Schunk Durafox™ Ceramics: Innovative material for processing aluminum melts

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 Durafox™ Ceramics have a significantly higher service life under such conditions than parts made of conventional materials. Schunk uses state-of-the-art manufacturing techniques and methods for material systems based on oxide fiber composites.

At a glance

At the beginning of all development work, a decision has to be taken as to the optimum material to be used. Thanks to their outstanding material-specific properties, parts made of Durafox™ Ceramics have an enormous potential for applications in heavily corrosive or oxidizing atmospheres. They have a high damage tolerance and resistance to changes in temperature, and can be used for temperatures up to 1,100 °C. System parts and auxiliary agents made of oxide ceramic composites are thus ideal for the processing of aluminum melts as well as for heat treatment applications (soldering or hardening processes) as well as numerous other areas of application. Use of these materials enhances product quality and reduces the time and energy required at the same time. Schunk is developing new manufacturing processes on an industrial scale. The wide spectrum of technological manufacturing approaches allows applications that were not viable previously to be served now.
The solution against wear, corrosion and contamination

Aluminum foundries and their plant manufacturers are confronted by wear and corrosion of the tool and plant components, as well as contamination in the aluminum melts. Dosing containers, dosing launders, ladles, crucibles and many other parts used for aluminum casting quickly become unusable or in need of repair due to aggressive aluminum melts. Up to now, the expenditure related to this was a major cost factor in this highly competitive industry. Components made of Durafox™ Ceramics play a decisive role in improving system and process conditions and thus make it possible to reduce the total costs in aluminum foundries.

Advantages compared with conventional materials

Materials previously used include refractory concrete, silicates, aluminum titanates and sialon ceramics, for example, or metallic materials based on iron. Ceramic materials are brittle and break easily. In addition, they can only have high material strength OR high thermal shock resistance, not both at the same time. Metallic materials have a high thermal conductivity and thus withdraw heat from the aluminum melts. At the same time, the high solubility of many metals in the aluminum melts causes high wear and leads to contamination of the melts. For this reason, the components which come into contact with the melt have to be sized regularly with a ceramic suspension. However, the sizing particles which become detached during use again lead to contamination and poorer cast part quality. As a result, all the parts and auxiliary agents currently used must be replaced or repaired regularly.

This problem in aluminum mold casting is solved by an innovative material class from Schunk: Durafox™ Ceramics. This is a fiber composite material which is composed mainly of two components: the reinforcing fibers and a matrix surrounding the fibers. In the case of the new Schunk material Durafox™ Ceramics, oxidic fibers and an oxidic matrix are combined to form the oxide fiber composite (OFC). The combination of fibers, matrix and their mutual interactions endows the overall material with higher-quality properties than the two components have to offer separately: thanks to the material combination the parts are strong yet ductile at the same time, so that brittle fractures no longer occur. In addition, the oxide ceramic composites are highly resistant to thermal shock and changes in temperature, permitting fast heating and cooling as well as a temperature gradient within a part without any problems whatsoever.

Conventional materials vs. Durafox™ Ceramics

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<thead>
<tr>
<th>Metallic materials (Structural materials mostly based on iron)</th>
<th>Durafox™ Ceramics</th>
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</thead>
<tbody>
<tr>
<td>Regular sizing or replacement required</td>
<td>No damage, no infiltration and no chemical interaction detectable</td>
</tr>
<tr>
<td>No continuous use in aluminum melts possible</td>
<td>Continuous use is possible</td>
</tr>
<tr>
<td>Ceramic materials (Aluminum titanate, aluminum nitride, silicon nitride)</td>
<td>Durafox™ Ceramics</td>
</tr>
<tr>
<td>No combination of high material strength and high thermal shock resistance possible</td>
<td>Iron nail driven through an Durafox™ Ceramics plate</td>
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<tr>
<td>Brittle fracture behavior, lack of ductility</td>
<td>Ductile material behavior</td>
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<td></td>
<td>No brittle failure</td>
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Specific customer solutions for optimized production processes

The special feature of Schunk Durafox™ Ceramics in connection with aluminum melts and air oxygen is the outstanding chemical resistance to liquid aluminum and its alloys. Even alkaline melts containing the elements sodium and strontium are non-critical. Advantageous wetting behavior prevents the Durafox™ Ceramics parts becoming wetted, which means solidified aluminum can be removed easily and without damage to the Durafox™ Ceramics. In addition, the material does not oxidize under air oxygen and can be used up to a temperature of 1,100 °C.

Durafox™ Ceramics parts offer a multitude of possibilities for optimizing the processing of aluminum melts. Through the use of Durafox™ Ceramics crucibles in induction furnaces, foundries in particular benefit from a higher cast part quality and reduced use of time and energy thanks to smaller distance between the melting charge and induction coil. Even solidification and re-melting in the same crucible is possible without any problems. When a dosing launder made of Durafox™ Ceramics is used, there is no chemical reaction between the melting charge and the launder, thus significantly reducing adhering materials. This prevents the casting skin from accumulating and the sizing process is not required. This reduces personnel and time requirements and makes a major contribution to minimizing overall costs.

Durafox™ Ceramics crucibles – all advantages at a glance:

- No contamination of the melts and higher cast part quality
- Greater output, less time needed for cleaning
- Costs reduced thanks to fast melting and problem-free re-melting in the same crucible
- No risk of brittle fracture and no loss of material strength under temperature, thus greater safety in operation
- Extension of tool life and service life
- Better handling thanks to lower part weight
- Constant thermal and electrical properties

Durafox™ Ceramics dosing launder – all advantages at a glance:

- No chemical reaction with the melt and thus no permanent adhering materials/no accumulation of casting skin
- No sizing necessary
- Enclosed version possible
- Cold run non-critical (the dosing launder can be freed from solidified aluminum by melting off)
- Reduced use of energy due to lower heat dissipation
- Reduced use of energy by avoiding overheating of the melt ovens
- Extension of tool life and service life
- Higher quality of cast parts
Application example dosing launder

In joint part development projects that have been carried out up to now, customers are impressed by the advantages of the Durafox™ Ceramics material. During the conventional aluminum melting process, the sizing of auxiliary agents is a time and resource-consuming procedure. Parts such as dosing and distributor feeders or either crucibles made of metallic, ceramic or graphite materials react with the aluminum melt and have to be freed from adhering materials and then repaired and sized.

In contrast, with parts made of oxide fiber composites it can clearly be seen that the material is ideally suitable for use in the aluminum melt. Unlike parts made of other materials, nothing sticks to the Durafox™ Ceramics dosing launders, for example, even without a size being applied. The cast/oxide skin can be removed easily – without damaging the part. Elimination of the sizing process significantly reduces expenditure and thus guarantees reduced costs and significantly higher productivity. In addition, the thin walls and closed design of the material allows the prevention of temperature losses during transport or overheating of the melt furnaces. This makes a further considerable contribution to reducing the use of energy.

Overall, the quality of the cast parts is increased and the components used remain serviceable for much longer as well. An increased service life, the elimination of the sizing process and reduced thermal loss directly reduce repair expenditure and the use of resources. Thus total costs are reduced and manufacturing processes become more profitable.

Oxide ceramic composites are impressive in heat treatment too

In heat treatment (for example for soldering and hardening processes), pure Durafox™ Ceramics racks are used for applications in an oxidative atmosphere. Alternatively, is used in combination with carbon-reinforced carbon for hybrid racks used for processes in an inert gas atmosphere. The three levels of the charging rack illustrated here are made of fabric-reinforced Durafox™ Ceramics panels. More complex mold parts can also be manufactured according to customer-specific requirements.

The main advantages of oxide fiber composites in heat treatment are shortened process times thanks to faster heating and cooling rates. The racks are resistant to thermal shock and changes in temperature and are warp-free. This makes it possible to increase the quality of heat-treated parts on the one hand and creates optimum conditions for the automatic loading and unloading of the batch carriers on the other.
Wide portfolio thanks to high level of flexibility

Schunk offers a wide range of manufacturing techniques for parts made of Durafox™ Ceramics, whereby specific solutions can be implemented for individual customer requirements. The versatile application possibilities and lightweight engineering offer plenty of room for completely new ideas.

Depending on the geometry and customer requirements, Schunk combines different fiber thicknesses, types of weaving and manufacturing processes to develop specific solutions. The use of winding technology allows various rotational symmetric and tubular parts as well as grid structure to be made. This manufacturing process is used for the production of containers or tubes, for example. So-called prepgs are used for panels or complex parts. The oxide fiber fabric is infiltrated by the matrix-forming slurry and results in the storable prepreg. This results in Durafox™ Ceramics panels which can be used to manufacture parts such as strips as carbonization protection. Molded parts from more simple through to extremely complex geometries are produced by placing the prepreg over mold-forming tools. The prepreg is draped according to load. This means that the material strength necessary for the application is in the right place.

Three questions to Philipp Kolbe, application engineer, about Durafox™ Ceramics

1. **What makes the material so unique?**
   Philipp Kolbe: Conventional monolithic ceramics are brittle and break easily. Oxide ceramic composites, on the other hand, can be used in extreme environmental conditions up to 1,100 degrees Celsius without any similar brittle behavior being observed, thanks to their thermo-mechanical properties and corrosion resistance. Figuratively speaking, you can drive a nail through a Durafox™ Ceramics panel without the panel as a whole failing. In addition, oxide ceramic composite materials are extremely resistant to changes in temperature. This means that fast heating and cooling are no problem whatsoever.

2. **What are the economic advantages of Durafox™ Ceramics?**
   Philipp Kolbe: For a start, this depends on the part and the installation situation. In the case of Durafox™ Ceramics crucibles in induction furnaces, energy saving is an important factor. Around half of the energy requirements in an aluminum foundry are related to melting the aluminum and keeping it warm. The thin-walled design of the Durafox™ Ceramics crucible makes it possible to reduce the clearance between the induction coil and the melt by the factor of ten. This means aluminum becomes fluid more quickly, thus saving time and energy costs. In addition, the aluminum can be melted and solidified in the same crucible without the crucible being destroyed. Expenditure and costs are also significantly reduced by elimination of the sizing process. This particularly concerns dosing launders and ladles made of Durafox™ Ceramics, where cleaning and downtime are significantly lower than with conventional materials. Expensive repairs are thus completely eliminated.

3. **What are the questions asked most often about Durafox™ Ceramics parts?**
   Philipp Kolbe: We often have to explain to our customers why the material is not brittle nor break easily, why it is significantly stronger than alternative materials, and can easily cope with fast changes in temperature. Once this has been explained, our customers are just as enthusiastic as we are. In day-to-day work, customers have to get used to handling the new material in a different way. This usually takes place quickly, however, because thanks to material properties such as chemical resistance and ductility, Durafox™ Ceramics parts make the production process less complicated and more effective for our customers.

Surface of fracture of porous Durafox™ Ceramics materials following destructive material test. The surface of fracture does not indicate correlated failure, rather it indicates filament and fiber bundle failure as well as a matrix fragmented in pieces.
A glimpse of the future: Schunk Innovation Center

Working with Durafox™ Ceramics is only just getting started. Feedback from industry has been completely positive so far. At the moment, Schunk is developing specific solutions in various projects together with customers, in order to continually expand the application possibilities. These include advanced developments in manufacturing technology and new material variants. In addition, existing applications can be protected from corrosion and wear by linings, inlays or coatings made of oxide ceramic composites. Furthermore, this new material class results in new application fields - particular for those where mechanical properties, corrosion, oxidation and resistance to changes in temperature are important. A new Innovation Center is currently being built at company headquarters in Heuchelheim/Germany, where the production of Durafox™ Ceramics parts will be housed from the end of 2020.

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Schunk is a global leading force in the development, production and use of carbon, ceramic, quartz and sintered solutions. Like no other, Schunk combines innovative strength and technological know-how with an extraordinary service orientation to supply a range of performances unique to the market. Schunk is a partner who offers you all the technological possibilities of a globally active company and can implement your ideas pragmatically and tailor-made to your requirements - whether these are for industrial large-volume markets or highly specialized niche markets.

The Schunk Group
The Schunk Group is a globally operating technology company with a global business unit structure. The company is a leading supplier of products made of high-tech materials - such as carbon, technical ceramics and sintered metal - as well as machines and systems - from environmental simulation and air conditioning to ultrasonic welding and optical machines. The Schunk Group has more than 9,100 employees in 29 countries and achieved sales of €1.35 billion in 2019.
Philipp Kolbe
Philipp Kolbe has been concentrating on oxide fiber composites for more than two years and wrote his diploma thesis on the subject. Together with Anna-Lena Spenler, he is the application engineer responsible for the development and design of parts made of Durafox™ Ceramics materials. The versatile application possibilities of the material are one particularly fascinating aspect of his day-to-day work.

Anna-Lena Spenler
Anna-Lena Spenler has worked for Schunk for more than 15 years and has been working as a product manager in Sales since completing her degree in Business Administration. In this capacity, she works on new application fields for Durafox™ Ceramics materials and is the company contact for customer-specific solutions. She loves working with customers to develop new ideas for this material class and putting them into practice.

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