotted here are the mean values from approx. 50 tensile tests. G.A. Röders boasts vast knowhow in vacuum technology and in designing and producing casting molds. For the tests, only the alloy was changed, all casting parameters remained the same.

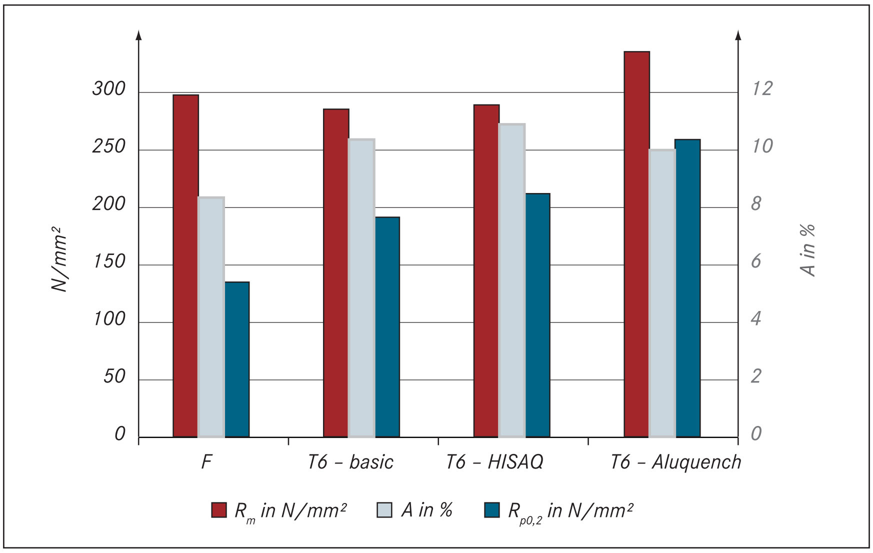


Figure 3: Material specifications of Silafont-38

Riveting and welding

The strength of a material also has an effect on its rivet setting performance. Higher strength materials require different rivets than materials of lower strength. Therefore, the geometry and parameters of the rivets were adjusted to suit the properties of Silafont-38. Thanks to the high ductility of Silafont-38, the riveted joints are crack-free (Figures 1 a and b as well as **Figure 4**). The materials are joined by self-pierce riveting, i.e. semi-tubular rivets set by means of riveting tongs. G.A. Röders tested the weldability of the new alloy by a welding test during production. For the test, the respective area of the material was fusion-welded by tungsten inert-gas (TIG) welding and the surface of the thus produced welded seam investigated. Despite the zinc contained in the material, this test showed that weldability was just as good as that of the standard alloy Silafont-36.

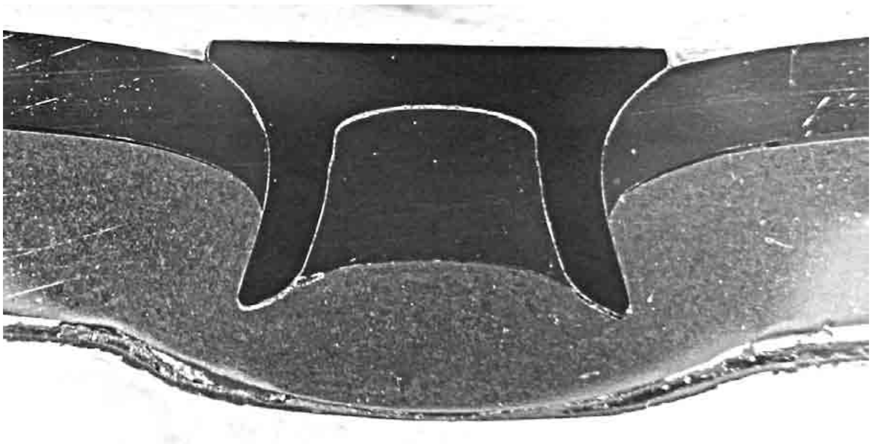


Figure 4: Microsection through the rivet

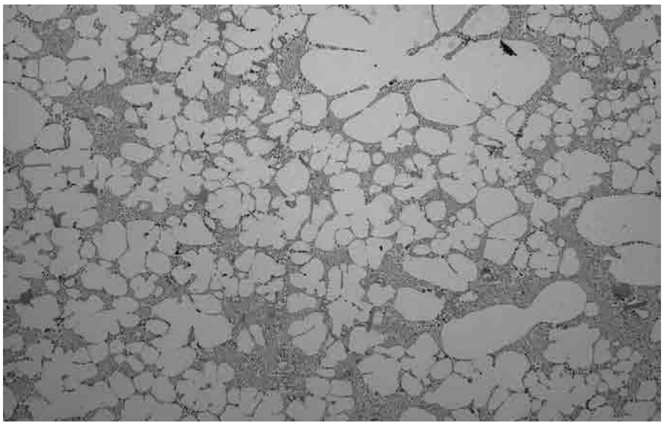


Figure 5: Microstructure in stage F

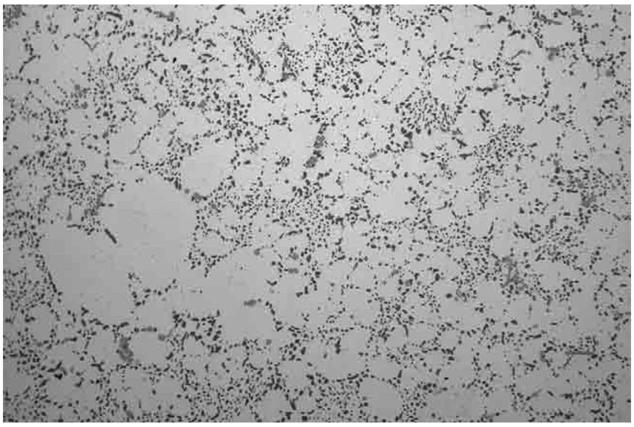


Figure 6: Microstructure in stage T6

Metallurgy and phase simulation

Figures 5 and 6 show microsections of the part at a magnification of 500. The stage designated as "F" is characterized by an ultrafine eutectic structure, which provides fairly good formability already in the as-cast state. The intermetallic phases are very small (below 10 µm) and evenly distributed. After a T6 heat treatment, the eutectic has a spheroized structure providing for high ductility. **Figure 7** shows the quasistatic state simulated with the JMatPro software on the basis of the Calphad databases. The here presented phases are generally large enough to show in a micrograph. The Si-containing eutectic phase plays a central role in the alloy. A finely distributed AlMnFeSi phase (alpha) is required to achieve high ductility. Other high-melting-point, intermetallic phases influence the fineness of the microstructure. In the investigated alloy, the Mg2Si eutectic does not precipitate as a major phase. Submicroscopic precipitations in the aluminium phase have a significant effect on the strength of the material. Such precipitations can also be calculated within the context of a phase simulation by JMatPro. **Figure 8** shows metastable MgSi phases, which are decisive for the strength properties

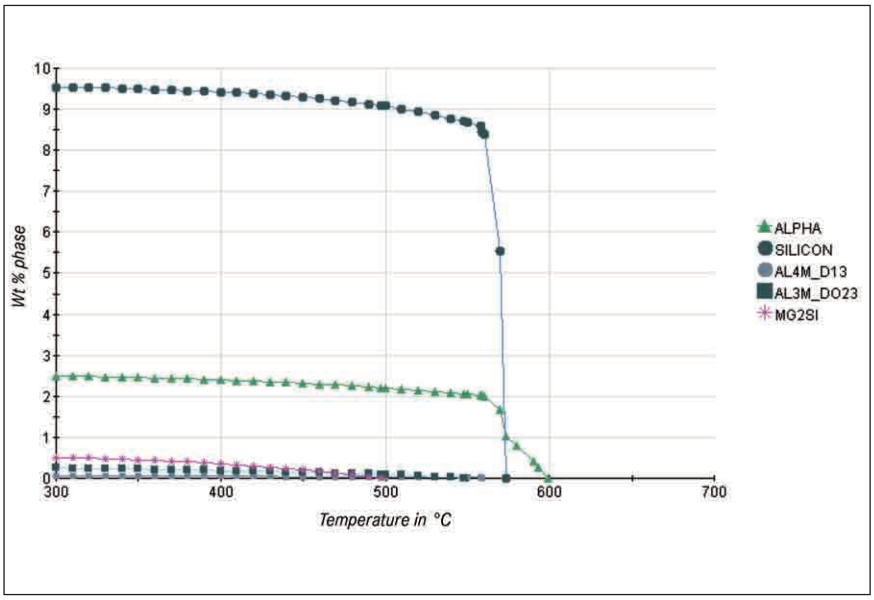


Figure 7: Quasistatic phase simulation

of the material. The characteristics of such phases depend on the initial material state (as-cast or heat treated) and the quenching conditions. If those phases have the right size, they give the material high strengths.

Corrosion resistance

A salt spray test under alternating conditions (ISO 9227) and an intergranular corrosion test (ASTM G110-92) were conducted at the Steinbeis Centre in Friedrichshafen, Germany. The corrosive behaviour of 3-mm plates made of Silafont-38 was examined and compared with the corresponding behaviour of other alloys provided by Rheinfelden Alloys. Evaluations of 336 hours of salt spray testing showed that the resistance to corrosion is appropriate and similar, for example, to that of Castasil-37 (AlSi9MnMoZr). While high-purity alloys predominantly corrode in the form of pitting, corrosion of Silafont-38 extends over a wider area.

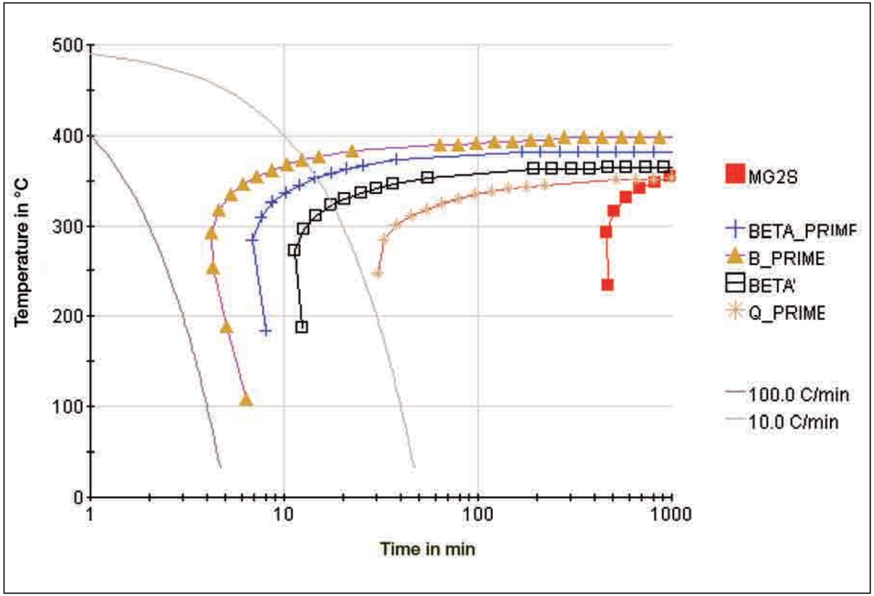


Figure 8: Dynamic phase simulation

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