Case Study of MATRA-S for PNL 7x7 Rod Bundle Blockage Test - I. Subchannel Analysis

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1. Introduction

We validated a subchannel analysis code, MATRA-S[1] in comparison with the 7x7 rod bundle blockage test of PNL[2]. MATRA-S has ability to solve equations with variable axial node sizes for complex flow field like flow paths blocked and to model flow blockage by reducing flow area and gap size.

The PNL 7x7 rod bundle flow blockage test was conducted to investigate the turbulent flow field at blockage in a fuel assembly. A part of flow areas were blocked or reduced by sleeves installed on center 3x3 rods. The blockages simulate fuel rod swelling or ballooning which may occur during the loss of coolant accident.

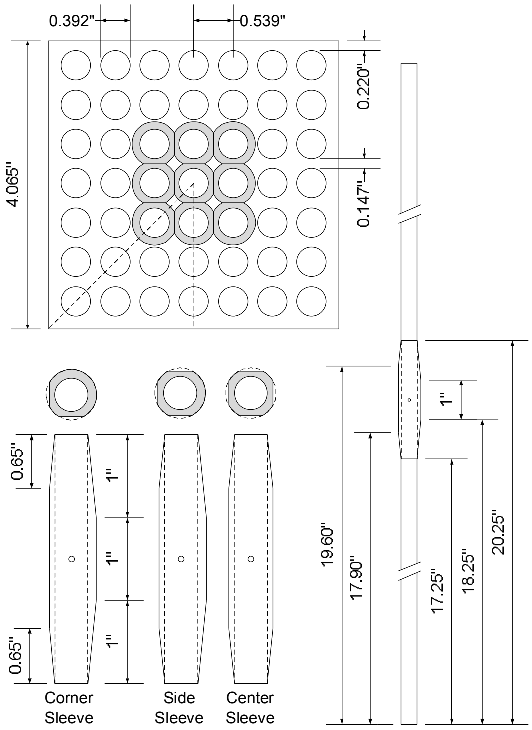
The test section consists of 57" long, 0.392" outer diameter, 7x7 rods with 0.539" pitch. There were three space grids of pressure loss coefficient of 1.14. Nine sleeves were installed on center nine rods at middle to reduce 17.9 ~ 70% of subchannel flow areas with respect to their location. Fig.1 (a) shows a cross sectional view of the test section and shapes of sleeves and their locations.

2. Subchannel Analysis

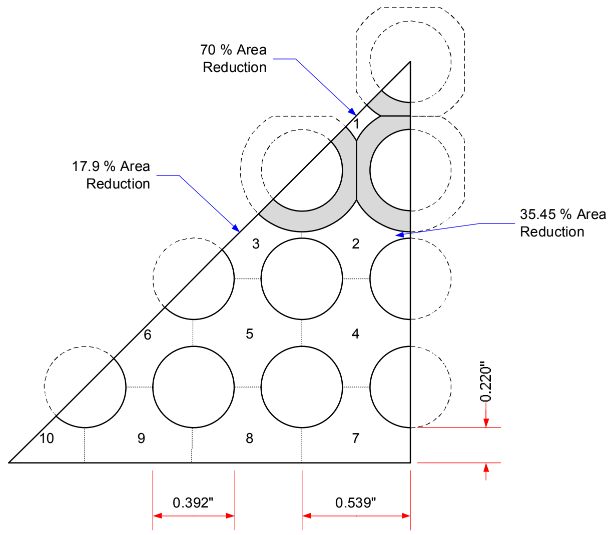
We have chosen data from 70% blockage at middle of two spacer grids of the PNL test to validate the abilities of MATRA-S code.

We modeled the PNL test section as a 1/8-symmetry rod bundle with ten subchannels as shown in Fig.1(b). And we modeled the blockage as subchannel flow area reduction as 0.3 for subchannel #1, 0.6455 for #2, and 0.821 for #3 respectively, and gap size reduction as 0.03 for gap #1 and 0.4429 for #2 respectively.

At first, we modeled the test with 25 uniform axial nodes and with 25 non-uniform axial nodes for the MATRA-S calculation. Fig.2 (a) shows dramatic rapid variation of measured local flow velocity along center line of subchannel #1. The ratio of measured local flow



(a) PNL Test Section.



(b) Subchannel analysis model

Fig.1. Schematic Diagram of the PNL Test Section.

velocity to average flow velocity increases to 1.4 and then drops to 0.6.

We studied sensitivity of non-uniform axial nodes for five options(0~4) for axial nodes when the number of axial nodes is fixed as 25 as shown in Fig.2(b). All of the five options show almost the same results. We can conclude that there are enough number of axial nodes within the blockage region and the results are valid.

3. Conclusion

We validated MATRA-S' ability to analyze complex flow field induced by flow blockage with PNL 7x7 rod bundle test. We could solve this problem successfully by modeling flow blockage as subchannels of reduced flow area and gap size.

MATRA-S predicted flow velocity profile along blockage in axial direction well with the measured data. It was efficient to adopt non-uniform axial node to use dense nodes near blockage and loose nodes far from blockage.

ACKNOWLEDGEMENTS

This study has been carried out under the R&D program sponsored by the Ministry of Science and Technology of Korea.

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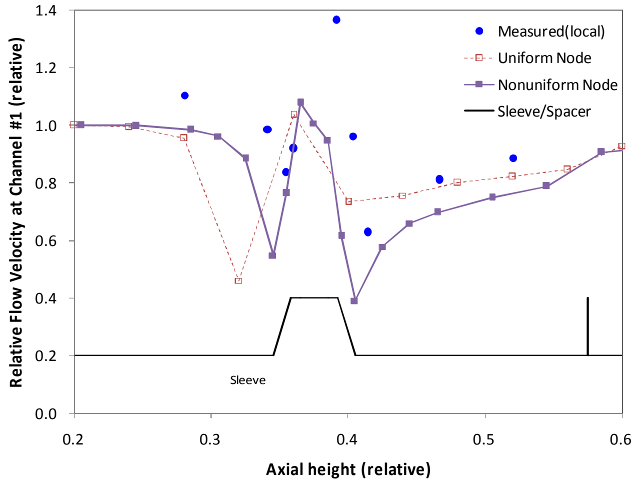
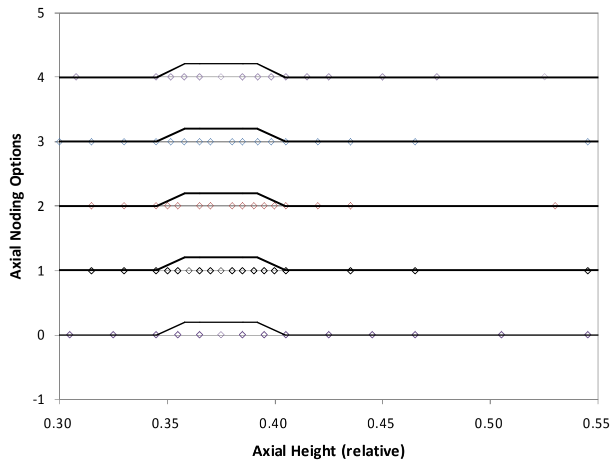
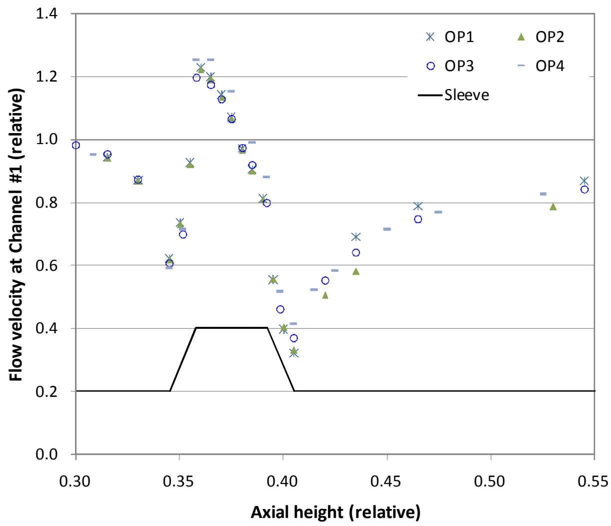
2. J. M. Creer et al., Effects of Sleeve Blockages on Axial Velocity and Intensity of Turbulence in an Unheated 7x7 Rod Bundle, BNWL-1965, Battelle, 1976/01.



(a) Uniform vs. Non-uniform Axial Nodes



(b) Axial Noding Options



(c) MATRA-S Results

Fig.2. Noding Options and Results