Cold crucible induction melting for nuclear waste vitrification: from numerical simulations to industrial operation

Emilien Sauvage*[1], Patrice Brun[1], Sophie Schuller[1], Milène Delaunay[1], Armand Bonnetier[1], Stéphane Lemonnier[1], Virginie Labe[1], and Régis Didierlaurent[2]

[1]CEA, DEN, DE2D, SEVT, LDPV (CEA) – CEA-Marcoule – BP 17171 - 30207 Bagnols-sur-Cèze Cedex, France

[2]AREVA NC LCV - CEA Marcoule – AREVA NC LCV – France

Abstract

Vitrification of high-level liquid waste is the internationally recognized standard to minimize both the environmental impact resulting from waste disposal and the volume of conditioned waste. In France, high-level liquid waste arising from nuclear fuel reprocessing has been successfully vitrified for more than 40 years with three major objectives: durable containment of the long-lived fission products, minimization of the final waste volume, and suitability for an industrial framework.
In this context, the CEA (French Alternative Energies and Atomic Energy Commission) and AREVA have acquired a unique experience on the Cold Crucible Induction Melter (CCIM) vitrification process through more than three decades of R&D and eight years of industrial operation at La Hague plant. This paper presents the CCIM technology from the numerical simulations development to the industrial operation at La Hague plant.

Numerical modelling of induction heating, fluid mechanism and thermal phenomena have been developed for many years. Induction simulation is coupled to thermal simulation with the Joule power density in the metallic part of the process as well as in the molten glass itself. The flow simulation is also coupled and takes into account the mechanical stirring, gas injection and even Lorentz forces if necessary. The radiative heat transfer and the Marangoni convection are simulated as well. All these phenomena are computed on the full 3D real geometry of the furnace thanks to the use of supercomputing center as the TGCC (Très Grand Centre de Calcul) of the CEA. Developments are under progress to include more chemistry in the simulations, such as a redox model or a digestion feeds model and to improve the accuracy and the predictability of such numerical modelisations.
The simulations have been extensively used in the design of the cold crucible inductive melter (CCIM) commissioned in 2010 at La Hague plant but also to enhance the working knowledge the phenomena occurring in the process. The potential benefits are gains on the reliability, the output capacity and the life time.

Keywords: cold crucible, nuclear waste glass, numerical simulation

*Speaker