HEAT-RESISTANT CASTING ALLOYS:

COST-SAVING POTENTIAL THROUGH ALLOY OPTIMIZATION

Within the framework of a joint research project with the Leoben University of Mining and Metallurgy and the ETH Zurich a model is being developed, which enables the optimized use of expensive alloying elements in heat-resistant casting alloys. AMAG casting is to employ this knowledge in its customer consulting, in order to ensure that the best possible alloy is selected for each application.

In the last issue of the Alureport [1], an initial article appeared regarding AMAG casting's research activities in the field of heat-resistant alloy development. This follow-up article now illustrates the interdependencies and interactions between different alloying elements. The elements involved consist of copper, nickel and magnesium, which are the elements most frequently mentioned whenever improvements in the heat resistance of aluminum are discussed.

There are numerous heat-resistant alloys in both the areas of casting and wrought products (in which alloys containing copper have good properties at high temperatures). However, a basic grasp of their interdependencies and the mechanisms for improved heat resistance is rare, although the long-term stability of such alloys has to be taken into special account.

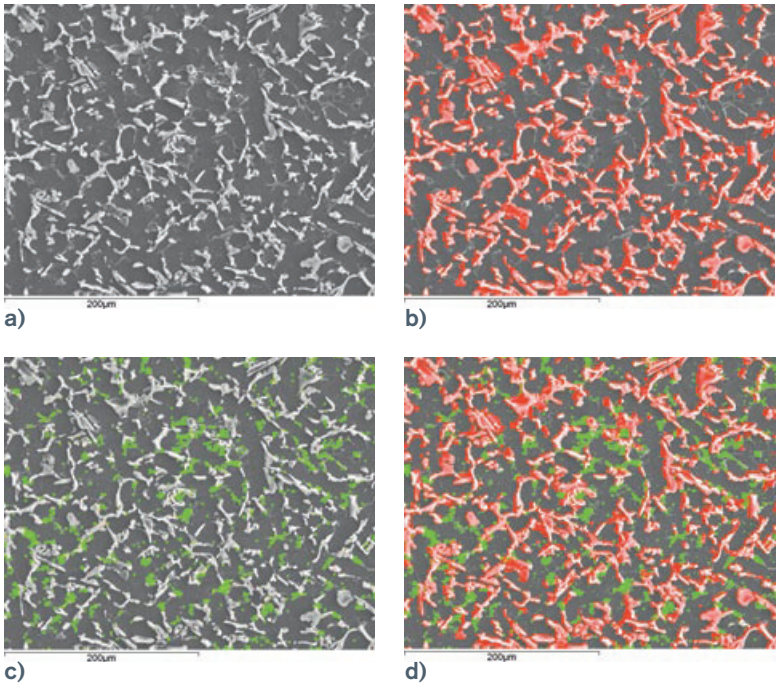
Wrought alloys can rarely be used for shape casting, where technological limitations such as reduced fluidity and a marked hot cracking tendency, etc. restrict their use. For these reasons, alloys containing silicon dominate the market and in order to enhance their heat resistance, Cu, Ni and Mg are often referred to in connection with improved properties at elevated temperatures "More is better" does not function in this case and recent results from our research indicate an upper level of under-eutectic Al-Si alloys cast in a conventional process.

In articles that discuss "heat-resistant casting alloys" the effect of single alloying elements is generally considered in a relatively isolated fashion. Consequently, there are usually no indications of the interactions between different elements. However, it is precisely a knowledge of these interactions that is vital to the economic production of alloys with maximized heat resistance.

Results

During this analysis, four main elements were identified that interact with each other and therefore have a significant effect on heat resistance [2]. These elements are Si, Cu, Mg and Ni, all of which have differing mechanisms that enhance alloy properties at elevated temperatures:

- Ni raises the heat resistance of Al-Si casting alloys by stabilizing the contiguity (structural strength) of the eutectic Si-network. This is accomplished via an increase in the volume fraction of hard particles (Ni containing intermetallic phases (IMP)) in the eutectic phase (see Fig. 1), but once a maximum is reached, an increase in the Ni content of the alloy does not additionally strengthen the Si-network.
- Cu and Mg increase heat resistance by generating secondary precipitates (Al2Cu, Mg2Si, Al2CuMg) which grow significantly when the alloy is overaged, but still help to increase yield and tensile strength due to "interfacial pinning".
- When the alloy contains all the aforementioned elements, intermetallic phases emerge that contain Cu, Ni and Mg. Therefore, the matrix is deprived of copper and the volume fraction of secondary precipitates is reduced along with their contribution to heat resistance. The fact that this Q-phase has been barely characterized thermodynamically and modeled illustrates the minimal extent of the observations of these interdependencies in the materials science field. ■



a) b) c) d)

Figure 1: SEM Depiction of the Si-Ni Network of an AlSi7Ni1.5 alloy after deep etching, without mapping (a), Si-mapping (b), Ni-mapping (c), Si-Ni mapping (d)

Literature
[1] Alureport AMAG (1/2011)
[2] F. Stadler, H. Antrekowitsch, W. Fragner, H. Kaufmann, P.J. Uggowitzer, „The effect of Ni on the high-temperature strength of Al-Si cast alloys", Materials Science Forum Vol. 690, (2011), 274-277

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Customer benefits

During this research project, numerous alloy composition variations were cast and analyzed. As a result, a matrix was created that compares the element concentration in the alloy to the real-world properties at raised temperatures. This AMAG knowledge can help customers and partners to obtain the properties they are seeking through optimized alloy composition. Thus the percentage of expensive alloying elements can be reduced with resultant improvements in competitiveness and greater efficiency with regard to the use of resources.