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Application of MATRA for Low Flow Subchannel Analysis – PNL 7x7 Blockage Test

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1. Introduction

The explicit scheme is easier to implement than the implicit scheme but time step size of the explicit scheme is limited by Courant number. And the explicit scheme usually requires much time to obtain a steady solution than the implicit scheme whose time step size is unlimited. Therefore the implicit solution scheme of MATRA(Multi-channel Analyzer for Transient and steady-states of Rod Array) has been widely used in thermal hydraulic design for analyses of steady states. However the implicit scheme of MATRA has a drawback in analyzing flow field under low pressure and low flow conditions. The implicit scheme of MATRA usually becomes unstable in analysis of those flow[1].

The explicit scheme of MATRA adopted algorithm of ACE(Advanced Continuum Eulerian) that was originally developed to analyze flow field where rapid density changes such as re-flooding whereas the implicit scheme can't[2]. The explicit scheme has been validated using the steady state and flow reduction transient tests at PNL 2x6 rod bundle[3,4]. And it was proved that the explicit scheme can successfully applied for problems that can't be solved by the implicit scheme. In this work, we applied the explicit scheme of MATRA to analysis of flow blockage tests at PNL 7x7 rod bundle[5].

2. Flow Blockage

In the view of thermal hydraulics, core is designed not to exceed the SAFDL(Specified Acceptable Fuel Design Limits) during any condition of normal operation including the effect of AOO(Anticipated Operational Occurrences). The fuel integrity can be assured by providing core with enough coolability to prevent overheating of clad and melting of fuel for PWRs(Pressurized Water Reactors). The core coolability may be degrade by blocking of flow passage from swelling or ballooning of fuel rod, and collection of debris after LOCA(Loss of Coolant Accident). Most vendors, for these reasons, have performed debris generation and core inlet blockage tests as well as analyses of effects of debris on the core coolability[6].

The effects of channel blockage on DNBR of SMART(System-integrated ModulAr ReacTor) also has analyzed by the authors using MATRA-S code which is a branch of MATRA code for SMART design[7]. In this study, authors assumed a subchannel has been blocked by one or more of circular shaped obstacles. The maximum flow blockage was assumed as 62% and it was successfully analyzed by the implicit scheme.

The flow blockage tests at PNL 7x7 rod bundle as shown in Figure 1 have been analyzed by authors. In these tests, the blockage ratios were 70% and 90% with sleeves installed around nine rods at the center to postulate swelling or ballooning of fuel cladding during LOCA in PWRs. The authors could have analyzed only 70% blockage because the implicit scheme of MATRA failed to solve flow field at 90% blockage. Figure 2 shows the measured subchannel velocity near sleeves along axial direction with predictions from the implicit scheme and the explicit scheme for 70% blockage.

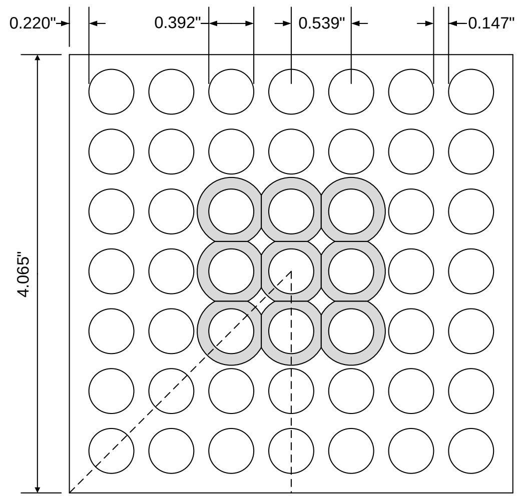

Fig.1 Test Section of PNL 7x7 Flow Blockage Test[5]

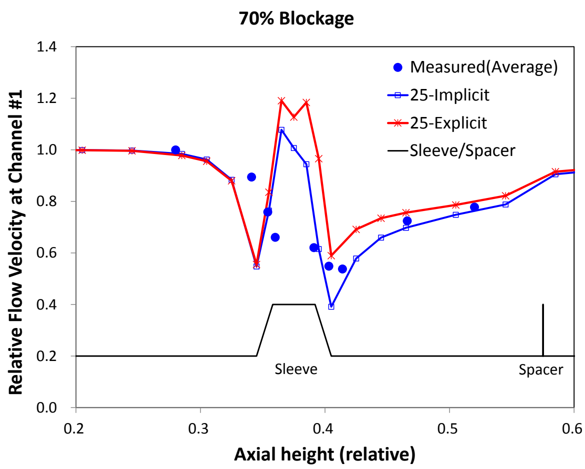

Fig.2 Flow Velocity at 70% Blockage

3. Analysis of 90% Blockage

The subchannel whose flow area is blocked 90% of the original flow area couldn't have been analyzed by MATRA with the implicit scheme. The flow velocity at subchannel #1 is almost zero at the downstream of the sleeves as shown in Figure 3. And the implicit scheme has failed to run for this problem. However, by the explicit scheme, flow field in 90% flow blockage can be analyzed as a transient problem as shown in Figure 3. And the predicted flow velocity agreed well with the measured velocity profile.

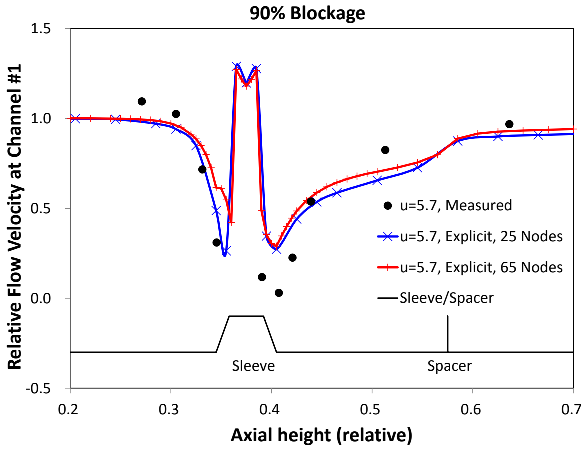

Fig.3 Flow Velocity at 90% Blockage

4. Conclusion

The explicit scheme of MATRA has been validated with measured data from PNL 2x6 rod bundle stead state and flow reduction transient tests and PNL 7x7 rod bundle flow blockage tests. And it is shown that the explicit scheme can be applied to analyze flow field under low flow conditions that the implicit scheme can't solve.

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