Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 26-27, 2017

Comparison of Safety Analysis Results between Two CANDU 6 Plants with the Existing Fuel and with the Modified Fuel

Dongwook Kho*
KHNP Central Research Institute, 70 Yuseong-daero, 1312-beongil, Yuseong-gu, Daejeon, 34101
**Corresponding author: dongwookkho@khnp.co.kr*

1. Introduction

A new modified 37-element fuel, which is the same as the existing 37-element fuel except slightly reduced center pin diameter, was developed by Canadian utilities several years ago, and then KHNP decided to commercialize the new fuel in Korea in 2013. The new fuel has better CHF(Critical Heat Flux) characteristic than the existing fuel. It is known that CHF value of the new fuel can even be enhanced upto 16.9% higher than the existing fuel at 5.1% diametral pressure tube creep[1].

At present the FSAR(Final Safety Analysis Report) with regard to the new fuel is being reviewing by a regulatory body. In preparing the FSAR Chap 15, the most recent versions of safety analysis codes were used, and the plant system thermal-hydraulic models of CATHENA(Canadian Algorithm for THErmal-hydraulic Network Analysis) [2] code were also newly developed. So in order to see the only effect of loading the new fuel into the CANDU 6 Wolsong NPP on the safety analysis results, simple comparison between the existing FSAR Chap 15 and the newly prepared FSAR Chap 15 would seem not to be enough. It is because there are many differences between analysis assumptions of the two FSAR Chap 15 as well as fuel difference, such as safety analysis codes used, plant system models of CATHENA code and consideration of plant system aging effect, etc.

Therefore two selected accidents were analyzed to compare the results and to see the only effect of loading the new fuel on the existing safety analysis results using two respective CATHENA CANDU 6 plants models with the existing fuel loaded and the new modified fuel loaded. A 2.5% RIH(Reactor Inlet Header) SBLOCA(Small Break Loss of Coolant Accident) and a total LOCL4(Loss of Class IV power accident) were selected because they were expected to be most affected by the enhanced CHF of the new fuel as slow transient accidents.

2. Analysis Method and Assumption

Each CATHENA model was developed for a Wolsong CANDU 6 plant at some aged condition with the existing fuel fully loaded and with the modified fuel fully loaded, respectively[3]. The two CATHENA CANDU 6 plant models are nearly the same except fuels: One is with the existing fuel and the other with the modified 37-element fuel. So, with these models it can be seen only the effect of the fuel difference on safety analysis results.

2.5% RIH SBLOCA is an accident with the largest break size and the most limiting case among CANDU 6 SBLOCA. Total LOCL4 is also the most limiting case in loss of class IV power accidents. Therefore it can be seen the effect of the enhanced CHF of the new fuel on safety analysis results of the two slow transient events.

2.1 2.5% RIH Small Break Loss of Coolant Accident

SBLOCA is an accident losing coolant inventory through a pipe break from the PHTS(Primary Heat Transport System), so long-term fuel cooling have to be ensured by ECCS(Emergency Core Cooling System) and thermal-hydraulic analysis have to be performed until long-term fuel cooling is confirmed. A CATHENA model for SBLOCA analysis consists of PHTS system model with 28 multiple average channels and a pressurizer, ECCS and secondary side feedwater and steam systems. From this plant system model, general behavior of the PHTS and secondary side systems and most process trip times can be calculated and boundary conditions at inlet and outlet reactor headers are also produced for single channel analysis. In single channel analysis, the maximum fuel, sheath and pressure tube temperatures can be obtained by assuming conservative and limiting channel and bundle powers. For an example, the O6mod channel has the lowest thermal margin to dyrout and is assumed to have bundle and channel power limits.

2.2 Total Loss of Class IV power Accident

Total LOCL4 is a Non-LOCA event where analysis scope is only about demonstration of trip coverage. There have to be generally at least two effective reactor shutdown trip parameters on each shutdown system before integrities of fuel, sheath, pressure tube and PHTS are lost. A CATHENA plant system model with RRS(Reactor Regulating System) functions and detailed two shutdown system models and without ECCS is used for the trip coverage analysis. The O6mod and B10 channel models are used to check fuel channel dryout and low flow trip time, respectively.

3. Results

3.1 2.5% RIH Small Break Loss of Coolant Accident

Fig. 1, Fig. 2 and Fig. 3 are pressures at RIH8(broken header), flows in corepass 4(broken corepass) and break discharge flow. In each figure there are two curves: one for the new fuel and the other for the existing fuel. In Fig. 1, Fig. 2 and Fig. 3 there were only slight differences in calculation results for the two cases. Also there were only small differences between the two cases in event sequence as shown in Table 1. Fig. 4 shows maximum fuel sheath temperatures in O6mod channels, and here sheath temperatures of the new fuel and the existing fuel showed big difference before 100 seconds, where sheath temperature of the existing fuel was increased upto 585.8℃ due to sheath dryout but that of the new fuel didn't show any rise.

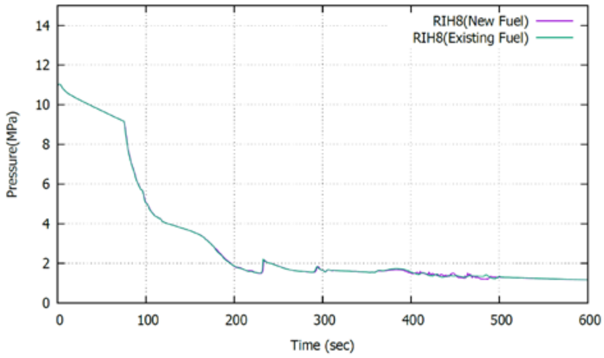

Fig. 1 RIH8 Pressure

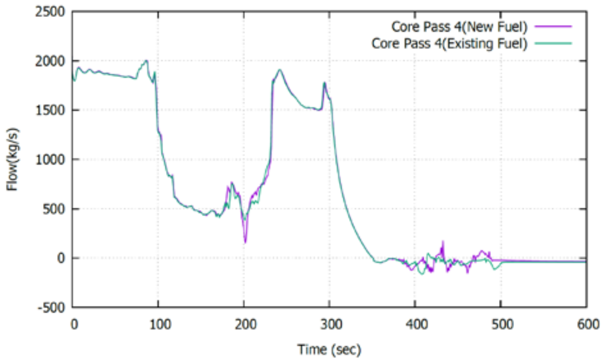

Fig. 2 Corepass 4 Flow

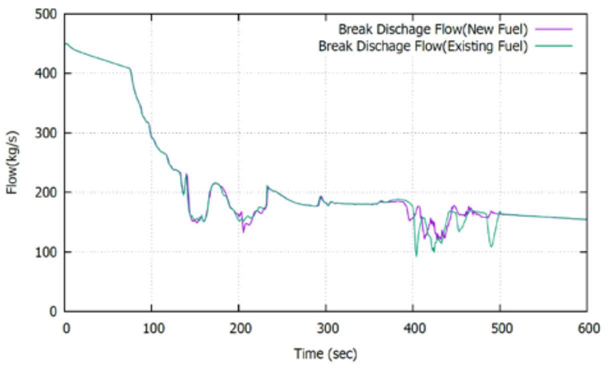

Fig. 3 Break discharge flow

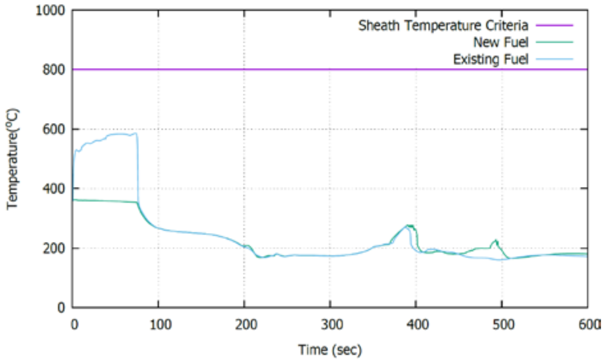

Fig. 4 Maximum fuel sheath temperature in O6mod channel

Table 1 Event sequence for 2.5% RIH SBLOCA

Event	New Fue (sec)	Existing Fuel (sec)
Break occurs	0	0
Low HTS pressure Second reactor trip signal	47.3	46.8
LOCA signal(5.25 MPa(a))	99.9	99.5
Loop isolation completed	119.9	119.5
Steam generator crash cooldown	121.0	120.6
ECC injection to broken loop begins	101.7	100.7
HP pump trip signal(2.6 MPa(a))	178.0	177.7
Broken loop refilled (loop void fraction < 1%)	233.5	232.8
Intact loop refilled (loop void fraction < 1%)	291.8	291.2
HP pump trip	298.0	297.7
Medium pressure ECC injection starts	952.3	955.8
Low pressure ECC injection starts	2271	2276

3.2 Total Loss of Class IV power Accident

Fig. 5 shows maximum fuel sheath temperature of the both the fuels when the reactors tripped on a latter signal among the second SDS1(Shutdown System No.1) trip signal and the second SDS2(Shut down System No.2) trip signal. From Fig.5, it was shown that enhanced CHF characteristic of the new fuel made fuel sheath dryout delayed about two seconds later than the existing fuel. Meanwhile, low flow trip times were nearly the same each other as 3.5 sec from the B10 channel analysis although it was expected that low flow trip of B10 channel with the modified 37-element fuel might occur slower than that with the existing fuel.

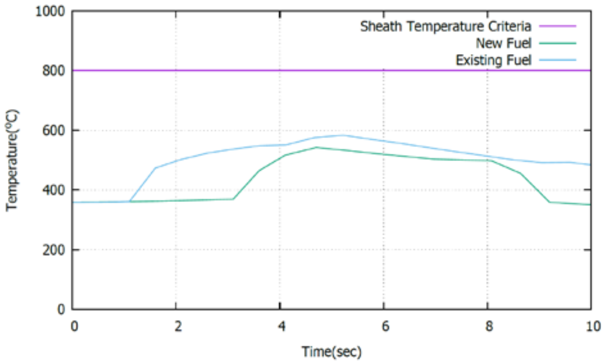

Fig. 5 Maximum fuel sheath temperature

3. Conclusions

In order to investigate the only effect of loading the modified fuel into CANDU 6 plant on safety analysis results, two CATHENA plant system models with the new fuel fully loaded and with the existing fuel fully loaded, respectively, were used to analyze two selected accident cases of 2.5% RIH SBLOCA and total LOCL4. From the analysis results above, it could be concluded that the new fuel has an effect of enhancing thermal margin in slow transient safety analysis results at aged plant condition.

REFERENCES

[1] R. A. Fortman, Critical Heat Flux and Post-Dryout Experiments Using The Modified 37-Element Fuel Simulation in Water, COG-08-2104, CANDU Owners Group Inc., July 2009.

[2] T. Beuthe and B. N. Hanna, User's Manual CATHENA 3.5.5.4 INPUT REFERENCE, 153-112020-UM-006, Rev.0, AECL, Oct. 2013.

[3] S. M. Kim, E. S. Ryu, S. C. You, D. H. Park, and D. W. Kho, Safety Analysis Report for Transition Core of Wolsong CANDU Modified 37-Element Fuel bundles, KHNP Central Research Institute, 2015-50003339-단-0302TR, May 2015.