Evaluation of the MATRA-LMR-FB Code for LMBWG Benchmark Tests of Central Blockage

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1. Introduction

The development of an accurate subchannel analysis code is essential for the design of an advanced nuclear reactor. This is because the accurate thermal-hydraulic design is one of the most important aspects for the safe and reliable operation of the reactor system. Further, the fuel pins are configured very compactly and the heat flux from the fuel rods is usually high in a liquid metal-cooled reactor (LMR). Therefore, it is important to maintain the integrity of the fuel rod configuration for the continuous operation of a liquid metal-cooled reactor.

However, the coolant subchannels of a subassembly could be blocked in a circumstance and the successful heat transport from the fuel rods to the heat exchanger through the coolant could be interfered. Even in this extremely abnormal situation, it is required to maintain the core coolability without exceeding the temperature limits. For the analysis of these kinds of blockage accident, the Korea Atomic Energy Research Institute (KAERI) has developed the MATRA-LMR-FB code [1], which is an enhanced version of MATRA-LMR code [2].

The MATRA-LMR-FB code uses the distributed resistance model [3] to describe the sweeping flow formed by the wire-wrap around the fuel rods and to model the re-circulation flow after blockage. The hybrid difference scheme is also adopted for the description of the convective terms in the re-circulating wake region of low velocity. Some state-of-the-art turbulent mixing models are implemented in the code [1] as an effort to describe correctly the mixing phenomena after the blockage. The accuracy of the code models was quite well validated for the experimental data with wire-wrap spacers. In this study, the predictability and the accuracy of the MATRA-LMR-FB code are evaluated for the experiments with spacer grids, which had been performed as benchmark tests for the development of the blockage analysis code in the Liquid-Metal Boiling Working Group (LMBWG).

2. Analysis

The LMBWG benchmark tests consist of the experiments with two types of flow path, the hexagonal and the triangular. The experiments for the hexagonal flow path, which have been performed at KfF Karlsruhe, were simulated in the present study. The test run number 1 and 6 are evaluated for the validation of the MATRA-LMR-FB code. Both tests used sodium as a working fluid and 49 % of the central part of the flow path was blocked. The inlet velocities were 4 m/s and 1 m/s for run 1 and 6, respectively. The inlet temperatures were about 400 °C for both tests. The simulated subassembly was the 169-pin bundle of SNR 300 geometry and 88 rods located in the blocked region were heated.

2.1 Modeling of KNS-169 Pin Test

The simulated test section is depicted in Figure 1. The test section length is modeled to be 1,016 mm and the 7 spacer grids are assumed to be located at every 150 mm. The axial length of the flow path is divided into 74 nodes. The blockage is formed at the center of the third grid from the bottom. The 15 mm-thick grid containing the blockage is divided into two axial nodes and the 3 mm-thick blockage is assigned to be located at the lower grid node. In the MATRA-LMR-FB model the grid spacers are modeled by imposing an artificial flow resistance. The inlet temperature and flow velocity are given as boundary conditions, which are summarized in Table 1.

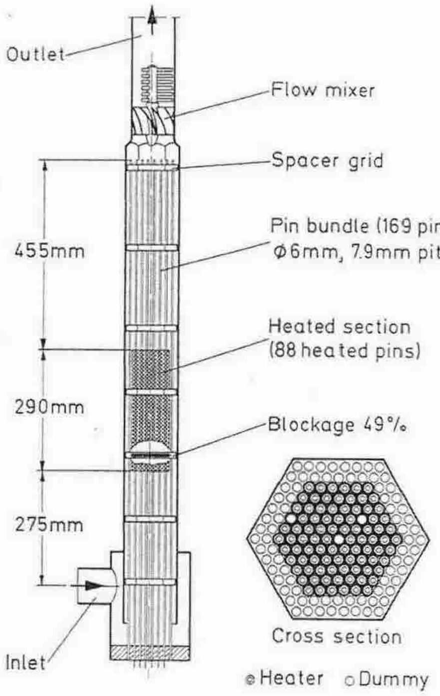


Figure 1. Schematics of the KNS 169-pin central blockage test

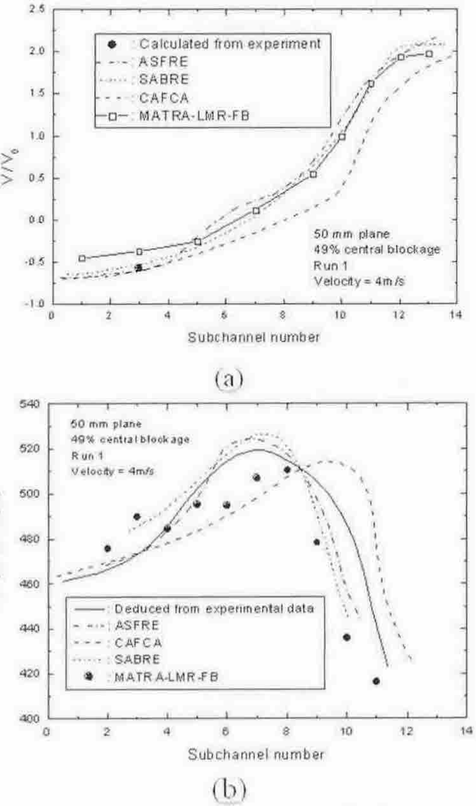
Table 1. Boundary conditions for the KNS-169 tests

Run No.	1	6
Flow velocity (m/s)	4	1
Inlet temperature (^oC)	404	404
Heat flux (W/cm^2)	67.7	17.9
Temp. gradient (K/m)	113	117

2.2 Results

The only experimental parameter measured directly is the temperature distribution along the axial flow path. Other information was deduced indirectly from the experimental condition and the measured temperatures. Therefore, the most important parameter for the evaluation of the code accuracy may be temperature field behind the blockage, peak temperature in a plane, the peak temperature and its location.

Figure 2 compares the velocity and temperature distributions predicted by several subchannel analysis codes. It is found that the MATRA-LMR-FB underpredicts the recirculation flow at the center of the blockage, which may come from the inaccuracy in the mixing characteristics and/or from the numerical diffusion.

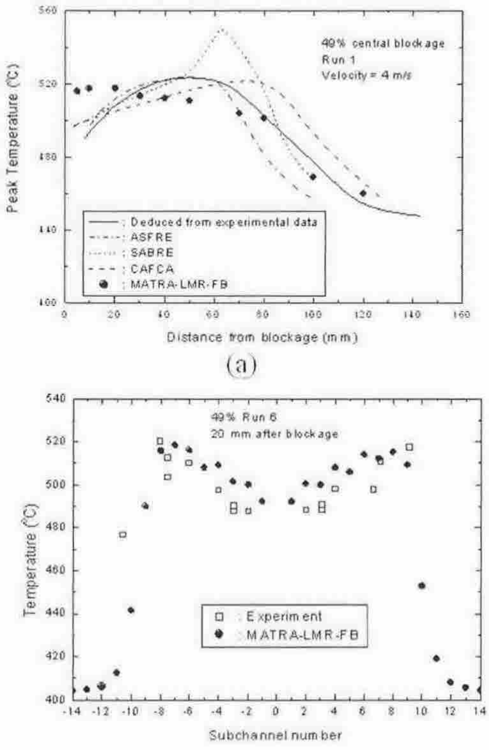


(a)

(b)

Figure 2. Velocity and temperature distribution (Run 1)

Figure 3(a) summarizes the variation of peak temperatures along the axial length. The peak temperature is predicted just after the blockage with the MATRA-LMR-FB code, which implies the location of recirculation wake is not preferable with MATRA-LMR-FB. Figure 3(b) shows the accuracy of MATRA-LMR-FB for Run 6 having a low inlet velocity. It is said that the code predicts the spatial temperature variations quite accurately



(a)

(b)

Figure 3. (a) Peak temperature along the axial length (Run 1)
(b) Temperature distribution at a plane (Run 6)

3. Conclusion

The general trends of velocity and temperature fields after a central blockage in a sodium flow path with a number of spacer grids can be predicted with the MATRA-LMR-FB code. For the enhanced prediction of the location of recirculation wake it is required to refine the spacer grid model and blockage model itself, which is important to describe correctly the pressure drop near the blockage and the grid plate.

REFERENCES

[1] H. Jeong, K. Ha, W. Chang, Y. Kwon, and Y. Lee, Modeling of Flow Blockage in a LMR Subassembly with a Subchannel Analysis code, Nuclear Technology, January, 2005 (to be published).

[2] W. S. Kim, Y. G. Kim and Y. J. Kim, A subchannel analysis code MATRA-LMR for wire-wrapped LMR subassembly, Ann. Nucl. Energy, Vol. **29**, p.303, 2002.

[3] K.S. Ha, H.Y. Jeong, W.P. Chang, Y.M. Kwon, and Y.B. Lee, Wire-wrap Models for Subchannel Blockage Analysis, J. KNS, Vol. **36**, p.165, 2004.