Implementation of Wolsong Pump Model, Pressure Tube Deformation Model and Off-take Model into MARS Code for Regulatory Auditing of CANDU Reactors

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1. Introduction

Korea currently has four operating units of the CANDU-6 type reactor in Wolsong. However, the safety assessment system for CANDU reactors has not been fully established due to lack of self-reliance technology. Although the CATHENA code had been introduced from AECL, it is undesirable to use vendor's code for regulatory auditing analysis. In Korea, the MARS code has been developed for decades and is being considered by KINS as a thermal hydraulic regulatory auditing tool for nuclear power plants. Before this decision, KINS (Korea Institute of Nuclear Safety) had developed RELAP5/MOD3/CANDU code for CANDU safety analyses by modifying the model of existing PWR auditing tool, RELAP5/MOD3. The main purpose of this study is to transplant the CANDU models of RELAP5/MOD3/CANDU code to MARS code including quality assurance of the developed models. This first part of the research series presents the implementation and verification of the Wolsong pump model, the pressure tube deformation model, and the off-take model for arbitrary-angled branch pipes.

2. Wolsong ANC Pump Model

In case of CANDU-6 reactor, most of the fuel channels downstream of the break location significantly voids in 0.5 ~ 2.0 sec into the accident due to rapid depressurization and massive discharge of the highly pressurized coolant into the containment. And as a result, the reactor power rises rapidly in a pulse shape due to inherent nature of CANDU-6 reactor physics. As the consequence of the LOCA accident can largely vary depending on how quickly the reactor shutdown system shuts the reactor down, an accurate prediction of the coolant density change and following local neutron power change in the core are greatly needed for the safety analysis codes. One of the most important factors significantly affecting this rapid decrease of the coolant density in the fuel channels is the pump characteristics of the reactor coolant pump. But that of the Wolsong reactor coolant pump is not implemented to MARS codes.

Therefore to correct this drawback, the pump characteristics of the Wolsong ANC pump that was already installed to RELAP5/MOD3/CANDU by KINS has been transplanted to MARS code, and its correctness was tested in this study. Tables 1 and 2 show the corrections to the MARS source files.

3. Pressure Tube Deformation Model

Under some postulated accident conditions in a CANDU reactor, a pressure tube would balloon or sag to contact its surrounding Calandria tube due to temperature increase. For the simulation of this phenomenon, the pressure tube deformation model expressed by local creep strain rate has been implemented in MARS code. For verification and validation, the simulation results by CATHENA and MARS for the LBLOCA transients of Wolsong Units 2/3/4 will be compared in the future studies.

For the implementation of the pressure tube deformation model, new subroutines Rate and Balloon are added in the heat structure solver module in MARS. Accordingly, some input/output procedures and related flow logics were modified. Figure 1 and 2 show the flow logics of subroutine Rate and subroutine Balloon.

4. Off-take Model for Arbitrary-Angled Branch Pipes

The phenomena of two-phase flow discharging from a stratified region through arbitrary-angled branch pipes are found in the flow through small breaks in horizontal cooling channels of a CANDU reactor during postulated loss-of-coolant accidents (LOCA), the flow distribution at the header-feeder systems during accidents and two-phase distribution in headers, where a certain incoming stream fed into a large header is divided among a number of discharging streams. Therefore, knowledge of the flow phenomena including the mass flow rate and quality of all discharging streams is obviously essential for the design and safety analysis of such systems. The off-take models for arbitrary-angled branch pipes were incorporated into HSEM (Horizontal Stratification Entrainment Model) inside the MARS code. To verify the improved MARS code, a series of benchmarks problems will be conducted to compare with the original MARS results without an off-take model. Especially, differences in the onset of gas/liquid entrainment and branch quality due to the model improvement should be checked in the verification.

5. Conclusion

In this study, MARS code has been improved for Regulatory Auditing of CANDU Reactors with Wolsong pump model, pressure tube deformation model and off-take model. The implementation was successfully done, but has not been fully verified and validated against simple conceptual problems and experimental data.

In order to predict the thermal-hydraulic behavior in the horizontal fuel channels(Pressure Tubes) during normal operating conditions and LOCA transients, the radiation heat transfer model and the subcooled boiling model should be developed and implemented in the future studies. Furthermore, safety analysis of a reactor inlet header 35% break with a loss of class IV power for Wolsong Unit 2 will be also performed using the improved MARS code. The simulation results of the MARS code would be compared with those of the CATHENA code.

Acknowledgement

This project has been carried out under the Nuclear R&D Program by MOST.

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Table 1. Description of modified modules in MARS for Wolsong pump model

Procedure	Description of Fix
Reading Inputs	Add a new condition statement to read "-3" option of CARD CCC0301 for using W2-ANC pump data
Reading Inputs	Add look-up tables of homologous torque and head curve data for W2-ANC pump.

Table 2. New arrays added to the reading procedure of pump data in MARS for Wolsong pump model

Array Name	Type	Dimen.	Description
hd3	REAL	I=136	Arrays of single-phase homologous head curve data for W2-ANC pump
tk3	REAL	I=94	Arrays of single-phase homologous torque curve data for W2-ANC pump

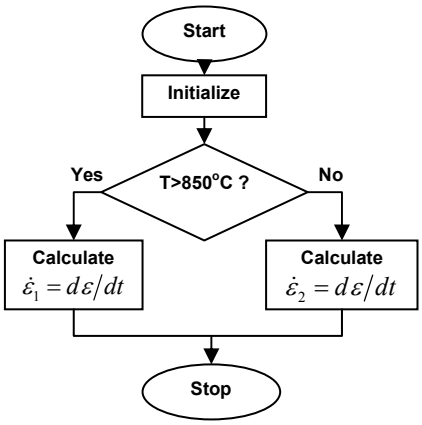

Figure 1. Subroutine Rate flow logic for the Pressure Tube Deformation Model

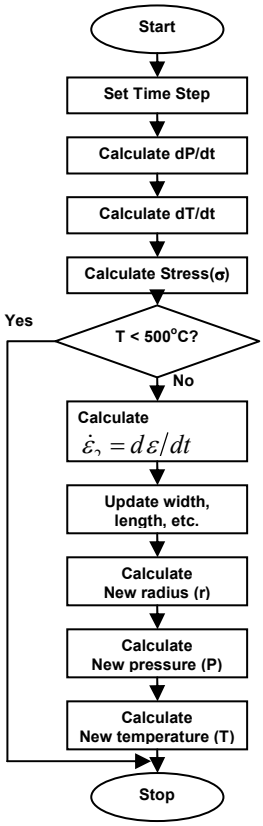

Figure 2. Subroutine Balloon flow logic for the Pressure Tube Deformation Model