Assessment of Liquid Film Width Model by Two-dimensional Liquid Film Experiment

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1. Introduction

Located on upper downcomer direct vessel injection (DVI) lines which are connected about 2.1m above the cold-leg is one of new design features APR1400. Since the emergency core coolant (ECC) injected through the DVI nozzles falls down as a liquid film on the core barrel, experimental study of liquid film is necessary. In this study, liquid film experiment has been carried out with a 1/10 scaled down facility in order to assess the previous liquid film width model; Yoon's model.

2. Liquid Film Experiment

The experimental facility, as shown like Fig. 1., was used to measure the falling liquid film data. It consists of water storage tank, pump, and 1.4 m × 0.62 m parallel slab geometry test section. The injected water impinges on the wall of test section and made a liquid film flowing down on the flat plate wall. And the water returned to the storage tank via the drain line at the bottom of the test section. The spreading width of the liquid film was measured by an image analysis. A transparent grid ruler was attached on the wall for this measurement.

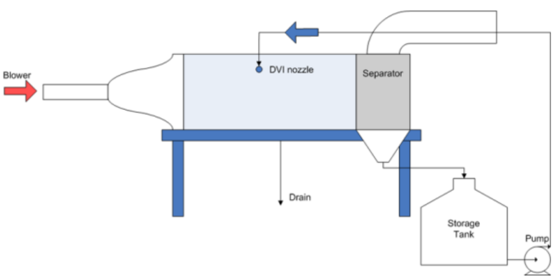


Fig. 1. Schematic view of liquid film experimental facility

Table I: Liquid Film Test Matrix

	Nozzle Diameter (m)	Inlet Velocity (m/s)
Test 1	0.022	0.5
Test 2		0.63
Test 3		0.79
Test 4		0.96

3. Liquid Film Model

Yoon et al. [1] proposed an analytical model that is able to predict the liquid film width on the flat wall.

3.1 Impingement phenomena

Yoon's model adopted Coleman and Richard's [2] suggestion, which said the boundary between the impingement region and the wall jet region for the impingement phenomena, was illustrated in Fig. 2. They showed that the radius of the impingement region is about 1.8 times that of the nozzle as Eq. (1).

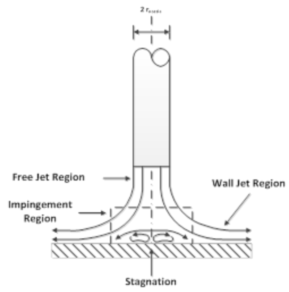


Fig. 2. Impingement phenomena

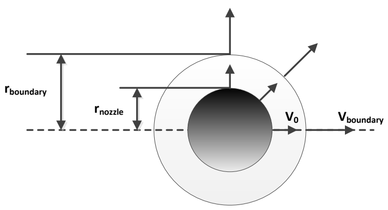


Fig. 3. Impingement region

$$r_{boundary} = 1.8 \times r_{nozzle} \tag{1}$$

And they assumed a concentric circle between nozzle and impingement boundary since the gravity effect can be ignored in the impingement region because the velocity of the impingement region is very high while the cross-sectional area of the flow is small. Thus the square of velocity is proportional to the potential logarithmic function, i.e.

$$V_{boundary} = \sqrt{\log r_{boundary} / \log r_{nozzle}} \tag{2}$$

4. Assessment Result

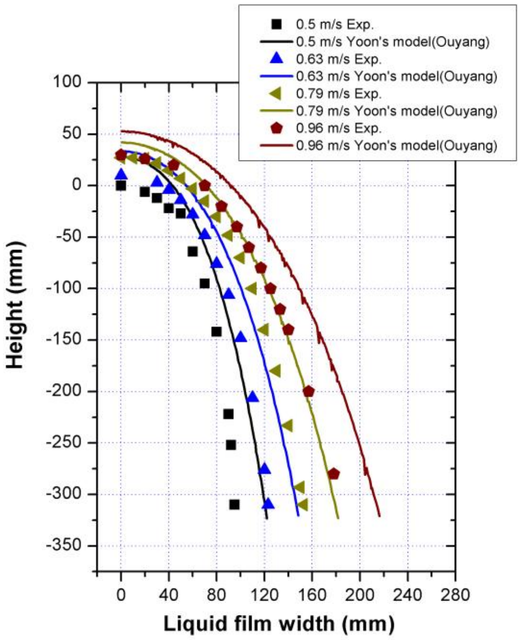
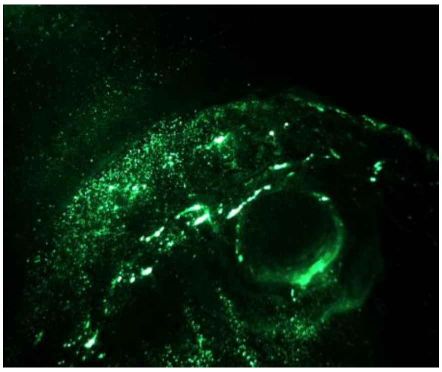
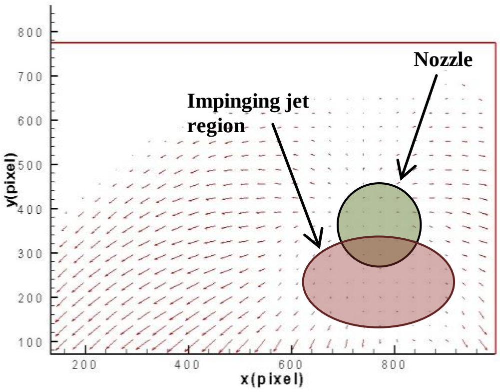


Fig. 4. Assessment result of Yoon's model (Ouyang's wall friction model) with experimental data.



(a) Original photography



(b) Local film velocity in impingement region after PIV post-processing

Fig. 5. Liquid film velocity measurement

Assessment results with varying inlet velocities, as shown at Fig.4., render two findings. One is that the degrees of liquid film width were predicted well, but the other is the initial locations were not appropriated.

For assessment of Yoon's model, Ouyang et al[3]'s wall friction model was used. Ouyang's model was developed by the experimental data available from the Stanford Multi-phase Flow Database (SMFD). It plays as an important role for prediction of degrees of liquid film width. Fig. 4. shows the Ouyang's wall friction model is proper to predict the degrees of liquid film width.

Contrastively, the concentric circle assumption of Yoon's model is dominant reason concerned with difference of initial location between experimental result and calculated one. Fig. 5. shows an original image taken in the present experiment and the local velocity profile of liquid film near the inlet nozzle. As shown in second figure which represents vector profile near the inlet nozzle, the impingement jet region was located lower than inlet nozzle. This means the concentric circle assumption of the Yoon's liquid film model is not proper to predict liquid film width.

5. Conclusion

In this study, the local liquid film experiment was conducted with a 1/10 scaled down facility to acquire liquid film data for assessment of the liquid film width model. Yoon's model with Ouyang's wall friction model predicts the degrees of liquid film width well, but it did not predict the initial locations properly.

Acknowledgments

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REFERENCES

[1] S.H. Yoon, Y.K. Park, K.Y. Suh, C.H. Song, M.K. Chung, S.J. Oh., "Direct Vessel Impingement Flow into Reactor Downcomer: Experiment and Analysis" , 16th International Conference on Structural Mechanics in Reactor Technology (SMiRT) Washington, DC USA (2001).

[2] Coleman, D. D. and Richard, S. S. "A study of Free Jet Impingement. Part 1. Mean Properties of Free and Impinging Jets," *J. Fluid Mechanics*, **volume 45**, pages 281-319 (1971).

[3] Liang-Biao Ouyang and Khalid Aziz, "Development of New Wall Friction Factor and Interracial Friction Factor Correlations for Gas-Liquid Stratified Flow in Walls and Pipelines", Western Regional Meeting SPE 35679, Anchorage, Alaska, Stanford University (1996).