Design of a Slag Sampler

/ CRISTIAN BONTOIU (1), IGNACIO MORENO-VENTAS BRAVO (1*), MARÍA BACEDONI MORALES (1), FELIPE JIMÉNEZ BLAS (2), IRENE RUIZ ORIA (3), FRANCISCO JIMÉNEZ (3), GUILLERMO RIOS RANSANZ (3)

(2) Departamento de Física Aplicada. Facultad de Ciencias Experimentales. Universidad de Huelva. 21701, Huelva (España).
(3) Atlantic Copper. Avenida Francisco Montenegro s/n. 21001, Huelva (España).

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).

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.

Heat Transfer Study

Heat transfer is analysed in the time frame of the initial separation process and the inherent error can be obtained by 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.
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.

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.

AKNOWLEDGMENTS

The authors would like to express their gratitude to the Atlantic Copper Company based in Huelva for funding the current research project (Ref. 10/2014) and providing useful information.

REFERENCES