Thermo-mechanical properties of magnesia carbon foam composites.

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ABSTRACT

Magnesia carbon (MgO-C) composites are used as refractory materials e.g. in steelmaking industry as lining for furnaces or for ladles. In the state of the art, magnesia carbon bricks consist of a periclase (MgO) phase with carbon inclusions and pores. In their applications, MgO-C bricks are subjected ot both quasi-static and dynamic thermal loading causing damage up to the mechanical failure. Dynamic thermal loading is called thermal shock. Recently, significant improvement of the thermo-mechanical behaviour was achieved by carbon foams where the pores were filled with MgO [1].

According to the applications as refractory materials modelling of MgO-C hybrid foams is not only a multiphase but also a multiphysics problem in which the displacement field and the temperature field has to be considered. Thermal damage in such materials arises by the material specific isotropic expansion of both phases due to permanent thermal stresses based on the different coefficient of thermal expansion (CTE) of MgO and C. But there are temporary thermal stresses emerging by temperature gradients causing mechanical damage, as well. Temporary thermal stresses arise not only in multiphase materials but also in homogeneous materials and vanish for elastically loaded samples at balance of temperature.

The present contribution focuses on MgO-C foams as two phase materials and the investigation of the structure-property relationship in order to reduce thermally induced stresses and damage in the hybrid foams. It is a transient (thermal shock) as well as static fully coupled thermo-mechanical problem. In general refractory materials are brittle ceramics, hence according to our previous work [2, 3] we used a linear elastic model with damage criterion to model the thermo-mechanical properties of magnesia carbon foam composites. In the presented work a modified elastic model with a kinematic coupling of the displacement and temperature field was used by a multiplicative decomposition of the deformation gradient into an elastic and a thermal part. It was assumed that the functions of motion and hence the deformation gradient of both phases (MgO and carbon) are equal. According to the different CTE of both phases they differ in their elastic and thermal part of the deformation gradient. The total elastic stress is the sum of the elastic stress of the MgO and carbon phase. To optimise the microstructure of MgO-C foams, the effect of changes in pore size, strut thickness and size effects was determined. For the invstigation of the thermal shock behaviour the results correlate very well with the experimentally motivated Hasselman relation [4] which describes the residual strength of refractories after thermal shock as function of the thermal shock difference. An improvement of the thermal shock resistivity can be achieved by reducing the MgO filled pore size, increasing the strut thickness of the carbon foam and by reducing the overall microstructure.

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