*Transactions of the Korean Nuclear Society Autumn Meeting*
*Gyeongju, Korea, November 2-3, 2006*

# Wall-Thinning Rate Evaluation of Pipes under Accelerated Flow Condition

S.M Lee,a J.M. Kim,a Y.S. Chang,a J.B. Choi,a Y.J. Kim,a Y.H. Choi,b
*a School of Mechanical Engineering, Sungkyunkwan Univ., 300 Chunchun-dong, Jangan-gu, Suwon, Kyonggi-do 440-746, Korea, yjkim50@skku.edu*
*b Korea Institute of Nuclear Safety, 19 Guseong-dong, Yuseong-gu, Daejeon 305-338, Korea*

## 1. Introduction

The wall-thinning phenomenon due to flow accelerated corrosion (FAC) has been considered as an important issue for integrity evaluation of nuclear piping systems. The failure accident of a feedwater pipe at Mihama Unit 3 nuclear power plant was a typical case caused by FAC [1]. In order to maintain the integrity of nuclear pipes during operation, the wall-thinning rate should be predicted by reliable engineering solutions based on experimental FAC tests [2,3]. In this paper, a closed form solution of wall-thinning rate for a nuclear piping system is proposed using the CHECWORKS™ program and the Chexal-Horowitz model [4,5].

## 2. Chexal-Horowitz Model

The Chexal-Horowitz model based on experimental test data generally includes water chemistry(dissolved oxygen, pH), environment(temperature, mass transfer, geometry, void fraction) and alloy content(Cr/Mo/Cu) parameters. The general formulation of this model in two phase flow condition is as follows:

$$E = F_1(T)\times F_2(AC)\times F_3(MT)\times F_4(O_2)\times F_5(pH)\times F_6(G)\times F_7(\alpha) \quad (1)$$

where, $E$ is wall-thinning rate(*mils/yr*), $F_1(T)$ is factor for temperature effect, $F_2(AC)$ is factor for alloy content effect, $F_3(MT)$ is factor for mass transfer effect, $F_4(O_2)$ is factor for dissolved oxygen effect, $F_5(pH)$ is factor for pH effect, $F_6(G)$ is factor for geometry effect and $F_7(\alpha)$ is factor for void fraction.

The CHECWORKS™ program utilizes this model to calculate the wall-thinning rate of piping components.

## 3. Problem Descriptions

As shown in Figure 1, a feedwater line of secondary piping systems was selected under the internal pressure of 900 psi, temperature of 440˚F and single phase water. The pipe is made of SA 106 Gr.B steel. The specific data of operation period, water treatment, power level etc, which were provided by CHECWORKS™ program, was used to determine the effects of several FAC parameters.

## 4. Results and Discussions

*4.1 Effects of FAC Parameters*

As depicted in Figure 2, wall-thinning rate analyses under various operation conditions were performed to determine the effects of several FAC parameters such as pH, dissolved $O_2$, chemical composition, mass transfer and etc. Table 1 represents the selected coefficient value of pipe shape.

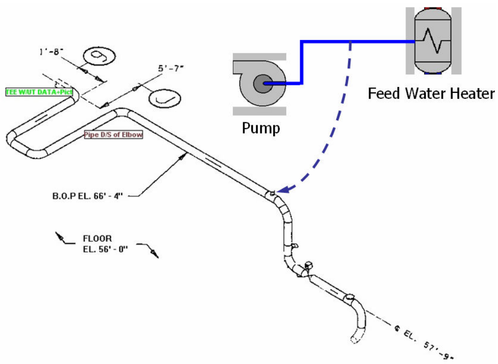
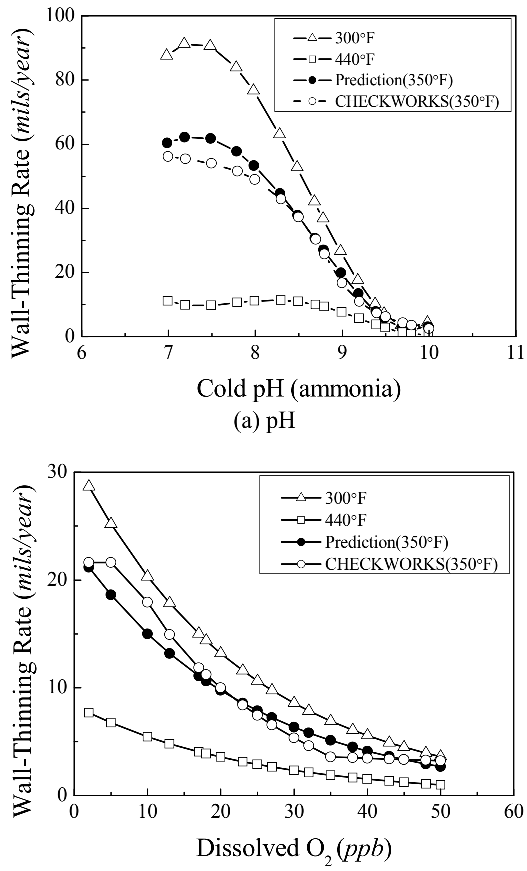


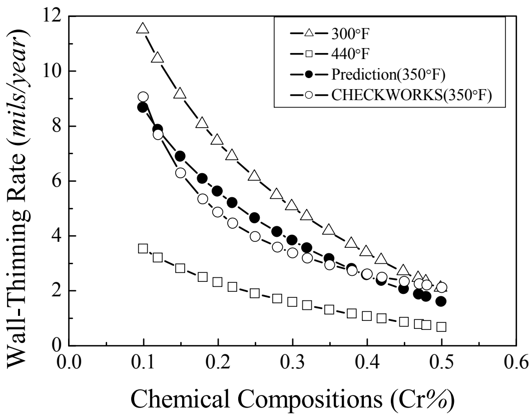

Figure 1. The example drawing image of a feedwater line



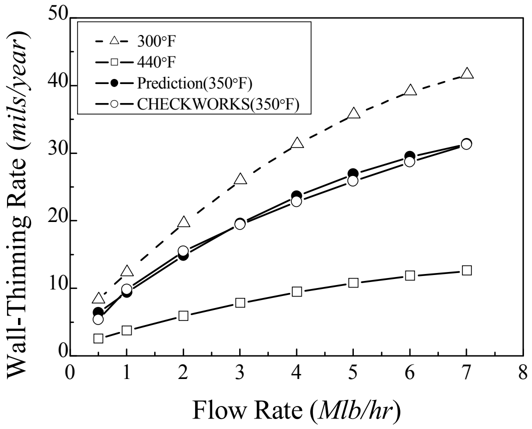

(a) pH

(b) $O_2$

Figure 2. The effects of chemistry and alloy contents parameters




(c) Chemical composition of Cr




(d) Mass transfer

Figure 2. (continued)

Table 1. Selected coefficient value of pipe shape

| Shape | Expander | | 90 Elbow | Straight Pipe | Valve | 45 Elbow | Orifice | Reducer | |
|---|---|---|---|---|---|---|---|---|---|
| | LE | SE | | | | | | LE | SE |
| Coeff. | 1.2 | 1.4 | 1.5 | 1.0 | 2.0 | 1.3 | 5.0 | 1.4 | 1.5 |

*4.2 Proposed Wall-Thinning Rate Formulation*

The maximum wall-thinning rate of a typical piping system made of carbon steels occurs at about 300˚F. Accordingly a modified formulation of wall-thinning rate was proposed at temperature of 300˚F and single phase flow (water) :

$$
\begin{aligned}
&E = C_1\{F_1(AC)\times F_2(O_2)\times F_3(pH)\times F_4(G)\times F_5(MF)\} - C_2 \\
&F_1(AC) = -5.8729\ln(AC) - 1.945 \\
&F_2(O_2) = 31.254\exp(-0.0431 O_2) \\
&F_3(pH) = 0.6697 pH^4 - 11.599 pH^3 + 0.9566 pH^2 \\
&\qquad + 799.78 pH - 3186.8 \\
&F_4(G) = 1 \quad \textit{for straight pipe} \\
&F_5(MF) = 1 \quad \textit{at flow rate} = 3.616\, Mlb/hr
\end{aligned}
\qquad (2)
$$

where, $C_1$ and $C_2$ are coefficients of total wall-thinning rate, *E,* which are presented in Figure 3.

*4.3 Discussions*

For same analysis cases, the wall-thinning rate using the proposed Eq. (2) was generally calculated higher than that utilizing the CHECWORKS$^{TM}$ program and the comparison results were shown in Figure 4.

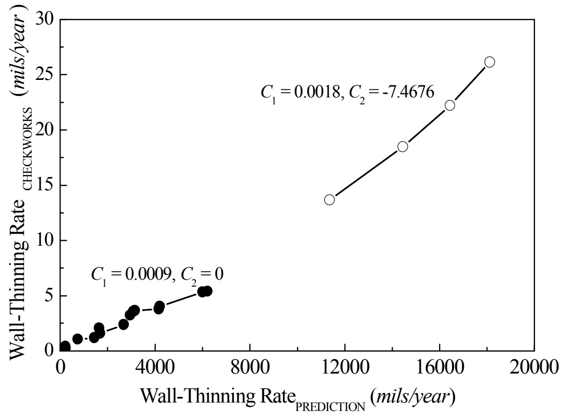



Figure 3. The coefficient $C_1$ and $C_2$ values of Eq. (2)

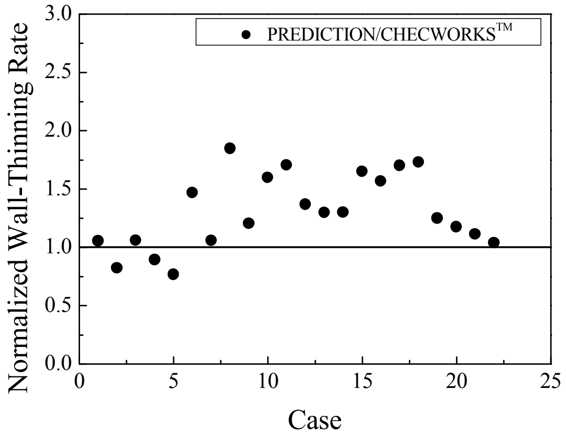



Figure 4. Comparison of wall-thinning rate between proposed Eq. (2) and CHECWORKS$^{TM}$ program

## 5. Conclusion

A modified formulation of wall-thinning rate for a nuclear piping system was proposed using the CHECWORKS$^{TM}$ program and the Chexal-Horowitz model.

## REFERENCES


[1] Korea Institute of Nuclear Safety, Accident Review Report of Mihama Unit 3 Nuclear Plant, KINS Report-040809F1, Korea, 2004.

[2] V.W. Kastner and K. Riedle, Empirishes Modell zur Berechnung von Materialabtragen durch Eorsionkorrosion, VGB Kraftwerkstechnik 66, pp. 1171-1178, 1986.

[3] H. Keller, Corrosion and Erosion Problems in Saturated-Steam Turbines, AIM Conf., pp. 22-28, 1978.

[4] B. Chexal, J. Horowitz, B. Dooley, P. Millett, C. Wood, and R. Jones, Flow-Accelerated Corrosion in Power Plant, EPRI/TR-106611-R11998.

[5] Electric Power Research Institute, CHECWORKS Computer Program User Guide, EPRI/TR-103496, 1994.