The Verification of AMBIKIN2D Code using Experimental Data by MSRE

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1. Introduction

The one point kinetics model due to simplicity is not a sufficient way to analyze the frequency response for reactivity insertion of the molten salt reactor which has moving fuel. AMBIKIN2D code has developed for resolving space-time problems frequently arisen in more precise nuclear safety assessment of the reactor. For code verification, MSRE experimental data tested in 1970 using U235 fuel is used. In this study a conclusion was made that the AMBIKIN2D code was a better way to get experimental result in high frequency region than the one point kinetics model

2. Theory and Model of AMBIKIN2D

2.1 2-D and 2-G Neutron Kinetics with Z-directional Fuel-flows

2 group neutron kinetics equations in an r-z geometry reactor where the fuel materials flow upwardly can be derived as follows:

$$\frac{1}{\upsilon_1}\frac{\partial\phi_1}{\partial t} = \nabla D_1\nabla\phi_1 + (1-\beta)\sum_{k=1}^{2}\nu_k\Sigma_{f,k}\phi_k - \Sigma_{tot,1}\,\phi_1 + \sum_{j=1}^{J}\lambda_j C_j$$

$$\frac{1}{\upsilon_2}\frac{\partial\phi_2}{\partial t} = \nabla D_2\nabla\phi_2 + \Sigma_{s,1\to2}\,\phi_1 - \Sigma_{a,2}\,\phi_2$$

$$\frac{\partial C_j}{\partial t} = \beta_j\sum_{k=1}^{2}\nu_k\Sigma_{f,k}\phi_k - \lambda_j C_j - u_z(t)\frac{\partial C_j}{\partial z},\ j = 1..J \qquad (1)$$

This model has not considered recirculation of delayed neutron precursors.

2.2 Modeling of time-dependent fuel material properties

Cross-section changes due to fuel-flows were approximated by introducing a pseudo-nuclide model as follows.

$$\frac{\partial\,\Sigma_{mi}}{\partial t} = (A_{mi} + B_{mi}\psi_i)\,\Sigma_{mi} - u_z(t)\frac{\partial\,\Sigma_{mi}}{\partial z} \qquad (2).$$

2.3 Implicit method and quasi-static scheme for numerical solution

For solving the finite difference approximation of Eq. (1), we first determine the steady state solutions iteratively converged with given flow velocity. Starting with this as initial conditions, implicit scheme of

$$\frac{\phi^{n+1}-\phi^{n}}{\Delta t} = \alpha B\phi^{n-1} + (1-\alpha)B\phi^{n} \qquad (3)$$

was applied where α was the over-relaxation factor.

As cross-sections generally changes as slow as flow velocity, a quasi-static approximation might be accurate enough, so that,

$$\frac{\Sigma_{mi,l}^{k'+1} - \Sigma_{mi,l}^{k'}}{\Delta\tau} = -u_z^{k'}\,\frac{\Sigma_{mi,l}^{k'+1} - \Sigma_{mi,l-1}^{k'+1}}{\Delta z} \qquad (4)$$

Reactivity feedback model of thermal-hydraulic condition changes are not incorporated in the code yet

2.4 Verification of AMBIKIN2D

For the verification studies of AMBIKIN2D, we attempted to reproduce theoretical and experimental dynamic analysis of MSRE which executed frequency response tests in 1970. MSRE dynamic stability experiments having observed power responses to rod-jog method in ORNL were tested and compared to the theoretical one point model results.

In this work dynamics test utilizing the flux-demand technique was performed with the 235U fuel loading and 8MW reference power level. Test patterns were employed during early and end of power operation.

The results of AMBIKIN2D were to be calculated frequency response as sinusoidal reactivity insertion. In this work calculations were examined in high frequency ranges, 0.1~1 radians, because calculations in low frequency ranges need to spend a lot of CPU times over ten days.

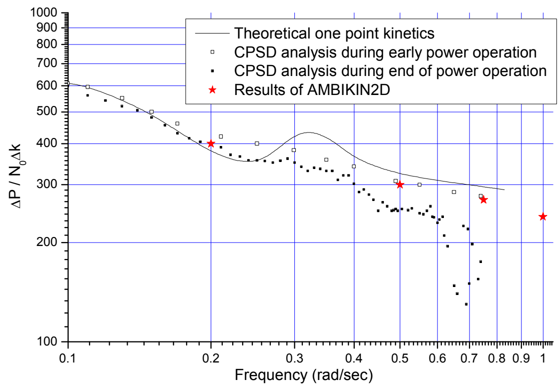

Figure 1 Amplitude ratio results of 8.0MW power level

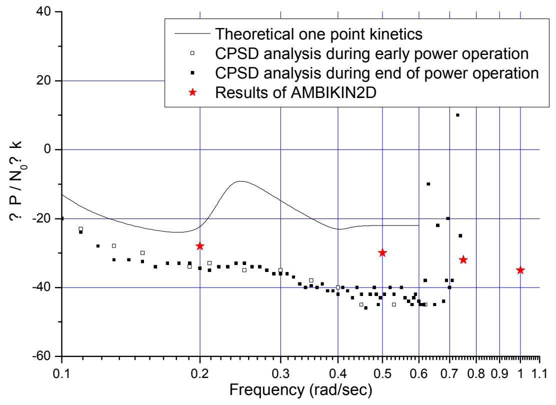

Figure 2 Phase shift results of 8.0MW power level

The calculation results that examined the one point kinetics model by ORNL were a better way to get experimental results in low frequency region but not in high frequency region. On the other hand the AMBIKIN2D is more appropriate way to get experimental results in high frequency region.

3. Conclusion

AMBIKIN2D code was developed for analyzing various transient cases of the fluidized-fuel nuclear energy systems. Also its verification for the purpose has been examined using theoretical and experimental dynamic analysis data of the MSRE.

For the future works, acceleration techniques to improve its iteration scheme are going to be evaluated. And reactivity feedback models of thermal-hydraulic condition changes are also to be incorporated.

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