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Estimating the Ore Volume in AC Smelting Furnaces Using Finite-Element Analysis of Surface Current Density

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Introduction

One of the primary reasons for large power fluctuations in smelting furnaces is loss of contact between the electrode and ore. Therefore one of important aspects of controlling power fluctuations is a predictive algorithm for the positioning of the electrode. Most of the existing solutions are non-model based algorithms that focus on blind prediction of load resistance. In this paper we propose a model-based approach that estimates the volume ratio of solid and liquid phases of the ore. The resulting estimates can then be used in predictive algorithms for vertical positioning of the electrode since the height of the ore is directly related to the volumes of solid and liquid phases.

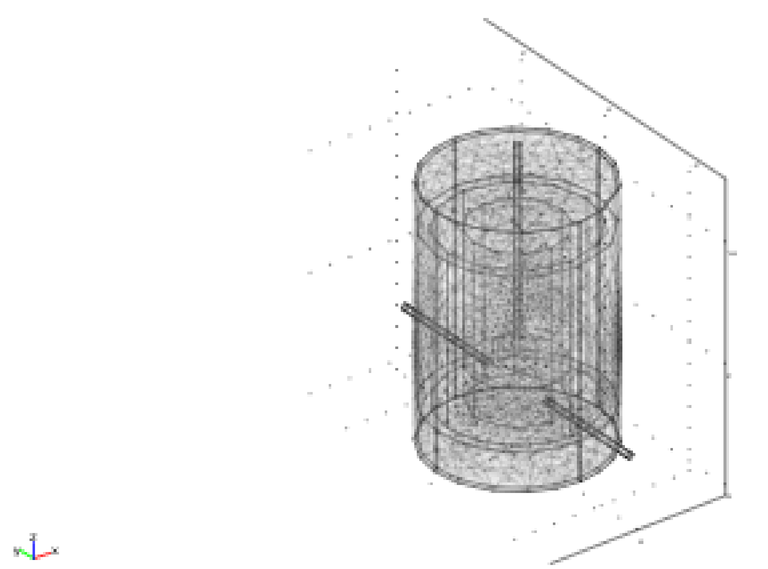

Figure 1: COMSOL Mesh of AC Smelting Furnace

Use of COMSOL Multiphysics

To this purpose we develop a finite-element model of AC smelting furnace using COMSOL Multiphysics software. We build coupled thermo-electromagnetic model and model the conductivity of the ore as temperature dependent. We assume that furnace is nickel smelting furnace and use somewhat simplified design (two layer temperature insulation) with electromagnetic shielding. According to information provided by Hatch McDonald, Inc., we assume there are ten (10) grounding points on the furnace shell and develop finite-element model for calculation of electric and induction currents in the electromagnetic shielding.

Furthermore we assume that the melted ore consists of multiple phases (pieces) and that shape of these pieces can be approximated with a prolate spheroid. We consider two cases: deterministic, in which the spheroid parameters (axes) are unknown, and Bayesian (probabilistic) in which spheroid parameters follow the Gaussian distribution. We then derive the measurement model in which the grounding currents are expressed as a non-linear function of solid ore parameters and estimate these parameters using least-squares optimization.

Expected Results

In Figures 2 and 3 we illustrate the mean square error in estimating the volume ratio (solid vs. liquid phase) averaged over 1000 simulations. The results presented in Figure 2 illustrate the error when the shape of ore is perfectly known. In Figure 3 we illustrate the same results but assuming that the shape and location of ore are unknown. As expected the estimation error is significantly larger but can still provide important insight into the internal state of smelting furnaces.

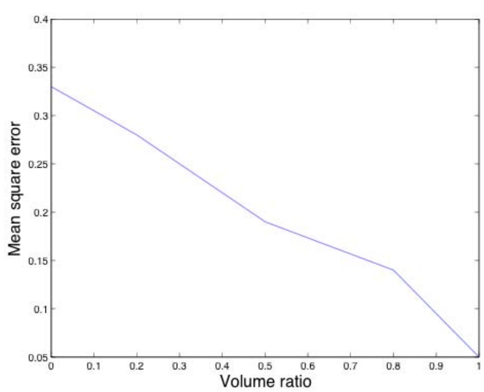

Figure 2. Single Phase – Known Shape

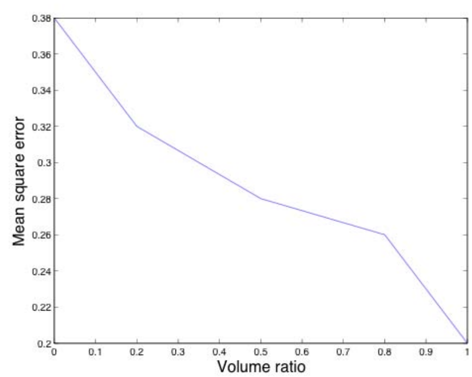

Figure 3. Two Phase – Unknown Shape

Conclusion

Considering the current state of industrial need for raw materials and price of energy the proposed approach provides potential of providing an insight into the state of melting ore in AC furnaces. To the best of our knowledge such information is currently unavailable. In addition being able to predict the volumes (or equivalently the height/shape) of the ore can improve currently existing blind algorithms and thus minimize the power fluctuations (i.e., losses). Furthermore we expect that significant improvement can be achieved if the volume of the liquid phase is modeled as a function of the total power delivered to the furnace and this topic is left for future research.