Investigation of Thermal-Hydraulic Characteristics on Aging Effect for CANDU Reactors

Jun Soo Yoo,[a] Yong Won Choi,[a] Chang Hwan Park,[a] Un Chul Lee,[a]
Dept. Nuclear Engr. Seoul Nat'l Univ., Shillim-dong, Kwanak-gu, Seoul, 151-744, kaks2000@snu.ac.kr

Manwoong Kim, Sang Kyu Lee, Hyun-Koon Kim,
Korea Institute of Nuclear Safety, Goosong-dong, Yusong-gu, Daejeon, 19, mwkim@kins.re..kr

1. Introduction

Considering that operating year of Wolsong Unit 1 gets close to the design life, 30 years, the aging effect due to the component degradation takes into consideration as an important safety issue. However, since the thermal-hydraulic effect due to the aging did not identify clearly, the safety analysis methodology is not well established so far. Therefore, in this study, the aging effect affected thermal-hydraulic characteristics was investigated and a preliminary safety analysis methodology considering aging effect was proposed

2. Thermal-hydraulic Characteristics Analysis

In this study, after identifying aging phenomena by component degradation in CANDU reactors, various elements are determined to analysis the thermal-hydraulic phenomena using RELAP-CANDU code. In addition, an uncertainty analysis is also conducted using the statistical method like a random sampling analysis. Thereafter the influence of aging effects on the safety is identified for CANDU reactors.

2.1 Ageing Effect Elements

As for CANDU reactors, the following ageing elements are considered in Reference 1.

Table 1: Ageing effects and applicable code input

Aging Effects	**Code Input**	
Neutron irradiation embrittlement	Conductivity change	Not considered
SCC	Small leak junction	Not considered
Corrosion	Roughness Junction loss coefficient Hydraulic diameter	Applied to sub-channel
Fatigue	-	Not considered
Stress relaxation	Hydraulic diameter	Not considered
Creep, Growth and Sag	Junction loss coefficient Hydraulic diameter Junction model option	Applied to sub-channel
Wear	Roughness	Applied to average channel
Pump degradation	Pump head Rated flow	Not considered
etc	etc	-

2.2 Safety Analysis

LBLOCA is considered as an accident scenario because it enables to identify thermal-hydraulic effects most obviously among most accidents. To analysis LBLOCA, an average channel, composed of 95 assemblies, is divided into 1 average channel and 3 sub channels to observe the local ageing effects as shown in Fig. 1.

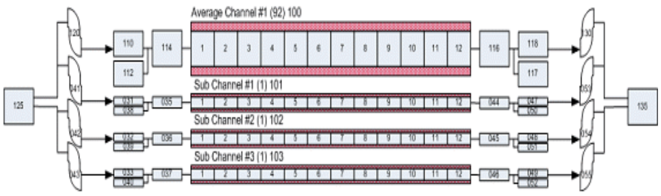

Figure 1: Core flow at sub channel 2 during steady state

Average channel 1: Effect of wear through wide region is applied.
Sub channel 1: Corrosion effect by ageing is applied.
Sub channel 2: Creep and Sag effect by ageing is applied.
Sub channel 3: Complex effect by ageing is applied.

2.3 Assumptions Estimation of the ageing model

Table 2: Ageing effects and applicable code input

Aging Effects	**Applied Variable**	**Assumed degree of ageing**	**Assumed ageing function**
Corrosion	roughness	1000.0% for 60year	$f = e^{0.039965x}$
	Junction loss coefficient	200.0% for 60year	$f = e^{0.0183102x}$
	Hydraulic diameter	5.0% for 60year	$f = e^{-0.000855x}$
Creep, Growth, and Sag	Volume area	5.0% for 60year	$f = e^{-0.00085}$
	Junction area	5.0% for 60year	$f = e^{-0.00085}$
	Junction loss coefficient	200.0% for 60year	$f = e^{0.0183102x}$
	Hydraulic diameter	2.5% for 60year	$f = e^{-0.000422x}$
Wear	roughness	50.0% for 60year	$f = e^{-0.01155x}$
	Junction area	2.0% for 60year	$f = e^{-0.000336}$
	Volume area	2.0% for 60year	$f = e^{-0.000336}$

2.4 Simulation of ageing effect using statistical method

We selected various values of variables using statistical method, random sampling to consider uncertainty.

3. Results

3.1 Results of ageing effects according to operation time

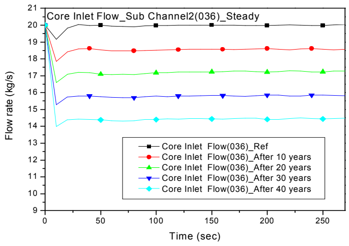

Figure 2: Core flow at sub channel 2 during steady state

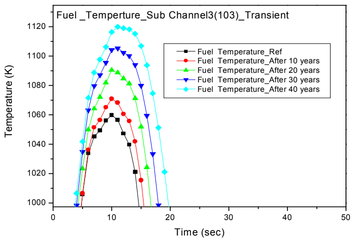

Figure 3: Fuel temperature at sub channel 3 during LBLOCA

3.1 Results when using statistical method

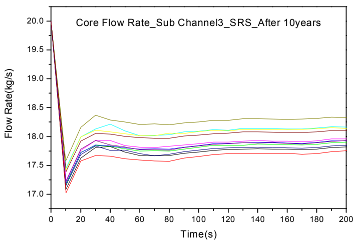

Figure 4: Core flow distribution at sub channel 3 during steady state after 10years

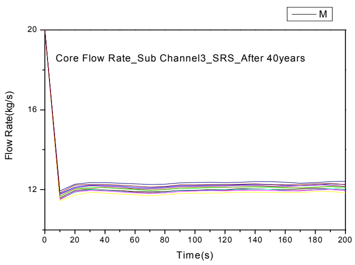

Figure 5: Core flow distribution at sub channel 3 during steady state after 40years

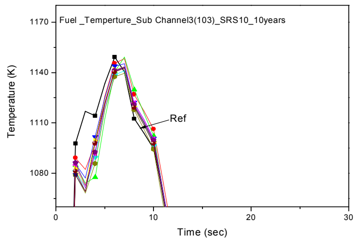

Figure 6: Fuel temperature distribution at sub channel 3 during LBLOCA after 10years

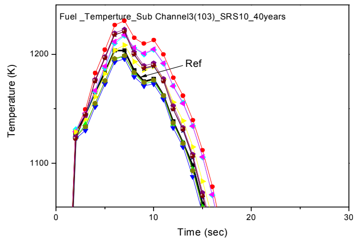

Figure 7: Fuel temperature distribution at sub channel 3 during LBLOCA after 40years

4. Conclusion

In this study, it is found that the thermal-hydraulic characteristics due to aging effects varies in accordance with the operation time during steady or transient state in CANDU reactors. To uncertainty analysis, it is recognized to apply the statistical method to the future research. In conclusion, as more realistic aging model is applied to, more reliable results of safety analysis could be achieved. Therefore, there is a need to consider more aging elements in the future study as follows: the changing rate of various variables by ageing, what variables should be chosen to consider ageing effects, how the change of variable by ageing is applied to code input, etc.

REFERENCES

[1] IAEA, “Assessment and management of ageing of major nuclear power plant components important to safety: CANDU Reactors assemblies” IAEA-TECDOC-1197, April 2001.

[2] IAEA, “Safety margins of operating reactors-Analysis of uncertainties and implications for decision making”,IAEA-TECDOC-1332, January 2003.