Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Measuring Velocity Profile in Scaled CANDU6 Moderator Tank using Particle Image Velocimetry

Han Seo [a], Hyoung Tae Kim [b], Jae Eun Cha [b], In Cheol Bang [a*]
[a]Ulsan National Institute of Science and Technology (UNIST)
100 Banyeon-ri, Eonyang-eup, Ulju-gun, Ulsan Metropolitan City 689-798, Republic of Korea
[b]Korea Atomic Energy Research Institute (KAERI)
Deokjin-dong, Yuseong-gu, Daejeon, 305-600, Republic of Korea
[*]Corresponding author: icbang@unist.ac.kr

1. Introduction

The Calandria vessel, which is called as CANDU6 moderator tank, is the actual reactor core including fuel channels and moderator in PHWR. The understanding of circulation patterns in Calandria vessel is important because the cooling capability is related to the moderator tank. Therefore, measuring velocity and temperature patterns in the Calandria vessel is the key factor for the safety of CANDU reactor. Various experimental and numerical efforts to predict and analyze the thermal-hydraulic characteristic of Calandria vessel have been made [1-2].

Yoon et al. [3] developed a CFD model for the CANDU6 moderator analyzing the velocity profile and the temperature distribution. Khartabil et al. [4] did an experiment to measure 3-dimensional velocity and temperature distribution in moderator circulation tests at a 1/4 scaled-down facility. Laser Doppler Anememetry (LDA) was used to detect the velocity profile and thermocouples detect the temperature distribution.

Previous study presented the velocity profile in a 1/40 scaled-down Calandria vessel and compared with CFD analysis [5]. In the present work, Particle Image Velocimetry (PIV) technique is used to obtain velocity profiles in a 1/8 scaled-down Calandria vessel.

2. Experimental Setup

2.1 Particle Image Velocimetry

A PIV technique was used for measuring velocity profile in a scaled-down Calandria vessel. Fig. 1 shows the PIV system installed for measuring velocity profile in the scaled-down Calandria vessel. Nd-YAG double-cavity laser beam comes from the vertical side of CCD camera. The light sheet is created in the vessel and CCD camera traces the particles that react with laser. After tracing particles with CCD camera, the velocity profile is analyzed by computer system. For this study, glass hollow spheres are used as particles.

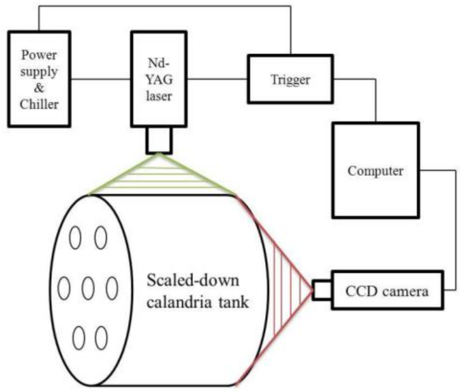


Fig. 1. PIV system with a scaled-down Calandria vessel

2.2 Preparation of a scaled-down CANDU6 moderator

The 1/8 scaled-down Calandria was designed with acrlylic to pass the laser sheet in the tank,

Fig. 2 shows the cross section of the scaled-down Calandria vessel. The scaled-down Calandria vessel was based on the CANDU6 moderator tank ant the scaled-down ration. The scaled-down ratio is 1/8 comparing with CANDU6 moderator tank. 380 acrylic pipes were installed in the tank to consider a matrix of Calandria tube/pressure tube including fuel elements in CANDU6 Calandria vessel. Two inlet nozzles are installed which have the same shape of actual Calandria vessel.

In actual Calandria vessel, 8 inlet nozzles are installed. 4 inlet nozzles are located in the same axis.

The experimental procedure is as follows. The water which contains the particle flows into the tank from two inlet nozzles with the same volumetric flow rate and comes out of the outlet pipe. The water which comes out from the outlet pipe goes into the inlet nozzles. The inlet mass flux is 531 kg/m^{2}s at each nozzle.

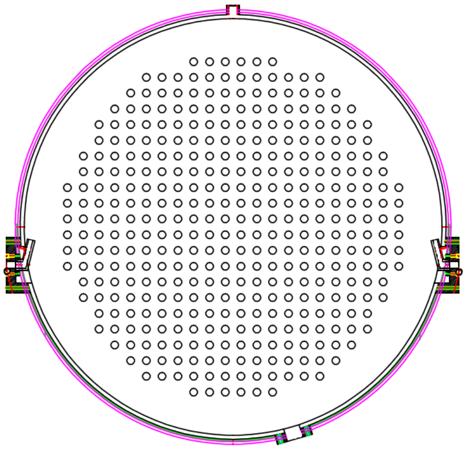
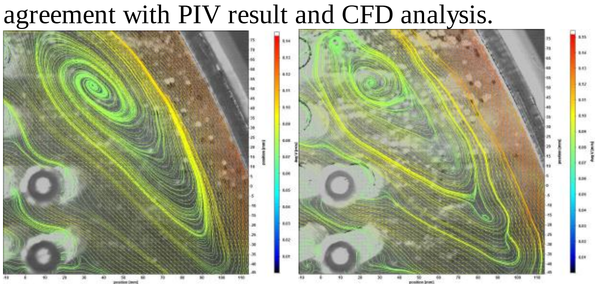


Fig. 2. Cross section of scaled-down Calandria vessel

3. Results and Discussion

The PIV experiments were carried out in different positions; left and right position of inlet nozzles. Full cross section of velocity profile was not obtained because acrylic pipe blocked to pass the laser sheet. The velocity vectors were obtained with the average velocity value of each position. 100 frames were analyzed for one result. Fig. 3 (a) shows the velocity profile distributed from the second position of the right inlet nozzle. Fig. 3 (b) indicates the velocity profile of the third position of right inlet nozzle. As shown in the Fig. 3, it is found that the velocity profile of each inlet nozzle position has not the same distribution profile due to the wall effect of the scaled-down Calandira vessel. Also, in the Fig. 3, there is vortex flow along the boundary where up-flow and down-flow meets.

To evaluate of the PIV result, CFD analysis is performed under the same condition of PIV experiment. About turbulence modeling in CFD analysis, we used k-epsilon model which has been implemented in most general industry standard model. The same trend of results can be obtained from CFD analysis result. Fig. 4 is the result of CFD analysis of whole cross section of the scaled-down Calandria vessel. It shows a good agreement with PIV result and CFD analysis.



(a) (b)

Fig. 3. The average velocity profile with (a) second position (b) third position of inlet nozzle (PIV)

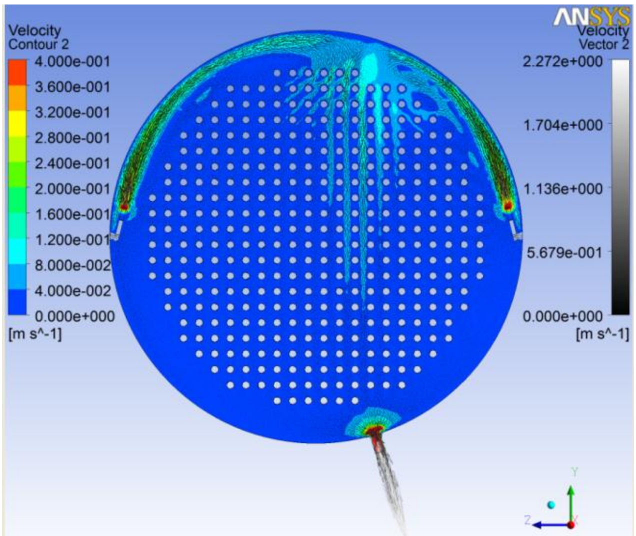


Fig. 4. The analysis of average velocity profile (CFD)

4. Conclusion

In the present work, PIV technique is used in the 1/8 scaled-down Calandria vessel to analyze the flow distribution..

The scaled-down of CANDU6 moderator tank is utilized to analyze velocity profile with PIV. In comparison with results using commercially-available CFD code, the PIV results are well matched.

For getting the PIV result of whole cross section of Calandria vessel, reflection mirror is needed to use to compensate the distortion of laser sheet due to the acrylic pipe.

The various experimental conditions such as flow velocity, temperature, and geometry (scale) will be more considered to get velocity profiles in the CANDU6 moderator circulation in terms of developing more accurate thermal-hydraulic models related to safety analysis.

REFERENCES

[1] M. Kim, S. Yu, H. Kim, Analysis on Fluid Flow and Heat Transfer Inside Calandria Vessel of CANDU-6 using CFD, Nuclear Engineering and Design, Vol.236, pp. 1155-1166, 2006.
[2] B.W. Rhee, C. Yoon, B. Min, CFD Simulation of the CANDU-6 Moderator Circulation, Under Normal Operating Conditions, ICONE10-22527, Apr.14-18, 2002.
[3] C. Yoon, J. H. Park, Development of a CFD Model for the CANDU-6 Moderator Analysis using a Coupled Solver, Annals of Nuclear Energy, Vol.35, pp. 1041-1049, 2008.
[4] F. KHARTABIL, B. DUFFEY, Velocity and Temperature Distribution Measurements Inside a Scaled Calandria in Support of CANDU X Passive Moderator Cooling System Design, GENE4/ANP, Sep. 15-19, 2003.
[5] H. Seo, H. T. Kim, and I. C. Bang, Comparison of Velocity Profile between Particle Image Velocimetry and CFD analysis in a Scaled-down Facility for CANDU6 Moderator Tank, KNS spring, May 17-18, 2012.