Simulation of Liquid First Wall Thermodynamics for Fast Ignition Reactors

＊Romero Rodrigo [1], Shigemori Keisuke [1], Iwamoto Akifumi[1], Tomoyuki Johzaki [2] and Yamanoi Kohei [1]

[1]Osaka University, [2]Hiroshima University

Abstract

The first wall in a fusion reactor provides structural support for the chamber. In the fast fusion KOYO-F design, a liquid metal cascade shields the wall from radiation and debris. This research investigates the thermal behavior of the cascade system during reactor operation using particle transport and CFD simulations.

Keywords: nuclear fusion, liquid metal, liquid wall, radiation damage, CFD, fast ignition, radiation shielding.

1. Introduction

In a fast ignition reactor, non-uniform radiation can damage the first wall, which supports the fusion reactor's structure, including lasers and detectors. In the KOYO-F design, a liquid LiPb cascade protects the wall from debris, alpha particles, and neutrons. While this system has been simulated, non-uniform radiation and thermodynamics remain unexplored. This research aims to study the thermodynamics of the KOYO-F liquid wall through simulation and propose design improvements, such as targeted cooling, based on the findings.

2. Simulation workflow

The following workflow is proposed to simulate the cascade system: A mesh of the cascade system geometry is created using Ansys [3] SpaceClaim. Then, the mesh is sent to PHITS [4] where a point alpha and neutron source is simulated to obtain the energy deposition. Finally, the energy deposit is imported to Ansys Fluent where CFD analysis of the liquid metal is done. As proof of concept, the workflow was tested with the spherical geometry presented in [5] and the radiation emitted is uniform.

Figure 1. Energy deposition contour.

3. Results

Energy deposited was 12 MW, close to the expected value. The open flow absorbed approx. 70% of the total energy. The lead reached extremely high temperature on the fusion facing side. This could be alleviated with the convection provided by mixing the surface and open flows, like in the original geometry.

4. Conclusion

The PHITS-Ansys workflow results are sensible, but there is room for improvement. Simplified geometry prevents accurate understanding of the cascade system. As future work, simulations of the full geometry of the liquid metal cascade system and non-uniform radiation source will be done.
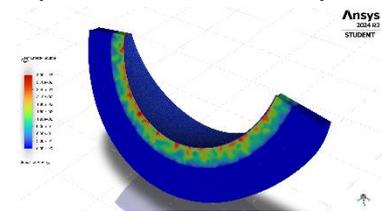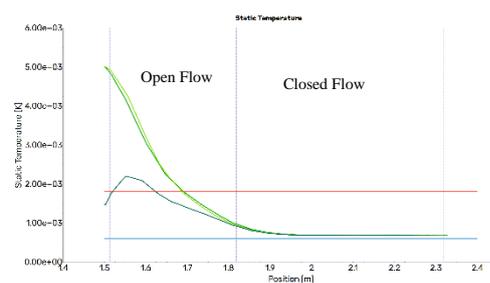

Figure 2. Temperature profile across the liquid wall at different sections.

References

[1] T. Norimatsu et al., J. Phys. IV France, vol. 133, pp. 841–843, Jun. 2006.

[2] Tomoaki Kunugi et al., Fusion Engineering and Design, vol. 83, no. 10, pp. 1888–1892, Dec. 2008.

[3] *Ansys® Student, Release 2024 R2*

[4] T. Sato et al., Journal of Nuclear Science and Technology, vol. 61, no. 1, pp. 127–135, Jan. 2024.

[5] T. Norimatsu et al., Nuclear Fusion, vol. 57, no. 11, p. 116040, Aug. 2017.