§33. Investigation of Cascade-typed Falling Liquid Film Flow along First Wall of Laser-Fusion Reactor

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To protect from high energy/particle fluxes caused by nuclear fusion reaction such as extremely high heat flux, X rays, alpha particles and fuel debris to a First-wall of an inertia fusion reactor, a "cascade-typed" falling liquid-film flow is proposed as the “liquid wall” concept which is one of the reactor chamber cooling and wall protection schemes: the reactor chamber can protect by using a liquid metal film flow (such as $Li_{17}Pb_{83}$) over the wall as shown in Fig. 1. This cascade-type First-wall for one step (30 cm height corresponding to 4 Hz laser duration) consists of a liquid tank having a free-surface for keeping the constant water-head located at the backside of the first wall, and connects to a slit which is composed of two plates: one plate is the first wall, and the other is maintaining the liquid level. In order to investigate the feasibility of this concept, the numerical analyses by using the commercial code (STREAM: unsteady three-dimensional general purpose thermofluid code) are performed, and the flow visualization experiments is also conducted.

In the numerical analyses, the water is used as the working liquid and an acrylic plate as the wall. These selections are based on two reasons:

(1) From the non-dimensional analysis approach, the Weber number ($We=\rho u^2\delta/\sigma$: ρ is density, u is velocity, δ is film thickness, σ is surface tension coefficient) should be the same between the design ($Li_{17}Pb_{83}$ flow) and the model experiment (water flow) because of the free-surface instability. The similarity law is as follows:

$$\frac{We_{water}}{We_{LiPb}} = \frac{\sigma_{LiPb}}{\sigma_{Water}}\frac{\rho_{Water}}{\rho_{LiPb}}\left(\frac{u_{Water}}{u_{LiPb}}\right)^2 = 1 \quad \therefore \frac{u_{Water}}{u_{LiPb}} = 1.21 \qquad (1)$$

The critical water velocity is 1.21 times of LiPb one. This is very convenient to conduct the experiment.

(2) The SiC/SiC composite would be used as the wall material, so that the wall may have the less wettability: the acrylic plate has the similar feature.

Figure 2 shows the comparison of the shape of the flow around the slit exit between the numerical and the experimental results in case of the critical flow condition (i.e., 0.80×10^{-2} m^3/min). The results are in fairy agreement. The liquid-film thickness near the slit exit is around 5 mm and is almost the same value obtained by both the numerical simulation and the experiment. According to these results, it can be said that the numerical simulation to predict the liquid-wall behavior is quantitatively validated by the flow visualization experiment and the fluid dynamic feasibility of the liquid-wall concept is also confirmed. However, in order to validate the applicability of the liquid-wall concept to the real reactor, it is necessary to perform the thermal-mixing and the heat transfer experiments of coolant flows in the near future.

The numerical simulation and the POP experiments regarding the cascade-type liquid-wall concept for the laser-fusion reactor based on the consideration of the similarity law are conducted. It is found that the stable liquid-film flow with sufficient thickness is naturally formed, i.e., the liquid-wall is stably established on the First-wall. Therefore, it seems that this liquid-wall concept might be applied to the actual reactor from the fluid dynamic point of view.

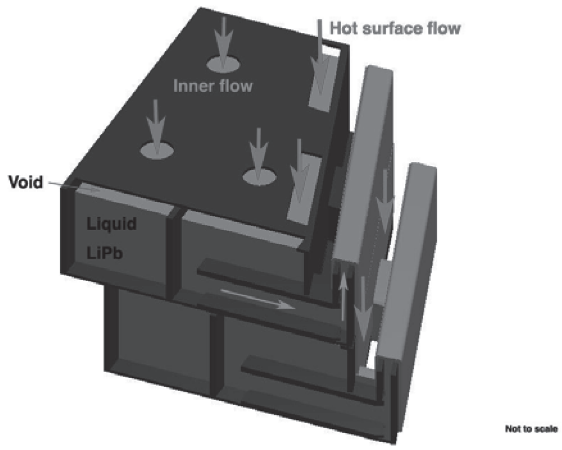

Fig. 1 Cascade-type liquid First-wall concept

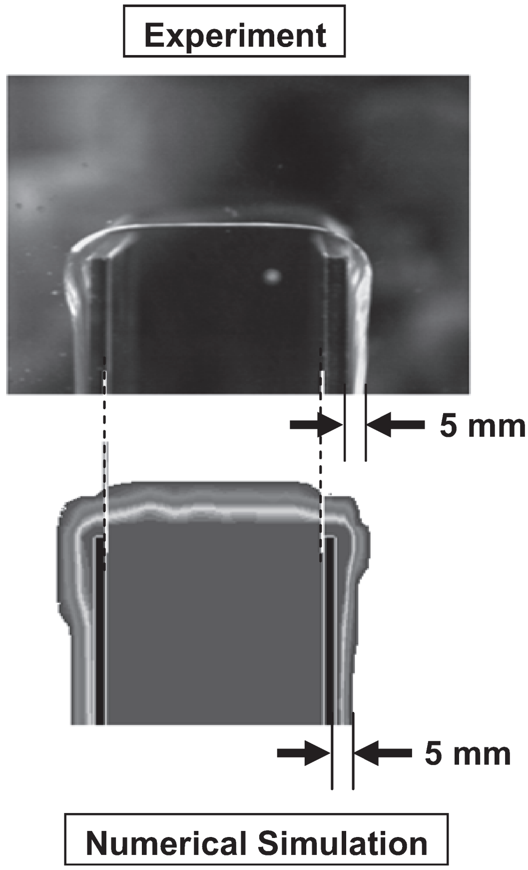

Fig. 2 Comparison between numerical simulation and flow visualization experiment