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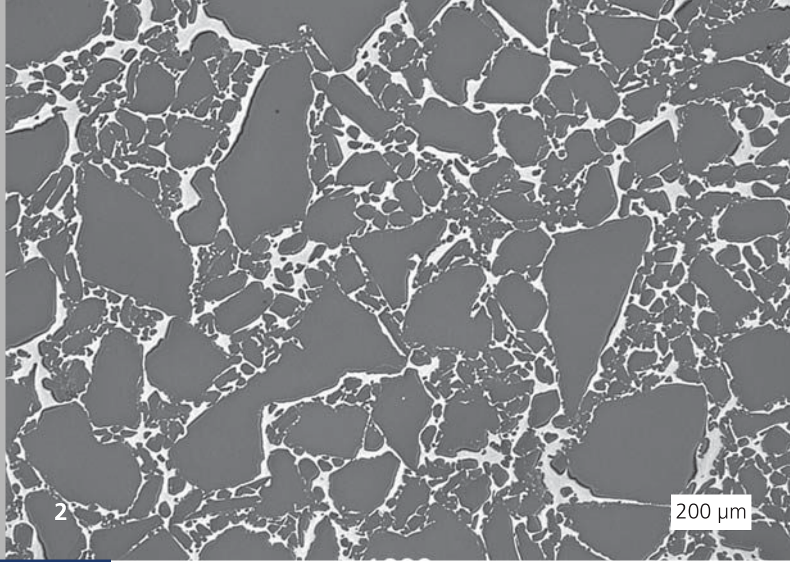


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# COMPLEX SISIC COMPONENTS VIA POLYMER CONCRETE CASTING TECHNIQUES

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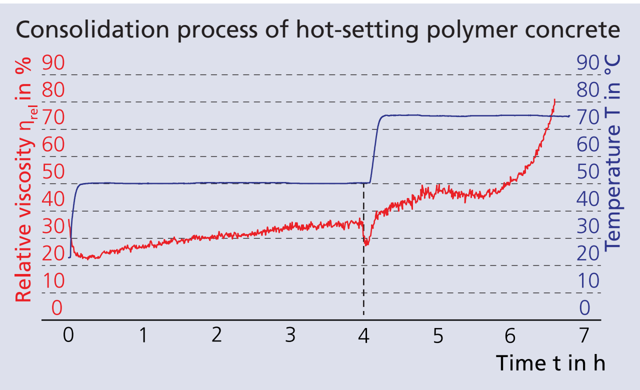
## Initial situation

The virtually shrinkage-free manufacturing process of silicon-infiltrated silicon carbide (SiSiC) ceramics is ideally suitable for the production of complex shaped and large-volume components. Slip casting as well as the machining of isostatically pressed SiC green bodies are conventional forming processes for the manufacturing of such ceramics. However, these methods have technological limitations when used for the manufacturing of components with high differences in wall thickness and/or complex undercuts. Nowadays, the production of such geometrically complex parts demands a modular design in combination with other additional processes that lead to significant cost-intensive processes that incur from material, machine and personnel expenses.

## Method of solution

The adaption of the polymer concrete production method offers an opportunity for the diversification of the molding with an economic processing method of SiSiC components.

Polymer concretes that primarily consist of a mixture of polymeric binder system and coarse grain SiC can be cast in open molds without pressure. The usage of elastomers and wax cores in the casting mold enables a single step manufacturing of large and complex green compacts having undercuts and wall thickness differences.




In this process, the polymeric binder and its curing progress has a significant influence on the success of the casting procedure. In order to maintain the casting processes, which may take several hours, the resin primary requires an adequate pot life. However, during the casting process, the binder also needs to cure quickly to prevent the sedimentation of the SiC fillers. In the meantime, the resin needs to have high carbon yield during the pyrolysis stage.

In order to meet these requirements, a novolak with a high carbon yield was used. To achieve the specific curing characteristics of this resin, it was necessary to develop a hardener combination of amine (hexamethylentetramine) and epoxy (bisphenol A diglycidylether) additions. Using this approach, the cure temperature of the resin was reduced below 80 °C, which is an important condition for the use of wax and elastomer preforms. After the consolidation, the polymer concretes are converted into SiSiC in two steps. During the pyrolysis step that takes place up to approx. 900 °C, the polymer matrix converts into a glassy carbon due to the splitting and the subsequent vaporization of low-molecular compounds. Afterwards, the porous body is infiltrated with liquid silicon, forcing a reaction with the carbon binders to a secondary SiC phase.

After the pyrolysis and silicon infiltration steps, the length decrease of the components amounts to merely 0.1 %. The corresponding shrinkage-free manufacturable SiSiC is characterized by a very coarse-grained texture with grain size diameters slightly higher than 1000 µm. Nevertheless, its mechanical properties are considerably good. The material's Weibull strength, correlated to a unit volume of 1 $mm^3$, amounts to

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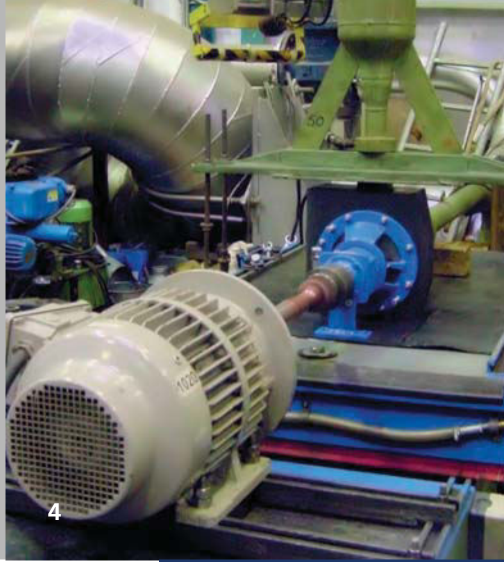

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175 MPa at a Weibull modulus of 17. Its fracture toughness of 2.8 MPa$\cdot\sqrt{m}$ as well as the achieved density of 3.05 g/cm$^3$ are in range of conventional SiSiC ceramics. The ceramics generally feature high hardness and wear resistance. Furthermore, it is gas-tight, chemically resistant against acids and solvents, temperature-resistant up to ca. 1300 °C and has a good thermal conductivity of ca. 150 W/m·K at room temperature.

**Technical applications**

The economic efficiency of this manufacturing method allows for the substitution of conventional materials used in chemical and plant engineering, such as steel or iron cast. Due to the outstanding chemical, thermal and tribological properties of SiSiC, longer lifetimes and/or higher productivity of machines are practicable.

Consequently, radial pump impellers were produced as first applications in cooperation with SICcast Mineralguß GmbH and Düchting Pumpen GmbH. In this context, the industrial casting units for the production of polymer concretes with batch sizes up to 600 kg were also successfully tested. The range of application of such ceramic pumps includes processes with challenging media, such as corrosive chemicals or abrasive particles-enriched suspensions. Recently, a radial pump impeller prototype with an external diameter of 436 mm, a load speed of ca. 1000 1/min and a nominal power of ca. 90 kW has passed a prototypical durability test.

In addition to the pump industry, there are further potential application areas, such as the production of nozzles, mills, heat exchangers or burners. Due to its high rigidity and its low thermal expansion coefficient, the ceramics are also well qualified for the production of housings and carrier systems in high-precision applications demanded in optical industry.

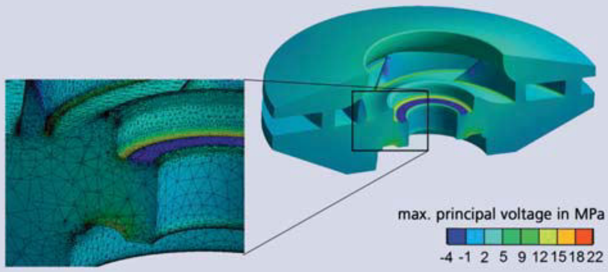
**Acknowledgement**

The presented works are results of the successful cooperation with the companies SICcast GmbH and Düchting Pumpen GmbH. Likewise, we want to thank the Federal Ministry for Economic Affairs and Energy for the sponsorship with-in the ZIM project KF2087322LL1.

**Services offered**

- Process and system development for reaction resin concretes and SiSiC structural ceramics
- Dimensioning and manufacture of application samples and prototypes
- Component and material characterization

FEM simulation of the stress distribution in the pump impeller




**1** *Casting process of reaction resin concrete.*

**2** *Structure of the coarse-grained SiSiC.*

**3** *Ceramic radial pump impeller (diameter of 250 mm).*

**4** *Pump test rig of partner Düchting Pumpen GmbH.*

**5** *Deflection nozzle (350 x 250 x 250 mm$^3$).*

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