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The Effect of PT Creep in Loss of Flow Accident for CANDU NPP

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1. Introduction

Pressure tubes in CANDU plants have expanded in radial and axial direction as they are located in high radiation environment along with high coolant temperature and pressure. The pressure tube creep which is radial expansion of the pressure tube is increasing as operating time is increased. As the amount of pressure tube creep is increased, the net coolant flow which effectively removes the heat generated from fuel rod is reduced. In terms of regional overpower trip (ROPT) assessment, reduced safety margin can be maintained by reducing operating power. But until now the effect of pressure tube creep on safety analysis is not considered yet. Here the effect of pressure tube creep on thermal hydraulics is considered here.

2. Analysis Methods

Pressure tube creep is modeled in CATHENA slave channel model for CANFLEX fuel core. The effect of PT creep on fuel integrity is assessed with O-6 high power channel. It is assumed that channel power is 7.3MW and maximum bundle power is 935KW. The creep for each bundle location is modeled by RC-1980 using wolsong-1 measured pressure tube data. Loss of flow is characterized by reduced coolant flow with the malfunction of PHT pump, pump seizure or small LOCA etc. Reduced flow can induce fuel failure due to fuel heating. Here the analysis is performed for loss of class IV which prevents the supply of power to all PHT pump.

2.1. Pressure tube creep

The amount of pressure tube creep in CANDU NPP is dependent on the radiation, coolant pressure and temperature. The measured data for pressure tube creep came from Wolsong-1 NPP. Total 51 channels were measured at four different times; 11, 17, 14 and 9 channels respectably at 1990, 1992, 1994 and 2001. Based on the measured creep data, the diametral creep for each fuel bundle location in all 380 channels is predicted using RC-1980 program. The accuracy of RC-1980 prediction is measured by comparing the prediction value with measured creep at the 51 measured channels. It is known that usually maximum creep reaches around 4~5% at end of plant lifetime. Figure 1 shows the amount of creep in terms of plant operating time.

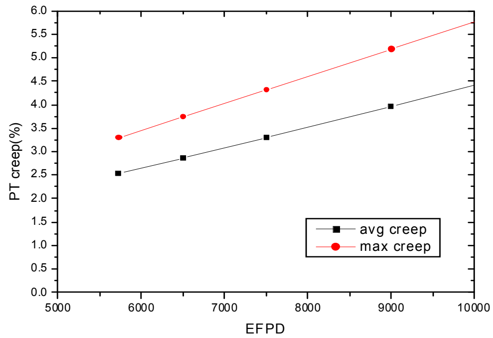

Figure 1 PT creep (%) vs. EFPD

Table 1 Steady state value at 103% FP

Parameters		Value
Outlet head pressure (MPa(a))	ROH 1	11.36
	ROH 3	11.36
	ROH 5	11.36
	ROH 7	11.36
Inlet head pressure (MPa(a))	RIH 2	10.03
	RIH 4	10.02
	RIH 6	10.02
	RIH 8	10.03
S/G drum pressure (MPa(a))		4.69
Inlet coolant temperature (℃)		268
Outlet coolant temperature (℃)		311
Core flow per pass (kg/s)		1,898
Pressurizer level (m)		12.5
Pressurizer pressure (MPa(a))		9.98

2.2. Loss of Flow Accident

The effect of pressure tube creep on thermal hydraulics is prominent in the accidents where loss of flow can affect fuel integrity. Class IV power supplies electricity to most pumps used in plants including PHT pump. Loss of class IV can reduce PHT flow and incur heat-cooling mismatch. Circuit analysis at 103% FP is performed with CATHENA and Loss of class IV transient is assumed to occur at 0.0 sec. The trip time for each trip parameter is shown in Table 2. For shutdown system 1, high pressure trip, high neutron power trip and low channel flow trip occurs. For the more detailed analysis, the header boundary conditions such as header pressure, coolant enthalpy and specific volume are transferred to slave channel analysis.

Table 2 Trip times for Loss of class IV

SDS1		SDS2	
HP	3.39 sec	HNP	3.59 sec
HNP	3.59 sec	HP	5.51 sec
LF	4.01 sec	DP	5.61 sec

HP : High pressure trip
HNP: High neutron power trip
LF : Low channel flow trip
DP: Header to Header Differtial pressure trip

2.3. Slave Channel Analysis

The effectiveness of shutdown system is analyzed in terms of fuel and fuel channel integrity. The pressure tube creep makes more coolant bypass the fuel, which can make fuel heat-up in loss of flow accident. The creep of pressure tube is modeled in slave channel with CREPT_PT module in CATHENA with Leung's heat transfer correlation.

2.3.1 Creep profile

The creep profiles in O6 slave channel are skewed cosine shape because the power at the inlet region is lower than central region [Figure 5]. Here after the value of creep means the maximum value of creep in a channel.

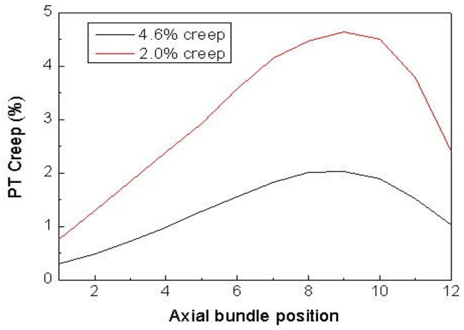

Figure 2 Reactor building pressure for 0.8% break

2.3.2 Fuel integrity

The integrity of fuel is guaranteed if design sheath temperature is less than 800℃. Loss of class IV power at 103% FP is simulated for various amounts of pressure tube creep. The sheath temperature for 4% PT creep case increases up to 874℃ at 8 sec compared with 789℃ for 0% creep case as shown in Figure 3. For 2% PT creep the maximum sheath temperature is increased to 852℃.

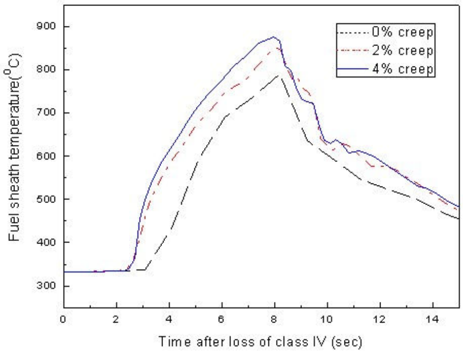

Figure 3 fuel sheath temperature for PT creeps

3. Results

The effect of pressure tube creep on the current safety analysis basis is examined for loss of flow accident. The maximum fuel sheath temperature for total loss of class IV is increased by around 80℃ and dryout time occurs earlier compared with current methodology. The effectiveness of trip parameter can be affected because the fuel integrity is one part of trip coverage analysis. The trip coverage analysis with PT creep effect will be further developed.

REFERENCES

[1] CATHENA Mod-3.5c Input Reference, 1999, AECL
[2] FSAR for Wolsong-2,3,4
[3] 86-03500-AR-009 CATHENA fuel channel model, AECL
[4] W1-CANFLEX-AR-015 Trip coverage analysis for loss of class IV power, KEPR