Study on Thermal-Flow Analysis of the Cold Crucible Induction Melter

Seokju Hwang*, Young Hwan Hwang, Mihyun Lee, and Cheon-Woo KIM

KHNP-CRI, 70, 1312-gil, Yuseong-daero, Yuseong-gu, Daejeon, Republic of Korea

*hsjhhhhh@khnp.co.kr

1. Introduction

Vitrification has been developed to treat radioactive wastes and considered a promising technology that can be applied to enhance the safety of radioactive waste disposal and to reduce the volume of radioactive wastes.

For efficient use of the vitrification technology, there is a need to perform academic research with the aim of establishing the optimum operating conditions for vitrification facility and determining the heat flow characteristics inside the Cold Crucible Induction Melter (CCIM) for acquiring high-quality vitrified solids.

2. Thermal-Flow Analysis

2.1 Analysis strategy

Thermal-Flow Analysis in the FLUENT 15.0. Under the presumption of abnormal state and incompressible flow, the volume of fluid (VOF) model, and standard k-ε turbulence model were applied to simulate the bubble behavior, molten glass and interface.

2.2 Assumptions for Efficient CFD analysis

Since the difference in electrical conductivity within the solid parts of the CCIM, melted glass, air, and water is very large, numerous grids are required for the accurate calculation of the temperature gradient and electrical conductivity gradient.

The effect of electromagnetic field from a coil to melted glass in CCIM is magnificent, while the effect to water and air is negligible.

The height of bubbler is not considered. Although the diameter of bubbler is only 3.6% of the CCIM diameter, the consideration of height bubbler doubles the number of grids.

The input height of the sparger was 200 mm in this study for the efficient calculation. Many case studies have proven that the height of the sparger has negligible influence on the temperature and electromagnetic field distribution.

The domain and grid configuration of CCIM in this study is shown in Fig. 1 and Fig. 2.

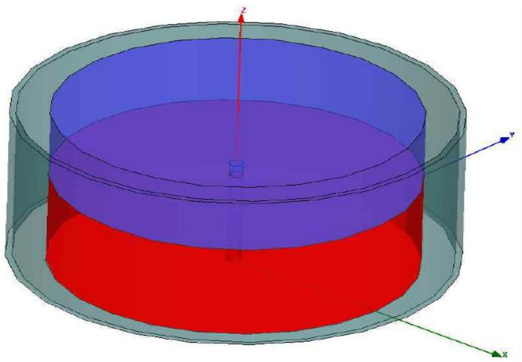

Fig. 1. Modeling of CCIM.

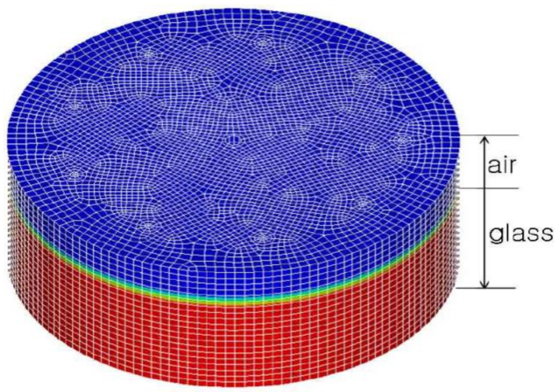

Fig. 2. Grid configuration of CCIM.

In the initial setup, the molten glass was placed from the bottom to the height of 0.15 m, and the air was placed from the height of 0.15 m and 0.3 m. For the analysis, around 3 million unstructured grids were used.

2.3 Analysis Conditions

The heat transfer by the electromagnetic field inside the CCIM was ignored in this study for the efficient calculation. In an actual CCIM, however, an electromagnetic field is induced by the current flowing through the coil and the temperature of molten glass increases. To solve the disagreement, the initial temperature was set as actual internal temperature of CCIM, which is 1150°C. Fig. 3 shows the initial temperature distribution used in this study. The physical properties and boundary conditions used in this study are shown in Table 1 and Table 2.

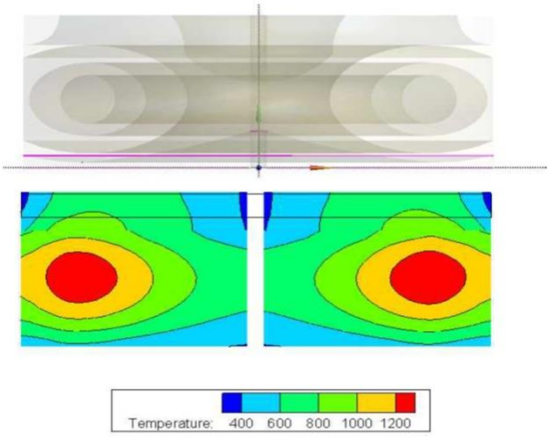

Fig. 3. Initial temperature distribution (y-section).

Table 1. Physical properties of the air and glass

	Density (kg/㎥)	Cp (j/kg·K)	Thermal Conductivity (W/m·K)	Viscosity (kg/m·s)	Molecular Weight (kg/kgmol)
Air	1.225	1006.23	0.0242	1.7894e-5	28.966
Glass	2350	1290	3	4.278	69.62

Table 2. Boundary conditions for interfaces

	Interface	Bottom Wall	Side Wall Air	Side Wall Glass
Heat Transfer Coefficient	80 $W/m^2 \cdot K$	300 $W/ m^2 \cdot K$	80 $W/ m^2 \cdot K$	30 $W/ m^2 \cdot K$
Free Steam Temperature	30℃	24℃	30℃	30℃

Fig. 4 shows the dimensions and boundary conditions of the CCIM.

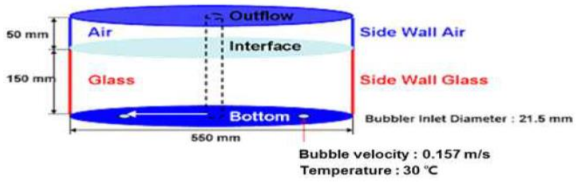

Fig. 4. Dimensions and boundary conditions of CCIM.

2.4 Analysis results

Fig. 5 shows the temperature distribution in the CCIM with respect to the time.

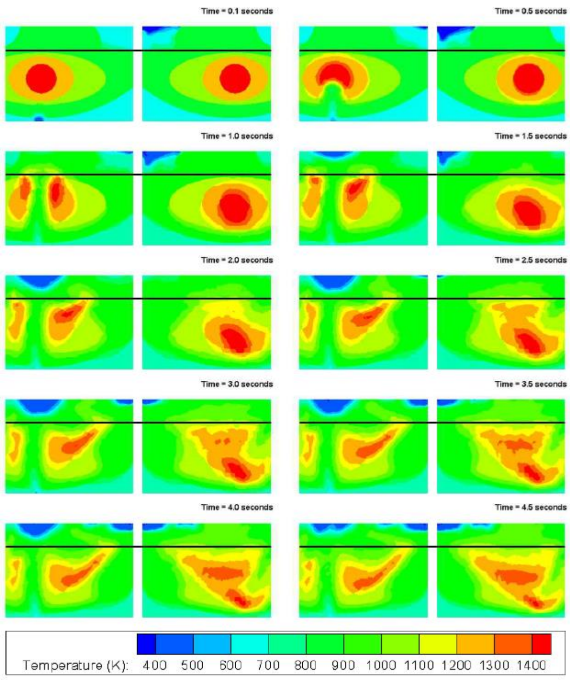

Fig. 5. Temperature distribution of central section.

3. Conclusion

The simulation model for CCIM is constructed with ~ 3 million unstructured grids. The temperature gradient, valuable information for the evaluation of stable operation of CCIM, was successfully simulated by performing the heat transfer and fluid dynamics analysis of CCIM.

REFERENCES

[1] G. Sugilal, "Experimental study of natural convection in a glass pool inside a cold crucible induction melter", International Journal of Thermal Sciences, 47(2008) pp. 918-925.