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Limit State Assessment of a 3-Inch Carbon Steel Pipe Tee of Nuclear Power Plant

Sung-Wan Kim [a*], Da-Woon Yun [a], Bub-Gyu Jeon [a], Min-Kyu Kim [b]
[a] *Seismic Research and Test Center, Pusan National University, Yangsan, Korea*
[b] *Smart Structural Safety & Prognosis Division, Korea Atomic Energy Research Institute, Daejeon, Korea*
[*] *Corresponding author: swkim09@pusan.ac.kr*

1. Introduction

This study presents a method for quantitatively analyzing the limit state that is required for performing seismic fragility evaluations on the crossover piping systems of nuclear power plants that use seismic isolation systems. The limit state was quantitatively defined using a damage index of Banon [1] that is based on dissipation energy when leakage occurred due to through-wall cracking, in a 3-inch carbon steel pipe tee.

2. Methods and Results

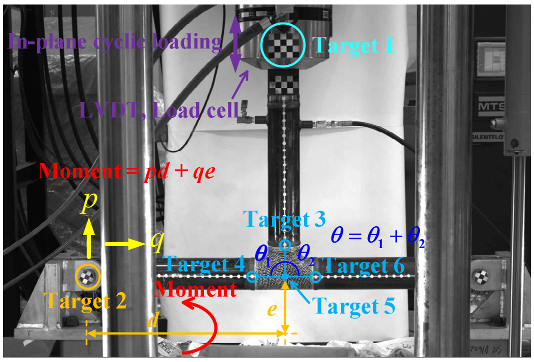

Fig. 1. Experimental setup

The test specimen is shown in Fig. 1, and it was fabricated by welding three 3-inch straight pipes of one 3-inch pipe tee. In this study, in-plane cyclic loading tests were performed by considering the amount of relative displacement acting on the pipe tee of a piping system which has the characteristics of a nuclear power plant equipped with a seismic isolation system. For the force displacement was applied at a sine wave of constant amplitude, adjusted from ±10, ±20, ±40, ±60, and ±80 mm, with consideration to the occurrence of cumulative plastic deformation. Displacement control was done sufficiently slowly at a speed of 40 mm/sec. It is difficult to measure nonlinear behavior in which through-wall cracks occur outside of the elastic region using conventional sensors in in-plane cyclic loading tests. Therefore, this study used an image measurement system [2] to intuitively measure the nonlinear behaviors of test specimens. Fig. 1 is an image captured by the image measurement system, and it shows the measurement locations for the moment and deformation angle. The feedback signal of the linear variable displacement transducer that was installed in the interior of the universal testing machine was synchronized with the response of Target 1, which was measured by the image measurement system. The moment ($M=pd+qe$) was calculated using the reaction force and the distance.

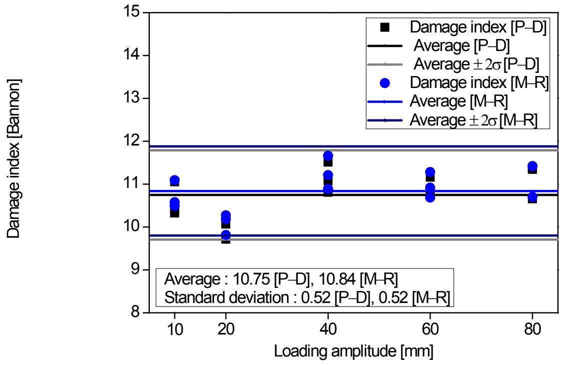

Fig. 2. Damage index of Banon for P−D and M−R

Fig. 2 shows the damage index of Banon calculated at all loading amplitudes for force−displacement (P−D) and moment−relative deformation angle (M−R) relations. Fig. 2 shows that the damage index is located between ±2σ of the average line. In addition, the average damage indexes can be used as typical values for limit states based on leakage caused by through-wall cracking.

3. Conclusions

The damage index of Banon was calculated for all loading amplitudes. The standard deviation for the damage indices calculated using the P−D and M−R relationships was less than 0.6. It was found that the damage indexes can be used to calculate quantitative limit states that depict actual failure in a nuclear power plant's piping system.

Acknowledgment

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