Leakage Line of the Elbow in the Nuclear Power Plant Piping System Using the Moment and Theta

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1. Introduction

Maintaining the integrity of major equipment in nuclear power plants is critical to the safety of structures [1]. In particular, the soundness of piping is a critical matter that is directly linked to the safety of nuclear power plants. Currently, the limit state of the piping design standard is plastic collapse, and the actual pipe failure is leakage due to penetration crack. In this study, the limit state of the steel pipe elbow, which is a vulnerable part of the nuclear power plant piping system, was defined as leakage, and an in-plane cyclic loading test was conducted. As it is difficult to measure the moment and theta of the steel pipe elbow using the conventional sensors, an image measurement system was used [2].

In this study, an image measurement system was used to measure the theta of the steel pipe elbow, and the NSSD (Normalized Sum of Squared Differences) was used to measure the displacement, which is required to measure the moment of the steel pipe elbow. Furthermore, the second-order shape function was used to measure the subpixels. For line recognition, which is required to measure the theta, the shape of the steel pipe elbow was enhanced using image filter processing, and the theta was measured using the Hough transform of the enhanced image This study proposed a leakage line using the relationship between the moment and the theta of a steel pipe elbow.

2. Methods and Results

Shown in Fig. 1 is the algorithm for measuring the displacement in the moment for the steel pipe elbow using the image measurement system, which consists of five steps. The first step is to acquire image files and arrange them in the order of time for measuring the time history of the displacement of the steel pipe elbow. The second step is to designate a control point within the ROI (Region of Interest) window in the obtained reference image whose displacement needs to be identified. The third step is to identify the coordinate with the maximum correlation through the calculation of NSSD (Normalized Sum of Squared Differences) to find the control points at which the target window most optimally matches the ROI window. The fourth step is to rearrange and correct for the location of the pixel using the second-order polynomial function to correct for the geometric distortion caused by the displacement and deformation, and to calculate the subpixel of the displacement. The fifth step is to analyze the pixel-based displacement using the pixel of the point with the optimal matching and the calculated subpixel information. Fig. 2 shows the algorithm for measuring the theta of the steel pipe elbow using MATLAB.

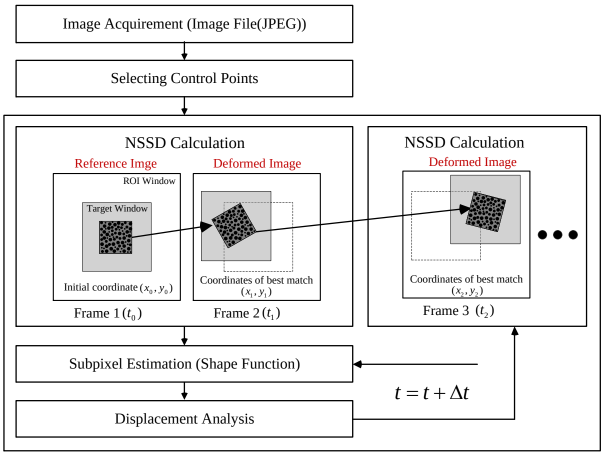

Fig. 1 Displacement measurement algorithm

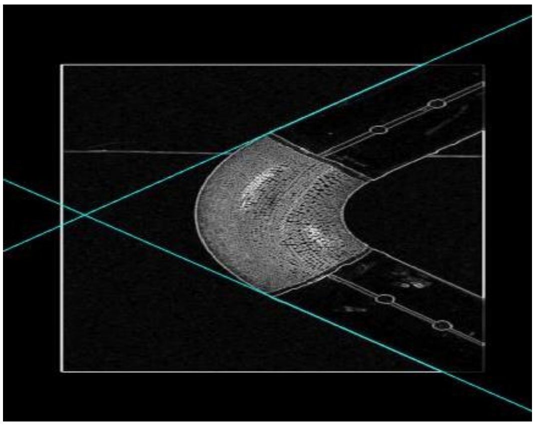
Fig. 2 Theta measurement using MATLAB

The measurement position of the steel pipe elbow is shown in Fig. 3. Target was installed in the jig for UTM (Universal Testing Machine) connection, and the loading amplitude measured using the image measurement system was compared with that measured at the LVDT (Linear Variable Differential Transformer) installed inside the UTM for synchronization. In addition, the moment was measured by multiplying distance d, which is the difference in horizontal deformation between target and the center of the elbow, which is the position of control point, and the force applied by the UTM.

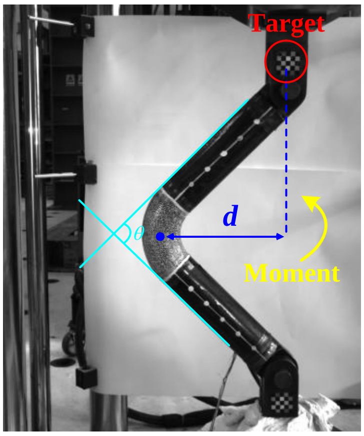

Fig. 3 Theta measurement using MATLAB

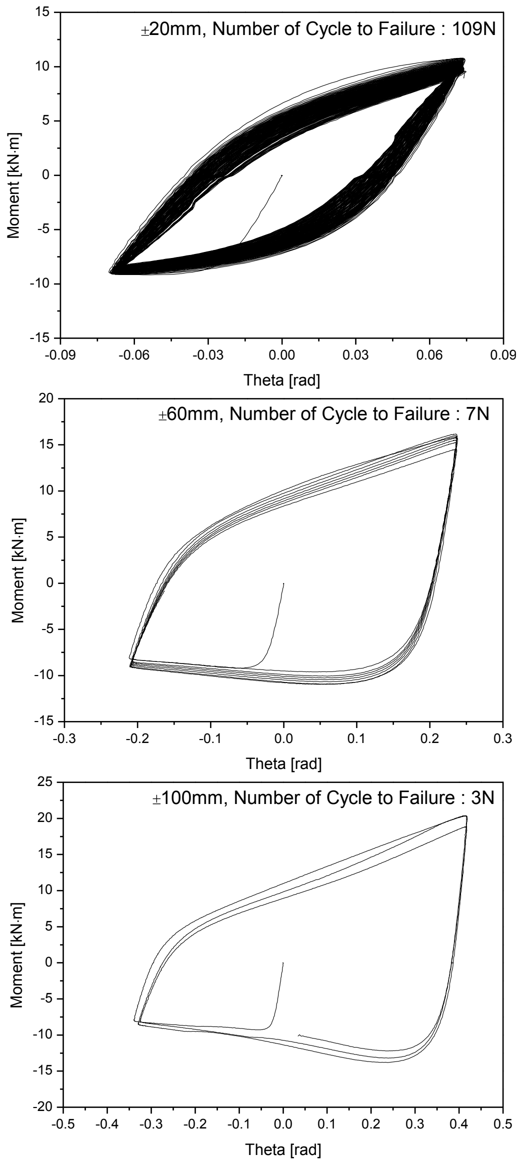

Fig. 4 Moment-theta hysteresis loops

Fig. 4 shows the hysteresis loops of the moment and theta measured in the in-plane cyclic loading test with the representative specimens for the ±20, ±60, and ±100mm.

Fig. 5 shows the leakage line that uses the relationship between the moment and the theta. The average regression curve calculated using the least-square method is shown in Fig. 5. Fig. 5 shows the relationship between the moment and the theta when leakage occurs in the steel pipe elbow. The determination coefficient was 0.96 or higher, indicating that the moment and the theta had a linear relationship.

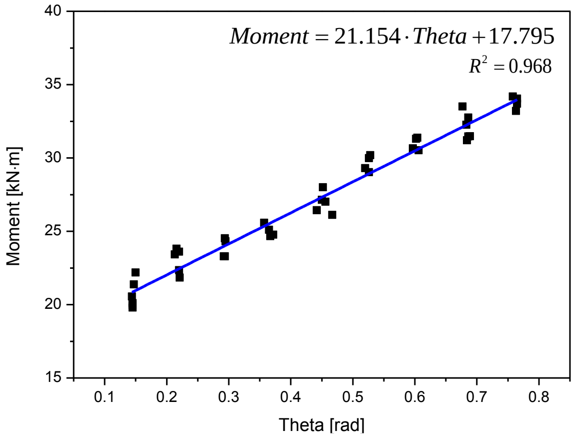

Fig. 5 Leakage line using moment-theta

3. Conclusions

The limit state and fatigue life against seismic loads were proposed by presenting the leakage for the moment and theta of the steel pipe elbow. Therefore, it is expected that the leakage line can be used as data for analyzing the limit state and fatigue failure behavior of the steel pipe elbow against earthquakes.

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