Assessment of COBRA-SFS Cycle4 With Various Single Phase Flow Tests

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1. Introduction

COBRA-SFS (Coolant Boiling in Rod Arrays - Spent Fuel Storage) code [1] has widely been used to analyze flow field and temperature profile in spent fuel storage canisters. The code was derived from the COBRA-IV [1], abilities to analyze spent fuel storage systems such as radiative and conductive heat transfer were added while two-phase flow related features were removed. And the code has been validated for many spent fuel storage systems and has shown the predicted temperatures agree well with measured. The flow mechanism within spent fuel storage system is natural circulation driven by temperature difference. It is hard to find a validation work about COBRA-SFS's ability to predict flow field rather than temperature profile under natural circulation. In this reason, we have assessed the COBRA-SFS Cycle4 code with various tests were performed at single phase flow.

2. Assessment

2.1 Flow Mixing Test at CNEN 4x4 Rod Bundle

This test measured flow velocity distribution at the subchannel exits at five different flow conditions at CNEN 4x4 Rod Bundle[3]. The measured values were integrated into a subchannel average velocity. This test can show the ability of COBRA-SFS of predicting turbulent mixing between subchannels. The turbulent mixing was modeled with a coefficient of 0.02 as listed in Eq.(1).

$$w'_T = 0.02 s_k \overline{G} \qquad (1)$$

The predicted values agreed well with the measured at center and side subchannels as shown in Fig. 1. However COBRA-SFS under-predicted velocity at corner subchannel and the discrepancy becomes the larger as the flow rate increases.

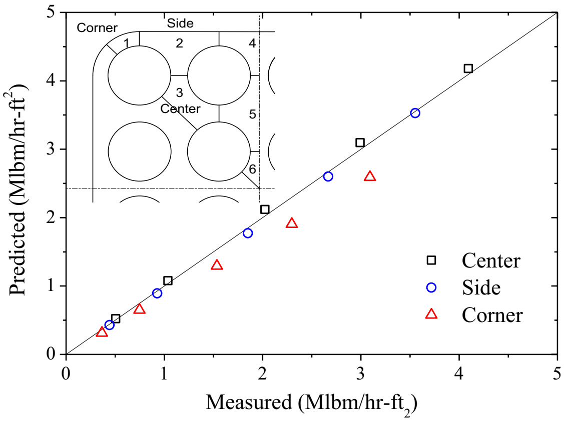


Fig. 1. Analysis of the Flow Mixing Test.

2.2 Flow Redistribution Test at WH Two-Assemblies

This test at Westinghouse observed flow re-distribution between two adjacent assemblies when one assembly was blocked [4]. The flow blockage at the right side was simulated by reducing the flow rate by 550 gpm whereas flow rate remains at 1100 gpm for the left. Each assembly consists of 38-inch long 196 rods in 14x14 square lattice.

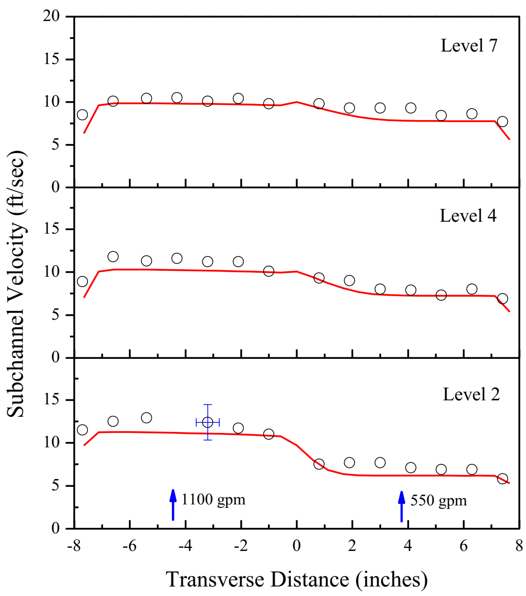


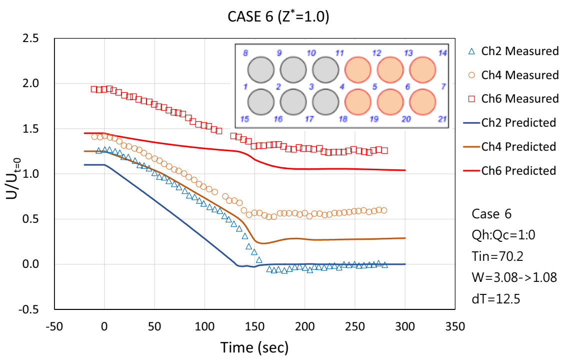
Fig. 2. Analysis of the Flow Redistribution Test.

Fig. 2 shows the flow redistribution between two assemblies and flow profile becomes uniform at the level 7 both of the measured and the predicted.

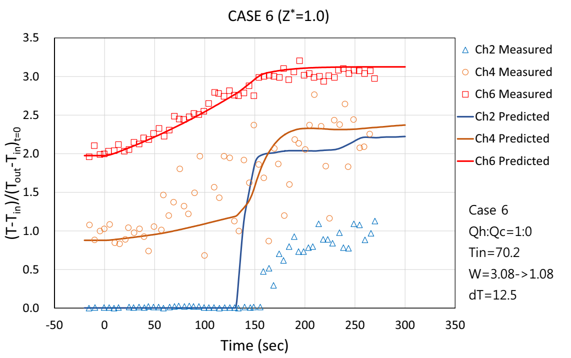
2.3 Low Flow Test at PNL 2x6 Rod Bundle

This test was performed under steady states and flow reduction transients at PNL 2x6 rod bundle [5]. The test measured the local flow velocity and temperature profile. The temperature profiles were measured with various non-uniform radial power distributions.

Fig. 3 shows the flow velocity and temperature profiles at the subchannel no. 2, 4, and 6 for the test case 6. The test case 6 was a flow reduction transient during 150 seconds while right half six rods were heated and the others were unheated. The measured flow velocity at the subchannel 2 dropped below zero after the transient ended as shown in Fig. 3(a). The predicted flow velocity at that subchannel became slightly negative around 130 seconds which was earlier than the measured. Fig. 3(b) shows the transients of non-dimensionalized temperature rise for the case 6. Temperature rises at the subchannel 4 and 6 agreed well with the measured whereas that of subchannel 2 was under-predicted.



(a) Flow Velocity



(b) Flow Temperature

Fig. 3. Analysis of the Flow Reduction Transient.

3. Conclusion

We have assessed COBRA-SFS Cycle4 code with three single phase flow tests before we apply the code to analyze temperature profile in a certain spent fuel storage system. The test cases used in this study are flow mixing test at CNEN 4x4 rod bundle, flow redistribution test at Westinghouse two 14x14 rod bundles, and low flow transient test at PNL 2x6 rod bundle. In the flow mixing test at CNEN 4x4 rod bundle, the flow velocity at the corner channel was under-predicted. In the low flow transient test at PNL 2x6 rod bundle, flow velocity at the cold channel became negative earlier than the measured and the temperature rise was over-predicted at that subchannel.

Acknowledgement

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