§31. 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. In order to investigate the feasibility of this concept, we conducted the numerical analyses by using the commercial code (STREAM: unsteady three-dimensional general purpose thermofluid code) and also conducted the flow visualization experiments. The numerical results suggested that the cascade structure design should be improved, so that we redesigned the cascade-typed first wall and performed the flow visualization as a POP (proof-of-principle) experiment as shown in Fig. 2.

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, (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.

The redesigned cascade-typed 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. This design solved the trouble of the previous design. The test section for the flow visualization has the same structure and the same height as the reactor design. The test section consists of three steps of the cascade-typed first wall, and the water is supplied to the tanks on the top and middle steps of the test section and then it makes liquid film flow on the first wall. When the water flow rate becomes over the Weber number coincident with the reactor design, the liquid film is stably flowing on the first wall for each step as shown in Fig. 3.

On the other hand, when the liquid flow rate decreases less than the above Weber number condition, the liquid film flow divides into two or more streams due to the wettability of the wall. However, since we can control the liquid flow rate, the thickness of the liquid film can be controlled, too. This suggests that it can control the liquid film flow velocity under the reactor condition.

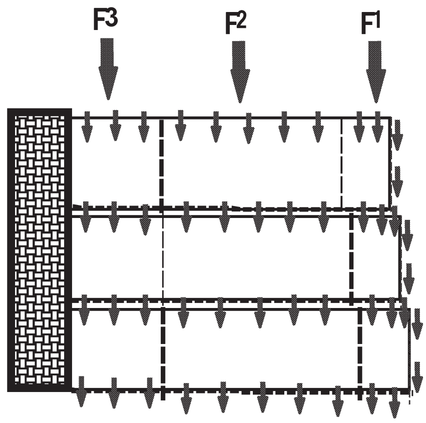

Fig. 1 Original design of Cascade-typed liquid first wall concept (F^1, F^2 and F^3 are the in-flow from the upper section

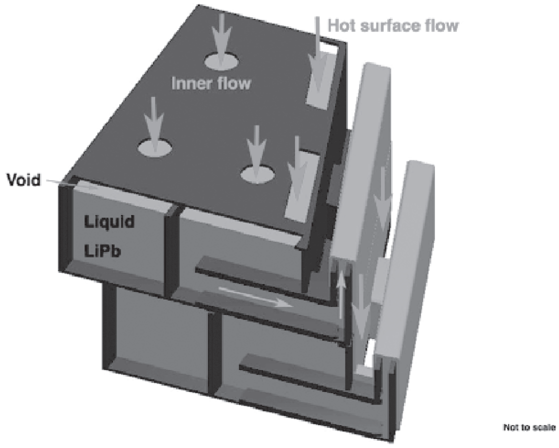

Fig. 2 Improved Cascade-typed liquid first wall concept

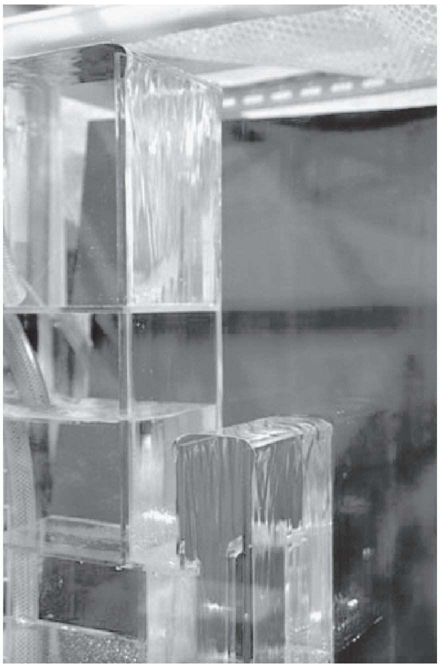

Fig. 3 Flow visualization by using water as a coolant and you can see the stable water falling film flow on the vertical wall of the test section