K1-MET

Competence Center for Excellent Technologies in Advanced Metallurgical and Environmental Process Development

Main location	Linz, Upper Austria
Other locations	Leoben, Styria
Thematic field	K1-MET has its focus on the modeling and simulation of metallurgical processes, including metallurgical raw materials and refractories with the goal of an optimal process control with respect to product quality, zero waste and the minimization of energy and raw materials.

Success story summary

Investigation of thermomechanical behaviour of a RH snorkel including tensile, shear failure and creep

Failure due to tensile and shear loads was considered in the thermomechanical modeling of a RH snorkel as well as creep to discover the failure mechanisms of the working lining during the process cycle. Stress paths show that shear failure due to hydrostatic compression predominates at the hot face of the working lining and tensile failure in some distance to the hot face during the submerging procedure. Relative compliant bricks and concretes could reduce the failure area due to tension. Irreversible strains from shear failure and creep at the hot face of the working lining give rise to the joint openings.

Success story

Objectives

The snorkels in the RH-degassers suffer both hot and cold thermal shock during the process cycles, as well as the intensive high temperature treatments. The task is to identify the failure mechanisms of the snorkel from the thermomechanical point of view, in order to provide the fundamentals for the further optimization of snorkel lining concepts.

Model and boundary conditions

A three-dimensional model was established to represent a slice of RH snorkel, which was cut in the axial direction consisting of half part of bricks with a consideration of symmetry, as seen in Figure 1. The working lining comprises three-layer magnesia-chromite bricks, and their properties related to tensile (concrete damaged plasticity) and shear (Drucker-Prager) failure models were determined in Lab CoC as well as the strain-hardening creep law (classical creep model) under high temperature compressive loads. The steel construction and monolithics were assumed to behave elastically. Free expansions of linings were allowed in the radial and axial directions expect the axial displacement constraint at the upper surface of the snorkel. The inner surface of the snorkel was preheated to defined temperatures in 7 hours, and then was submerged into 1600 °C liquid steel. After 35 min treatment, the snorkel was pulled out of the liquid steel bath and waited for the next submerging.

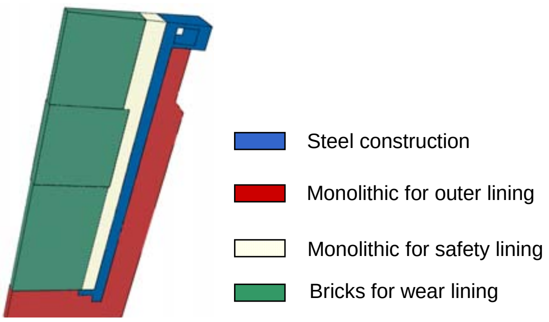

Figure 1: Three dimensional representation of a RH snorkel.

Results and Economic Impact

Due to the thermal expansion of the refractory linings and the constraint of the steel shell, the hot face of the working lining receives the circumferentially compressive stresses. Shear failure due to the hydrostatic compression was observed predominately at the hot face of the lowest brick of the working lining during the submerging in terms of the stress path analysis. Meanwhile, failure due to tensile loads appeared in some distance to the hot face of the lowest brick of the working lining. Free expansion at the hot face of the bricks and external mechanical loads contribute to the crack propagation inclined to the bottom surface of the lowest brick. To reduce the failure due to tensile loads in the bricks, several lining concepts were considered by employing different compliant materials for the bricks and monolithics. For comparison in Figure 2 the gray area shows the equivalent plastic strain larger than 0.001. The abscissa is given by the form of Young's modulus of the brick/ Young's modulus of the monolithic. The maximum principle stress in the inner corner area of the outside concrete and the elongation of the steel construction end in the axial direction were also used to evaluate the impact of various lining concepts. It is clear shown that with increasing Young's modulus of the monolithic, the damage area became smaller in the lowest brick, nevertheless the maximum principal stress and the elongation increased dramatically. Further decreasing the Young's modulus of the brick reduced the failure area, but the maximum principle stress was still quite high as well as the elongation. A rather compliant combination of the brick and monolithic exhibited moderate maximum principle stress in the outside monolithic and elongation of the steel construction without significant increasing the failure area of the lowest brick. Beside the shear failure, creep of magnesia-chromite material also resulted in irreversible strains at the hot face of the working lining. Joint opening was expected in both the circumferential and axial directions.

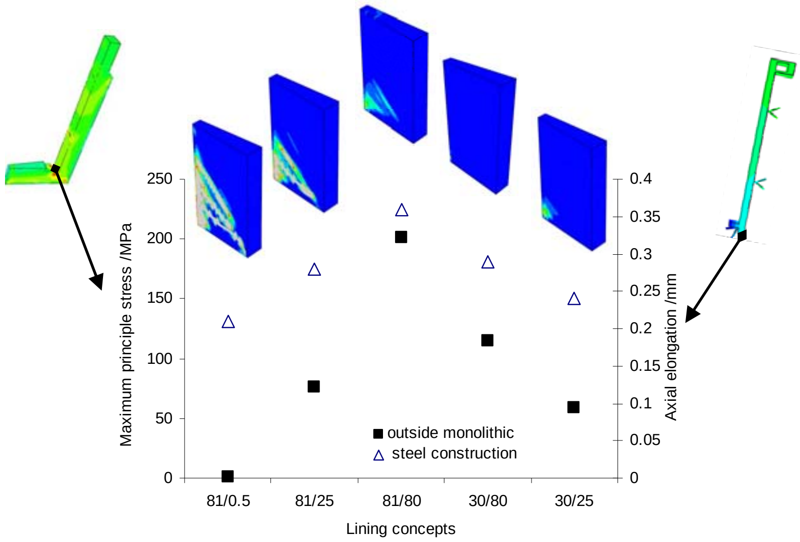

Figure 2: The influences of lining concepts on the failure area of the lowest brick, the maximum principal stress in the outside monolithic and the elongation of steel construction end in the axial direction.

Impact and effects

The modeling activities including plastic models provide not only a more accurate description of the thermomechanical behaviour of the snorkel linings, but also show a common procedure applicable for the evaluation and simulation of other industrial vessels

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