A Comparison of the Predicted Tube Plugging Rate for Alloy 600HTMA Steam Generator

Myung Hwan Boo [a*], Yong Seok Kang [a]
[a] *Nuclear Engineering & Technology Institute, Korea Hydro & Nuclear Power Co. Ltd., 25-1Jand-dong, Yuseong-Gu, Daejeon, KOREA, 305-343*
[*]Corresponding author: *bright@khnp.co.kr*

1. Introduction

To manage components that are used in long term operations such as steam generation, it is important to know the tube plugging rate, which can cause the performance degradation. The life of components can be predicted by the method using determinism and probability theory. With a method using probability theory, damage prediction of tube is possible [1, 2] .

In this study, damage prediction for steam generation (SG) tube is performed using Weibull distribution and predicted plugging rate (life) is compared with the simple sum plugging number and case by case (failure cause) plugging number.

2. Methods and Results

2.1 Weibull Distribution Function

The Weibull distribution is widely used to analyze the cumulative loss of performance, i.e., breakdown, of a complex system in engineering. The Weibull distribution is also available to express variable failure phenomena by changing parameters of some regular relation according to the operating time of the facilities. The formula for the probability density function of Weibull distribution is generally presented the following equation.

$$f(t)=\left(\frac{b}{\theta-t_o}\left(\frac{t-t_o}{\theta-t_o}\right)^{b-1}\right)\exp\left(-\left(\frac{t-t_o}{\theta-t_o}\right)^{b}\right) \quad (1)$$

where, *f(t)* is the probability density function, t is time (EFPY: Efficiency Full Power Years), t_o is the failure occurrence waiting time, b is the slope of Weibull function (the failure occurrence increasing rate), and θ is the time constant.

Integrating Eq. (1) into time, the formula of the Weibull probability density function is reduced to Eq. (2), which is called the cumulative probability density function (*F(t)*). Eq. (2) is also linearly expressed Eq. (3).

$$F(t)=\int_{t_o}^{t} f(x)dx = 1-\exp\left(-\left(\frac{t-t_o}{\theta-t_o}\right)^{b}\right) \quad (2)$$

$$LnLn\frac{1}{1-F(t)} = -bLn(\theta-t_o)+bLn(t-t_o) \quad (3)$$

In case of failure predication using Weibull distribution function, two parameters instead of three parameters is generally used by applying a zero value to the failure occurrence waiting time (t_o) as in the following:

$$LnLn\frac{1}{1-F(t)} = -bLn(\theta)+bLn(t) \quad (4)$$

In this paper, the Weibull distribution function using Eq. (4) recommended by EPRI is applied to predict the future tube plugging rate.

2.2 Summary of Tube plugging status

Table 1 presents the tubes plugging status of Unit A SG. In the table, time (EFPY, Effective Full Power Years) is assumed to be 90%. The cumulative tube plugging rate is based on the simple sum plugging numbers and the case by case number of a failure cause. The cumulative tube plugging is gradually increased in proportion to the increase of operation time and the major failure cause is the wear.

Table 1 Tube Repair Status of Unit A SG tubes

Time (EFPY)	Cumulative plugging rate (%)				
	Wear	SCC	Ect.	Sleeving	Sum
0.9	0.00	0.00	0.00	0.00	0.00
1.8	0.00	0.00	0.00	0.00	0.00
2.7	0.02	0.00	0.00	0.00	0.02
3.6	0.11	0.00	0.02	0.00	0.13
4.5	0.26	0.00	0.02	0.00	0.29
5.4	0.47	0.27	0.03	0.00	0.71
6.3	0.71	0.46	0.04	0.02	1.25
7.2	0.93	0.46	0.05	0.05	1.48
8.1	1.05	0.46	0.05	0.11	1.60
9.0	1.29	0.46	0.05	0.14	1.84
9.9	1.45	0.46	0.05	0.17	2.00
10.8	1.45	0.46	0.06	0.18	2.01

2.3 The Weibull function for tube plugging rate

Fig. 1 shows the relationship between *Ln*(t) and *LnLn*(1/(1-F(t))) for the total plugging rate to operation time for whole EFPY presented at Table I using Eq. (4) and the regression lines and the coefficient of determination (R^2) are also drawn up on Fig 1. The Weibull function has a good relationship.

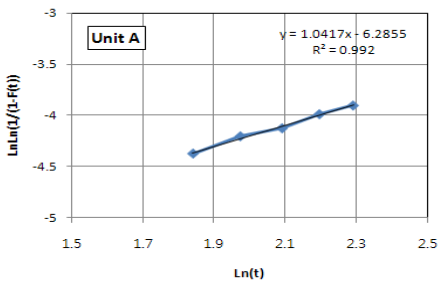
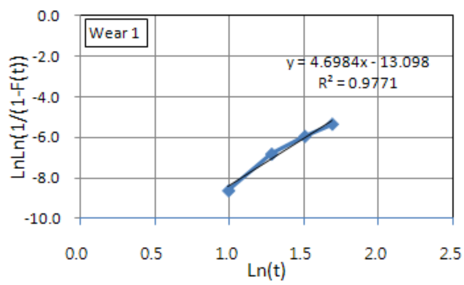


Fig. 1 Relationship between *Ln*(t) and *LnLn*(1/(1-F(t)) for Simple Sum

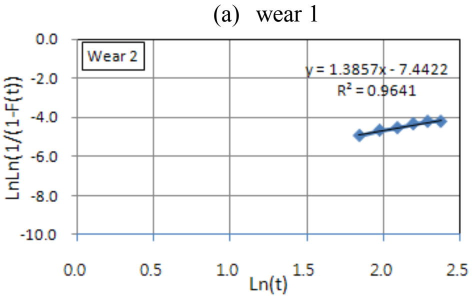
Table 2 presents the Weibull Function for wear (Sample Case). In case of wear, the plugging rate is big in the early stage of operation, but the plugging rate decreases over a given period. Fig. 2 shows the relationship between *Ln*(t) and *LnLn*(1/(1-F(t))) for wear plugging.

Table 2 Weibull Function for Wear (Sample Case)

t(EFPY)	*Ln*(t)	Cum. plugging rate (%)	$LnLn\frac{1}{1-F(t)}$	
0.9	0.11	0.00	-	
1.8	0.59	0.00	-	
2.7	0.99	0.02	-8.61	(a)
3.6	1.28	0.11	-6.82	
4.5	1.50	0.26	-5.94	
5.4	1.69	0.47	-5.35	
6.3	1.84	0.71	-4.94	(b)
7.2	1.97	0.93	-4.67	
8.1	2.09	1.05	-4.55	
9	2.20	1.29	-4.34	
9.9	2.29	1.45	-4.22	
10.8	2.38	1.45	-4.22	



(a) wear 1



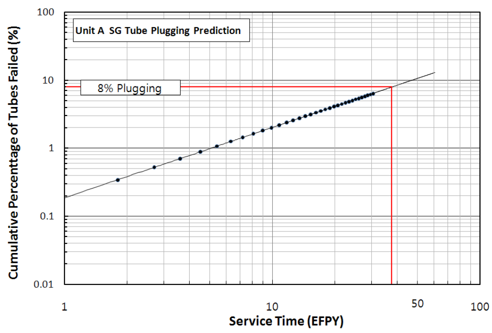
(b) wear 2

Fig. 2 Relationship between *Ln*(t) and *LnLn*(1/(1-F(t))) for the Wear Plugging Rate (Sample Case)

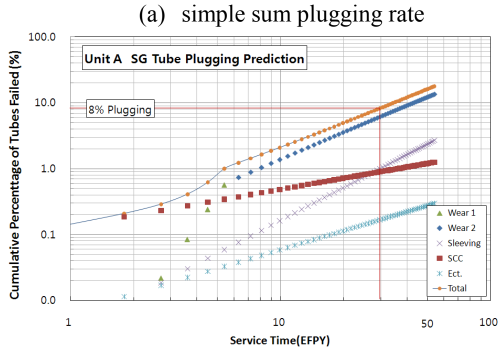
Because a lot of wear occurs in the early stage of operation, wear should be evaluated by dividing the operation into stages which shows an increasing plugging rate at different stages.

2.4 Prediction of Tube plugging rate

Fig. 3 shows the predicted tube plugging rate of the simple sum plugging rate and the case by case plugging rate for unit A SG. Comparisons of the simple sum plugging rate and case by case plugging rate, the simple sum plugging rate is longer than the case by case plugging rate to reach the critical plugging rate 8%. In Fig. 3(b), wear is the biggest cause of the tube plugging. The plugging rate to reach the critical plugging rate of 8% is 38 EFPY and 29 EFPY, respectively.



(a) simple sum plugging rate



(b) case by case plugging rate

Fig. 3 Predicted Tube Plugging Rate for Unit A SG

3. Conclusions

The tube plugging rate is predicted more detail for the case by case plugging rate than for the simple sum plugging rate using the Weibull function. In case of the simple sum plugging rate, the time to reach the critical plugging rate of 8% is longer than the case by case plugging rate.

REFERENCES

[1] EPRI TR-1003589, “Pressurized Water Reactor Generic Tube Degradation Predictions”, 2003.
[2] M. H. Boo, S. R. Jeong, Development of Degradation Prediction Model for Alloy 600MA Tube Using Weibull Function, K-PVP, pp.119, 2010.