§17. Ultrasonic Measurement of Velocity Profile of Lead-Lithium Duct Flow

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A liquid metal is expected to be in use as a coolant since it has a low value of Prandtl number. For an example, a nuclear fusion reactor is expected to employ a liquid metal as a coolant. One of liquid metal candidates for the fusion reactor is lead-lithium eutectic alloy (PbLi).[1)] In a magnetic confinement fusion reactor, a plasma confining magnetic field exists even in a blanket region. Because of this, a liquid metal flow, such as PbLi flow, is reconstructed by the strong magnetic field, which is known as magnetohydrodynamic (MHD) flow. In order to design a fusion energy conversion system of the fusion reactor, we need to comprehend a complex fluid flow in a fusion reactor environment, where the lead-lithium flows under an influence of a magnetic field. It is because, when we evaluate heat and mass transfers in the blanket, a fluid flow field needs to be evaluated. Although, no flow velocity profile measurement techniques had been developed. Therefore, we employ ultrasonic Doppler velocimetry (UDV) in the present study.

In a previous study[2)], a swirl flow experiment was suitable for the first test. However, its flow field was 3-dimensional, and complicated. Because of this, the experiment configuration was not suitable for evaluating UDV measurement accuracy. A simple flow field serves for the measurement accuracy evaluation. A steady circular pipe flow is employed in the present study.

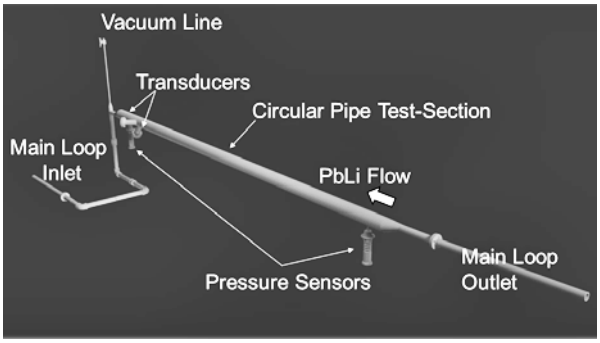

Fig. 1. Schematic drawing of test-section.

Figure 1 illustrates a schematic drawing of a test-section employed in the present study. The test-section is installed onto PbLi thermofluid loop at NIFS (Oroshhi-2). A main part of the test-section is a straight circular pipe, 1900 mm in length, 41.2 mm in the inner diameter, and made of SUS304. In downstream side of the main circular pipe, the transducers which are the identical model employed in the previous study. High-temperature pressure sensors are mounted on the test main pipe to measure PbLi gauge pressures. The distance between the upstream pressure sensor and the transducers is more than 40D, where D is the inner diameter of the main part. That is long enough compared to a flow fully-developed length. Because of this, the PbLi flow is expected to be fully-developed in the region where UDV detects flow velocities.

Figure 2 is a measurement result of a spontaneous velocity profile of the PbLi pipe flow when the flow rate is 16.2 L/min, which correspond to Reynolds number of 469. Therefore, the flow regime is laminar. The Hagen-Poiseulle flow is expected to be developed in the transducer region. The Hagen-Poiseulle flow velocity profile calculated from the flow rate is depicted as well in Figure 2 for the purpose of comparison.

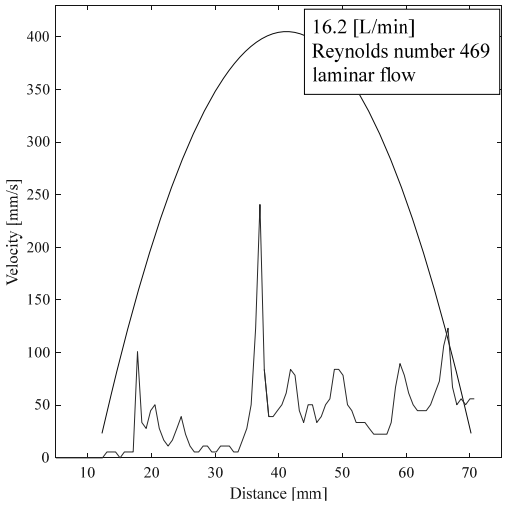

Fig. 2. Measurement result of spontaneous velocity profile of PbLi pipe flow, and expected laminar flow velocity profile.

The velocity profile measured with UDV under the above mentioned condition is underestimated with respect to the theoretical prediction. The other result obtained is that the flow velocity profile fluctuates in time, although the flow regime is laminar. We speculate that it is because an amount of flow tracer particles contained in PbLi is insufficient for a successful UDV measurement. Although in the previous measurement, an amount of the naturally-contained particles was sufficient[2)]. What makes this difference is speculated to be PbLi purity. The PbLi employed in the previous study was from Atlantic Metals & Alloy, that was alloyed in an atmospheric condition[3)]. However, the PbLi employed in Oroshhi-2 loop was alloyed in the Ar-gas glove box where an oxygen concentration was extremely low of less than 1 ppm, and also made from high-purity lead and lithium. Based on this process, the PbLi in the Oroshhi-2 loop is expected to have less amount of oxides particles than the commercial PbLi. In order to stabilize the measurement, seeding some artificial tracer particles suitable for PbLi is favorable.

1) Abdou, M. et al.: Fusion Eng. Des. **100** (2015) 2.
2) Ueki, Y. et al.: Fusion Sci.Technol. **60** (2011) 506.
3) Smolentsev, S. et al., Fusion Eng. Des. **88** (2013) 317.