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Original Article

A Failure Estimation Method of Steel Pipe Elbows under In-plane Cyclic Loading

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ABSTRACT

The relative displacement of a piping system installed between isolated and nonisolated structures in a severe earthquake might be larger when without a seismic isolation system. As a result of the relative displacement, the seismic risks of some components in the building could increase. The possibility of an increase in seismic risks is especially high in the crossover piping system in the buildings. Previous studies found that an elbow which could be ruptured by low-cycle ratcheting fatigue is one of the weakest elements. Fatigue curves for elbows were suggested based on component tests. However, it is hard to find a quantitative evaluation of the ultimate state of piping elbows. Generally, the energy dissipation of a solid structure can be calculated from the relation between displacement and force. Therefore, in this study, the ultimate state of the pipe elbow, normally considered as failure of the pipe elbow, is defined as leakage under in-plane cyclic loading tests, and a failure estimation method is proposed using a damage index based on energy dissipation.

1. Introduction

The seismic requirements for nuclear power plants (NPPs) have been enhanced after the Fukushima nuclear accident caused by the earthquake near Tohoku, Japan in 2011. To satisfy these new requirements, many studies have been conducted on the application of isolation systems which can secure a higher seismic capacity without major changes to existing designs. However, partial isolation in an NPP can cause a large relative displacement of piping systems connecting isolated structures to nonisolated structures.

A piping system, one of the most important parts of a nuclear power system, was classified as S/O (screen out) in the 2002 probabilistic risk assessment by Korea Hydro &

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Nuclear Power Co. [1] because it is hard to effect a large relative displacement of a piping system under a non-isolated system. However, the seismic risk of a main steam pipe in an NPP can increase due to a large relative displacement of a piping system, by applying a partial isolation system. A leakage from a pipe system in an NPP can be classified as a critical accident due to the possibility of radiation leakage. To predict a leakage in a piping system, a probabilistic safety assessment should be conducted on the piping system in accordance with NPP standards. Definition of failure is one of the most important parameters needed to make an appropriate prediction in probabilistic safety assessment. Therefore, it is necessary to define the final state of a piping system to ensure the safety of NPPs under seismic conditions.

Many studies have been conducted on piping systems under seismic conditions in order to identify weak components and to perform nonlinear behavior analysis based on experimental and analytical methods.

Dynamic behavior analysis of piping systems under seismic conditions using a seismic table was performed by Touboul et al in 1999 [2]. According to their study, plastic behavior could occur at the pipe elbow under seismic conditions.

Experimental research on the dynamic behavior of typical piping systems in NPPs has been performed for several years by the Japan Nuclear Energy Safety Organization and the Nuclear Power Engineering Corporation [3]. Cyclic loading tests and shake-table tests for piping components have been performed in the research processes.

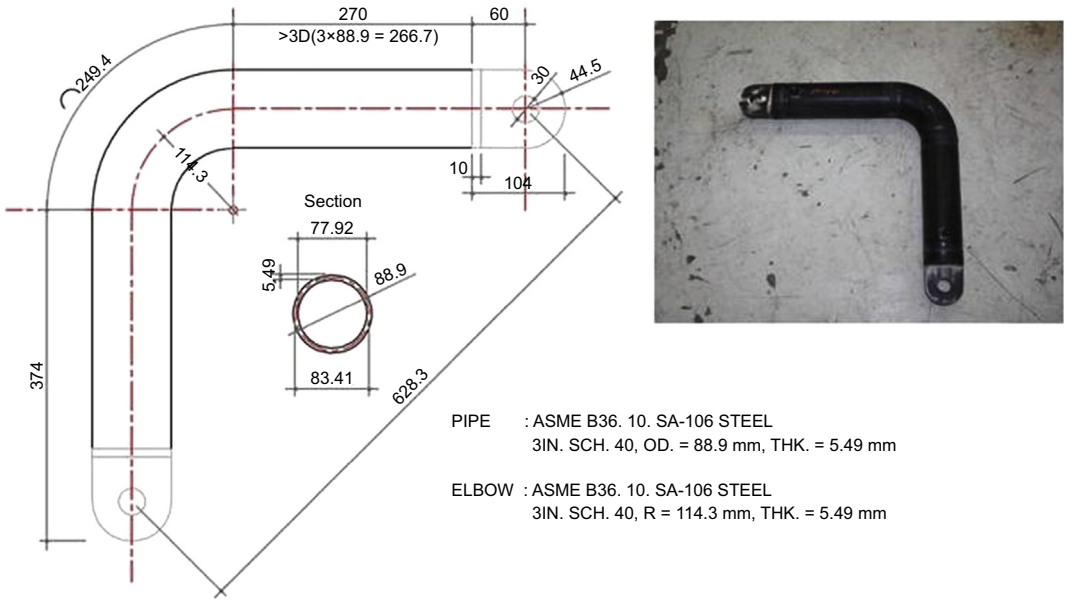

Fig. 1 – Description of test specimen. OD, outer diameter; R, radius; THK, thickness.

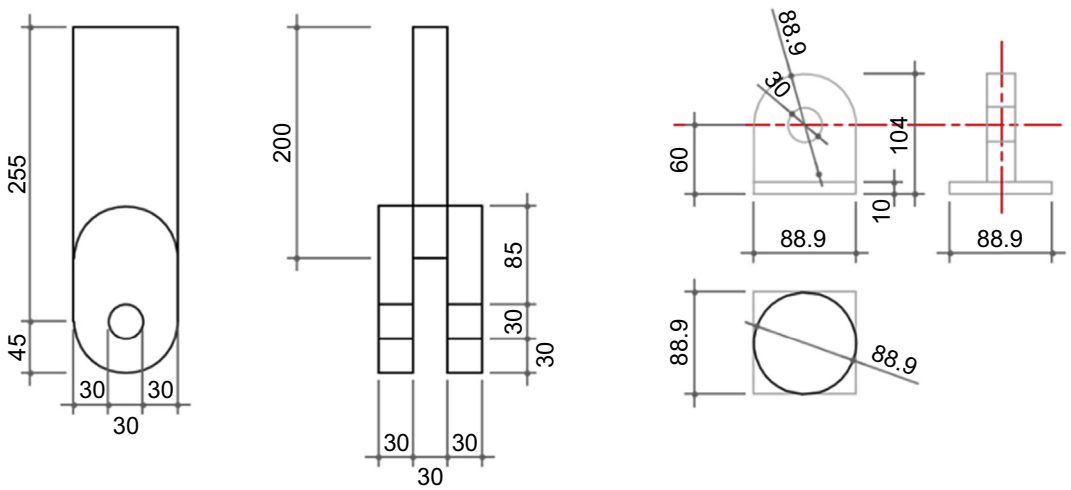

Fig. 2 – Description of connection zig.

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