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A Study on Effect of Local Wall Thinning in Carbon Steel Elbow Pipe on Elastic Stress Concentration

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1. Introduction

Feeder pipes that connect the inlet and outlet headers to the reactor core in CANDU nuclear power plants are considered as safety Class 1 piping items. Therefore, fatigue of feeder pipes should be assessed at design stage in order to verify structural integrity during design lifetime. In accordance with the fatigue assessment result, cumulative usage factors of some feeder pipes have significant values [1]. The feeder pipes made of SA-106 Grade B or C carbon steel have some elbows and bends. An active degradation mecha-nism for the carbon steel outlet feeder piping is local wall thinning due to flow-accelerated corrosion [2]. Inspection results from plants and metallurgical examinations of removed feeders indicated the presence of localized thinning in the vicinity of the welds in the lower portion of outlet feeders, such as Grayloc hub-to-bend weld, Grayloc hub-to-elbow weld, elbow-to-elbow, and elbow-to-pipe weld [2]. This local wall thinning can cause increase of peak stress due to stress concentration by notch effect. The increase of peak stress results in increase of cumulative usage factor. However, present fatigue assessment [1,3] doesn't consider the stress concentra-tion due to local wall-thinning. Therefore, it is nece-ssary to assess the effect of local wall thinning on stress concentration.

This study investigates the effect of local wall thinning geometry on stress concentration by per-forming finite element elastic stress analysis.

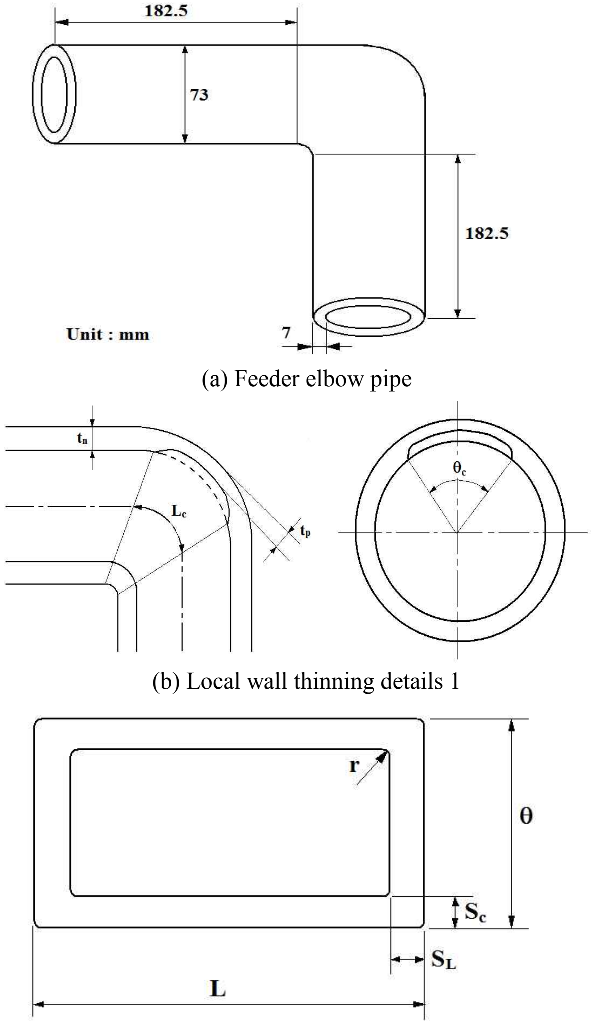
2. Methods and Results

2.1 Methods

Fig. 1 shows configuration of the local wall thinning in elbow pipes. t_n is nominal thickness, t_p is wall thinned thickness, L_c is length of the wall thinning along elbow pipe axis, θ is circumferential length of the wall thinning, S_L is transition length along elbow pipe axis, S_c is transition circumferential length of the wall thinning, and r is radius of wall thinning corner.

Fig. 2 depicts a representative finite element model developed by using the commercial finite element flaw modeling program, FEA-Flaw [4]. Table 1 presents geometric variables of the various finite element models. It is assumed that the local wall thinning is located on extrados, frank or intrados of the elbow.

Finite element elastic stress analysis is performed by using the commercial finite element analysis program, ABAQUS [5].



(a) Feeder elbow pipe

(b) Local wall thinning details 1

(c) Local wall thinning details 2

Fig. 1. Configuration of the local wall thinning.

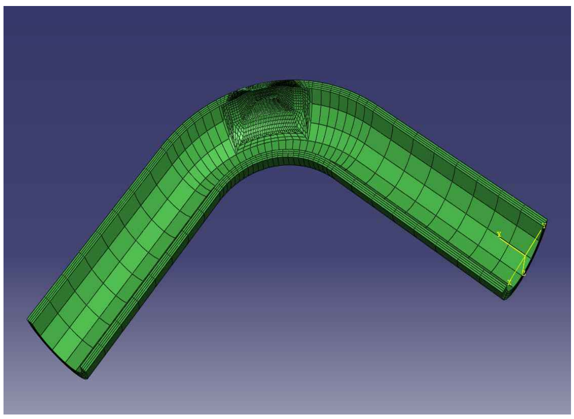


Fig. 2. Finite element model.

Table 1: Geometric Variables of the Various Finite Element Models

Case	$(t_n-t_p)/t_n$	L_c/D_o	$2\theta/\pi$	Ratio of S_L & S_c to L_c & θ	Ratio of r to min(S_L, S_c)
1	0.3	0.75	0.5	0.3	0.18
2	0.5	0.75	0.5	0.3	0.18
3	0.7	0.75	0.5	0.3	0.18
4	0.5	0.5	0.5	0.3	0.18
5	0.5	1	0.5	0.3	0.18
6	0.5	0.75	0.25	0.3	0.18
7	0.5	0.75	0.75	0.3	0.18
8	0.5	0.75	0.5	0.2	0.18
9	0.5	0.75	0.5	0.34	0.18
10	0.5	0.75	0.5	0.3	0.15
11	0.5	0.75	0.5	0.3	0.2

2.2 Results

Fig. 3 shows Tresca effective stress distribution of Case 1 under uniform normal operating internal pressure. As shown in the figure, it is found that maximum Tresca effective stress occurs near the notch of local wall thinning.

Fig. 4 depicts variations of maximum Tresca effective stresses vs. $(t_n-t_p)/t_n$. From the figure, it is identified that maximum Tresca effective stresses increase with the local wall thinning thickness.

Fig. 5 presents variations of maximum Tresca effective stresses vs. L_c/D_o. As depicted in the figure, maximum Tresca effective stresses increase with the axial length of local wall thinning.

Fig. 6 shows variations of maximum Tresca effective stresses vs. $\theta/2\pi$. As shown in the figure, it is found that maximum Tresca effective stresses decrease with the circumferential length of local wall thinning.

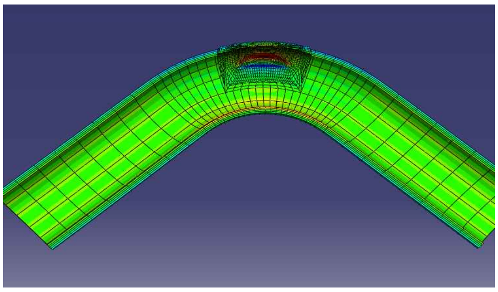


Fig. 3. Tresca effective stress distribution of Case 1 under uniform normal operating internal pressure.

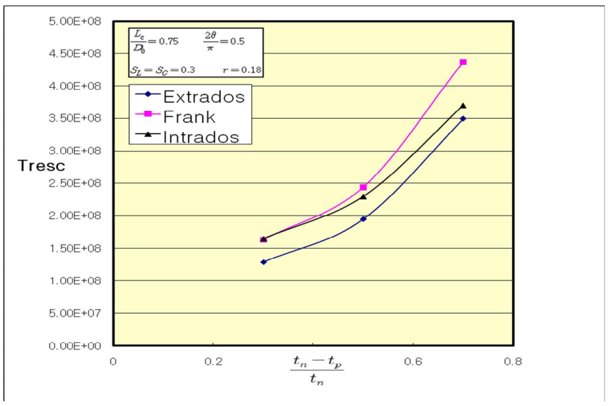


Fig. 4. Variation of maximum Tresca effective stresses vs. $(t_n-t_p)/t_n$.

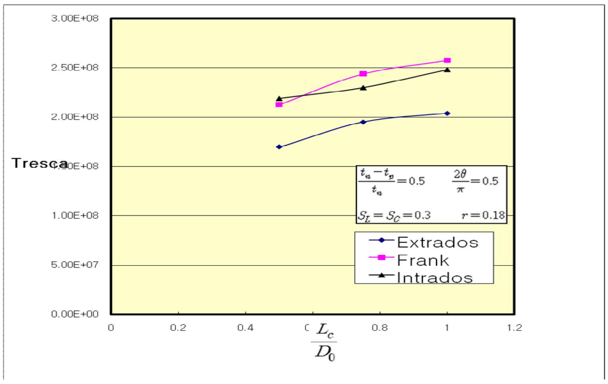


Fig. 5. Variation of maximum Tresca effective stresses vs. L_c/D_o.

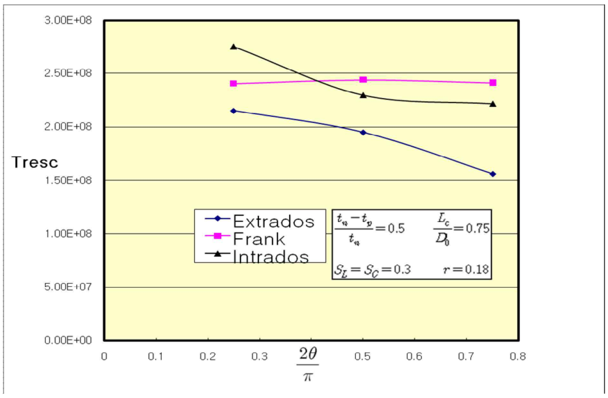


Fig. 6. Variation of maximum Tresca effective stresses vs. $\theta/2\pi$.

3. Conclusions

Based on the study results about the effect of local wall thinning in feeder elbow pipe on elastic stress concentration, the following findings are identified:

- Maximum Tresca effective stress occurs near the notch of local wall thinning.
- Maximum Tresca effective stresses increase with the local wall thinning thickness.
- Maximum Tresca effective stresses increase with the axial length of local wall thinning.
- Maximum Tresca effective stresses decrease with the circumferential length of local wall thinning.

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