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Measurement of Velocity Profiles in a scaled Transparent Test Blanket Module

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1. Introduction

A liquid breeder for the test blanket module (TBM) program in ITER using helium (He) as a coolant has been developed in Korea. The inlet pressure and temperature of He coolant passing through the first wall (FW) are assumed to be 8 MPa and 300 ^{o}C, respectively. To distribute the working fluid in each TBM mock-up channel, a manifold was designed and installed in front of the mock-up. The outlet condition of the coolant is depended on applied heat and coolant condition, distributed from the manifold. This means that the measurement of the coolant characteristics is needed to provide exact each channel condition for securing safety margin.

Korea has developed two kinds of TBM for ITER; a Helium cooled solid breeder (HCSB) TBM and a Helium cooled molten lithium (HCML) TBM, respectively. Under the HCML TBM project, a 1/6 scaled mock-up of the TBM FW has been fabricated in Korea Atomic Energy Research Institute (KAERI) [1-2]. The size of the scaled mock-up is 260 mm height and 444 mm width. As coolant channels in the mock-up, there are rectangular shape of 10 channels with 10 mm height and 20 mm width. The scaled mock-up was manufactured by hot isostatic pressing bonding method using SS316L. Three components of the scaled mock-up were prepared; a front part of cooling channel 10 mm height with 20 mm width, a front cover plate, and a back plate. The front plate and the cover were bonded by welding, and the welded part and the back plate are attached by HIP process.

A pair of manifolds, to distribute the coolant uniformly into 10 channels of the scaled mock-up, were designed and fabricated. The designed manifolds were then welded in inlet and outlet positions of the mock-up. To measure the flow distribution in each channel, the ultrasonic flowmeter (UFM) was used and the values were compared to a conventional flowmeter. Before the flow distribution test of the scaled mock-up, a calibration procedure was conducted with a single channel mock-up using the UFM and the flowmeter. The result showed a good agreement between the UFM and the flowmeter values in the single channel. The same test procedure conducted on the scaled mock-up; the velocity of each channel was measured by the UFM and total mass flow rate was measured with the flowmeter. The estimated velocities distributed from the manifold were simulated by ANSYS-CFX. However, there was a discrepancy between the measured and the simulated values [2]. The current manifold could not provide uniform flow rate to the each channel or there would be a measurement error using the UFM in the specified mock-up. This means that the UFM measurement method should be validated with other analysis tools, such as particle image velocimetry (PIV) system and differential pressure (DP) transmitters. Therefore, a scaled transparent TBM facility was manufactured to validate the application of the UFM, by comparing the PIV system.

2. Experimental Setup

2.1 Transparent TBM facility

To measure and visualize of the velocity field in the flow channel of the TBM, a transparent TBM facility was fabricated based on the scaled TBM mock-up developed in Korea [1-2]. The reference TBM used ferritic martensitic steel as the structural material for the TBM first wall with hot isostatic pressing bonding method. The reference mock-up had 260 mm height, 444 mm width, and 435 mm depth with reducing the number of flow channel from 60 to 10. To apply the PIV system and the UFM, transparent material of acrylic was used. A number of flow channel in the scaled transparent TBM mock-up are 10; each flow channel has 20 mm in width and 10 mm in height. The thickness of a front cover plate and a back plate is 6 mm and 15 mm, respectively. Each flow channel has two holes that are connected to differential pressure (DP) transmitter or manometer. The transparent TBM mock-up had 266 mm height, 450 mm width, and 438 mm depth. The design of the transparent manifold was based on the reference manifold. The transparent manifold consists of a coolant inlet, ten-channel outlet, and four plates to distribute the coolant into the outlet uniformly. Figure 1 shows the design of the transparent TBM; TBM mock-up, manifold, and TBM test facility.

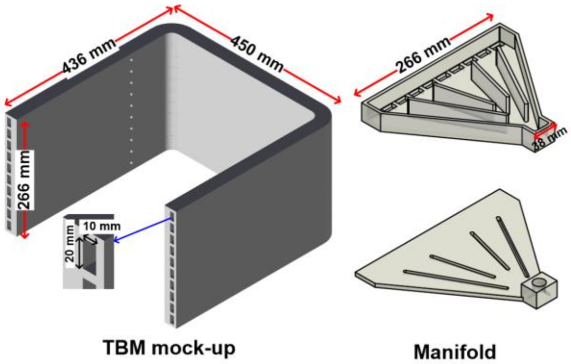


Fig. 1. Design of transparent TBM mock-up and manifold.

3. Results and Discussion

A preliminary experiment using a single transparent channel and the main experiment with the transparent TBM test facility were performed. The purpose of the preliminary experiment with the single transparent flow channel was to verify that the UFM could be used in the transparent material. The area of the single transparent channel had the same structure as the channel of the TBM mock-up. Turbine flowmeter (TFM), PIV, and UFM were used to get the averaged velocity patterns of the single channel. The inlet flow of the single transparent channel was controlled by the pump invertor and various flow conditions were considered. Figure 3 shows the experimental result using the transparent single channel. The flow speed was increased and decreased stepwise, as shown in Fig. 3(b). The result showed that the application of the UFM in the transparent flow channel is comparable with the TFM and the PIV results. Therefore, the main experiment with the transparent TBM test facility was conducted.

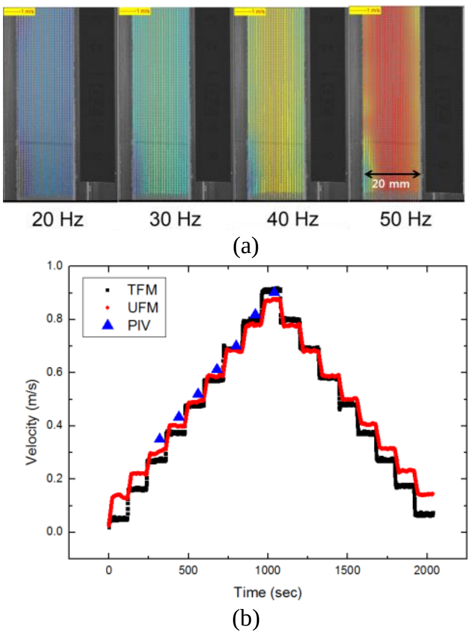
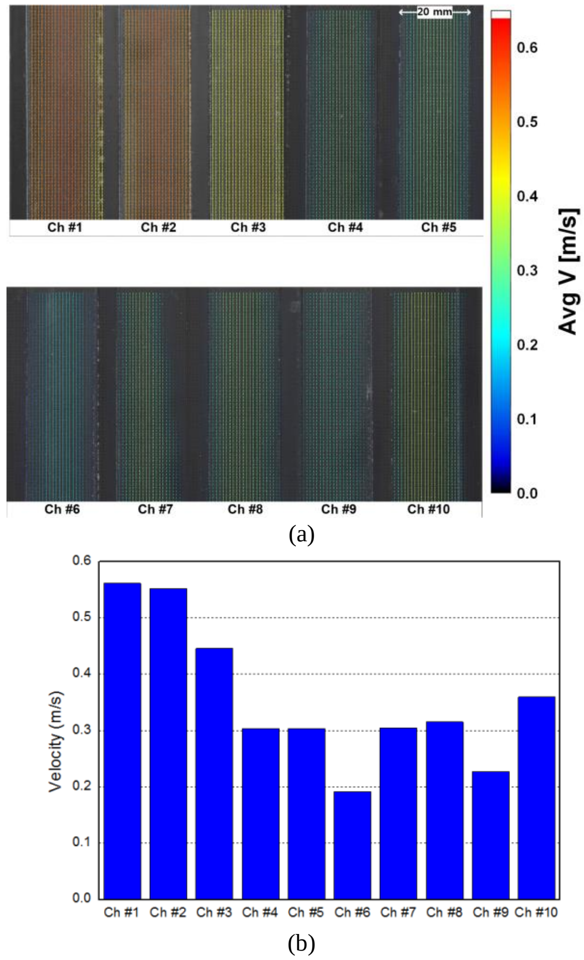
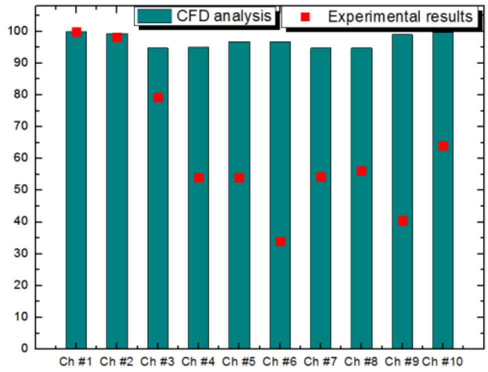


Fig. 3. Preliminary experiment with a single channel: (a) PIV results, (b) TFM, UFM, and PIV results

The measurement position of the TBM test facility was the upper part of the TBM mock-up, as shown in Fig. 2. The velocity profiles of the 10 channels were obtained using the PIV system. The average inlet flow rate was 30 LPM. As shown in Fig. 4(a), the average velocity field of each channel showed different flow pattern. In addition, Fig. 4(b) showed the obtained velocity at a certain position of each channel. The results indicated that the inlet flow was concentrated on the channel 1, 2, and 3. The maximum velocity was appeared at channel 1 having a value of 0.613 m/s. On the other hand, the previous CFD study related to the manifold showed that the distributed flow from the manifold was uniform, as shown in Fig. 4(c) [1]. The inlet flow injected into the manifold was not well equally distributed. In the present study, the flow path line to the manifold was curved, thus the non-uniform flow distribution of the flow was appeared.





(c)

Fig. 4. Preliminary experiment with the transparent TBM: (a) velocity field of each channel, (b) channel velocity at a certain position, (c) Comparison flow distribution between CFD analysis [1] and experimental results

4. Conclusions

A preliminary experiment using a single transparent channel and the experiment with a transparent TBM were conducted using the PIV system. The single channel result showed that the UFM system could be used in the transparent material with comparison of the PIV and TFM results. The experiment with the transparent TBM facility showed that the flow distribution was not equally spaced due to the curved flow path injecting into the manifold. Further study related to the transparent TBM facility will be conducted by changing the inlet flow line of the manifold. In addition, UFM and DP transmitter will be installed on the transparent TBM facility to provide the measurement methodology of the UFM.

REFERENCES

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