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Validation Study of MATRA Code for PNL 7 by 7 Flow Blockage Test

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1. Introduction

Flow blockage problem is mainly concerned in both a safety analysis on loss of coolant accident (LOCA), loss of flow accident(LOFA) and a core thermal-hydraulic design on DNB estimation by an abnormal flow blockage. Concern on the hydraulic design on DNB estimation under abnormal operating condition is slightly different. The abnormal operating condition may occur at postulating an isolated flow blockage in the hot channel which may enhance or deteriorate critical heat flux(CHF) at the unblocked condition.

On the other hand, such a LOCA or LOFA condition, fuel rod overheating may occur. As clad temperatures increases during an accident, internal fuel rod pressure may cause clad swelling or ballooning which could lead to coolant blockage. Most of experiments on flow blockage is focused on the heat transfer and flow distribution under these accident condition.

The objective of this study is to evaluate the local flow distribution prediction of MATRA code on flow blockage condition as a prerequisite study to conduct the DNB estimation under an isolated flow blockage condition. The PNL 7x7 experiment[1] is selected as a validation data of subchannel code because this experiment provides the local flow distribution averaged on subchannel area.

Sequential validation works of MATRA code on PNL 7x7 experiments were performed by same author groups [2,3,4]. It is demarcated with previous work since full set of experiment data is validated using recent verified numerical algorithm in which severe blocked test, 90% flow blockage and hypothetical 99% blocked channel, can be calculated.

2. Methods and Results

2.1 PNL 7by7 Experiment

PNL 7x7 experiment was performed to provide information regarding turbulent flow structure resulting from disturbances by postulated sleeve blockage which is simulating deformed nuclear fuel rod under LOCA condition. The information was obtained with a LDA by measuring the local mean axial velocity and turbulent intensity at axial locations along the subchannels.

The results indicated that a recirculation zone existed for approximately five subchannel hydraulic diameters downstream from the blockage. The flow required approximately 50 subchannel hydraulic diameters to completely recover from the effects of the blockage. The results were found to be independent of Reynolds number. The flow rate by blockage was confined to those few subchannels containing blockages. Flow increases were detected in the subchannels adjacent to the blockage since flow was diverted around the blockage.

Blockage tests were conducted with the 70 percent and 90 percent blockages located midway between two spacers and 90 percent blockages located adjacent spacer. Subchannel area averaged velocity was derived with measured points of the local velocity in subchannel. Measurement uncertainty in local velocity and area averaged velocity was estimated with 11%[1]. Table 1 shows the test conditions used in validation of MATRA code. Detail experimental condition and geometry is described in reference [1].

Table I: Test condition

	70% blockage	90 % blockage
Inlet axial velocity (ft/sec)	5.7	2.7, 5.7, 10.7
Blockage location	Midway	Midway/ Adjacent spacer

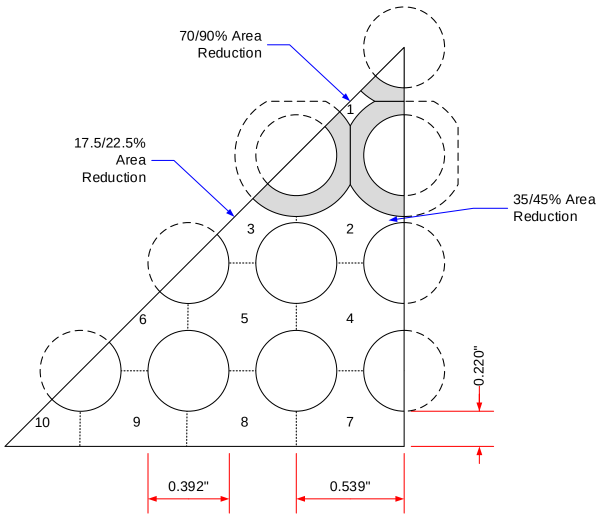

Fig. 1. Subchannel analysis model for 70% and 90% flow blockage condition

2.2 MATRA Model

Two different numerical schemes are applied to compare the experimental data. Seo[3] estimated the explicit scheme has a good ability to predict the low mass flow condition and recirculation condition. In addition, he suggested the optimized axial variation node and model coefficient to capture the experimental results[3].

Same subchannel model and axial node proposed by Seo[3,4] was used incorporating a 1/8 symmetry rod bundle as shown in Fig. 1. The blocked subchannel is located at channel 1 and adjacent channels with blockage are channel 2 and 3. The comparison with measurements was conducted based on subchannel averaged velocity with channel 1 to 6.

2.3 Results of 70 % Flow Blockage

Velocity data of 70 % flow blockage located midway between spacer 1 and 2 was compared with MATRA prediction as shown in Fig. 2. Subchannel 1 to 3 influenced by blockage shows the velocity jetting in the downstream tapered region of the blockage which is well captured by MATRA code. Prediction of flow recovery region at downstream and velocity decrease point at upstream of sleeve are good agreement with experimental data. Velocity distributions on the adjacent channels of blockage, channel 4 to 6, present the good match with measured values in Fig. 2

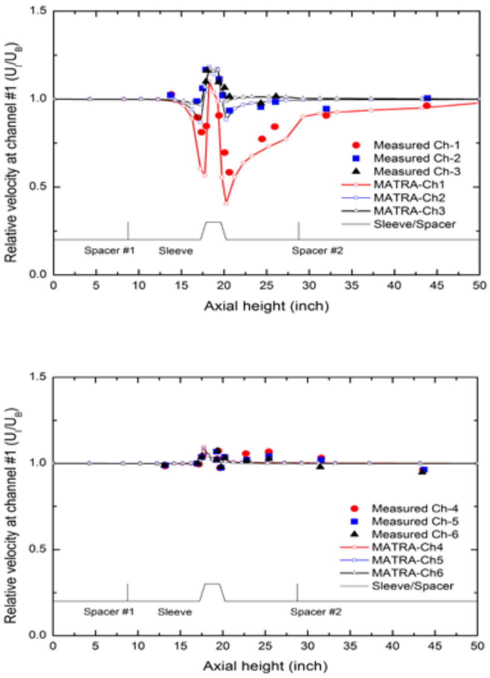

Fig. 2. Comparisons of MATRA-S prediction with relative velocity data with channel 1 to 6 for flow blockage of 70 %

2.4 Results of 90 % Flow Blockage

MATRA prediction of two kinds of 90% flow located midway between spacers and adjacent spacer are performed. Figure 3 shows the comparisons of MATRA with measured data at 2.7 ft/sec, 5.7 ft/sec, and 10.7 ft/sec on the case of blockage location midway between spacers.

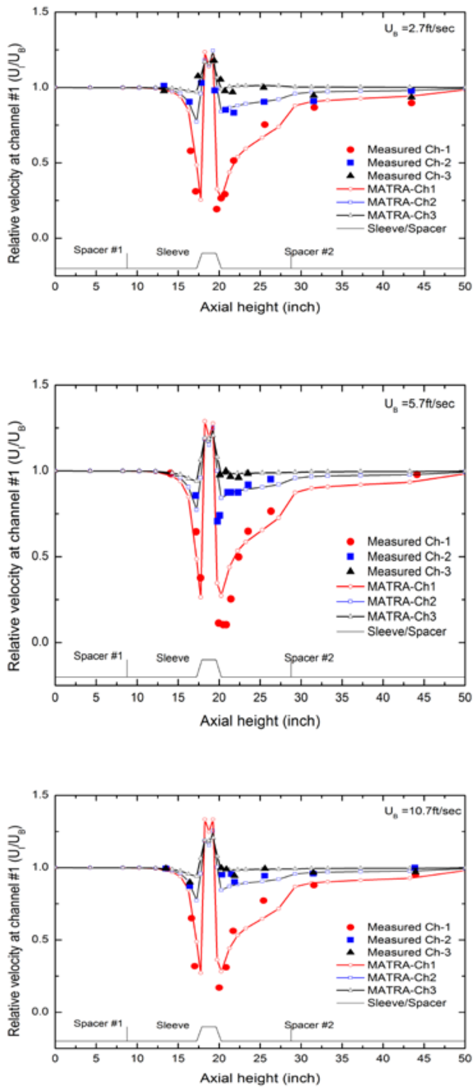

Fig. 3 Comparisons of MATRA-S prediction with relative velocity data with channel 1 to 3 for flow blockage of 90% considering inlet velocity 2.7, 5.7, 10.7 ft/sec.

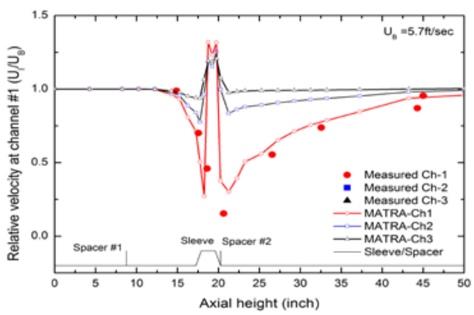

Fig. 4 Comparisons of MATRA-S prediction with relative velocity data with channel 1 to 3 for flow blockage of 90% at adjacent spacer

MATRA prediction on the recovery profiles from upstream to downstream of sleeve essentially coincide with the experimental data in Fig. 3. However, flow jetting appeared in prediction was not detected on measurements. In the report[1] the discrepancy was inferred with two reasons: firstly the measuring volume could not be positioned in the core of the blockage. The other is that jetting may not have actually existed which will be estimated with the assistance of CFD.

In the case of adjacent spacer with 90 % flow blockage, MATRA code can be used to simulate flow blockage and predict well with measurement although COBRA-IIIC code[1] failed to run this case due to numerical stability problem as shown in Fig. 4.

3. Conclusions

The MATRA code using both schemes has been performed to estimate the prediction accuracy on the flow blockage condition in which flow recirculation and jetting phenomena occurred. Predicted velocity distributions show entirely good agreement with the experimental data provided with PNL 7x7 test.

Based on this results, it will be shown sufficiently that MATRA code can evaluate DNB estimation under an isolated flow blockage condition in the following study.

ACKNOWLEDGMENT

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