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Effect of Applying a New PDO Correlation on CANDU 6 SBLOCA

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1. Introduction

Post-Dryout(PDO) correlations for CANDU 37-element bundle were developed over ten years ago and have been used in safety analysis for CANDU reactors in Canada. The PDO correlations are used for predicting heat transfer coefficient between dryout surface of 37-element fuel bundles and two-phase coolant in fuel channel for gaining more margin in terms of fuel sheath than fully developed film boiling correlations in slow transient events of Design Basis Accidents (DBA). Recently, new PDO correlations were developed for additional thermal margin by predicting more realistic heat transfer coefficients in developing film boiling mode[1, 2].

Some of the above PDO correlations were implemented in CATHENA code[3]. One of them, the 6th option[2] in CATHENA DEV-PDO models, which predicts minimum developing PDO heat transfer coefficient with best estimate approach and applying uncertainty of the correlation against measurement data and which seems to adopt statistically reasonable approach for gaining thermal margin.

PDO correlations have not been used up to recently in domestic safety analysis for Wolsong, CANDU 6 NPPs. So, in this paper, a slow transient accident, Small Break Loss Of Coolant Accident (SBLOCA) was analyzed including some trip coverage analysis with and without applying the 6th or 1st developing PDO option in CATHENA code in order to check how much thermal margin could be gained. The 1st option has been used in Canada as a lower-bound, limiting correlation and is less conservative than the 6th option. CATHENA simulation results for them were presented in terms of fuel sheath temperature.

2. Analysis Method and Assumptions

2.5% break area cases at Reactor Inlet Header (RIH) was simulated because it's the largest break size in SBLOCA, and trip coverage cases of SBLOCA were analyzed at 100% Full Power(FP) for 0.1 ~ 3.0% break area size with RRS frozen.

2.1 CATHENA Models

A general CANDU 6 CATHENA system model and single channel models were used to perform the analysis mentioned above. The CATHENA system model consists of PHTS, secondary side system, Emergency Core Cooling System (ECCS). The PHTS has 7 multiple average channels per each corepass with 2 loops which represent 380 fuel channels with typical figure-of-eight configuration. The secondary side system was modeled from deaerator to turbine inlet. Details of the CATHENA models are given in the references[4-8]. Trip Coverage was analyzed with a separate CATHENA model[9] with point reactor kinetics model, which is almost the same as the previous system model except more detailed plant control programs and the fact that it doesn't have ECCS. 11 EFPD aged condition was considered for the analysis.

2.2 Used DEV-PDO options in CATHENA

The 2nd Option(DEV-PDO-2 in CATHENA) is a best-estimate developing PDO correlation which suit calculating heat transferred from fuels to coolant without conservativeness. So, this option was applied in both of circuit analysis and single channel analysis. However, the 1st and the 6th options were used in single channel for predicting highest sheath temperature in which heat isn't transferred from fuel to coolant.

3. Results

3.1 2.5% RIH Break Circuit Analysis

Although using PDO correlation other than fully developed film boiling correlation can affect only heat transfer in developing film boiling mode, it may change vapor generation rate in fuel channel. So some results of circuit analysis were checked. Fig.1 shows the header pressures of core pass 4 as a result of circuit analysis. There are only a little pressure differences between the cases with and without 2nd developing PDO option. Also there were generally no significant differences in mass flow rates and void generations in core pass 4 despite of more void generation in low power channels.

3.2 2.5% RIH Break Single Channel Analysis

Fig. 2 shows maximum fuel sheath temperatures of O6mod channel with regard to applying developing PDO option 1 or 6. In a case of 2.5% RIH break of SBLOCA, maximum fuel sheath temperature is far below 800℃ and it already has much thermal margin without DEV-PDO option in terms of fuel sheath temperature. But, when the developing PDO options were applied, thermal margin amounted nearly 100℃ at about 400 sec in terms of sheath temperature. Meanwhile, maximum sheath temperatures were close between the cases with DEV-PDO-1 and DEV-PDO-6

3.3 100% Full Power Trip Coverage of SBLOCA

In general trip coverages for each Shutdown Systems at 100% FP with RRS frozen were not changed due to applying developing PDO option 1 or 6 in CATHENA. However, applying PDO correlation in circuit model caused a little earlier pressure increase in reactor outlet header, and so did reactor power. It is thought to be attributed to a little more heat transfer to coolant and void generation.

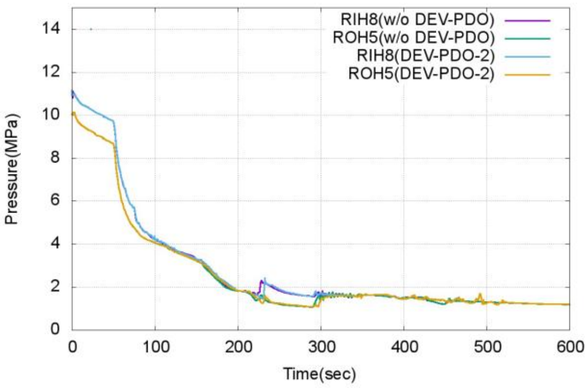

Fig. 1 Core Pass 4 Header Pressures with and without DEV-PDO-2 option

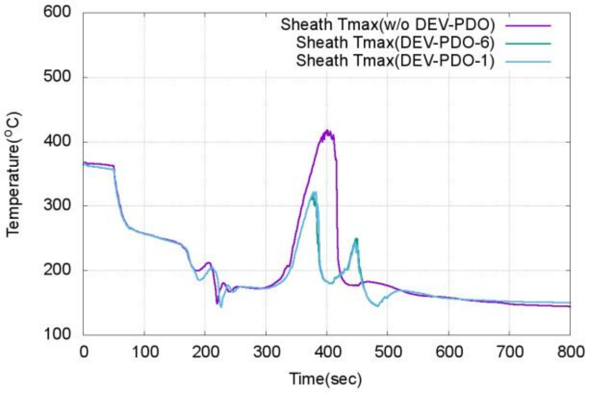

Fig. 2 Maximum Fuel sheath Temperature with and without DEV-PDO-1 or DEV-PDO-6

4. Conclusion

PDO correlations have been used in CANDU safety analysis in Canada instead of those for fully developed film boiling, but they haven't been used in domestic safety analysis for Wolsong NPPs. So using PDO correlation options in CATHENA code, their effect on SBLOCA briefly examined.

When developing PDO options were used in some cases, considerable thermal margin could be gained in terms of fuel sheath temperature. However there was only small difference in sheath temperatures when DEV-PDO-1 or DEV-PDO 6 option in CATHENA was used.

REFERENCES

[1] A. Tahir, A. Popescu and J. Sun, "Improving The Post Dryout Methodology," COG-12-2055, CANDU Owners Group Inc., June 2013.

[2] Y. Guo, "Best-estimate Correlations for Predicting Minimum Post-Dryout Heat Transfer Coefficients in 37-element Bundles," COG-06-2060, CANDU Owners Group Inc., Oct. 2007.

[3] T. G. Beuthe and B. N. Hanna, "CATHENA 3.5.4.4 GENHTP Input Reference,"153-112020-UM-007, Rev.0, AECL, 2013.

[4] B. J. Moon and T. M. Kim, "CATHENA Above Header Model," 59RF-03500-AR-010, Rev.0, KEPCO-E&C, 2008.

[5] B. J. Moon, "CATHENA Fuel Channel Model," 59RF-03500-AR-009, Rev.1, KEPCO-E&C, 2009.

[6] S. R. Kim and C. W. Kim, "CATHENA Secondary Side Model," 59RF-03500-AR-011, KEPCO-E&C, 2008.

[7] S. R. Kim and B. J. Moon, "CATHENA Emergency Core Cooling System Model," 59RF-03500-AR-012, Rev.1. KEPCO-E&C, 2009.

[8] B. J. Moon, "CATHENA Slave Channel for Wolsong Fuel and Fuel Channel Model," 59RF-03500-AR-003, KEPCO-E&C, 2009.

[9] S. R. Kim, "CATHENA Trip Coverage Model," 59RF-03500-AR-002, Rev.1. KEPCO-E&C, 2009.