THERMAL HYDRAULIC ANALYSES ON STABILITY AND SAFETY OF HIGH-SPEED FREE-SURFACE LITHIUM FLOW FOR IFMIF TARGET DESIGN

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The International Fusion Materials Irradiation Facility (IFMIF) is an accelerator-based intense neutron source for testing fusion materials. To remove maximum total heat of about 10 MW deposited by 40 MeV- deuteron (D) beams with a current of 250 mA, the liquid lithium (Li) target with high speed up to 20 m/s has been employed. The high-speed avoids Li boiling and significant Li vaporization at a free-surface of the flow, and a centrifugal force generated in the Li flow along a concave flow channel enough increases boiling point of the liquid Li. In the Engineering Validation and Engineering Design Activities (EVEDA) started in 2007, construction and operation of EVEDA Lithium Test Loop simulating IFMIF Li target system in hydraulic condition (excepting target width about 1/3 of the IFMIF target) and impurity condition (nitrogen, hydrogen, oxygen and others contents in Li) have been conducted to validate a stable safety operation of the Li loop with a high-speed flow for a long time. In the EVEDA, also engineering design of IFMIF target system is done.

The targets have thin back plates with minimum local thickness of 1.8 mm as parts of the concave flow channel. Maximum thermal deformation of a back plate without any countermeasure was predicted 2.6 mm in a former thermal structural analysis [1]. This paper deals with two-dimensional (2D) and three dimensional (3D) hydraulic and thermal-hydraulic analyses performed for designs of the EVEDA and the IFMIF targets. Effects of thermal deformation of the back plates upon hydraulic and thermal hydraulic stabilities of the Li flow, which should be smooth one along a concave channel with maintaining inner pressure to avoid boiling, were clarified. Deformation of the back plate up to 0.3 mm was acceptable, while the maximum deformation of 2.6 mm caused a significant pressure reduction below a limit to avoid Li boiling. Also effects of displacement of a back plate and gap between a back plate and a target assembly in case of a replaceable back plate were clarified. The results are to be used to determine acceptable tolerances in design and acceptable variations in safety operations.

This paper deals with also a 3D hydraulic analysis simulating a back plate rupture as safety consideration for the IFMIF target system. Flow velocity and flow rate of liquid Li scattering from a rupture hole to outer side of a back plate under vacuum condition were estimated. For also another case of a pressurized condition, deviation of Li flow due to air coming through a hole was estimated. This paper deals with also a thermal hydraulic analysis of Li flows injected into a quench tank, which is downstream of the target flow, for design of compact tank maintaining Li flow with uniform temperature and low flow velocity.

[1] K. Watanabe, M. Ida, H. Kondo, M. Miyashita and H. Nakamura, “Thermo-structural analysis of target assembly and back plate in the IFMIF/EVEDA Lithium Test Loop”, to be published in Journal of Nuclear Materials.