The Sensitivity Analysis of Axial Pressure Tube Creep Profile for Dryout Power in PHWR

Euiseung Ryu [a*], Youngae Kim [a]
[a]*KHNP Central Research Institute, 1312-70 Yuseongdae-Ro, Yuseong-Gu, Daejeon 305-343, Korea*
[*]*Corresponding author: esryu2002@khnp.co.kr*

1. Introduction

CANDU nuclear power plants have been decreased reactor power caused by aging. One of the aging phenomenons in PHWR is pressure tube diametral creep. As diametral creep increases, the coolant flow through the inside suchannels of fuel bundle is reduced, consequently it makes decrease of CHF(Critical Heat Flux) value. For applying of this diametral creep effect, crept pressure tubes(3.3%, 5.1% peak) have been used during CHF test in Canada, Stern Laboratory from the 1990's[1, 2]. The Stern Laboratory performed the CHF tests with only one axial pressure tube creep profile per 3.3%, 5.1% peak crept channel and made CHF correlation including creep factor from the CHF test results. Wolsong nuclear power plants also have utilized the same CHF correlation derived by CNL.

Pressure tube diameter creep rate is function of fast neutron, coolant temperature, and coolant pressure in a channel. It means that various axial pressure tube creep profiles exist in PHWR due to the history of operating conditions. Usually, CHF correlation is used during ROP(Regional Overpower Protection) Trip Setpoint Analysis or Safety Analysis in PHWR. The sensitivity analysis for CHF effects using various creep profiles is needed. This paper summarizes the comparison results of dryout power between CHF test creep profile and estimated creep profiles of Wolsong units.

2. Analysis Method

The tube liners used for the 37-element fuel bundle CHF test series are designed to provide an axial creep profile, representing as aged pressure tube with a maximum 3.3% and 5.1% of diametral creep and the same axial creep profiles are used from the 1990's. Wolsong units experienced different operational flow conditions in all 380 channels, it means the various axial creep profiles exists based on operating history.

To assess the CHF effects between test axial creep profile and Wolsong's axial creep profiles, subchannel analysis is performed with ASSERT-PV 3.2 code. The ASSERT-PV code is to calculate thermal hydraulic parameters in a horizontal PHWR fuel channel including pressure drop, dryout power, dryout location and post-dryout fuel sheath temperature for steady state or slow transient conditions[3].

The ASSERT model used in this analysis simulated modified 37-element fuel bundle for CHF experiments conducted by Stern Lab.[4]. The model includes: test fuel geometry(fuel bundle diameter, pitch circles, inter element spacer heights, bearing pad heights), pressure tube diameter and axial creep profile. Flow subchannels are modeled 60 nodes, illustrated in Fig. 1.

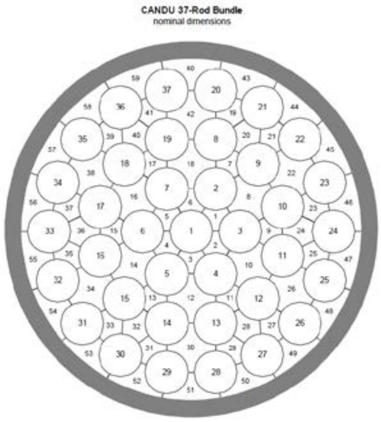

Fig. 1. Element and subchannel numbering scheme

To assess the CHF sensitivity, calculated the dryout power changing with

1) various test conditions(inlet temperature, mass flow rate, outlet pressure)
2) test axial creep profile and Wolong predicted axial creep profiles(380 channels)

The channel wise maximum diametral creep rate of the same reactor is very different at the same FPD(Full Power Day). It is very typical in PHWR because the history of operational condition is very different per each channel. To match with the 3.3% and 5.1% of test creep condition, the amplitude of peaked creep rate for Wolsong is increased by 3.3% and 5.1%.

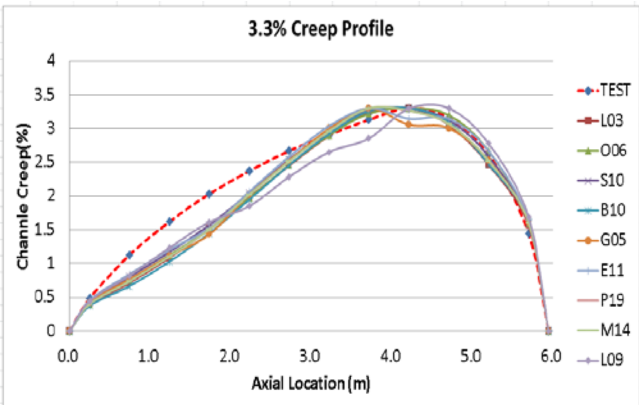

Fig. 2. 3.3% Test and Wolsong's creep profiles

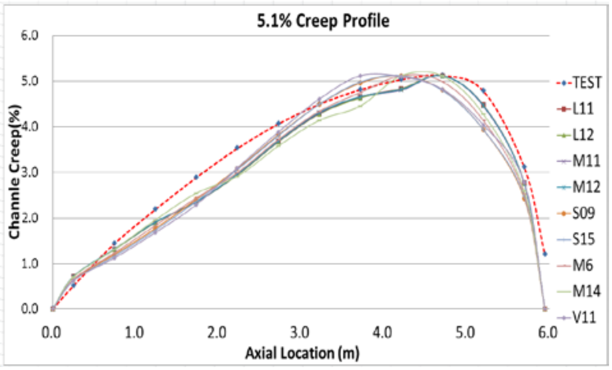

Fig. 3. 5.1% Test and Wolsong's creep profiles

3. Analysis Result

3.1 Dryout power sensitivity with test conditions

For the dryout power sensitivity analysis with test conditions(inlet temperature, mass flow rate, outlet pressure), used 124 test conditions for 3.3% and 123 test conditions for 5.1% creep independently with six creep profiles which are a CHF test profile and five Wolsong's creep profiles(B10, G5, L3, O6, S10 channel). These channels are usually used for confirming the fuel channel integrity in safety analysis. As a result, the dryout power value with test axial creep profile is slightly smaller than dryout power values with Wolsong's creep profiles at all test condition cases. Table 1 and Table 2 show the %deviation of dryout power compared with test creep profile in 3.3% and 5.1% creep. The deviation for 5.1% creep is larger than in 3.3% creep.

Table 1. % Deviation of dryout power compared with test creep profile in 3.3% creep(124cases)

Channel (Used Creep profile)	Average Deviation (%)	Maximum Deviation (%)	Minimum Deviation (%)
B10	1.23	3.05	0.03
G05	1.15	3.00	0.22
L03	1.24	3.04	0.10
O06	0.97	1.60	0.10
S10	0.82	1.59	0.07

Table 2. % Deviation of dryout power compared with test creep profile in 5.1% creep(123cases)

Channel (Used Creep profile)	Average Deviation (%)	Maximum Deviation (%)	Minimum Deviation (%)
B10	1.87	4.67	0.46
G05	1.81	4.63	0.56
L03	1.90	4.61	0.49
O06	1.41	5.05	0.38
S10	1.14	3.62	0.09

Minimum deviations show positive(+) values, it means dryout power with Wolsong's Creep profiles are larger than with test creep profile in all flow conditions. Fig. 4 is illustrated the comparison of dryout power with various creep profiles at test condition 258℃, 9MPa. It shows that the calculated dryout powers maintain a consistency regardless of flow conditions.

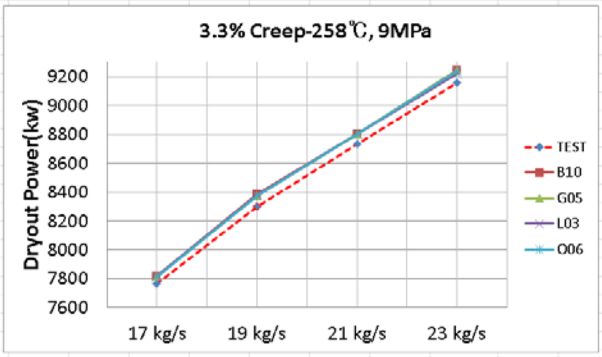

Fig. 4. Comparison of dryout power with 3.3%(258℃, 9MPa)

3.2 Dryout power sensitivity with 380 creep profiles

In order to evaluate the sensitivity for axial creep profiles of Wolsong, a CHF test creep profile and 380 all creep profiles with five flow conditions were used. Table 3 shows the boundary condition for each sensitivity calculation case to compare dryout power between 5.1% test creep profile condition and 5.1% Wolsong creep profiles(380 each).

Table 3. Simulated flow condition for comparison dryout power with 381 axial crept(5.1%) profiles

Flow Condition (No.)	Inlet Temperature (℃)	Outlet Pressure (MPa)	Mass Flow Rate (kg/s)
CASE1	256.6	10.0	23.08
CASE2	263.3	11.0	17.00
CASE3	268.4	9.0	19.03
CASE4	265.5	10.0	20.96
CASE5	257.6	11.0	20.98

As a result, the dryout powers of test profile are slightly smaller than those of 380 Wolsong creep profiles in CASE1~CASE5. It shows the derived CHF correlation using Stern test data is conservative than using real channel creep condition. %deviations of dryout power for CASE1, CASE2, and CASE4 are shown in Fig. 5 ~ Fig. 7, respectively. These show all of those are positive(+) values. It means that dryout power using Wolsong 380 creep profiles are larger than those using test creep profile.

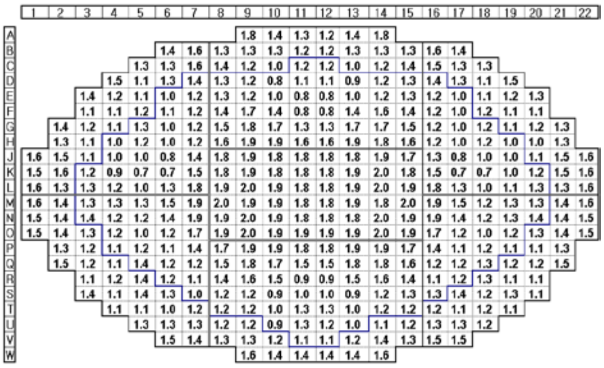

Fig. 5.
% Deviation of CASE1
% Deviation = [(Dryout Power $_{Wolsong's\ Profile}$ / Dryout Power $_{Test\ Profile}$) -1] x 100]

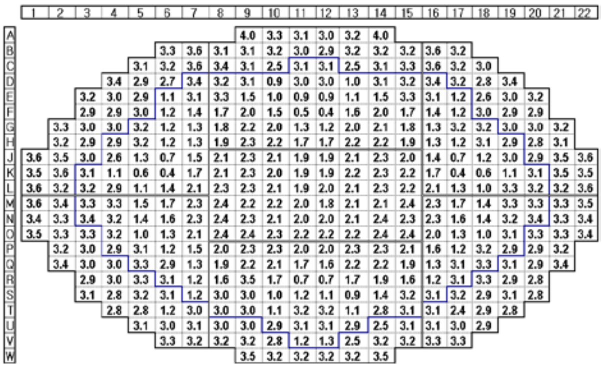

Fig. 6.
% Deviation of CASE2
% Deviation = [(Dryout Power $_{Wolsong's\ Profile}$ / Dryout Power $_{Test\ Profile}$) -1] x 100]

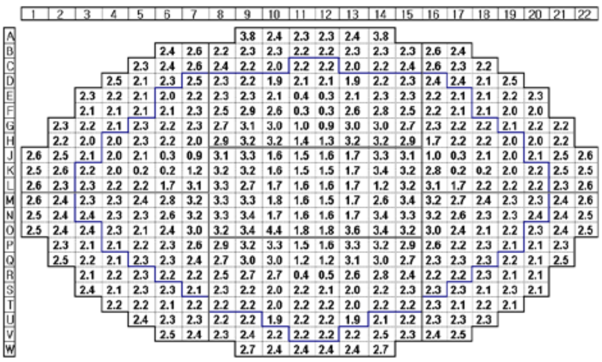

Fig. 7.
% Deviation of CASE4
% Deviation = [(Dryout Power $_{Wolsong's\ Profile}$ / Dryout Power $_{Test\ Profile}$) -1] x 100]

3. Conclusions

The effect of axial pressure tube creep profile for dryout power in fuel channel is evaluated by using Stern Lab. CHF test creep profile and 380 channel creep profiles of Wolsong. The dryout powers at 3.3% and 5.1% test conditions are slightly smaller when using 380 Wolsong channels creep profiles. These also show that the simulated dryout powers maintain consistency regardless of flow conditions. In conclusion, the derived CHF correlation using Stern Lab. test creep profile is conservative to use reactor analysis.

REFERENCES

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