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

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1. Introduction

To develop high flax 14MeV neutron source for study on fusion reactor materials, IFMIF (International Fusion Materials Irradiation Facility) has been designed under international collaboration. In present design of IFMIF, liquid metal lithium is employed to be D^+ beam target, and neutrons are generated by D^+- Li nuclear stripping reaction. The lithium flows down along a concave back wall at a velocity of approximately 15 m/s. This flow is irradiated by deuteron beams of 40 MeV, whose center is located 175 mm downstream from the nozzle

To predict variation of neutron flax in time and space, it is necessary to have knowledge of lithium target flow behavior, especially, generation and growth of surface perturbations and thickness variation.

2. Experimental facility

The present experiment was carried out with the lithium loop at Osaka University. A test section of free surface flow is mainly consisted of a two staged nozzle and a 70mm wide straight flow channel. The nozzle geometry is almost the same as the JAERI design. By the nozzle, rectangular flow of 10 mm height and 70 mm width is formed. Flow velocity can be up to 15m/s under pressure, and 5 m/s under vacuum.

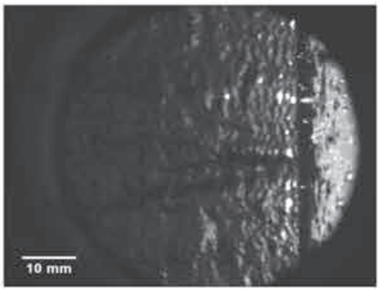
3. Results and Summary

Figure 1 show pictures of lithium free surface taken by a CCD camera with a strobe which half width of emission is approximately 20 micro seconds. Flow directions are right to left in the pictures.In the pictures, longitudinal disturbances with slightly angle to flow direction, that is called surface wake, were observed.

The surface wake is generated at corners between the nozzle and side walls of the flow channel, and at the nozzle edge probably because chemical compounds attached at the edge. The wake shape was compared with analytical study of Lamb[1], and showed good agreement. By the analysis, wakes from the corners have less affect to beam irradiation region.

On the flow surface, small waves that wavelength is around 1 mm were also observed. The waves were not observed in the velocity region of less than 3m/s, and have periodicity to flow direction in the velocity region of around 5 to 9 m/s. the periodic waves was compared with a liner stability theory on a free surface shear layer underneath of free surface around the nozzle edge[2]. The results show good agreement. In the velocity region of more than 10m/s, waves have no periodicity and were consider being turbulent flow.

Surface height variation was measured by a contact probe. When the probe contacts with the lithium flow surface, an electrical circuit between the probe, lithium flow and the flow channel is closed. And the contact with the flow surface can be detected. Figure 2 shows results of the measurements. The measurement position was at the center of the beam region that is 175 mm downstream from the nozzle. The figure shows average thickness of the flow by the plots, and thickness variation by the bars against mean flow velocity. The average thickness increases as the velocity increase in the velocity region of 2 to 8m/s. And the thickness decreases to the initial thickness of 10mm in the velocity region of more than 8 m/s. The thickness variation is probably caused by surface wakes. The amplitude of the height variation increases monotonically, and it is approximately 2 mm at the velocity of 15 m/s. The variation is considered to be caused by the surface waves and wakes from the edge. In present experiment, the nozzle edge is fouled by the chemical compounds, and that compounds seem to increase the surface variation as surface wake. Further experiment with cleaner nozzle is planned to be conducted and the results will be reported soon.



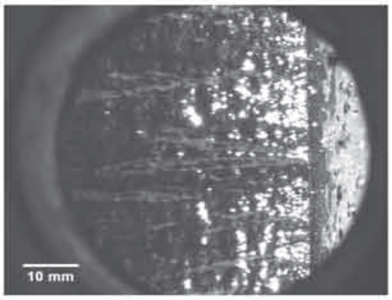


Fig.1. Pictures of lithium flow surface
Upper : Mean velocity is 7 m/s
Bottom : 13 m/s

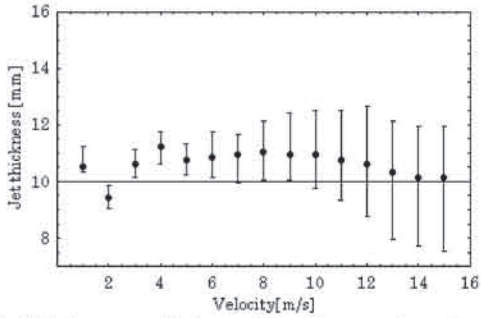


Fig.2. Thickness variation of the flow against the mean velocity at the beam center

Reference

[1] H.Lamb, Hydrodynamics, article 256 and 272, sixth ed 1932, Cambridge University Press
[2] K. ITOH, H. NAKAMURA and Y. KUKITA, "Free-surface Shear Layer Instabilities on a High-speed Liquid Jet" Fusion Technol., Vol.37, pp.74-88, (2000)