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Expert Fachmedien GmbH
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Management: Paul Robert Hoene
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Editorial department:
Dr. Hubert Pelc (managing editor/responsible)
Phone: +49(0)211/1591-230 E-Mail: hubert.pelc@dvs-hg.de
Dr.-Ing. Paul-Eberhard Keilbar
Phone: +49 (0)341/9410237 E-Mail: keilbar@t-online.de
Sylvia Hanagan (editorial assistant)
Phone: +49(0)211/1591-231 E-Mail: sylvia.hanagan@dvs-hg.de

Editorial committee of INTERCERAM – Refractories Manual:
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Layout & printing: Kraft Druck GmbH, Industriestraße 5–9,
D-76275 Ettlingen, Germany

Advertisements:
Christiane Czech (responsible)
Phone: +49 (0)211/1591-157 E-Mail: christiane.czech@dvs-hg.de

Subscription:
Expert Fachmedien GmbH
Alexander Werum
Reader service
Große Hub 10, D-65344 Eltville
Tel.: +49(0)6123/9238-223, Fax: +49(0)6123/9238-244
E-Mail: interceram@vuservice.de

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"Best" Refractories?

When I was in the university, my classmates and I often had interesting discussions on various topics with the teacher of our refractory course, one of which was on the subject of so-called "best" refractories. Although there was actually no scientific definition of a best refractory, WATER was then regarded as one since it could be used to cool critical areas in an industrial furnace to protect key operational linings or avoid the use of expensive refractories. Two important industry applications of water cooling systems often came to my mind then. One was cooling used in the hearth area of a blast furnace to protect carbon refractories and the other application was on the roof and sidewalls of an EAF furnace to avoid requiring expensive refractories.

In this editorial, I would like to describe two other types of best refractories I "discovered" in published work. One is SLAG and the other is POROSITY. Why is slag a best refractory? The reason is that a slag layer can be formed in situ in an industrial furnace and act as an additional consumable lining, protecting the expensive refractories behind it. A typical example is the "slag splashing" technique used in a BOF furnace to generate an in situ slag lining on top of expensive MgO-C bricks. A second example is freezing slag in an EAF furnace onto its steel panel. The frozen slag layer acts as a refractory. A third application is in situ generation of a protective slag layer on the refractories used in a cement kiln.

Why is porosity also regarded as a best refractory? The answer is that many novel types of refractories can be developed by carefully playing with it, resulting in substantial benefits. Unlike water and slag, pores are a constituent of the refractory and can therefore have significant and direct effects on its microstructure and overall performance. Introducing well-designed levels of pores in a refractory, with appropriate shapes and sizes, can have many advantages. Decreased thermal conductivity acts to better insulate the refractory, reducing energy loss and alleviating other related overheating problems. Secondly, a reduction of elastic modulus leads to improved thermal shock resistance. Third, replacement of dense by more porous aggregates can avoid any need for intensive pressing and high temperature sintering, saving energy and reducing overall production cost. Finally, replacement of solid parts with porous substitutes results in lightweight refractories and significant savings on raw materials.

In spite of these considerations, there are some concerns about identifying porosity as a "constituent" refractory property. One is a possible decrease in corrosion resistance and mechanical strength. Fortunately, recent studies reveal that when porosities are carefully designed, e.g. by introducing micro/nano sized pores in refractory aggregates, corrosion resistance can still be comparable to the attributes of refractories with denser components. Recent work also found that replacement of dense aggregates with porous ones need not cause a significant decrease in mechanical strength. This is because the overall strength of a refractory is mainly determined by its weak matrix rather than by aggregate density.

Nevertheless, before routine commercial production and industrial scale application is possible, considerable R&D is certainly needed to further address other important issues. One open question, for example, is how to best engineer porosities in a refractory. Although many techniques have been proposed and attempted, they all suffer from several disadvantages. Alternative techniques need to be developed to solve these problems, which will lead to fruitful areas for future research.

Shaowei Zhang
Chairman of the
Editorial Committee
s.zhang@exeter.ac.uk