

Effect of Local Wall Thinning at Crown on the Collapse Moment of Elbow

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1. Introduction

Local wall thinning due to flow accelerated corrosion is one of degradation mechanisms of carbon steel piping in nuclear power plant (NPP). Thus, the local wall thinning has regarded as a main concern of carbon steel piping system in terms of safety and operability of NPP. Recently, the integrity of piping components containing the local wall thinning has become more important in maintaining the reliability of nuclear piping system. A number of studies have been performed to develop the methodology for integrity evaluation of piping components with local wall thinning [1~3]. However, the effect of local wall thinning on the integrity of pipe bends and elbows was not yet systematically investigated. Only, our previous study evaluated the effect of local wall thinning locating at intrados and extrados [4].

In this study, thus, the collapse moment of elbow containing wall thinning at crown is evaluated under various thinning shapes and loadings using finite element analysis. It is compared with results of intrados or extrados wall thinning to investigate the effect of circumferential thinning location on the collapse behavior of wall thinned elbows.

2. Finite Element Analysis

2.1 Analysis Model

In the analysis, a 90-degree elbow with $R_m/t_{nom}=10$ and $R_b/R_m=3.0$ was considered, and it was assumed the local wall thinning is located at crown. Fig. 1 illustrates the dimensions of wall thinned elbow. The combined internal pressure and bending moment was considered as an applied load. The internal pressure regarded was 0 ~ 20MPa, and two types of in-plane bending mode, closing and opening mode, were considered.

Three-dimensional finite element model was used in the analysis. Considering geometrical symmetry, only one fourth of the elbow was modeled. In the model, the elbow was connected with straight pipes of length equal to 10 times of mean radius to allow free ovalization. The symmetry boundary condition was considered, and the bending moment was applied by rotating end section of straight pipe. The elastic-plastic finite element analysis was performed using ABAQUS program.

2.2 Determination of Collapse Moment

The collapse moment of elbow under in-plane bending is able to be defined various methods. In this study, the collapse moment of elbow was obtained by

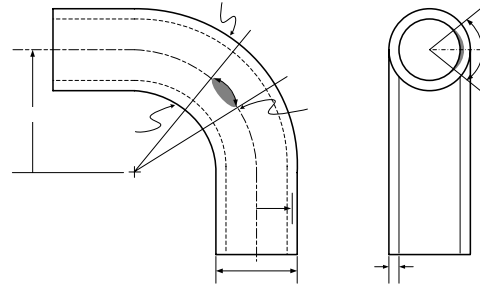


Figure 1 Definition of dimensions of wall thinned elbow

twice-elastic slop (TES) method from the moment versus rotation curve. According to the former studies [5], this method is the easiest to use and results are the most reproducible. Also, ASME recommends this method. On the other hand, the collapse moment was defined as maximum moment, when the intersection between TES line and moment versus rotation curve was located beyond the maximum moment.

3. Results and Discussion

3.1 Effect of Circumferential Thinning Location

From the results of analysis, we estimated the collapse moment of wall thinned elbow and presented as weakening factor (w) that is defined by collapse moment normalized with collapse moment of not-thinned elbow.

As shown in Figs. 2 and 3, for both bending modes, the weakening factor was almost linearly decreased with increase in thinning depth, length, and circumferential angle, regardless of circumferential thinning location. The reduction in weakening factor was more significant for a wall thinning locating at crown compared with for a wall thinning locating at intrados and extrados. The dependence of collapse moment of wall thinned elbow on circumferential thinning location is related to the different stress state along the circumference under bending load. That is, the reduction in collapse moment by local wall thinning is significant when the wall thinning is located at higher stressed area. This is well represented by the comparison of stress distributions in bend region of wall thinned elbow.

3.2 Effect of Internal Pressure

For closing mode (Fig. 2), the weakening factor was obviously increased with increasing internal pressure for a wall thinned elbow at crown, in comparison with for a wall thinned elbow at intrados or at extrados.

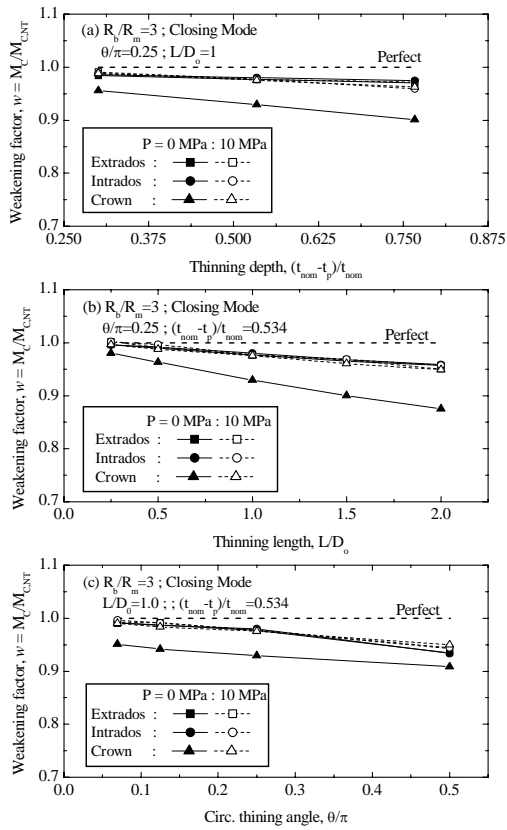


Figure 2 Dependence of collapse moment of wall thinned elbow on the defect shape for each location under closing mode bending

For opening mode (Fig. 3), the weakening factor was slightly decreased with increasing internal pressure, and the effect of internal pressure was clearer for intrados wall thinned elbow rather than for crown wall thinned elbow. Therefore, it is recognized that the effect of internal pressure on the collapse moment of wall thinned elbow is dependent on the circumferential location of thinning defect and bending mode. This is associated with the effect of internal pressure on deformation behavior of elbow. In the elbow, the internal pressure mitigates ovalization of elbow cross-section and increases stress in the wall. Therefore, the increasing collapse moment with internal pressure is induced by the mitigation of ovalization, and the decreasing collapse moment with internal pressure is caused by over stress due to pressure at thinned area.

4. Conclusions

In this study, the collapse moment of elbow containing wall thinning at crown was evaluated under various thinning shapes and loading conditions using finite element analysis, and it was compared with that of elbow containing wall thinning at intrados or extrados.

The results of analysis showed that the reduction in collapse moment of the elbow by local wall thinning is more significant for a defect locating at crown than for a

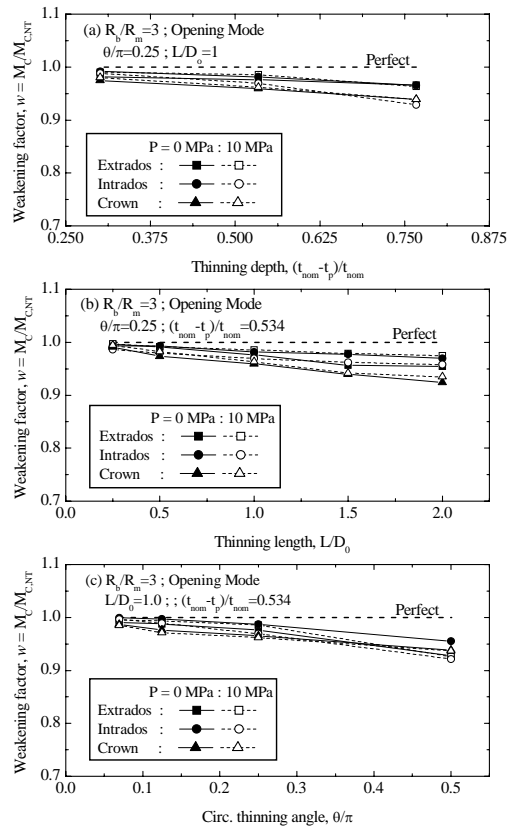


Figure 3 Dependence of collapse moment of wall thinned elbow on the defect shape for each location under opening mode bending

defect locating at intrados or at extrados. Also, the effect of internal pressure on the collapse moment of wall thinned elbow depends on the circumferential location of thinning defect and applied bending mode.

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