Application of the MARS/CANDU Code to Safety Analyses of the Wolsong NPP's

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1. Introduction

The MARS code is being considered by KINS(Korea Institute of Nuclear Safety) as a thermal hydraulic regulatory auditing tool for CANDU-type NPP's in Korea. Before this decision, KINS had developed the RELAP5/MOD3/CANDU code for CANDU safety analyses by modifying the model of the existing PWR auditing tool, RELAP5/MOD3. The CANDU models of the RELAP5/MOD3/CANDU code such as the Wolsong Pump model, the Off-take model for arbitrary-angled branch pipes, the radiation heat transfer input model and the subcooled boiling model have been transplanted into the MARS code.[1] In this study, the improved MARS code is applied to safety analysis of the Wolsong Unit 2 and evaluated by comparing with the CATHENA results and the previous MARS results, which is also a procedure of a quality assurance.

2. LOCA Analyses of Wolsong Unit 2

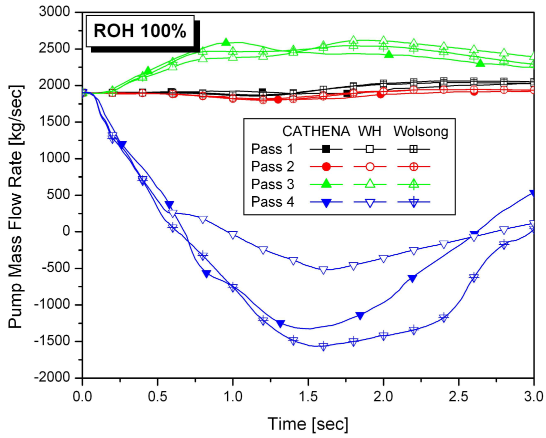
This section presents the application of the Wolsong ANC pump model and the off-take model for arbitrary-angled branch pipes to LOCA(Loss Of Coolant Accident) safety analyses of the Wolsong Unit 2. Also, the MARS and CONTAIN coupled simulation of RIH 35% LOCA without Class IV power is performed.

2.1 LOCA Analyses with the Wolsong ANC Pump Model

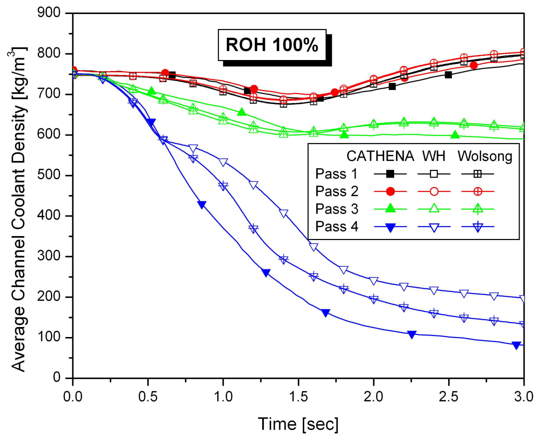
For validation of the Wolsong ANC pump model, LB LOCA analyses of the Wolsong Unit 2 have been performed for RIH(Reactor Inlet Header) 35% Break, ROH(Reactor Outlet Header) 100% Break, and PSB(Pump Suction Break) 50%. The coolant density change in fuel channels is the crucial factor to determine the reactor power pulse, because the density changes largely affect void reactivity during 0.5~2 seconds of transients before shutdown rods are inserted. Figure 1 shows pump mass flow rate and average channel coolant density for ROH 100% LOCA transient. Pass 1 and 2 are in the intact loop, and pass 3 and 4 are a non-critical pass and a critical pass in the broken loop. The coolant density changes most dramatically in the Pass 4, because it is downstream of the break. From Fig. 1, it is observed that the difference of pump mass flow rates is directly proportional to the difference of density changes. The results by using the Wolsong ANC pump model seems more closer to the CATHENA results than those obtained by using Westinghouse pump model. The remaining discrepancy between the CATHENA results and the MARS results with Wolsong pump model is thought to be caused by the mass flow mismatches of feed/bleed line system, pressurizer surge, and ECCS connections, etc.

2.2 LOCA Analysis with the Improved Off-take Model

The phenomena of a two-phase flow discharging from a stratified region through arbitrary-angled branch pipes are found in the flow distribution at the header-feeder systems of a CANDU reactor during postulated loss-of-coolant accidents (LOCA), where a certain incoming stream fed into a large header is divided among a number of discharging streams. The Offtake models for arbitrary-angled branch pipes implemented in the MARS code had been verified through conceptual



(a) Pump mass flow rate



(b) Average channel coolant density

Fig. 1. ROH 100% LB LOCA transient with the Wolsong ANC pump model.

problems [1]. The improved MARS code is now applied to safety analysis of a RIH 35% break without Class IV power for the Wolsong unit 2. This case is a bounding accident to produce the maximum fuel cladding temperature among all LB LOCA's. Initial reactor power was assumed to be 103% accounting for the local reactor power uncertainties, and the exit qualities at ROH were set to be ~4.8% considering aging effects. In this study, a coupled calculation with a reactor physics code was not performed to avoid any additional origin of discrepancy, and the transient reactor power for each pass was treated as a data table as shown in Fig. 2(a).

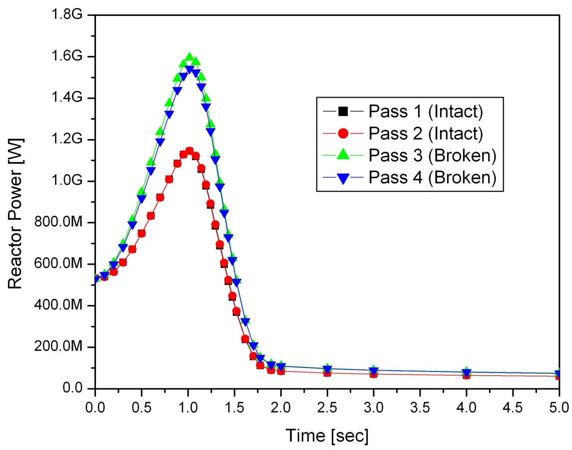
Figure 2(b) shows fuel cladding temperatures during the transient. The MARS simulation with and without the new Offtake model predict very different fuel cladding temperatures at the 7-th node of Pass 4(critical pass). In the case of inactivating the new Offtake model, the fuel cladding temperatures and qualities of four groups (depending on the branching angles of the feeder pipes) are similar. But with the new Offtake model activated the fuel cladding temperatures and qualities of four groups show independent trends, which assures that different entrainment correlations are applied for each groups depending on the branching angles.

2.3 MARS-CANTAIN2.0 Coupled Calculation of RIH 35% without Class IV Power

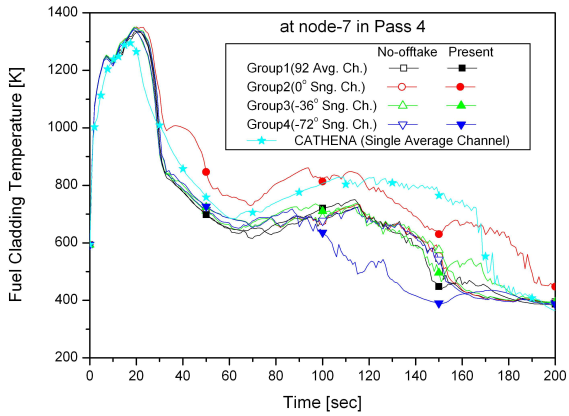
For regulatory auditing of containment calculations, KINS has been trying the MARS-CONTAIN coupled system for the CANDU NPP's. So far, the MARS simulation adapted a time-dependent-volume to model containment and the environmental pressure and temperature were set to be constant. However, by coupling MARS and CONTAIN2.0 through the time-dependent-volume, the pressure and temperature of the containment are fed back for the MARS calculation. In the early stage of LOCA transients, the thermal-hydraulic behavior of a PHT(Primary Heat Transfer) system does not change by coupled calculation. But, after 300 seconds of the transient when pressure of the broken loop decreases lower than 0.4 MPa, increasing containment pressure would reduce the break discharge and the pressure reducing rate of PHT.

3. Conclusions

The improved MARS code is applied to safety analysis of the Wolsong Unit 2 and evaluated by being compared with the CATHENA code and the previous MARS code. It is proved that the Wolsong pump model and the Offtake model for arbitrary-angled branch pipes work properly, and that the improved MARS code can be applied to safety analysis of the CANDU reactors. Also, a coupled simulation of the MARS and CONTAIN 2.0 was performed to account for the feedback effect of containment pressure and temperature.



(a) Reactor powers at intact and broken loops



(b) Fuel cladding temperatures at node-7 in Pass 4

Fig. 2. RIH 35% LB LOCA transient with the Offtake model for arbitrary-angled branch pipes.

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