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Deformation Angle Measurement of a Steel Pipe Tee Using Image Measurement System

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1. Introduction

Upon installing a seismic isolation device on a nuclear power plant, the device takes on the suppression of seismic loads. This is expected to bring about a larger displacement than what is seen prior to the installation of the seismic isolation device. Depending on the displacement change, the seismic risk for some equipment can increase. Particularly in case of the piping system (elbow and tee), which is used for connecting the structure isolated from seismic events with common structures, the seismic risk is expected to rise significantly. Therefore, by selecting the facilities with an increased seismic load risk due to the installation of the seismic isolation device and by performing a probabilistic seismic risk analysis, the seismic performance should be verified.

In this study, the limit state of a steel pipe tee, is the fragility part of the seismically isolated nuclear power plant's piping system, is defined as rupture or leakage. To verify the validity of measuring the deformation angle of the steel pipe tee by using an image measurement system, an in-plane cyclic loading test [1] was conducted so that deformation angle that are too large to measure using a conventional sensor could be measured effectively.

2. Deformation Angle Measurement Method

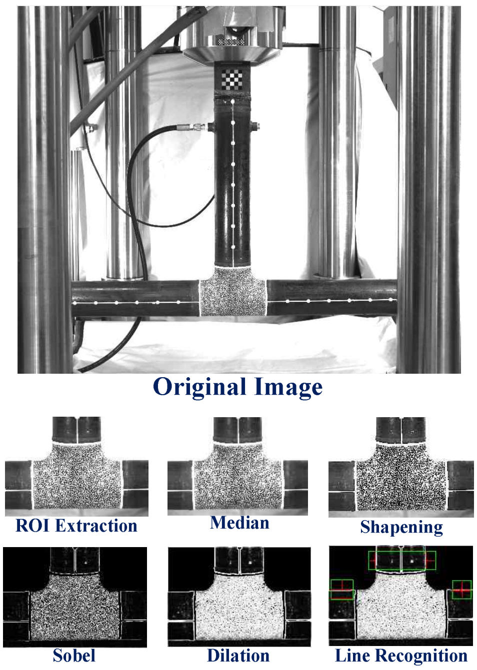
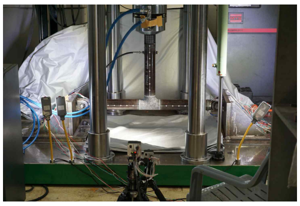


Fig. 1. Deformation Angle Measurement Using Line Recognition

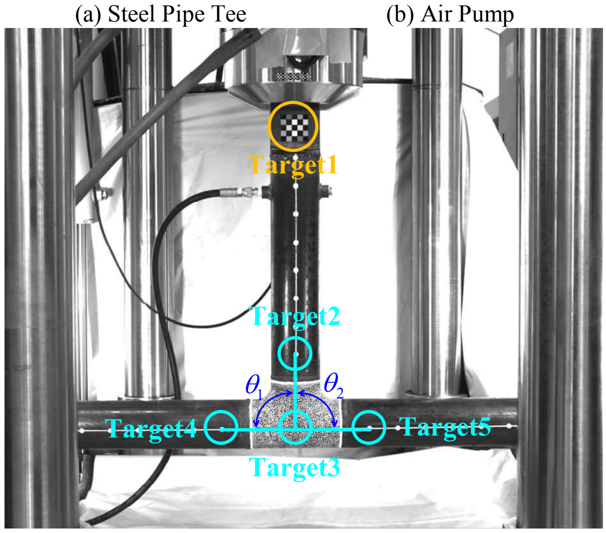
Fig. 1 shows the algorithm [2] for measuring the deformation angle of the steel pipe tee, and is classified into 6 steps. Regarding a region in the steel pipe tee desired for the measurement of deformation angle, the ROI (Region of Interest) window is extracted. By using the median and sharpening filters [3], the shape of the steel pipe tee is enhanced. By using the Sobel operators on the enhanced shape, the boundary of the steel pipe tee is extracted. To facilitate the line recognition, Dilation mask is applied to expand the outermost pixel. In addition, the deformation angle is measured through the line recognition by using the Hough transform [4] of the steel pipe tee's shape.

3. In-plane Cyclic Loading Test Using Steel Pipe Tee



(a) Steel Pipe Tee

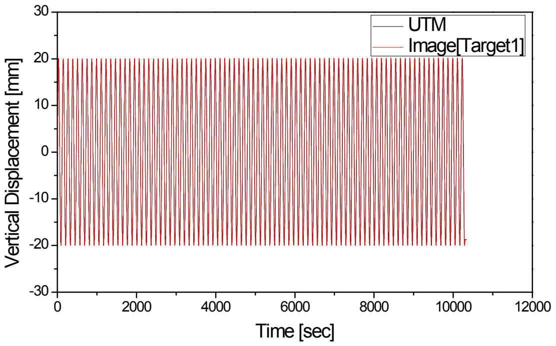
(b) Air Pump



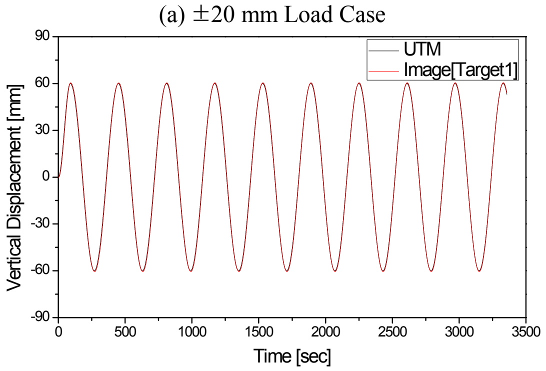
(c) Installed Target

Fig. 2. Experimental Setup

The setup location of the sensor is shown in Fig. 2. Fig. 2 (a) shows the steel pipe tee installed on the UTM, while it shows the lighting installed to minimize the noise caused by optical influences. Fig. 2 (b) refers to the air pump used for the internal pressurization of the steel pipe tee up to a pressure of 3 MPa. Fig. 2 (c) shows Target 1 installed to confirm the behavior of the UTM (Universal Testing Machine) and Targets 2 through 5 to compare the deformation angles using the measured displacements with the deformation angles extracted from the line recognition through image enhancement of the shape of the steel pipe tee. During the experiment, the image measurement system was used to obtain 2448 × 2048 pixel images at 2 frames per second. The UTM was measured at a data acquisition speed of 2 Hz.

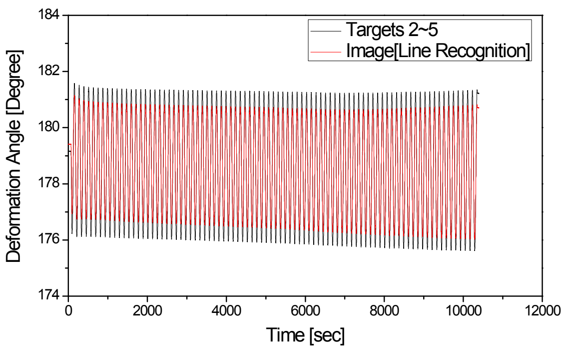


(a) ±20 mm Load Case

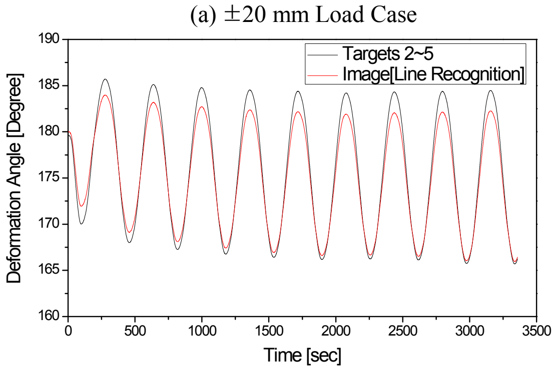


(b) ±60 mm Load Case

Fig. 3. Comparison of Response Measured from UTM



(a) ±20 mm Load Case



(b) ±60 mm Load Case

Fig. 4. Comparison of Measured Deformation Angle

Fig. 3 shows the graph comparing the responses measured from the LVDT (Linear Variable Differential Transformer) of the UTM in the in-plane cyclic loading test with the responses measured using image. The two responses matched each other well. Fig. 4 shows a comparison between the deformation angle using the displacement measured by using Targets 2 through 5, and the deformation angle measured by using the Hough transform of the image applied with the line recognition. In the figure, a phase difference can be seen at all points. This is because the local variation occurred in the steel pipe tee during the in-plane cyclic loading test.

4. Conclusions

This study suggested a non-contact type measurement method through image analysis, based on an image measurement system, which measured the deformation angle during the in-plane cyclic loading test of a steel pipe tee. The deformation angle measured from the image data, which underwent line recognition, has accuracy similar to that of the deformation angle extracted by using targets, thus verifying the validity of the image data. In addition, by using the image measurement system the deformation angle at a remote distance can be measured without the installation of a conventional sensor. Therefore, the deformation angle, as measured, are expected to become major factors for defining the failure criteria of the piping system of a seismically isolated nuclear power plant in the future.

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