A study on the Wall Thinning Management of Small Bore Carbon Steel Piping in Nuclear Power Plants

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1. Introduction

Flow Accelerated Corrosion (FAC) is one of the main degradations in the secondary system of power plants. To manage the wall thinning caused by FAC, the nuclear power plant of Korea have been adapted the CHECWORKS Program which developed by the U.S. Electric Power Research Institute. CHECWORKS is based on the FAC theory of Chexal-Horowitz, which is one of the FAC theories. CHEWORKS has been developed to predict and manage the wall thinning of piping caused by FAC. However, it has known that CHECWORKS cannot be applied to small bore piping due to the socket type welds which make the geometrical discontinuity. Thereby, it is difficult to analyze the inner flow which is an important factor of analysis of wear rate. Ultrasonic Thickness (UT) measurements on small bore piping, which is prone to wall thinning, has widely used. The selection of small bore piping for UT inspection depends on the experience of the FAC manager of power plants. In this circumstance, some small bore piping sensitive to FAC may not be selected in the scope of measurement to manage the FAC. In this study, the appropriate FAC theories have been reviewed and compared with the site UT measurement data to apply the FAC management for small bore piping.

2. Methods and Results

2.1 Review FAC models and select piping to review

To determine the FAC predictive models for small bore piping, existing models for large bore piping have been reviewed, such as Kastner, Chexal-Horowitz, Sanches-Caldera, Bignold model, etc. Table I shows the variables that are included in each of these models [1]. Kastner and Chexal-Horowitz models handle more variables than the others.

Table I: Variables reflected in several FAC predictive models

Variables	Kastner	Chexal-Horowitz	Sanchez-Caldera	Bignold
pH	O	O	O	O
Oxygen	O	O	-	-
Velocity	O	O	O	O
Temperature	O	O	O	O
Alloy	O	O	-	-
Geometry	O	O	O	O
Pipe Size	-	O	O	O
Time	O	-	-	-

Therefore, Kastner and Chexal-Horowitz models were selected to review the applicability of FAC predictive model for small bore piping. We applied the above two FAC predictive models to small bore piping in power plants and calculated the predictive wear rate of the small bore piping. To verify the results of the calculated wear rates of each model, the small bore piping which have many UT measurement data were selected for review. Table II shows the selected small bore piping to be reviewed in this study which is four lines of a nuclear power plant. It is actually known that this small bore piping were sensitive to FAC.

Table II: Systems and lines for review of the FAC predictive model for small bore piping

System	Line	UT Data
Reheater Drain& Vent	Reheater1A/B to Heater 6A/B	26
Feedwater Heater & Deaerator Venting	Heater 5B to Condenser	7
Steam Drain	LP Extraction Heater 3 to Condenser	44
	LP Extraction to Condenser MSR to Condenser	34

2.2 Kastner Model

Equation (1) illustrates the FAC predictive model for Kastner model.

$$\dot{m} = 8.0\cdot 10^{-6}\cdot k_c\cdot[B\cdot e^{N\cdot V}\cdot[1-0.175\cdot(pH-7)^2]\cdot 1.8\cdot e^{-0.118}\cdot g+1]\cdot f_t \quad (1)$$

In the FAC predictive model, wear rates ($\dot{m}$) depends on geometry factor (k_c), operating time (T), pH, dissolved oxygen (g) inside piping and variable functions (N, V, f) [2]. To determine the detail operating condition of small bore piping, NFA (Network Flow Analysis) included in CHECWORKS program as the thermal hydraulic analysis tool was used. Fig. 1 shows the comparison of the wear rate calculated by Kastner model and the actual wear rate based on UT measurement data in single phase. The dashed line indicates the wear rate based on the UT measurement data and the bold line means the wear rate calculated by Kastner model. As shown in Fig.1, most of the wear rates calculated by Kastner model were higher than those of UT measurement data. We could not find the any similarity between the results by Kastner model and UT measurement data.

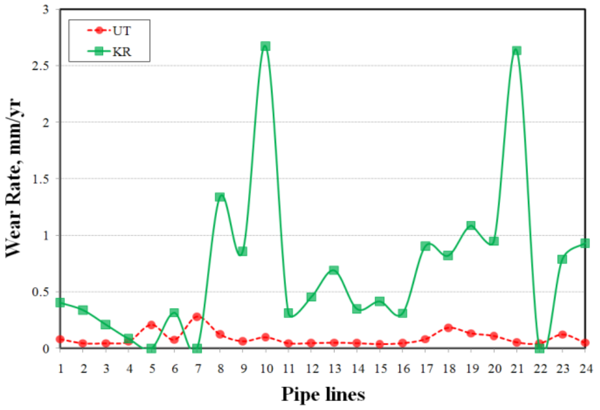

Fig. 1. Comparison of the wear rates calculated by Kastner and UT measurement data

2.3 Chexal-Horowitz Model

Equation (2) illustrates the FAC predictive model for Chexal-Horowitz model

$$\dot{m} = F_1(T) \cdot F_2(pH) \cdot F_3(allcont) \cdot F_4(h) \cdot F_5(O_2) \cdot F_6(G) \cdot F_7(\alpha) \quad (2)$$

In the FAC model, the wear rate ($\dot{m}$) depends on the temperature (T), pH, alloy contents (allcont), mass transfer coefficient (h), dissolved oxygen (O_2), geometry (G) and void fraction (α).

Chexal-Horowitz theory was not suggested in detail such as equation (1) of Katsner. To apply the Chexal-Horowitz theory, CHECWORKS based on the Chexal-Horowitz theory was adapted to analyze the wear rate for small bore piping.

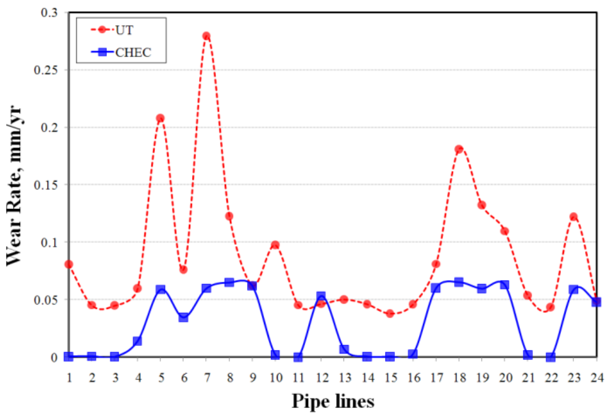

Fig. 2. Comparison of the wear rates calculated by CHEWORKS and UT measurement data

Fig. 2 depicts the comparison of the wear rates calculated by CHECWORKS and based on UT measurement data. The dashed line shows the wear rate based on the UT measurement and the bold line means the wear rate calculated by CHECWORKS. As shown in Fig.2, the wear rates based on UT measurement data were higher than those by CHECWORKS. However, the configuration of the wear rate calculated by CHEWORKS was similar to the result based on the UT measurement.

2.4 Modification of the CHECWORKS Results

Fig. 3 shows the comparison of the wear rates calculated by the modified CHECWORKS and UT measurement data. According to the fact of the similar pattern between CHECWORKS and UT measurement data, it may be conjectured that the effective wall thinning management method may be used for small bore piping. The dashed line show the modified wear rate based on the result by CHECWORKS. The dashed line was revised with a mean value of the gaps between the wear rates by CHECWORKS and UT measurement data. We have identified that CHECWORKS program may be used to manage small bore piping as subsidiary method.

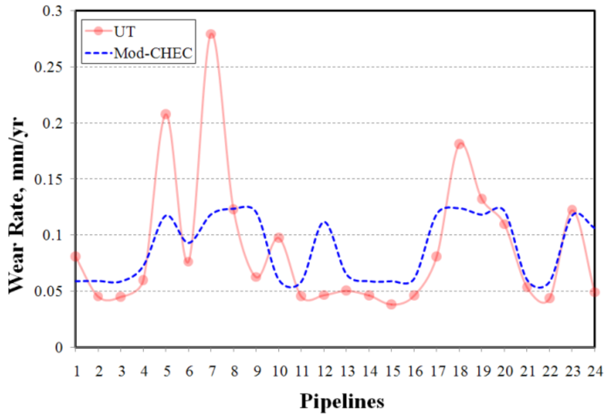

Fig. 3. Comparison of the wear rates calculated by the modified CHECWORKS and UT measurement data

3. Conclusions

It was found in this study that Chexal-Horowitz FAC theory might be applied to the small bore piping in power plant as the predictive management tool of FAC as the subsidiary method. It is difficult to analyze the flow affected by FAC because of the discontinuity of socket weld of small bore piping. It has known that CHECWORK based on Chexal-Horowitz FAC theory could not predict the precise wear rate of small bore piping. However, the about two times value of the wear rate result by CHECWORKS could envelope the 75% of wear rate result of the UT measurement. Moreover, the most sensitive locations to FAC were similar to those by CHECWORKS. Therefore, we have concluded that it may use the CHECWORKS program to select the locations for UT thickness inspection for wall thinning management of small bore piping instead of depending on the experience of the FAC manager in sites.

REFERENCES

[1] JSME, Codes for Power Generation Facilities-Rules on Pipe Wall Thinning Management, 2005.
[2] Ronald Balliger, Monitoring Corrosion in Nuclear Piping Systems, MIT, 1999.