Materials

Oxide Fiber Composites for Aluminum Casting

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Technical parts are subjected to an extreme load during the processing of aluminum melts in heavily corrosive and oxidizing environments, while at high temperatures and subjected to great fluctuations in temperature. System parts and auxiliary agents made of Oxide Fiber Composites (OFC) have a significantly higher service life under such conditions than parts made of conventional materials.

A special feature is the composition of the OFC materials, which are mainly made up of aluminum oxide (Al2O3) and do not contain any silicon share.
(Source: Philipp Kolbe, TU Bergakademie Freiberg)

The increasing demands made on materials for tool and system components for **processing aluminum melts**, in order to counteract wear and soiling, can no longer be easily met through conventional materials. The focus in the foundry industry is shifting more and more to the development and examination of suitable materials the most important property of which is to exhibit chemical resistance combined with favorable physical material characteristics such as strength, ductility or thermal shock resistance during the processing of aluminum melts. So-called **oxide fiber-reinforced oxide ceramics** (or oxide fiber composites, OFC), represent a relatively new material class.

Outstanding Corrosion and Oxidation Characteristics

With these OFC materials, oxide ceramic fibers are embedded in a porous oxide ceramic matrix. Specific energy-dissipative micro-structural failure mechanisms lead to quasi-ductile, damage-tolerant material behavior. In contrast to non-reinforced, monolithic ceramics, local breaches on the component do not lead to overall system damage. This can be demonstrated by the crack-free puncturing of a nail through an OFC panel (Fig. 1).

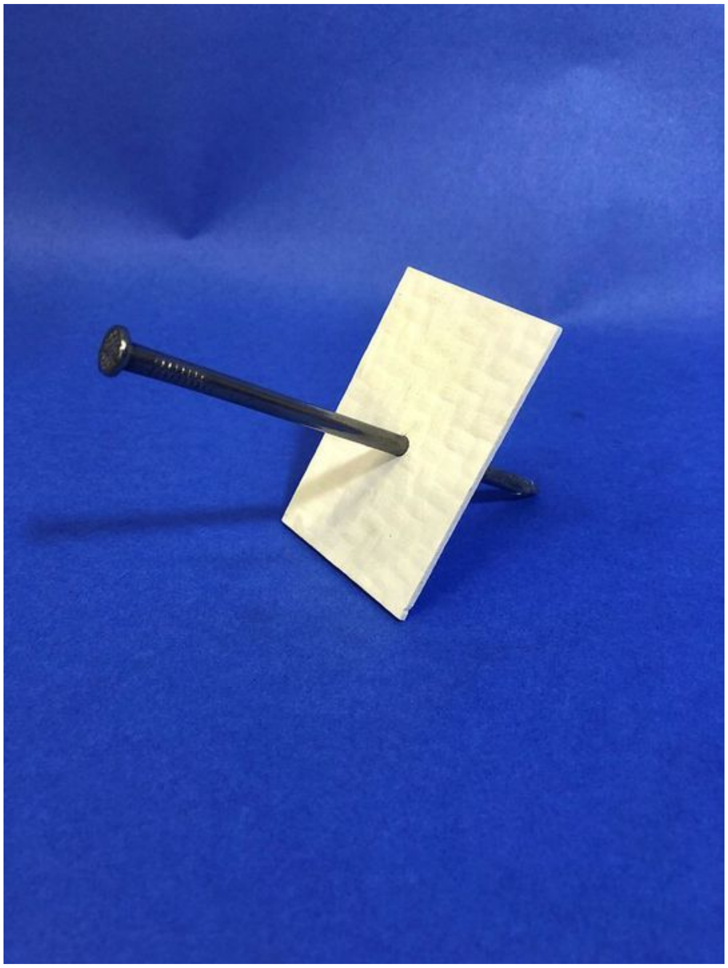

Figure 1: Local breaches on the component do not lead to overall system damage as can be demonstrated by the crack-free puncturing of a nail through an OFC panel.
(Source: Philipp Kolbe)

This material behavior also makes mechanical processing through turning, milling or drilling possible, which offers additional options and **design freedom** compared with conventional ceramics. A further special feature is the composition of the OFC materials, which are mainly made up of aluminum oxide (Al_2O_3) and do not contain any silicon share, thus resulting in outstanding inherent corrosion and oxidation characteristics in connection with aluminum melts and atmospheric oxygen. This proves chemical resistance to liquid aluminum and its alloys as well as an extremely advantageous wetting behavior and easy removal of solidified aluminum from OFC components (Fig. 2).

Also, from the physical point of view, these materials are ideal for use in aluminum melts. Special note must be taken of the **high material strength and damage tolerance** under thermo-mechanical load. This very good resistance to changing thermal conditions guarantees OFC components a constant material strength during immersion processes in aluminum melts (Fig. 3), a significant advantage compared with non-reinforced, monolithic ceramics. In addition, the OFC materials stand out due to favorable thermal characteristics. The low thermal conductivity and realization of thin wall thicknesses are of particular benefit here. The density of the material of less than 3 g/cm³ and the **thin-wall design option** also make lightweight engineering possible and improve handling compared with components made of conventionally used materials.

Figure 2: Solidified Aluminum melt from OFC materials can be easily removed from a dosing container.
(Source: Philipp Kolbe)

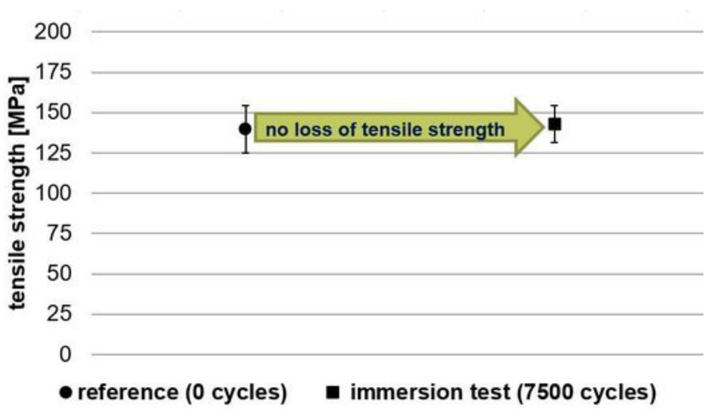

Figure 3: There is tensile strength for OFC specimens after immersion tests in AlSi9Cu3 alloy.
(Source: Philipp Kolbe)

Application

The use of OFC components for the processing of aluminum melts permits a significant enhancement of product and process characteristics. Accordingly, the OFC material class has the potential to improve or substitute components for handling aluminum melts which in current industrial practice are made of metallic, ceramic or graphite materials.

This results in various benefits, depending on the application case. In the case of dosing launders and distributor feeders (Fig. 4), expenditure and costs can be significantly reduced by the elimination of the sizing process and the reduced use of energy by avoiding overheating and reduction of temperature losses on account of a thin-walled, closed design. Additionally, an increased service life and a higher casting part quality can be expected since no washing of ceramic particles out of the launder or sizing particles takes place. In addition, greater process reliability can be achieved thanks to the exclusion of the

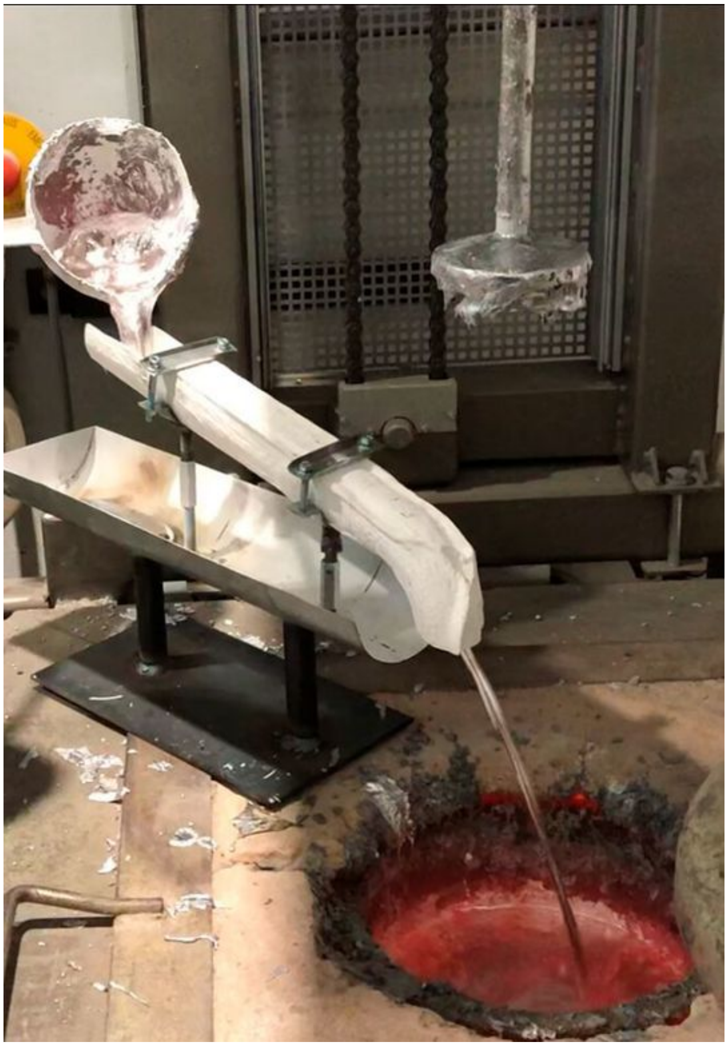

Figure 4: In the case of dosing launders and distributor feeders, expenditure and costs can be significantly reduced. *(Source: Philipp Kolbe, TU Bergakademie Freiberg)*

Figure 5: The OFC material developed can also be used for the design of melting crucibles for aluminum melts. *(Source: Philipp Kolbe)*

risk of brittle fracture. Thus, total **costs are reduced** and manufacturing processes become more profitable.

The OFC material developed can also be used for the design of melting crucibles for aluminum melts (Fig. 5). Soiling entering through the crucible material is minimized on account of the advantageous wetting behavior and the chemical resistance of the material. Furthermore, the OFC material demonstrates outstanding resistance to aggressive aluminum melts and oxygen-affine, highly reactive materials such as sodium or strontium which were used for modification. This means crucibles made of OFC can be used for variable alloy compositions and at the same time offer the possibility of almost complete output, since sticking is excluded.

The very good resistance to changing thermal conditions and form stability during thermal cycles permit uses up to a maximum temperature of 1100 °C. The crucibles do not have to be heated to operating temperature and brittleness or softening of the crucibles when used permanently is excluded. Aluminum melts can solidify and be melted again in an OFC crucible without any problems, and thus represent a significant improvement compared with the state of the art. The thin wall thickness and thermo-mechanical properties of the material make it particularly suitable for **application in induction furnaces**. The reduced distance between the melt and the induction coils allows material to be melted at much shorter intervals than when using the state-of-the-art method and leads to energy saving. The damage-free and straightforward cleaning of OFC components also represents significantly less effort for production employees. The lightweight engineering structure is an advantage from an ergonomic point of view.

Advantages for Aluminum Foundries

With the aid of OFC components many optimized refractory applications can be realized for aluminum foundries and their employees. The main characteristics and advantages of the innovative material for the processing of aluminum melts can be summarized as follows:

- combination of high material strength and ductility under thermo-mechanical load,
- outstanding thermo-mechanical properties,
- high damage tolerance, no risk of brittle fracture,
- very good resistance to changing temperatures,
- resistance to corrosion and oxidation,
- chemical resistance to aluminum melts and atmospheric oxygen,
- advantageous wetting behavior,
- no reaction with sodium, strontium,
- easy removal of solidified aluminum,
- low thermal conductivity,
- thin wall thickness of the components,
- lightweight engineering thanks to fiber reinforcement and density < 3 g/cm^3,
- no penetration of aluminum in porous material

New Fields of Application

The applications presented do not cover the entire product portfolio conceivable. This material class opens completely new fields of application and possible future component developments, from singular components and applications through to composite material structures, for example on the basis of inlays or reinforcements in existing systems. Thanks to the advantageous thermo-mechanical and chemical-physical characteristics, the reduced use of energy and time and the improved process conditions, the OFC material presented is pioneering in the processing of aluminum melts and contributes to minimizing the overall costs of foundries.