Why not Using Ceramics – Trends from Ceramics Research

Within the Fraunhofer AdvanCer Alliance/DE, four institutes have pooled their capabilities to form a coordinated range of services aimed at using advanced ceramics in the creation of individual system solutions for industrial partners. Below, two examples from the successful project work showing the advantages of advanced ceramics in specific industrial applications are presented.

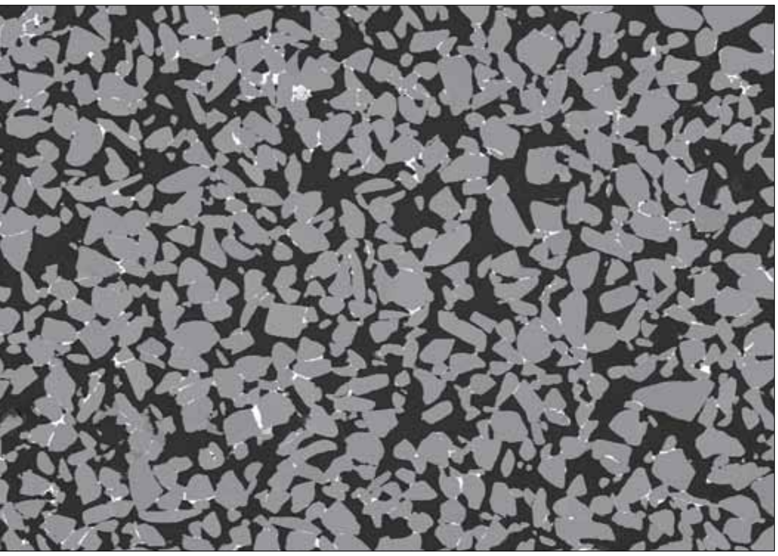

Fig. 1
Porous ceramics used as a diaphragm in aluminium and zinc alloy melts

Gas-permeable, high-temperature resistant ceramics for appliances in metallurgy and metal processing

For a number of applications in metallurgy and metal processing, diaphragms are used to enable pressure compensation in hollow cavities in components while preventing filling of the cavities with the molten material. In hot-dip finishing, e.g., a flat steel band is refined by turning it through a molten metal bath. Currently, hollow rollers are used for guiding the steel band. Hollow rollers show a lower mass moment of inertia, enabling higher band speed, less roller wear, and higher steel band surface quality. However, they are also subject to a risk of excess pressure building up in the inner space due to gas expansion during or after dipping of the roller into the melt bath. Undesired deformation or, in the worst case, bursting can result.

In a joint cooperation with an industrial partner, Fraunhofer IKTS has been developing new gas-permeable ceramics for appliances in metallurgy and the metal processing industry to solve the instability problem in hollow rollers. A small disk made of these ceramics is inserted into the hollow journal of the roller, releasing the expanding gas from the roller into the melt. The ceramics are hardly wetted by the melt and pores are small enough to allow gas to permeate but prevent intrusion of the melt, even at high melt pressures. With the help of these porous ceramics, gas can be discharged quickly and overpressure in key functional components can be prevented.

In this application, the ceramics withstand the melt pressure exerted by aluminium and zinc at 680 °C and 480 °C, respectively, at a bath height of 2,5 m. The ceramics are also heat-resistant up to 1200 °C in air and resistant to corrosion by light metal melts. Therefore, the proven principle can be applied to other alloys after preliminary testing.

Additionally, a steel mounting device for securing and sealing of the porous ceramics in the hollow roller was developed. The porous ceramic disk can also serve as an active safety device that acts as a rupture disk in case of an extreme pressure increase, preventing deformation or even bursting of the hollow roller by guiding the gas into the environment.

The innovative porous ceramics have already been successfully tested in lab and industrial environments.

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Influence of humidity and temperature on the fatigue behaviour of silicon nitride springs

In several engineering applications such as power generation or chemical processes, there is a high demand for advanced components, e.g., springs which are resistant against high temperatures as well as corrosion. They also have to provide a reliable and maintenance-free usage without changing their technical properties. In this focus, ceramic materials may expand the application range of springs in comparison to metals, as they are additionally electrically isolating and nonmagnetic. Ceramic springs have already been processed for many years. However, there is lack of understanding in the time-dependent mechanical strength behaviour at static or cyclic loading in corrosive media or at high temperatures which is necessarily required to evaluate their system reliability.

For this reason, Fraunhofer IWM and Fraunhofer IKTS focused this aspect by a detailed evaluation of the fatigue behaviour of silicon nitride in the BMWi-founded project "EndurSpring" (grant number: 19125 BG). Since silicon nitride materials are characterized by a high level in mechanical properties (high strength and fracture toughness), they offer a superior potential for manufacturing of ceramic springs. Experimental investigations and numerical simulations were applied in this project to determine characteristic mechanical values and to describe the microstructural responses which depend on dynamic loading and environmental conditions. Whereas the silicon nitride springs were manufactured at Fraunhofer IKTS, the cyclic loading tests were conducted at Fraunhofer IWM.

Special focus was placed on the loading conditions of the ceramic spring. Besides the common uniaxial state of stress during cyclic 4-point-bending a torsional loading of particular samples with bone-shaped geometry was applied. The complex stress distribution in the ceramic samples was calculated using FEM. The fracture surfaces were analysed after cyclic bending via SEM to describe crack origins and growth characteristics. Based on this approach and a purposeful live time prediction the design of ceramic springs was defined with respect to the specific loading conditions.

First results were obtained with dynamic loading tests of real spring geometries offering a promising potential of ceramic springs based on silicon nitride for technical use. Further studies in real spring applications will be conducted in the next step of the project. These tests are necessary to validate the material models and to reliably design and manufacture ceramic springs for specific requirements at high temperatures and in aqueous media.

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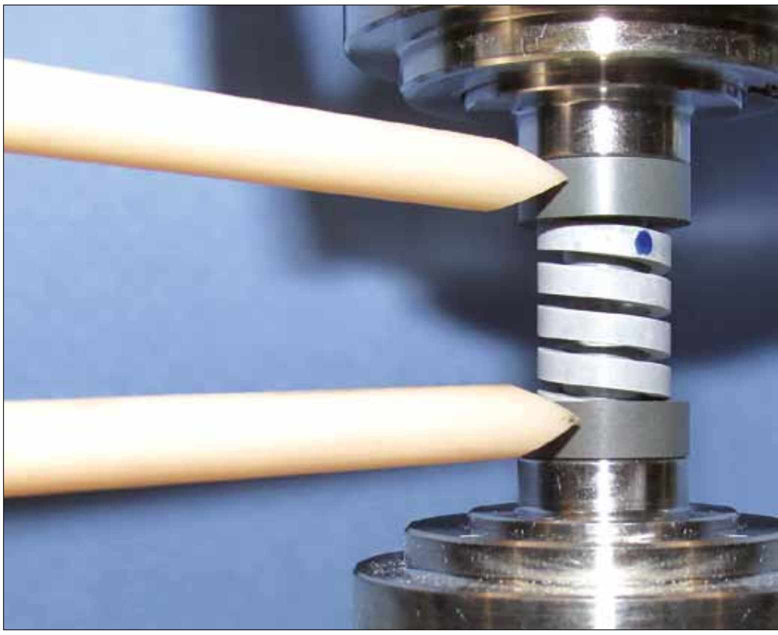

Fig. 2
Test setup for high-temperature testing of ceramic springs

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