Effects of Phase Change on Beryllium Melt Stability, Motion, and Splashing in Fusion Devices

Cheng Zhang, Gennady Miloshevsky

Virginia Commonwealth University, Richmond, VA, USA

Beryllium (Be) will be used as a first wall material in ITER due to its high thermal conductivity, low density, and high strength. However, a critical problem using Be tiles is melting under intense thermal loads, melt layer formation, macroscopic melt motion, and splashing with ejection of melt droplets into a plasma. This phenomenon has been a great concern for ITER and future fusion devices. Be droplets which ejected from the melt surface can drastically affect the performance and stability of fusion plasma. The melting of Be was observed on the upper dump plate tiles in JET reactor.\(^1\) The pressure, mass density, velocity of Be vapor, and variations of temperature at the melt layer interface can influence the splashing of Be melt. Therefore, it is important to understand the physics mechanisms governing the Be melt motion and splashing under the relevant ITER conditions.

The CFD model was developed to treat the coupled flow of liquid metal and its vapor.\(^2,3\) The model is implemented within the OpenFOAM toolbox, a free open source CFD software package. This model is capable to predict the hydrodynamic effects of vapor on melt layer motion, splashing, non-linear growth of melt waves, and ejection of molten droplets. The modeling accounts for the effects of thermal, viscous, gravitational, and surface tension forces at the vapor-melt interface. In this study, we investigate the effects of Be phase change (rate of Be melt-vapor transformation) on the topology of the melt surface, development and growth of waves, melt motion, splashing, and droplet ejection. The key part of the developed model is accounting for temperature effects and phase changes due to melt evaporation. The evaporation model was validated against the Stefan problems. The influence of heat and mass transfer across the vapor-melt interface on melt layer stability is also investigated. The results provide an understanding of how the rate of phase change affects the development of melt structures and waves at the vapor-melt interface. These results may facilitate interpretation of JET experiments\(^1\) and provide insights into the melt layer phenomenon of interest to ITER.

\(^1\) I. Jepu et al Nucl. Fusion 59 (2019) 086009
\(^2\) G. Miloshevsky et al Nucl. Fusion 54 (2014) 033008
\(^3\) G. Miloshevsky et al Nucl. Fusion 54 (2014) 043016

*Work supported by the U.S. Nuclear Regulatory Commission under Grant No. 31310018M0047