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Cold crucible for HLW vitrification : advances in the feed and PGM behaviour modelling

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A cold crucible induction melter is in operation in La Hague plant, which is operated by ORANO since 2010 for the vitrification of HLW arising from D&D operation and old reprocessing of high Molybdenum content fuel. The well-known advantages of the cold crucible compared to the hot metallic inductive melter are (i) a higher elaboration temperature (ii) an extended lifetime and (iii) a better homogeneity obtained by mechanical stirring and gas bubbling. As a result, the global production capacity is expected to be higher as well as the PM concentration in the glass.

A part of the development of this technology is made with the help of numerical simulation of the glass flow and heating by direct Joule effect thanks to the high frequency induction power unit. In this paper, the last effort of 3D modelisation of the Platinum-Group-Metals (PGM) particles behavior in the glass and chemical reaction kinetics of the feed are detailed.

During the melting, the glass generally shows a homogeneous liquid phase seeded with non-soluble heavy platinum-group-metal particles mainly made of palladium and ruthenium dioxide. Previous studies [1] reported spatial discrepancies of the local volume fraction of particles in the melt because of particles settling with time. This migration of particles towards less agitated bottom parts of the crucible affects the dynamical, electrical and thermal state of the melt because of concentration-dependent electrical conductivity and viscosity of the suspension. A theoretical one-fluid transport model was developed with the help of small scale experiments carried out with a HLW glass simulant. The model is coupled with existing 3D thermo-hydraulic numerical codes, thus enhancing the precision of heat flux predictions between the melt and the crucible.

The feed modelling is also under development. From vitreous precursors (Sodium alumino-borosilicate glass frit) and calcined waste (a mixture of about thirty oxide and nitrate compounds obtained after calcination step), a succession of processes such as impregnation, denitration, crystallization and dissolution occur in order to solubilize the waste into the vitreous network. Mainly focus on thermal and chemical (0D models) approaches the objective aim at coupling the reaction kinetics laws of thermally activated processes (denitration, crystallization, dissolution) to the magneto-thermo-hydraulic model in order to model both physic and chemistry of glass synthesis. The experimental methodology based on the characterization of thermo-activated reaction kinetics by differential and gravimetric thermal analysis (TGA/DTA) and the kinetic parameters identification (such as activation energy, reaction order, pre-exponential factor) [2] [3] will be described. Moreover, an example of simulation integrating the chemical equation solved with CFD tools will be presented and discussed.

[1] Yoshiyuki Iso, Shinsuke Matsuno, Hiroyuki Uchida, Isamu Oono, Toshiki Fukui, and Takaaki Ooba. Numerical simulation of platinum group metal particles behavior in a Joule-heated glass melter. *Journal of Power and Energy Systems*, 2:815–825, (2008).

- [2] J. Chun, D.A. Pierce, R. Pokorný, P. Hřma « Cold Cap reactions in vitrification of nuclear waste glass: Experiments and modelling », *Thermochimica Acta*, (2013).
- [3] H. Yunqing, « Theoretical Study Of Thermal Analysis Kinetics », *Theses and Dissertations—Mechanical Engineering*. 35, (2014).