Subchannel Analysis Capability of the Best-Estimate Multi-Dimensional System Code, MARS 3.0

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1. Introduction

During the early stage of the MARS code development [1], the reactor vessel thermal-hydraulics code, COBRA-TF, was consolidated into the RELAP5 code as a three-dimensional (3D) hydrodynamic module. COBRA-TF adopts a two-fluid, three-field model for two-phase flows on rectangular Cartesian coordinates or sub-channel coordinates. In addition, COBRA-TF has special models for flow mixing phenomena in rod bundles, such as turbulent mixing model and void drift model. Thus, COBRA-TF can be used for subchannel analysis of light water reactors.

Recently, the subchannel mixing model of the MARS 3D module was assessed using a wide range of experimental data and, finally, the void drift model of the MARS 3D module has been improved [2].

The 3D reactor kinetics code, MASTER, was also coupled to the MARS code. Therefore, the coupled calculation capability of system thermal-hydraulics, subchannel analysis, and 3D reactor kinetics is available in the MARS code.

In this paper, the subchannel analysis capability of the MARS code is explained and the application method is suggested [3]. The results of demonstration calculations are also presented.

2. Main Feature of the MARS Subchannel Analysis Module

Figure 1 shows the MARS code structure. The RELAP5 and COBRA-TF codes were implicitly coupled, resulting in the 1D and the 3D module of MARS, respectively. Meanwhile, the MASTER code was explicitly integrated to MARS to provide local core power behavior in steady state or transient conditions. This code structure enables the coupled calculation of system thermal-hydraulics, subchannel analysis, and 3D reactor kinetics, which can greatly reduce the excessive conservatism of currently popular "off-line" calculations.

As can be seen in Fig. 1, two subchannel modules are available in MARS; COBRA-TF (the MARS 3D module) and COBRA-III/CP. The COBRA-III/CP module can be used only if a coupled calculation of 3D reactor kinetics with "*refined coupling option*" is adopted (see Fig. 1). In this case, the MARS 3D module is used as a reactor vessel T/H module rather than a subchannel analysis module. In the case of "*basic coupling option*" or without the MASTER module, the MARS 3D module is used as a subchannel analysis module.

In the MARS 3D module, the classical Lahey's void drift model is employed for sunchannel flow mixing. The AECL Lookup table is implemented for DNBR calculation.

3. Subchannal Analysis using the MARS code

The MARS code can be used for subchannel analysis of light water reactors in parallel with 3D reactor kinetics in the following two ways.

3.1. Preliminary Analysis of Minimum DNBR Using "Refined Coupling Option"

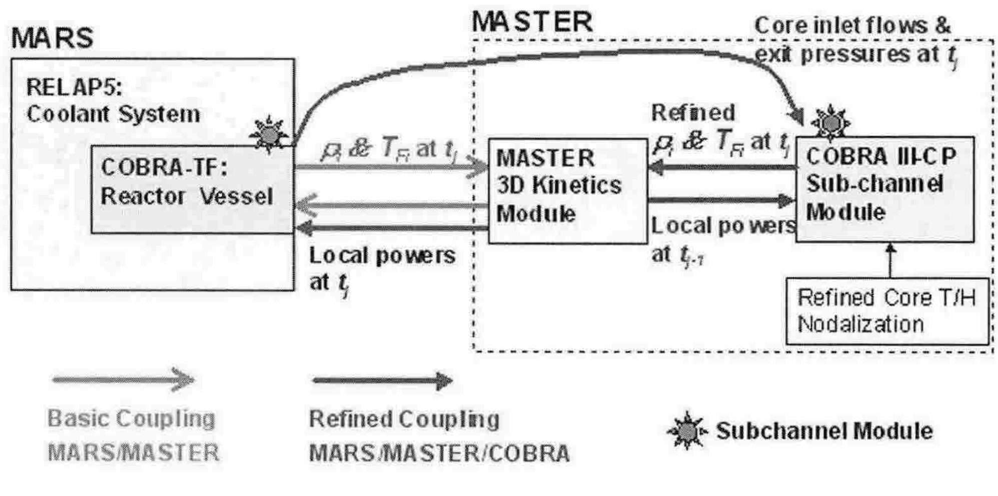

Fig. 1. The MARS code structure

The objectives of this calculation are to perform preliminary DNBR calculation and to find the location of the fuel assembly (FA) that is expected to contain hot subchannels. In this calculation, the refined coupling option should be used. The users need to prepare the following input data:

(a) RCS T/H input for the MARS 1D module.
(b) Reactor vessel T/H input for the MARS 3D module.
(c) Reactor kinetics input for MASTER
(d) Refined core T/H input for COBRA-III/CP in MASTER

Figure 2 (a) and (b) show examples. As shown in Fig. 3, transient DNBR can be obtained from this calculation and, then, the location of the hot assembly is found.

3.2. On-Line Subchannel Analysis Using "Basic Coupling Option"

When the location of the hot assembly is identified, subchannel meshes for the MARS 3D module are prepared (See Fig. 2(c) that shows an example of 1/4 FA subchannel mesh) and embedded into that location. Then, the MARS calculation with "basic coupling option" is carried out to perform so-called on-line subchannel analysis. Figure 4 shows void fraction behaviors in the hot channels of a sample transient. The channel numbers in Fig. 4 are shown in Fig. 2(c). These results clearly show the stability and robustness of "on-line" subchannel calculation.

4. Conclusions

The MARS code has been improved so that the coupled calculation of system thermal-hydraulics, subchannel analysis, and 3D reactor kinetics can be performed. This feature can greatly reduce the excessive conservatism of existing "off-line" calculations.

The application method for subchannel analysis is suggested in two ways: (a) preliminary analysis of minimum DNBR and (b) on-line subchannel analysis. The feasibility of the method is clearly shown from the results of sample calculations.

REFERENCES

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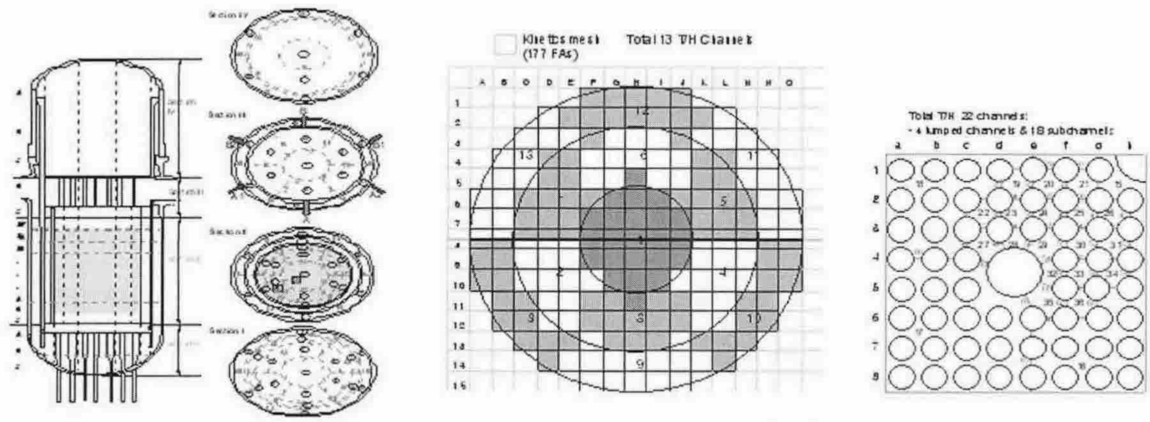

(a) Reactor vessel T/H. (b) Core T/H and reactor kinetics. (c) Hot channel analysis

Fig. 2. MARS nodalization for the coupled calculation of system T/H, subchannel analysis, and 3D reactor kinetics.

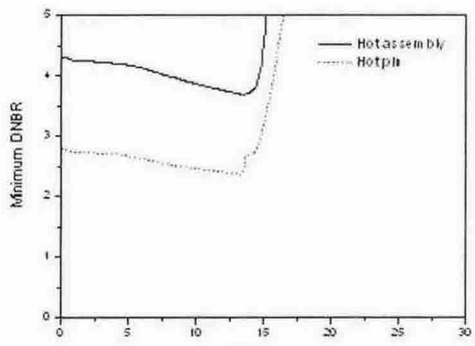

Fig. 3. Preliminary analysis of minimum DNBR.

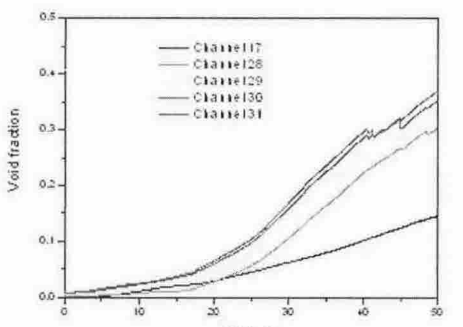

Fig. 4. On-line subchannel analysis: hot channel void fraction.