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Assessment of the MARS Subchannel Mixing Model Using 8x8 Rod Bundle Test Data

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1. Introduction

The MARS code is a best-estimate multi-dimensional thermal-hydraulic system code. The three-dimensional (3-D) module of the MARS code, developed from the COBRA-TF code, has a subchannel flow mixing model for rod bundles [1]. In addition, the critical heat flux correlation of the AECL lookup table has been implemented in the MARS 3-D module. Thus, the MARS 3-D module can be used for the hot channel analysis.

In this paper, the subchannel flow mixing model of the MARS 3-D module was assessed using the NUPEC BFBT 8x8 rod bundle test data [2].

2. Subchannel Flow Mixing Model of the MARS 3-D Module

The flow mixing between adjacent subchannels is generally divided into three components; diversion cross flow, turbulent mixing, and void drift. In the MARS 3-D module, the diversion cross flow is modeled by solving the transverse momentum equations. For turbulent mixing and void drift between adjacent subchannels, the modified Lahey's model [3] was employed. In the modified model [1], the net mass flux of gas phase from subchannel i to j due to the turbulent mixing and void drift is represented by

$$w''_{g,i-j} = \left(\frac{\varepsilon}{l}\right)_{1\phi} \theta \left\{ (\alpha\rho)_{g,i} - (\alpha\rho)_{g,j} - K_{VD} \frac{G_i - G_j}{\overline{G}_{i,j}} \rho_{g,i-j} \right\}, \tag{1}$$

where ε is eddy diffusivity and l is the subchannel mixing length. $(\varepsilon/l)_{1\phi}$ has the unit of velocity and is called single-phase "turbulent velocity." θ is a two-phase multiplier for the turbulent velocity. α and ρ are void fraction and density, respectively. G_i is the total mass flux at channel i. K_{VD} is the void drift coefficient [1]. It is represented as

$$K_{VD} = 0.112 + 16.4 e^{-0.329P} \tag{2}$$

where P is the pressure in MPa. Similarly, the net mass flux of liquid phase from subchannel i to j due to the turbulent mixing and void drift is represented by

$$w''_{l,i-j} = \left(\frac{\varepsilon}{l}\right)_{1\phi} \theta \left\{ (\alpha\rho)_{l,i} - (\alpha\rho)_{l,j} + K_{VD} \frac{G_i - G_j}{\overline{G}_{i,j}} \rho_{l,i-j} \right\}. \tag{3}$$

For the entrained-liquid phase in the MARS 3-D module, the mixing model is not applied.

3. A Brief Description of The 8x8 Rod Bundle Test

The NUPEC BFBT full-size bundle test [2] was used in this work. The test facility has a full range of steady-state test capability under typical BWR operating conditions and can also simulate unsteady characteristics of BWR operational transients. The full-scale BWR simulated fuel assembly of an 8x8 rod bundle was installed in the test facility.

Two kinds of void distribution measurement systems, X-ray CT scanner and X-ray densitometer were used (See Fig. 1). Void distributions were measured in fine-mesh using the X-ray CT scanner at a point 50 mm above the heated zone under steady-state cases. The X-ray densitometers were used to measure cross-sectional average void fractions during transients.

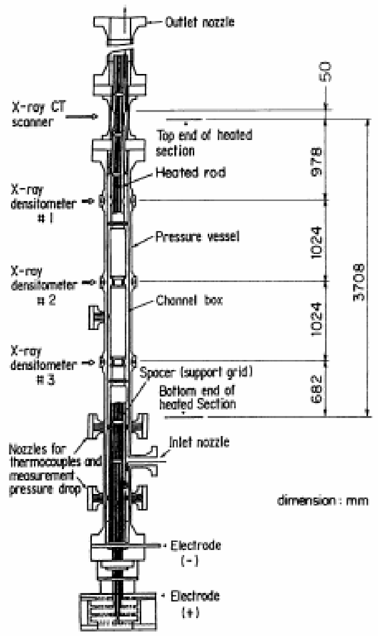
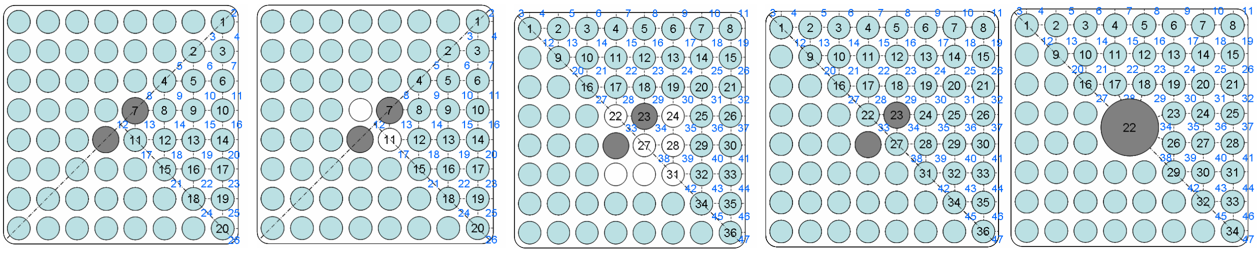


Fig. 1. Cross-sectional view of the test section [2].

4. The Results of the MARS Calculations

Among the various steady-state tests with different fuel assemblies, 15 tests were used for this assessment. The fuel assembly types and its MARS input models are depicted in Fig. 2. For the MARS calculation, 1/2 or 1/4 symmetry assumptions, depending on the bundle geometry and radial power distributions, were used for computational efficiency. 24 axial meshes were used for the heated region. The steady-state subchannel void distributions above the top end of the heated region are compared in Figs. 3 through 7.



(a) Types 0-1 (b) Type 0-2 (c) Type 0-3 (d) Type 1 (e) Type 4

Fig. 2. The fuel assembly type and its MARS input model: Channel and rod numbers are given.

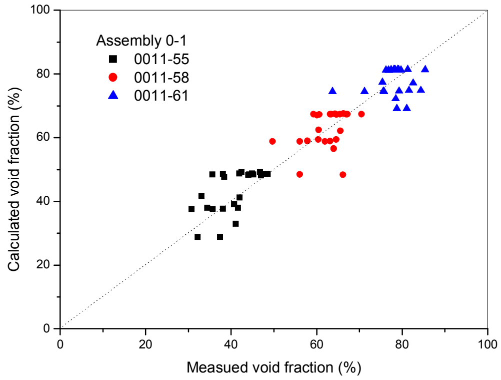


Fig. 3. Void fractions at Assembly 0-1.

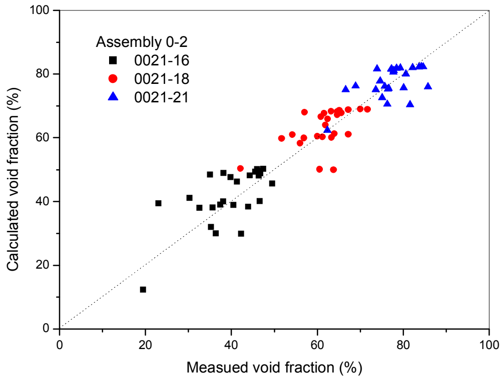


Fig. 4. Void fractions at Assembly 0-2.

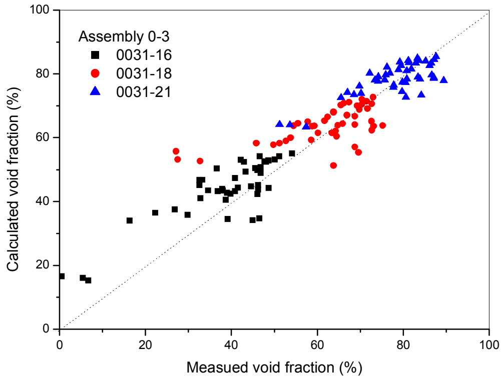


Fig. 5. Void fractions at Assembly 0-3.

4. Concluding Remarks

The subchannel mixing model of the MARS 3-D module was assessed using the NUPEC BFBT rod bundle test data. The results of the assessment showed that the MARS code can predict the subchannel void distributions very well. The average and the stand deviation of the P/M of the subchannel void fractions decreased as the void fraction increases.

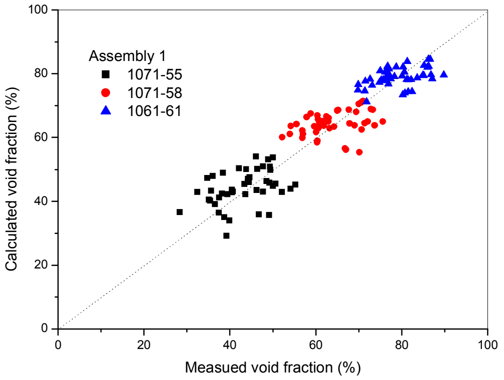


Fig. 6. Void fractions at Assembly 1.

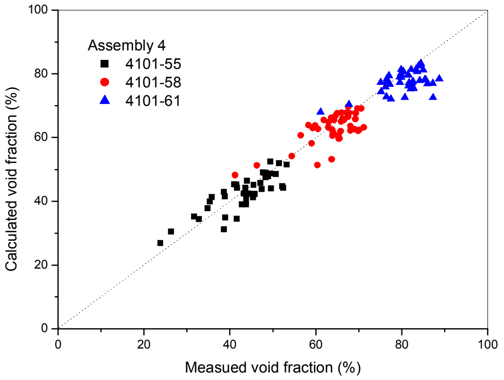


Fig. 7. Void fractions at Assembly 4.

References

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[3] Lahey, Jr., R.T. and Moody, F. J. 1993. *The Thermal Hydraulics of a Boiling Water Reactor,* 2nd Ed., ANS, La Grange Park, Illinois USA, pp. 168-184.