10 Years of Werkstoffzentrum Rheinbach GmbH

On the occasion of the 10th anniversary of the foundation, we had the opportunity to meet its founder, Prof. Dr. Wolfgang Kollenberg. He gave us an overview on the history of the Materials Centre Rheinbach and the fields of its activity with emphasis on refractories and technical ceramics.

1 Introduction

In 1996 Dr. Wolfgang Kollenberg, the former vice-director of DIFK, Deutsches Institut für Feuerfest und Keramik (German Institute for Refractories and Ceramics) in Bonn, founded the Werkstoffzentrum Rheinbach GmbH. From the early beginning the company concentrates on refractories and technical ceramics. Werkstoffzentrum is oriented towards the market. Its aim is to be as close as possible to the technological questions and problems of the client. Therefore not only testing but also development and consulting are the main activities.

Starting in the Technology Centre Rheinbach the company could grow with the increasing business. In 2003 Werkstoffzentrum moved into a new building with an office area of 400 m^2 and a laboratory area of about 500 m^2. Recently the laboratory area has been expanded by another 650 m^2. Also the number of employees growed during the years and reaches today 21.

2 Testing of refractories and ceramics

During the first years the complete testing lab has been established. Werkstoffzentrum has a comprehensive range of equipment for

- chemical analysis
  - X-ray fluorescent analysis
  - loss of ignition
  - determination of silicon carbide, organic and inorganic carbon
- mineralogical characterization
  - X-ray diffraction analysis
  - optical microscopy
  - scanning electron microscopy and elementary analysis
  - bulk density, water absorption and open porosity
  - grain size analysis
  - specific surface area
- physical and technological testing
  - thermal expansion from -150 °C to 1700 °C
  - hardness tests
  - static and dynamic Young's modulus
  - strength tests (bending, crushing, indirect tensile)
  - hot bending strength
  - abrasion test up to 1400 °C
  - load softening and creep testing
  - thermal shock test, thermal fatigue
  - determination of work of fracture

Beside refractories and ceramics, Werkstoffzentrum is also the right partner for characterising and testing metals.

3 Development of castables

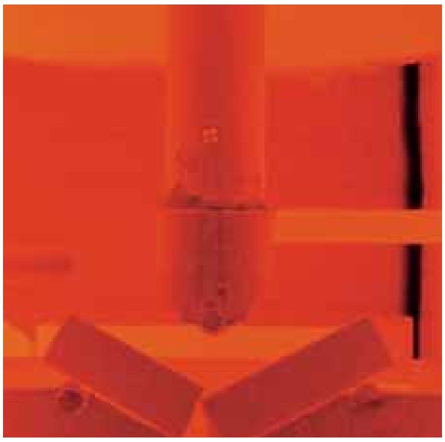
Beside the analytical lab, a technical centre is laid-out especially for the main sectors of refractories and technical ceramics. Starting from various raw materials, shaped and unshaped products can be developed. In the field of refractories especially self-flowing and vibration castables are developed with a focus on no-cement castables. Actual work is carried out on sol-gel binding systems and the addition of nanoparticles. The development of new refractories concentrates on microstructure design to improve the behaviour of the material in consideration to the application. Therefore, in most cases, the first step is an investigation of the corrosion and wear behaviour of actually used material.

4 Thermal shock behaviour

Refractories are used for the lining of high temperature plants. Under mechanical load they shall not loss dimensionally stability, must be consistent under application conditions und have to resist sudden temperature changes without any loss of physical stability. Technological testings at room temperature, as they are done at the Werkstoffzentrum Rheinbach, can assure quality control. Recommended test methods are the determination of porosity, cold bending strength, compression strength and investigation of a microstructure by scanning electron microscopy (SEM).

Scanning electron microscopy

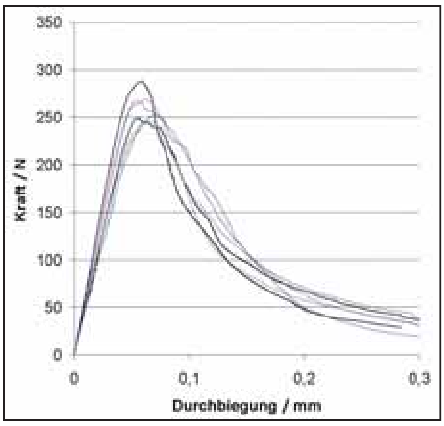
Thermal testing however gives additional information about the materials under application conditions. These are e.g. investigations of hot abrasion testing, hot bending strength, thermal expansion or testing of the thermal shock resistance.



Hot bending test

At the Werkstoffzentrum a method for the investigation of hot-abrasion resistance has been developed according to ASTM 704-88. This method allows getting information about a materials ability to resist abrasive wear under a certain application temperature. SiC particles are used as abrasives, which are blasted onto the sample under well defined conditions and temperatures up to 1400 °C.

The hot-bending strength is measured at temperatures up to 1600 °C by the three-point measuring method. With an additional displacement transducer the stress- strain curve can be archived and the Young's modulus may be quantified.



Load – bending curve of notched bars to characterize work of fracture

The thermal shock resistance of both oxide and non-oxide refractories is measured. The investigation of graphite containing refractories plays a special role because these samples are heated up in inert gas atmosphere. According to the selected method, crack propagation or the remaining bending strength according to Hasselman or thermal fatigue may be assessed. Actually the determination of the work of fracture by using notched test bars has been investigated to get more information of crack propagation and fracture resistance in refractories with respect to the thermal shock behaviour.

5 Brazilian disk test

For the characterisation of materials, the determination of their strength – especially their tensile strength – is of major importance. However, the direct testing of the tensile strength of brittle materials is very complex.

At the moment, test set-ups as the three-point or four-point bending tests prevail. Their disadvantage is the low part of volume that is actually charged with load and the strong dependency of the quality of the samples surface and their dimensions. An attractive alternative is the indirect testing of tensile strength by the so-called Brazilian disk test. This method is conventional used for the testing of concrete.

Brazilian disk test

Opposite to those methods used for ceramics, the crack onset during the Brazilian disk test is in the samples centre and not at the edges. This leads to the special advantages: simple sample geometry, small influence of the surface quality, small samples, large effectively loaded volume, low variation. In addition, samples from relatively small fragments, e.g. different horizons of material after application, can be prepared.

6 Waste incineration plants

During the last years investigations were also carried out about the mechanism of corrosion

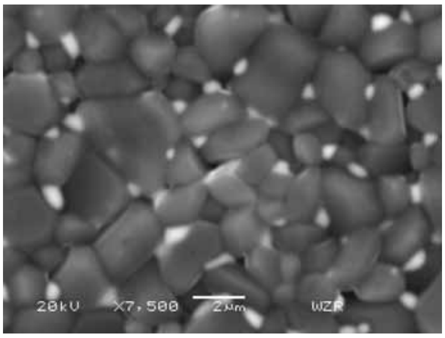
Sampling in a plant

within the lining of waste incineration plants. On this base, now it is possible not only to give analytic expertise in case of failure, but also a continuously cooperation with the operator of these plants to optimize the casting. Especially aspects of quality control during the lining are of interest to the clients.

By comparing laboratory results with corroded materials after several months in plant, it is now possible to find analytical methods to evaluate alternative refractories or linings. In a special area it was possible to increase the lifetime of the lining by using alumina- in stead of SiC castables. The smooth change was enabled by first testing and comparing the materials in lab and then running test fields.

7 Technical ceramics

Beside refractories the main focus of Werkstoffzentrum is on technical ceramics. Similar to refractories, the aim of development is microstructure design. The microstructure of a material defines its properties and the microstructure itself is defined by the raw materials and additives on one side and by the processing (mixing, shaping, sintering etc.) on the other side. Therefore the selection and treatment of raw materials and the choice of adequate additives with respect to the shaping technology are of significant relevance. In this context also nano-scaled particles as an additive to micro-scaled particles have been investigated. For example it could be shown, that the mechanical properties were significantly improved by the addition of 5 vol.-% of nano-scaled zirconia to alumina, with an average particle size of 0.8 µm.



Alumina, toughened with nano-sized zirconia particles

8 Prototyping of ceramic components

In the metal industry and especially in the polymer industry methods of rapid prototyping are state of the art. Therefore it's possible to produce components directly basing on CAD data. Within a few hours highly complex and filigree structures can be realized.

The basic problem of ceramic materials is that their potential is widely unknown among engineers and constructors. Therefore the application of fast, computer-aided processes for the production of prototypes is essential for these materials.

Long development cycles are the result of a long and costly production process, including modelling, moulding, mould optimization, raw materials processing, forming, sintering and post processing. Both, producer and user need methods for fast and competitive supply of prototypes.

In the last months Werkstoffzentrum provided different methods allowing generating ceramic prototypes within a very short time (5–10 days). These kinds of prototypes should show the same properties as the repetition part.

Two technical solutions – hot casting and 3D printing – were both developed and tested.

For hot casting, it's basically possible to use tools from plastics. The moulds may be produced by known techniques of rapid prototyping or by modelling. For the casting of the components by means of hot casting, a mould is needed, which is dependable form-stable at temperatures between 60 and 110 °C. The following de-binding is exactly adjusted to the expected demands of the materials. The resulting brown body is fired at well defined temperature, time and atmosphere. In order to complete the process safely the brown body must have certain strength.

For 3D printing binder and powder have to be exactly adjusted. The binder is subject to high defined demands, because it's responsible for the adhesion of the particles and the resulting strength of the green body. The intention is to fire the green body shortly after the removal from the remaining powder bed.

For both variations it's a major intention to produce components with properties equal to

3D printing of ceramic components

those of the mass production, mainly focussing on the parts density. Because this is not yet achievable in the printing process, it's possible to infiltrate the component in a second step in order to achieve a closed surface of the part. Time and costs of development may be reduced significantly and in addition the time to launch new ceramic components to the market may be shortened.

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