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

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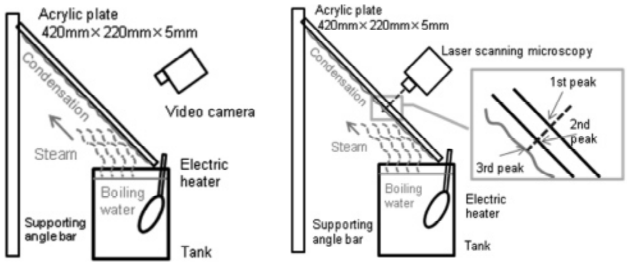
To protect from high energy/ particle fluxes caused by nuclear fusion reaction to a first wall of a laser-fusion reactor such as “KOYO” reactor, the “cascade-type” falling liquid-metal film flow was proposed as a “liquid wall” concept which was one of the reactor chamber cooling and wall protection schemes [1]. In the previous study, the authors concluded that the cascade type falling liquid film on the flat plate was able to be realized based on the flow visualization experiment and the numerical calculation by using the commercial code (STREAM: unsteady three-dimensional general purpose thermofluid code) [2]. The liquid wall on the saw-shaped corner was also investigated [3].

In this study, the proof-of-principal experiments and the numerical simulations were conducted in order to investigate on the stable formation of the condensed liquid-metal film flow formed on the ceiling of the reactor chamber. The liquid-metal vapor produced by laser-pulse irradiation will be condensed on the relatively cold ceiling of the reactor chamber. The condensed liquid-metal vapor makes many droplets on the ceiling, and then the droplets will agglomerate, and eventually make the liquid film on the ceiling surface. This liquid-metal film will flow from the ceiling to the liquid first-wall.



(a) (b)

Fig. 1 Experimental apparatus for the vapor condensation

Figure 1 shows the experimental apparatus for the condensation experiments. In the actual design, the working fluid is a liquid lead-lithium (PbLi), and the material of the ceiling wall is a ferrite steel. In this study, water is used as the working fluid and the material of the plate is made of an acrylic resin. We assumed that a fundamental process of the liquid-metal condensation might be similar to that of the water condensation. These proof-of-principal experiments were also focused on the effect of the wettability of the wall surface. The vapor released by the boiling water flows up along the plate and then it is condensed on the surface of the inclined plate. The behavior of vapor was visualized with a video camera as shown in Fig.1(a). The liquid-film thickness formed on the inclined wall surface was also measured with the confocal laser scanning microscopy up to 1000 Hz within a micro-meter accuracy (Fig.1(b)). The actual thickness of the liquid-film formed on the wall was about 100 m.

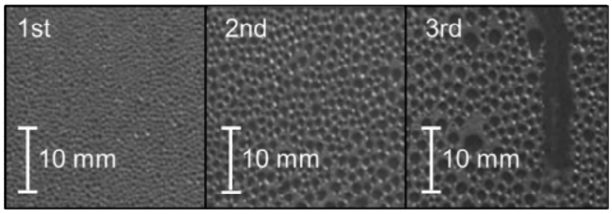


Fig. 2 Experimental results for large contact angle

Fig. 3 Experimental results for small contact angle

Figure 2 and 3 show the experimental results under the condition that the contact angle is large (means a bad wettability) and small (a good wettability). For a bad wettability case, many small droplets were formed on the wall surface and they flowed down along the wall surface after they grow and coalesce with the surrounding droplets. For a good wettability case, the wall surface was covered with the thin liquid film, and the liquid film flowed along the wall surface. In this case, the liquid never fell away from the wall surface as long as the water vapor was supplied during the condensation process.

Figure 4 shows comparison of results of the multiphase thermo-fluid simulations using by STREAM and experimental results for the same condition.

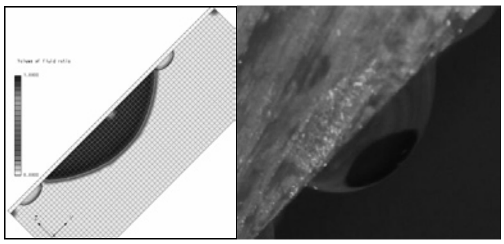


Fig. 4 Comparison of Numerical and experimental results

In this study, the experiments of water as the working fluid and the numerical simulations were conducted to investigate the behavior of the droplets and liquid film on the ceiling wall regarding the wettability effects of the wall surface. In the future works, the experiments by using liquid metal (PbLi) should be conducted, and then its results will be compared with the results of the present study.

1) Kozaki, Y., et al.: Proc. 7th Int. Conf. on Emerging Nuclear Energy Systems (1993) 76
2) Kunugi, T. et al.: Fus. Eng. & Design **83** (2008) 1888
3) Kawara, Z. et al.: Fus. Eng. & Design **85** (2010) 2181