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Study on Developing Degradation Model for Nuclear Power Plants With Ageing Elements Affected on Operation Parameter

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1. Introduction

As a part of development the evaluation system of safety margin effects for degradation of CANDU reactors,[1] it is required that the degradation model represents the distribution of each ageing factor's value during operating year. Unfortunately, it is not easy to make an explicit relation between the RELAP-CANDU parameters and ageing mechanism because of insufficient data and lack of applicable models.

So, operating parameter related with ageing is used for range determination of ageing factor. Then, relation between operating parameter and ageing elements is analyzed and ageing constant values for degradation model are determined. Also the other ageing factor is derived for more accurate ageing analysis.

2. Analysis of relation between ageing elements and operation parameter

In this chapter, the sensitivity study is conducted to analyze the trend of operating variable with ageing factor changing.

2.1 The sensitivity study for analysis of relation between ageing elements and operation parameter

The major operating parameters that are changed with ageing factors are selected as table I. Then sensitivity analysis is performed to understand the trend of operating parameter. And these results will be utilized to determine constant values for degradation model. The major results are represented as figure 1~3 and table II.

TABLE I

The operating parameter related variation of ageing factors

Ageing Component	The operating parameter	Related ageing elements
Fuel Channel	Reactor Inlet Header Temperature	Fuel channel roughness, Fuel channel loss coefficient, Fuel channel hydraulic diameter, Fuel channel flow area, S/G roughness, S/G hydraulic diameter, Pump head, Pump rated flow,
	Reactor Inlet Header Pressure	
	Reactor Out Header Pressure	
	RIH-ROH Δ P	
	Flow	
Pump	HT suction pressure	
	HT discharge pressure	
	HT Pump Δ P	
Steam Generator	S/G Inlet Temperature	
	S/G Outlet Temperature	

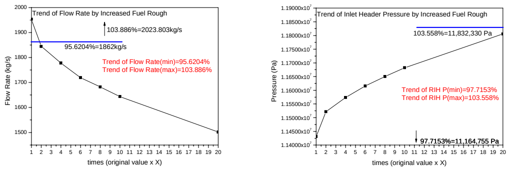


Fig. 1. Sensitivity Study of relation between ageing elements and operation parameter (fuel channel roughness)

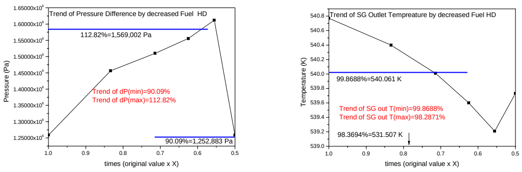


Fig. 2. Sensitivity Study of relation between ageing elements and operation parameter (fuel hydraulic diameter)

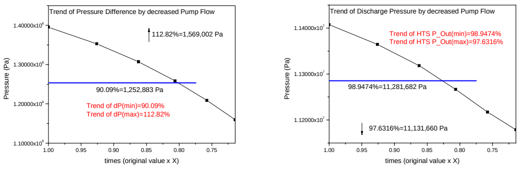


Fig. 3. Sensitivity Study of relation between ageing elements and operation parameter (Pump rated flow)

Upper results show behavior of operating parameter with variation of ageing elements. Also these results represent that there are some relations between ageing elements and operating parameters. If the effects on operation parameter are regarded as single effect with one ageing element, it is possible to determine the constant values of degradation model conservatively.

2.2 Determination of ageing constants for degradation model

At First the degradation model is made with weibull distribution and bath-tub curve as the Eq. (1). And ageing constant values are determined using the results of sensitivity study and realistic data of operation parameter. Table II shows the determined constant values (C) and degradation model. Each constant value is determined to have the longest range. Because it is for covering all range as possible as.

$$\lambda(t) = C(t-r)^{m-1}$$

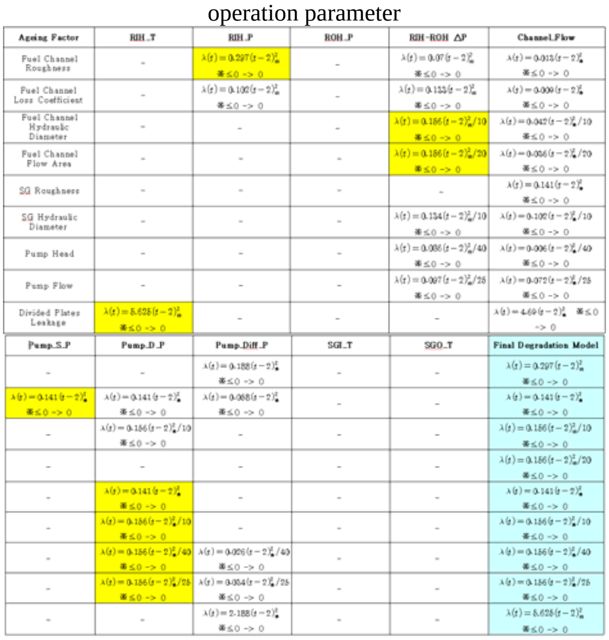
=> $m = shape\ \ parameter$ Eq. (1)

$r = threshold\ \ time$

$C = ageing\ \ const$

TABLE II

The Degradation Model with ageing elements affected on operation parameter



Ageing Factor	RIH_T	RIH_P	ROH_P	RIH-ROH ΔP	Channel.Flow	Pump.S_P	Pump.D_P	Pump.Diff_P	SGI_T	SGO_T	Final Degradation Model
Fuel Channel Roughness	-	$\lambda(t)=0.297(t-2)_{※}^{2}$ ※≤0 -> 0	-	$\lambda(t)=0.07(t-2)_{※}^{2}$ ※≤0 -> 0	$\lambda(t)=0.013(t-2)_{※}^{2}$ ※≤0 -> 0	-	-	$\lambda(t)=0.188(t-2)_{※}^{2}$ ※≤0 -> 0	-	-	$\lambda(t)=0.297(t-2)_{※}^{2}$ ※≤0 -> 0
Fuel Channel Loss Coefficient	-	$\lambda(t)=0.102(t-2)_{※}^{2}$ ※≤0 -> 0	-	$\lambda(t)=0.133(t-2)_{※}^{2}$ ※≤0 -> 0	$\lambda(t)=0.009(t-2)_{※}^{2}$ ※≤0 -> 0	$\lambda(t)=0.141(t-2)_{※}^{2}$ ※≤0 -> 0	$\lambda(t)=0.141(t-2)_{※}^{2}$ ※≤0 -> 0	$\lambda(t)=0.068(t-2)_{※}^{2}$ ※≤0 -> 0	-	-	$\lambda(t)=0.141(t-2)_{※}^{2}$ ※≤0 -> 0
Fuel Channel Hydraulic Diameter	-	-	-	$\lambda(t)=0.156(t-2)_{※}^{2}/10$ ※≤0 -> 0	$\lambda(t)=0.042(t-2)_{※}^{2}/10$ ※≤0 -> 0	-	$\lambda(t)=0.156(t-2)_{※}^{2}/10$ ※≤0 -> 0	-	-	-	$\lambda(t)=0.156(t-2)_{※}^{2}/10$ ※≤0 -> 0
Fuel Channel Flow Area	-	-	-	$\lambda(t)=0.156(t-2)_{※}^{2}/20$ ※≤0 -> 0	$\lambda(t)=0.036(t-2)_{※}^{2}/20$ ※≤0 -> 0	-	-	-	-	-	$\lambda(t)=0.156(t-2)_{※}^{2}/20$ ※≤0 -> 0
SG Roughness	-	-	-	-	$\lambda(t)=0.141(t-2)_{※}^{2}$ ※≤0 -> 0	-	$\lambda(t)=0.141(t-2)_{※}^{2}$ ※≤0 -> 0	-	-	-	$\lambda(t)=0.141(t-2)_{※}^{2}$ ※≤0 -> 0
SG Hydraulic Diameter	-	-	-	$\lambda(t)=0.134(t-2)_{※}^{2}/10$ ※≤0 -> 0	$\lambda(t)=0.102(t-2)_{※}^{2}/10$ ※≤0 -> 0	-	$\lambda(t)=0.156(t-2)_{※}^{2}/10$ ※≤0 -> 0	-	-	-	$\lambda(t)=0.156(t-2)_{※}^{2}/10$ ※≤0 -> 0
Pump Head	-	-	-	$\lambda(t)=0.086(t-2)_{※}^{2}/40$ ※≤0 -> 0	$\lambda(t)=0.006(t-2)_{※}^{2}/40$ ※≤0 -> 0	-	$\lambda(t)=0.156(t-2)_{※}^{2}/40$ ※≤0 -> 0	$\lambda(t)=0.026(t-2)_{※}^{2}/40$ ※≤0 -> 0	-	-	$\lambda(t)=0.156(t-2)_{※}^{2}/40$ ※≤0 -> 0
Pump Flow	-	-	-	$\lambda(t)=0.097(t-2)_{※}^{2}/25$ ※≤0 -> 0	$\lambda(t)=0.072(t-2)_{※}^{2}/25$ ※≤0 -> 0	-	$\lambda(t)=0.156(t-2)_{※}^{2}/25$ ※≤0 -> 0	$\lambda(t)=0.034(t-2)_{※}^{2}/25$ ※≤0 -> 0	-	-	$\lambda(t)=0.156(t-2)_{※}^{2}/25$ ※≤0 -> 0
Divided Plates Leakage	$\lambda(t)=5.625(t-2)_{※}^{2}$ ※≤0 -> 0	-	-	-	$\lambda(t)=4.69(t-2)_{※}^{2}$ ※≤0 -> 0	-	-	$\lambda(t)=2.188(t-2)_{※}^{2}$ ※≤0 -> 0	-	-	$\lambda(t)=5.625(t-2)_{※}^{2}$ ※≤0 -> 0

3. S/G divider plate leakage area as ageing factor

3.1 S/G divider plate leakage area

According to realistic data [4], the most of CANDU reactors that are considered as reference reactor have leakage on Divider Plate. And leakage area of divider plate is measured as 30~210cm^2. Also it affects operating parameters. For example, the Fig 4 represents inlet header temperature of Gentilly-2(CANDU reactor), there is rapid temperature drop on 1995 after replace Divider Plate. This shows that leakage of S/G divider plate affects increase of reactor inlet header temperature (RIH T). Because, in Steam Generator, Divider Plate isolates hot coolant passing through the heat exchanger from cold coolant which don't, so Divider Plate Leakage is considered as one reason of inlet header temperature increment. Then the nodalization is modified for consideration of Divider Plate Leakage and the Divider Plate Leakage Area is included as ageing factor.

The Fig 6 shows the result that is applied divider plate leakage. It represents increase of inlet header temperature with increase of leakage area.

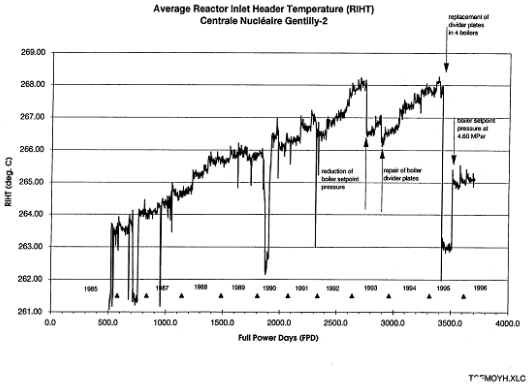


Fig. 4. Average reactor inlet header temperature (RIH T)[4]

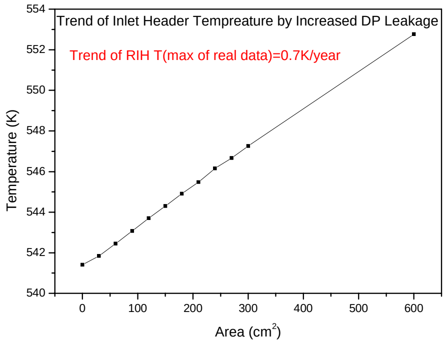


Fig. 5. Average reactor inlet header temperature with change of S/G divider plate leakage area (RIH T)

4. Conclusions

In this study, the method to determine ageing element range using real values of operating parameter is suggested. For this, the correlation analysis between operating parameters and ageing factors is performed. And ageing constant values are determined for degradation model. From the real NPP data, also the other ageing factor is included newly. This research could be contributed to development of degradation model with realistic data.

REFERENCES

[1] Y.W. Choi, M.W. Kim, "Development of Evaluation System of Safety Margin Effects for Degradation of CANDU Reactors Using RELAP-CANDU", ICAPP 2008, Jun 2008

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

[4] Richmond consulting service, "Technical consultative report about assessment of ageing safety issues for CANDU reactors", Feb 2008.