AMAG TopCast® Alloy Designer

Innovative, recycling cast alloys as a response to future component requirements

The intensifying pressure for innovation, which initially emanates from the automotive industry, constitutes a special challenge for R&D in the cast alloys field. Consequently, demanding material solutions for new products and also the upgrading of existing components are increasingly the focus of the teamwork between AMAG casting GmbH and its partners.

In addition, the growing demand for the greater use of recycled aluminium and the related rise in the recycling quota are also of growing significance. This is because recycled aluminium only requires roughly 5 per cent of the energy needed for the production of primary aluminium from alumina. A fact that, within the context of the current CO_2 discussion, constitutes a weighty argument in favour of the use of recycled aluminium.

Targeted technological optimization of the chemical composition with the possibility of simulations and forecasts with regard to mechanical values are of increasing importance, in order to precisely determine the range of special customer requirements in advance.
With this objective in view, AMAG casting initiated intensive efforts aimed at the optimization of AlSi9Cu3Fe (EN-AC 460000), which is the most frequently employed recycling alloy and is used for a variety of applications in both high pressure die casting (HPDC) and permanent mold casting areas as a cost-effective primary material.

Owing to the fact that as a rule the tolerances of the alloying elements permit extensive limits, the mechanical properties and casting characteristics fluctuate within a relatively large range. Indeed, in the course of numerous discussions with customers, it became apparent that in spite of constant casting parameters, this sizeable latitude with regard to chemical composition can lead to sudden losses and process instability caused by, e.g.

- Fluctuating mechanical properties
- Cavities and pores (X-ray rejects)
- Casting defects due to the poor fluidity and mold filling capacity

Conversely, the increased demands on cast components with regard to strength, ductility and heat resistance, etc. mean that with growing frequency, tailor-made alloys are required for specific areas of application.

In view of the fact that to date no reporting had occurred in the specialist literature on this subject, AMAG casting started work on the characterization and optimization of the AlSi9Cu3Fe alloy and repeatedly publicized the results. /1-4/

The influence of the main alloying elements on the mechanical properties was determined on the basis of a systematic testing plan. Moreover, the casting technology characteristics were established by means of specimen casting and the corresponding assessment of the results.

The statistical evaluation of the extensive data material resulted in the deduction of a computer model for the forecast of mechanical properties and casting characteristics using regression analysis. This model was then implemented in the form of a company software application, the AMAG TopCast® Alloy Designer, which is known as the AMAG TCAD for short. As a consequence, a tool is now available that allows the determination of the optimum alloy composition for a specific customer application within the standard for the AlSi9Cu3Fe (EN-AC 46200) alloy.

The quality and precision of the model are demonstrated by Fig. 1. The comparison of the measured and computer values for the yield strength and the corresponding correlation are indicative of the excellence of the model and the high level of reproducibility that can be achieved.

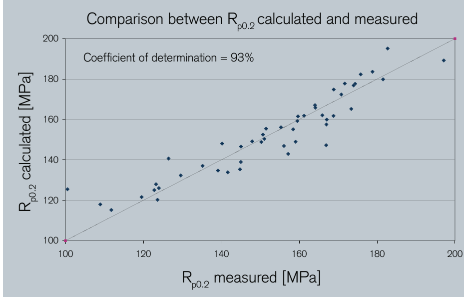

Fig. 1: Calculation model for yield strength, comparison of measured and corresponding calculated values

Input of the analysis	Comparative alloy[1] AMAG A	New alloy[1] AMAG B
Si	11.00	11.00
Cu	3.50	2.25
Mn	0.55	0.30
Mg	0.50	0.10
Fe	1.20	0.40
Zn	0.30	0.50

[1] red: Outside of the limit of AB-46000 (HPDC-variant)

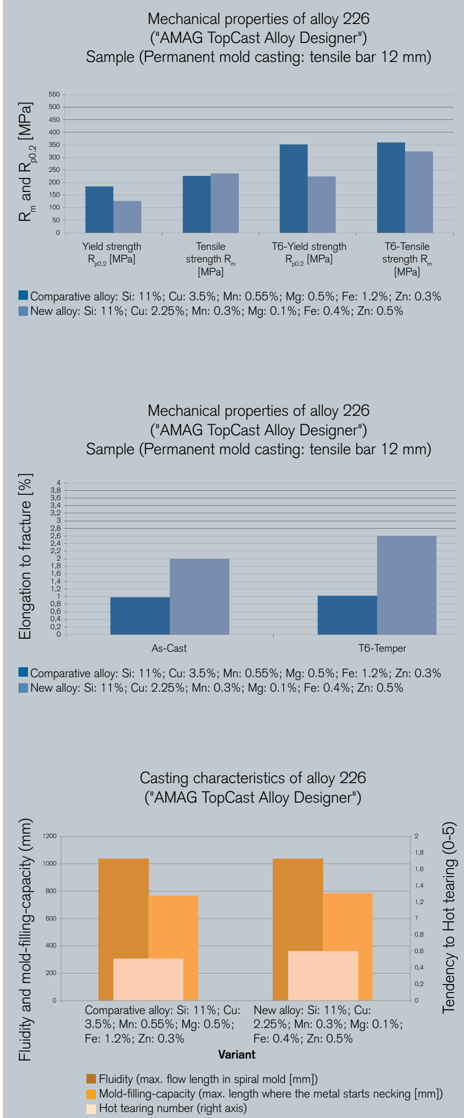

Fig. 2: The AMAG-TCAD operating surface

As a result of the ongoing extension and optimization of AMAG TCAD software, the current version stands out due to the following special features:

- Statements concerning the qualitative and quantitative influence of the alloying elements Si, Cu, Fe, Mn, Mg and Zn
- Inclusion of significant interaction among the alloying elements (when these stand up to metallurgical interpretation)
- Predictions of the influence of optimized T6 heat treatment
- Fluidity and mold filling capacity forecasts
- Predictions concerning the tendency of the alloy towards macro- and micro-cavities, as well as pitting
- Feeding behavior forecasts
- Calculation of the mechanical properties in real cast components depending on local solidification rate

Fig. 2 shows some of the elements used in the current operator surface of the AMAG TopCast Alloy Designer, as employed for targeted customer consulting. The mechanical properties and casting technology values are calculated for two differing (freely selectable) analyses (AMAG A and AMAG B). The given mechanical characteristics are valid for the "defect-free" structure of a 12 mm standard tension bar (without grain refinement and modification).

However, die casters are especially interested in the mechanical properties that they can achieve themselves with regard to differing positions in the cast component, e.g. at critical cross-sections. Therefore, the influence of local solidification rate was integrated into the model for this purpose. Rapid solidification results in a fine grain structure in combination with an increase in elongation at fracture and tensile strength in combination with a slight, simultaneous increase in yield strength (Hall-Petch relationship). Local solidification rate can also be determined from the casting technology solidification simulation, or indirectly by means of an evaluation of a microsection. Therefor the cell size in the structure is determined on actual cast parts with a sample taken from the point in question. Using AMAG TCAD, the mechanical properties can then be forecast for this position.

In order to verify the values predicted by AMAG TCAD for mechanical properties, differing, representative HPDC- parts were analyzed. During this process, tensile specimens from differing wall thicknesses were deliberately tested and the cell size measured in the microsection from ruptured samples. In addition to cell size, the "1/root of cell size" term was also calculated. This derives from the Hall-Petch relationship as an influencing variable upon the mechanical properties and as the example in Fig. 3 shows, the forecasts of the model correspond accurately with the actual component characteristics of the HPDC-cast components in the thin wall thickness range.

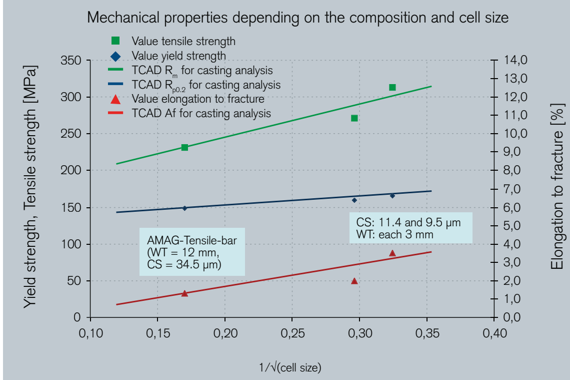

Fig. 3: Mechanical properties of high pressure die cast part – car oil pan

Customer Advantages

With the development of the new AMAG TopCast® Alloy Designer software on display, AMAG casting has taken a major step forward in its role as a competent partner for the advice of customers concerning their material selection.

All in all, the following options are available for the practical use of AMAG TCAD for our customers:

1. New cast parts. Once the local solidification rate is known (by means of the casting technology solidification simulation), targeted alloy selection can take place in line with the required mechanical characteristics.

2. Serial production cast parts. Alloy composition optimization aimed at improving mechanical properties. Reduction in casting rejects through an improvement in casting technology characteristics (e.g. fluidity, cavity behavior, ...).

3. Quality checks at critical casting positions. The AMAG TCAD values are valid for defect-free castings (no modification or heat treatment). Should the actual measured values for elongation at fracture and tensile strenght be below the predicted figures, this means that more or less clearly definable defects can be anticipated at the respective specimen positions (pores, pitting, oxide, ...). This technological benchmarking shows directly the optimization potential available with regard to the melt quality and/or the dimensioning of casting and feeding systems.

Bibliography

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