Design of a Slag Sampler

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INTRODUCTION

High-efficiency demands for new flash-smelter furnaces (Schlesinger 2011) require a better understanding of the thermal and chemical phenomena occurring at the interface between the slag and matte immiscible melts. A particularly interesting aspect is the dynamics of matte drops as they enter the layer of slag and further fall towards the bottom of the furnace. Little is known about the separation process and this is due mainly to the lack of experimental devices which are able to operate at high temperatures.

The concept of a new slag sampler currently being developed at University of Huelva is presented along with preliminary simulation results. Unlike bare steel bars commonly used for sampling, this device, designed to work in pressurized cooling conditions, shall enable the capture of larger layers of slag in a predetermined time frame.

METHODS

The sampler is made of two coaxial tubes connected at one end such that the coolant (water) can flow from the inner tube to the outer one (Fig. 1).

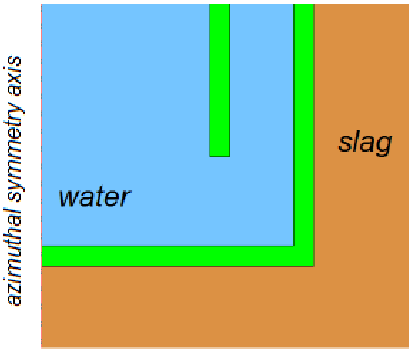

fig 1. Sampler axial cross section.

Pressurized water flow can be optimized for a given geometry such that its velocity allows an efficient heat transfer, once the sampler is immersed in slag. Water flow through sampler removes heat at a rate high enough to produce undercooling of slag melt around the sampler, allowing transition of the melt into glass at 1100°C. A layer of slag with matte drops captured inside can thus be extracted pulling out the sampler.

Numerical modelling of the device has been carried out using the Comsol Multiphysics software with appropriate rheological data of molten slag. The computational procedure consist of two distinct numerical steps whose coupling allows transient modelling of the slag/water temperature:

- fluid flow study (stationary).
- heat transfer study (time-dependent).

Due to the simplicity of the model the problem of time-dependent cooling can be studied in Comsol taking benefit of the azimuthal symmetry of both geometry and physical phenomena involved.

RESULTS

The solution provided by the combination of the two studies enables estimates for the temperature variation across the slag and water domains.

Fluid Dynamics Study

Water enters the inner tube from the upper end and fills the outer tube through the contact at the lower part of the sampler. Initial input conditions can be written as uniform or position-dependent flow velocity, mass flow or pressure. A particular distribution of the velocity field can be seen in Fig. 2, for an input flux of 10 kg/min. This design makes the water flow faster within a cone which forms at the end of the inner separating wall.

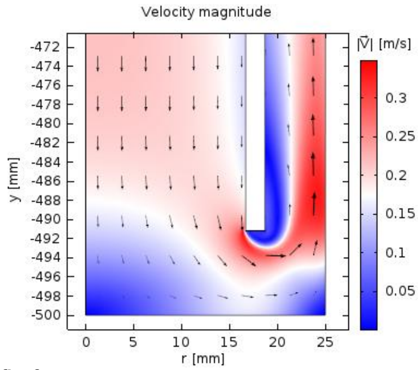

fig 2. Water velocity distribution across sampler axial cross section.

Inhomogeneous water flow is therefore recorded at the outer wall. Further development shall focus on the geometrical refinement for both tubes in order to address this problem.

Heat Transfer Study

Heat transfer is analysed in the time domain setting up boundary conditions in accordance with the initial temperature of the water and slag domains, as well as temperature constraints at the input port of the water flux (4°C) and at the outer boundaries of the slag domain (1300°C). This study is coupled to the solution of the flow model. Thus, metal and fluids temperatures are computed iteratively, considering the motion of the water domain. An important issue here is the performance of the mesh and a figure for the inherent error can be obtained inspecting the temperature gradient across the water/slag interface at t = 0. Ideally, the gradient between the two temperatures should span over an infinitely small region but this is never possible in practice. As shown by Fig.3, mesh errors are in the range of 200 μm while the glass layer is expected to be a few mm thick. This ratio should be acceptable.

palabras clave: Escoria, Pirometalurgia del cobre, Horno Flash, Fusión Flash del cobre.

key words: Slag, , Copper pyrometallurgy, Flash furnace, Copper flash smelting.

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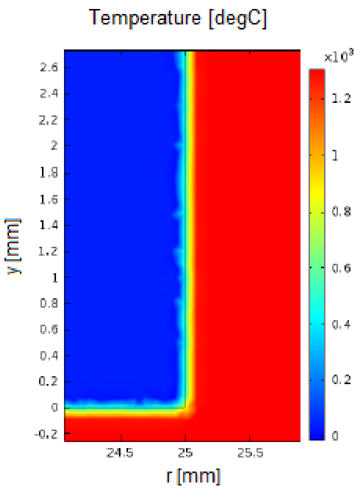

fig 3. Temperature distribution at t = 0 seen across an axial cross-section through the sampler.

Water flow creates a temperature drop within a region of slag surrounding the sampler. Its radial thickness is modelled a function of water flux. If a particular temperature gradient in the slag is desired, the water velocity can be tuned up and down and volumes of slag caught between two temperature levels can be located numerically. For example Fig. 4 shows the 1100°C isothermal lines in 2D (or surfaces in 3D) as they evolve in time.

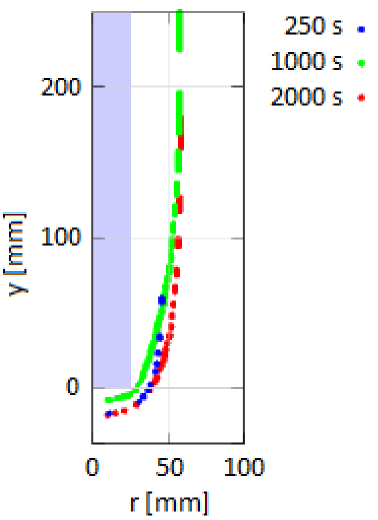

fig 4. Isothermal lines recorded for 1100°C around the sampler at various times after the immersion of the sampler into the slag layer.

Temperature variation across the water and slag domains can be better visualized observing it along an arbitrary reference axis drawn from the centre of the sampler radially outwards at different times. An example is given in Fig.5 where the reference axis has been fixed of half the sampler height.

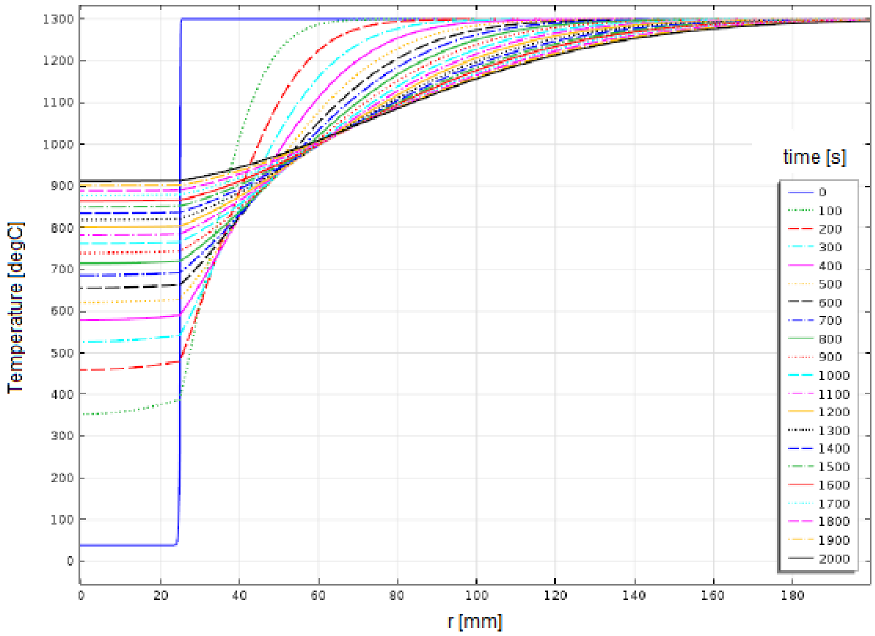

fig 5. Time temperature evolution across sampler and slag domains. Time range goes from 0 to 2000 s. Initial temperature within sampler is 40 °C and temperature of slag around sampler is 1300 °C.

This kind of coupled studies, which allow to ascertain the water flux variation effects, enable realistic estimates for:

- thickness and location of the slag glass layer.
- optimum extraction time of the sampler

CONCLUSIONS AND FUTURE WORK

Basic concepts for a slag sampler model have been presented with examples of numerical simulation studies which are currently in progress. Among many important issues, further development shall approach the problems of:

- mechanical stability.
- water boiling.
- material degradation.

such that a prototype could be eventually tested.

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