§25. Experimental Study on Liquid Lithium Flow for IFMIF Target

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This paper reports experimental and numerical studies on a high-speed, free-surface flow of liquid lithium (Li) simulated an IFMIF target. Thickness distribution of the flow was measured by an electro-contact probe which was developed for measuring the flow thickness and waves on the flow surface. Numerical simulations were conducted and compared with the experimental results.

In the current design of the IFMIF, liquid metal Li is employed as the target and is formed as a flat plane jet of 25 mm in depth and 260 mm in width, and flows at the high speed of 15 m/s. Research and validation of flow stability of the lithium flow is one of the key issues on development of IFMIF.

The Experiment was carried out at a Li circulation facility in Osaka University. Schematic of the test section is shown in Fig.1. The test section has a 1/2.5 scaled nozzle designed for IFMIF and straight flow channel, and creates Li free-surface flow up to 15 m/s. The free-surface flow was photographed by a CCD camera. The typical result is shown in Fig.2. This is consists of two pictures, which were taken from the two viewing ports shown in Fig.1 (left). The flow directs from right to left in the figure and the edge of the nozzle falls on x=0 line. The side walls of flow channel are set at y=0 and 70 respectively. As shown in the figure, many wave patterns are observed on the surface. Those are mostly parallel to the flow direction in the second picture. Dominating wave patterns are observed to be generated from the corners of the nozzle and side walls, i.e. (x,y) = (0,0) and (0,70). It was indicated that the thickness of flow was strongly affected by the wave patterns.

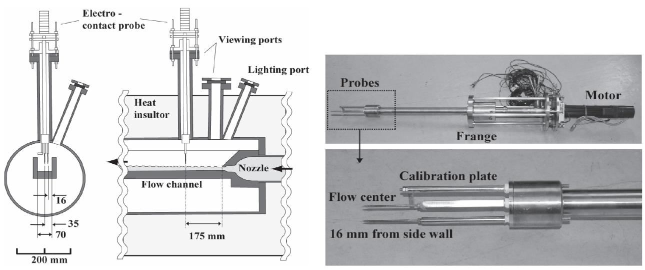

Fig.1. Test section (left) and electro-contact probe (right).

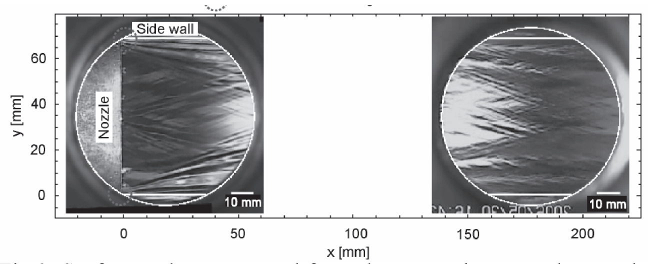

Fig.2. Surface wakes generated from the corner between the nozzle and the side wall.

The thickness distribution caused by the wave patterns was measured by the electro-contact probe as shown in Fig.1.(right). The method of the measurement is described in detail[1]. Analytical study was also conducted by quoting the study on wave pattern made behind an object moving water (or fluid) surface such as ship's wake[2]. Further numerical calculation by a fluid dynamics code was attempted. Figure3 shows one of results of the analytical study and numerical calculation. In the figure, the position of crest of the wave patterns in varying velocity and contact angle are shown in both numerical calculation (denote by plots) and analytical results (denoted by thin dashed line). These agreed very well over wide velocity region and different contact angle between fluid (Li in this case) and the side wall.

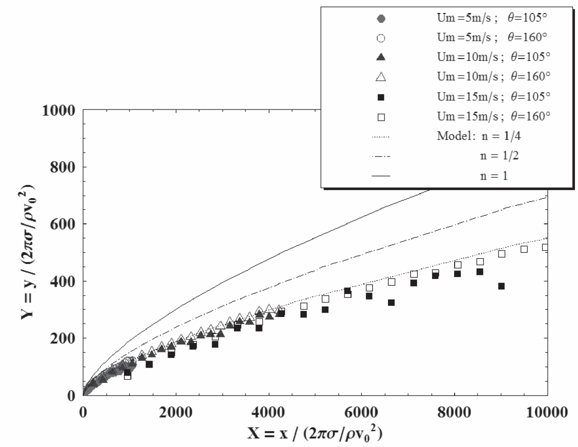

Fig.3. Calculation results of the position of crest of the surface wakes in varying velocity and contact angle.

Finally, the experimental measurement, the analytical and numerical results were compared in dimensionless form as shown in Fig.4, where σ, ρ and v_0 in the axes are surface tension, density and Li mean velocity respectively. These comparison showed good agreement between them and clarified effects of the waves on the flow. As a conclusion of the study, it was shown that the waves generated at the nozzle corner had an insignificant effect on the beam irradiation region of the current IFMIF design.

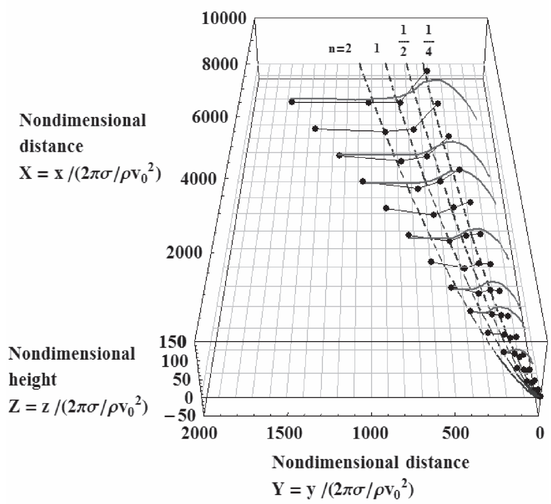

Fig.4. Comparison between experimental measurement, analytical and numerical calculation result.
(Black dots, blue dashed line and red bold line denote measurement, analytical and numerical results respectively. The numerical result is shown in the case which contact angle is 140 degree.)

[1]T. Kanemura, H. Kondo, T. Muroga, H. Horiike, et al. "Investigation of free-surface fluctuations of liquid lithium flow for IFMIF lithium target by using an electro-contact probe", To be published in Fus. Eng.
[2] H.Lamb, Hydrodynamics, article 256 and 272, sixth ed, Cambridge University Press