Study on Calculation of Uncertainty and Range of Ageing Elements using Measured Data of Fuel Channel Flow Rate

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1. Introduction

As a part of development the evaluation system of safety margin effects for degradation of CANDU reactors, [3] it is required the selection of ageing elements to analyze the thermal-hydraulic effects using RELAP-CANDU code. 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, in this study, to compensate lack of data and applicable models, measured data of fuel channel flow rate related with ageing are used for determination of range and uncertainty of ageing elements. Then, degradation model is upgraded through application of this result.

2. Analysis of dependency between ageing elements and fuel channel flow rate

In this chapter, the sensitivity study is conducted to analyze the dependency of fuel channel flow rate with ageing elements changing. And the degradation model is upgraded using measured data of fuel flow rate.

2.1 The sensitivity study

The major operating parameters that are changed with ageing elements are selected as table I. Then sensitivity analysis is performed to understand the dependency between ageing elements and fuel channel flow rate. Also relative values for fuel channel flow rate with time are analyzed as table II and Fig 1. As these results, during nine years, about 2.7% of flow rate is decreased due to ageing.

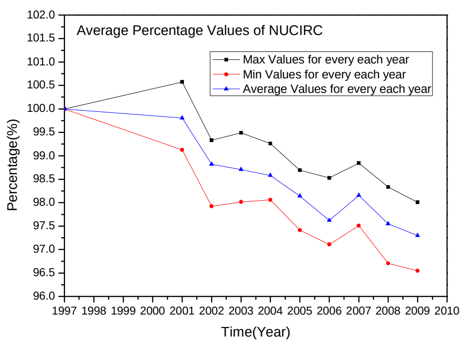

Fig. 1. The behaviors of channel flow rate with time

TABLE I

The operating parameter related variation of ageing elements

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	

TABLE II

Relative values for fuel channel flow rate with time (%)

	2001	2002	2003	2004	2005	2006	2007	2008	2009
Max per 1year	100.575	99.3334	99.4909	99.2622	98.6937	98.5261	98.8454	98.3354	98.0079
Min per 1year	99.1249	97.9257	98.0161	98.061	97.4156	97.1108	97.5104	96.7067	96.5463
Averageper1year	99.8043	98.8187	98.7079	98.5804	98.1429	97.6224	98.1564	97.5486	97.2995

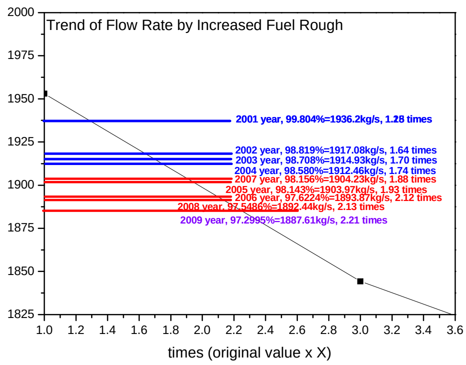

Fig. 2. Sensitivity Study of relation between ageing elements and operation parameter (fuel channel roughness)

Upper results show behavior of fuel channel flow rate 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. So variation of each ageing element with time is determined using data of relative values for fuel channel flow rate of wolsong unit 2. For example, case of fuel roughness, it is increased about 2.21 times for nine years. Where, average values for one year are used.

2.2 Upgrading of 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 analysis and realistic data of operation parameter. Table II shows the determined constant values (C), degradation model and uncertainty.

$$\lambda(t) = C(t-r)^{m-1}$$
$$\Rightarrow \; m = shape\ parameter \qquad \text{Eq. (1)}$$
$$r = threshold\ time$$
$$C = ageing\ const$$

TABLE II

The Degradation Model with ageing elements affected on operation parameter

Ageing element	Degradation model	Uncertainty($\pm\sigma$)
Fuel Channel Roughness	$\lambda(t) = 0.013(t-2)^2_※$ $※ \le 0 \to 0$	$\sigma = 1.86707\%$
Fuel Channel Loss Coefficient	$\lambda(t) = 0.009(t-2)^2_※$ $※ \le 0 \to 0$	$\sigma = 1.86707\%$
Fuel Channel Hydraulic Diameter	$\lambda(t) = 0.042(t-2)^2_※/10$ $※ \le 0 \to 0$	$\sigma = 1.86707\%$
Fuel Channel Flow Area	$\lambda(t) = 0.036(t-2)^2_※/20$ $※ \le 0 \to 0$	$\sigma = 1.86707\%$
SG Roughness	$\lambda(t) = 0.141(t-2)^2_※$ $※ \le 0 \to 0$	$\sigma = 1.86707\%$
SG Hydraulic Diameter	$\lambda(t) = 0.102(t-2)^2_※/10$ $※ \le 0 \to 0$	$\sigma = 1.86707\%$
Pump Head	$\lambda(t) = 0.006(t-2)^2_※/40$ $※ \le 0 \to 0$	$\sigma = 1.86707\%$
Pump Flow	$\lambda(t) = 0.072(t-2)^2_※/25$ $※ \le 0 \to 0$	$\sigma = 1.86707\%$
Divided Plates Leakage	$\lambda(t) = 4.69(t-2)^2_※$ $※ \le 0 \to 0$	$\sigma = 1.86707\%$

3. Conclusions

In this study, base on established study, the method to determined ageing element range and uncertainty is suggested using realistic data. Also degradation model is upgraded using measured data of fuel channel flow rate for wolsong unit 2. For this, the dependency analysis between operating parameters and ageing elements is performed. Also ageing constant values are recalculated for degradation model using these results.

So, this research could be contributed to development of degradation model with realistic data.

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