CFD Simulation of Molten-Salt Suction Drain from a Pyrochemical Reactor

Kwang-Rag Kim*, Sung-Ki Kim, and Hyo-On Nam
Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Republic of Korea
*krkim1@kaeri.re.kr

1. Introduction

Pyrochemical processing based on molten-salt electrolysis is preferred over the conventional wet process for treating spent nuclear fuels in view of several advantages such as its simplicity and less secondary wastes, etc. [1]. This process typically involves the dissolution of spent fuel into a molten-salt media.

The transfer of molten-salt to a next unit process is one of the most common and important operations in the molten-salt based integrated pyroprocessing technology. During the handling radioactive molten-salt fluids, the important issues are maintaining containment and preventing dose exposure for operators.

A transport application of the mechanical pumps has significant disadvantages in this area of the high-temperature molten salt system because of the leakage problems and maintenance of moving parts.

Recently, no-moving-parts pumping technologies have been tested in the molten salt applications such as gravity transfer or suction pumps [2].

In this study, a CFD (Computational Fluid Dynamics) modeling approach was proposed and simulated to illustrate the suction behaviors in the molten-salt tank draining system.

2. Theory

2.1 Free surface model

Free surface with a immiscible fluid flow is encountered in the multiphase system of salt-argon.

The numerical model directly solves the equations governing an incompressible isothermal multi-fluid flow within a CFD platform. The dynamics of two (or more) immiscible fluids are governed by the Navier-Stokes and continuity equations [3]:

$$\nabla \cdot U = 0 \qquad (1)$$

$$\frac{\partial U}{\partial t} + \nabla \cdot UU = -\frac{1}{\rho}\nabla P + \frac{1}{\rho}\nabla \cdot \tau + g + \frac{1}{\rho}S \qquad (2)$$

where t, U, P, g, S, ρ, and μ represent the temperature, velocity, pressure, stress tensor, acceleration due to gravity, surface force due to surface tension, density and viscosity of the fluid.

2.2 VOF model

In addition, the modeling of the free surface flow (or multiphase flow) requires a further coupled volume tracking approach. A recognized method is the so-called VOF (volume of fluid) models, which incorporate a moving free boundary [4]. This is done by defining a volume fraction F (or degree of filling) in each computational cell, which can take the following values:

$$F = \begin{cases} 1 & \text{in cells full of a particular fluid} \\ 0 & \text{in cells devoid of that particular fluid} \\ 0 < F < 1 & \text{cell contains free interface} \end{cases} \qquad (3)$$

The location of the interface is not explicitly tracked, but is instead captured by the distribution of F, since F takes the values $0 \leq F \leq 1$ in interface cells. In order to track the location of the interface, a continuity equation for F is established in the following form:

$$\frac{\partial F}{\partial t} + \nabla \cdot (UF) = 0 \qquad (4)$$

The equations presented above can be solved numerically using the commercial CFD code, in which the control volume method is used to discretize the transport equations.

3. Results and discussion

Tank draining of high temperature molten-salt system was simulated using the volume of fraction model in a CFD platform. This approach is a volume tracking technique applied to a fixed Eulerian mesh.

Representative simulation results are presented to illustrate the capabilities of this method for a molten-salt/argon system. Simulation is transient and solved as a two immiscible multiphase fluid. The salt level is decreased during that salt flows out the transport pipe generated from a suction effect which effectively empties the tank (Fig. 1). The salt level fluctuation was slightly observed in the CFD demonstration.

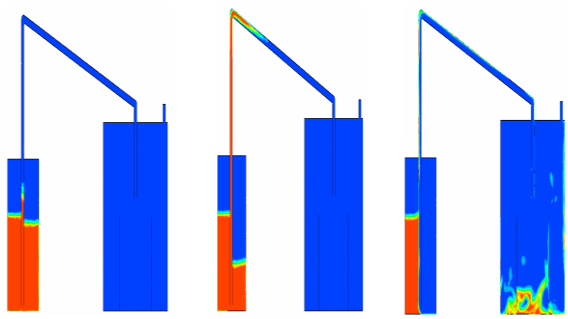

Fig. 1. CFD Simulation of Molten-Salt Suction Drain.

4. Conclusion

A CFD model has been demonstrated to simulate the draining out of a molten-salt tank using a suction dip system. It was found that this approach was capable of tracking a technology of salt transport system.

REFERENCES

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