Testing of Refractories and Refractoring

For more than 45 years the Aachen Institute of Mineral Engineering has been successful in testing and developing refractory materials. During that time requirements for these materials increased due to both higher processing temperatures and tightening up production efficiency demands. This guided into optimized conventional refractory products which can only be achieved by applying high grade, oxide as well as non-oxide, synthetic raw materials and innovating production technologies. Major impulses in developing high performance materials have been initiated by process innovations out of steel industries, waste incinerators dispose and coal gasification.

In order to meet with this specific requirements new test methods have been developed to assess the suitability and reliability of these materials under extreme operating conditions. The Aachen Institute of Mineral Engineering intensively participated in development and improvement of new testing procedures being involved in various expert organisations and boards. So, tests after DIN, EN-DIN, ASTM, AFNOR and BS -standards, as well as non-standard tests which simulate special operating conditions are available.

Range of application of refractory materials

Iron making industry
- blast furnaces
- hot blast stoves
- blast tyers
- hot blast main systems
- blast furnace runners

Steel making industry
- pig iron transport vessels
- pig iron collector vessels
- oxygen steel converter
- electric arc furnaces
- steel casting laddles
- treatment laddle for secondary metallurgical processes
- steel degassing vessels
- refractory parts in continuous casting systems
- refractories for heating and heat treatment furnaces: soaking pits, pusher type furnaces, rotary hearth furnaces, walking beam furnaces, walking hearth furnaces, roller-hearth furnaces

Iron- and steel-casting foundry
- cold and hot blast cupolas
- crucible and channel induction furnaces
- transport and casting laddles
- nozzles

Coke ovens
Metallurgical treatment and casting of nonferrous metals
- anode-baking furnaces
- melting-holding furnaces for Al
- refractory parts in continuous casting systems for Al
- reverberatory furnaces for Cu
- Pierce-Smith-converters
- anode-drum furnaces for Cu
- slag-cleaning furnaces for Cu
- Cu-melting furnaces

Boilers and power plants, fireboxes
- municipal incinerators
- special refuse incinerators
- melting chamber boilers
- combustion chambers, burner rigs

Coal gasification plants
- refractories for hot gas purifiers

Ceramic and enamelling industry
- tunnel kilns
- bugie hearth furnaces
- enamelling kilns
- roller furnaces

Refractory and heat resistant materials

Shaped refractory products
- SiO₂-rich products
- fireclay products
- high alumina products
- products on base of sesquioxides
- products on base of zirconium
- forsterite bricks
- basic bricks
- commercial (groups A 25 - A 40);
- silica-rich, acid-resistant, graphite-containing, SiC- and cordierite-containing, kaolinite-products;

Cement and alkaline earths industry
- rotary kilns for cement, dolomite and magnesite
- shaft kilns

Glass industry
- glass melting tanks
- regenerators for glass melting tanks
- electric furnaces

Refractory heat-insulation materials

Chemical industry
- combustion chambers
- hot gas generators
- liquid waste incinerators
- sulfur incinerators
- crackers
- reformers
- carbon black generators
- petrol chemistry plants

Unshaped refractory materials

For monolithic linings, repairs, prefabricated refractory parts, as laying and jointing materials, plastic mixes, ramming, gunning, slinging and fritting mixes; refractory castables. Unshaped refractory and semi-refractory materials for laying, jointing and sealing shaped and unshaped products: mortars, mastics, adhesives

bonding: hydraulic, ceramic, chemical, organic

groups: oxidic: SiO₂, Al₂O₃, Cr₂O₃, MgO, CaO; non-oxidic: SiC, Si₃N₄C

refractory castables: regular castables (RC), liquidified (DCC), medium cement (MCC), low cement (LCC), ultra low cement (ULCC), no-cement (NCC)

Refractory insulating materials

- insulating materials up to 1100°C
- refractory lightweight bricks up to 1900°C
- ceramic fibre products up to 1800°C
## Microstructural Characterisation of Raw Materials and Refractory

### Chemical analysis
- X-ray fluorescent analysis
- Atomic absorption spectrometry (AAS)
- Ion chromatography
- Infrared spectrometry
- Wet chemistry
- Coudometry

### X-ray diffraction analysis
- Qualitative and quantitative analysis
- Low-angle diffraction
- High-temperature diffraction up to 2000°C

### Light microscopy
- Polarisation microscopy in reflected light
- Fluorescence microscopy in reflected light
- Polarisation microscopy in transmitted light
- Wetting microscopy up to 1700°C

### Scanning electron microscopy
- Including X-ray microanalysis
  - Energy-dispersive (EDX, semi quantitative)
  - Wave-length-dispersive (WDX)

### Transmission electron microscopy (TEM, 300 kV)
- High resolution, EDX, STEM
- Sample heater up to 1200°C

### Analysis of macrostructure
- Analysis of mono- and multiphase polycrystalline structures

### Determination of density and porosity
- True density (pycnometer)
- Bulk density, shaped or granular materials (fluid displacement and measure method)
- Open porosity (permeability to gases, air diffusion)
- Pore size distribution
- Mercury displacement method
- Water-air displacement method
- Systems for the analysis of microstructures

### Specific surface
- Single point of adsorption process (Brunauer)
- Gas adsorption, BET-method
- Air penetration

### Grain size analysis
- Laser granulometry
- Sedimentation analysis
- Air separator
- Screen analysis, particle size analysis

### Mechanical and Thermo-mechanical Properties

#### Strength at ambient temperatures
- Crushing strength
- MOE, transverse strength (3- and 4-point bending)
- Weibull statistics
- Tensile cleavage strength
- Static E-modulus
- Young’s modulus

#### High Temperature Strength
- Hot crushing strength
- Hot transverse strength
- Creep under transverse/flexural stress
- Hot abrasion resistance

#### Stress/deformation behaviour at high temperatures
- Thermal expansion (dilatometry)

### Refractoriness
- Determination of first stage longitudinal resonance frequency (according to Kottas)
- Kβ-factor (fracture toughness)
- Determination of work of fracture
- Determination of hardness of surfaces

### Stress cracking resistance
- Bimule grinding machine

### Resistance to acids
- By grinding
- By sand blasting impact

### Thermal shock resistance
- Air quenching method
- Water quenching method

### Thermal Analysis
- Thermal decomposition reactions, vapourisation
- Thermal shock between two high temperatures

## Tests on Specific Refractory Product Types and Raw Materials

### Unshaped Products

#### Chemical and Refractory Materials
- Density, bulk density, permeability to gases
- Cold crushing strength after preliminary firing
- Determination of interzonal strength
- Determination of volatile contents and residual carbon contents

#### Raw Materials
- Determination of suitability of quartz sands and gravels for refractory production according to §3.4

### Ceramic Bonded Basic Bricks
- Pyrolytic cone equivalent
- Pyrolytic cone equivalent
- Pyrolytic cone equivalent
- Resistance to acids

### Ceramic Fiber Materials
- Diameter of ceramic fibres
- Light microscopic methods
- SEM
- Shot content
- Bulk density, thickness
- Permanent change in dimensions on heating
- Classification temperature
- Resilience and compressibility
- Tensile strength

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