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Numerical simulation of a thermo-hydro-mechanical problem in steel industry

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In iron and steel industry it is of vital importance to minimize the wear that refractory linings suffer during several stages of the basic oxygen steelmaking process. This process uses hot metal as feed material for steel production, which is obtained in the blast furnace (BF) alongside with slag. Both materials are removed from the BF through a taphole and poured onto the blast furnace runner, a trench-like structure composed by several layers of concrete refractories. Its function is to enable separation of hot metal and slag as they flow donwstream due to their different densities.

Wear assessment and minimization are among the main design and operation concerns at a blast furnace runner. Usually, its first layer of concrete, known as working layer, has to be replaced after every two months in order to avoid greater damage in the remaining layers. The wear suffered by the refractories is due to a combination of factors, namely, corrosion due to the chemical attack of slag and erosion due to the flow of both hot metal and slag along the runner. Moreover, big thermal stresses play an important role due to the extreme heat environment, with temperatures of around 1500ºC. Wear of the refractory lining is also believed to be strongly related to the position of the so-called critical isotherms, which are difficult to obtain experimentally due to the hostile environment, posing a big challenge to experimentation. This motivates the usage of numerical simulation to investigate these phenomena.

In this work, a multiphysics 3D model defined on a runner at the ArcelorMittal company in Veriña, Asturias, is proposed in order to find the position of the critical isotherms and the thermal stresses. First, the turbulent flow of the three immiscible phases -air, hot metal and slag- is solved. The velocity field is used to compute the temperature in the solid layers that compose the blast furnace runner, solving the conjugate heat transfer problem. Radiative heat transfer among the slag free surface and the refractory lining is also accounted for using the s2s model. The different layers of materials are modeled using temperature dependent properties. Finally, the temperature field is supplied to a mechanical model, which allows to compute the thermal stresses in the solids.

The resulting temperature field is validated using experimental data measured by ArcelorMittal.

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