Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 19-20, 2022

Failure criteria for a carbon steel pipe tee under in-plane cyclic loading

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1. Introduction

The structural response of a piping system to a strong earthquake manifests as low-cycle fatigue caused by large external forces that create plasticity. It can be seen that this is the case in crossover piping systems that are exposed to cyclic loading, which is large repetitive relative displacement that is characteristic of seismic isolation systems. The damage the crossover piping system in this kind of cyclic loading scenario can be defined as failure due to damage accumulation. However, quantitatively confirming structural damage due to seismic load is a difficult task. Therefore, various damage indexes have been examined to quantify the structural damage that target systems experience due to repetitive external forces such as seismic load and to evaluate vulnerabilities [1].

Damage due to cumulative plastic deformation can be taken into account using plastic dissipated energy, and an energy dissipation index has been proposed. A cumulative plastic deformation index that takes into account the different weights of the plastic deformation of various cycles was proposed, and an index that takes into account cumulative work was also proposed. The damage index that was proposed by Park and Ang is also a type of cumulative damage. This index consists of a linear combination of ductility and energy dissipation. The damage index proposed by Banon is based on a non-linear combination of ductility and energy dissipation.

2. Methods and Results

As shown in Fig. 1, the inside of the test specimen was filled with water, and an air booster was used to apply 3 MPa of internal pressure. Then, the in-plane cyclic loading tests were performed. In this study, the tee in the piping system was determined as the vulnerable part in the event of a seismic load, and a piping component composed of the three-inch standard piping of SA106, Grade B, and SCH 40 of ASME B36.10 and a tee was fabricated and used. The diameter of the piping was 88.9 mm, and its thickness was 5.49 mm. The length of the straight pipe was more than three times the diameter so that plastic behavior could occur in the tee, and the straight pipe was attached by welding.

Fig. 2 shows the calculation of the average damage indexes for force–displacement when the loading amplitude ranges from 40 to 200 mm. The average damage index of Bannon exhibited a smaller variation than other damage indexes, which indicates that the average damage index of Bannon was distributed closer to the average value.

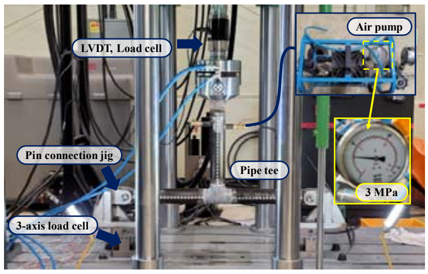

Fig. 1. Experimental setup

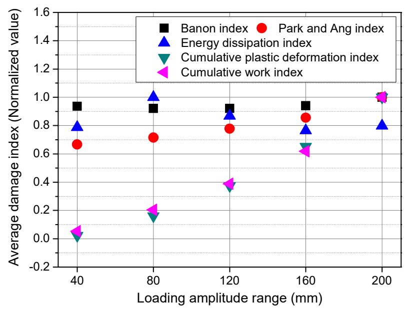

Fig. 2. Average damage indexes

3. Conclusions

In this study, the failure mode of the carbon steel pipe tee was defined as the leakage caused by a through-wall crack. In the limit state, damage indexes must be distributed with a small variation from the average value. Therefore, it was found reasonable to use the damage index of Bannon rather than other damage indexes to express the failure criteria for the carbon steel pipe tee.

Acknowledgment

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry and Energy (MOTIE) of the Republic of Korea (No. 20217910100150).

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