Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2017

Failure Strain and Deformation Angle Measurement for a Steel Pipe Elbow Using Image Signal under In-plane Cyclic Loading Test

Sung Wan Kim [a*], Bub Gyu Jeon [a], Dong Uk Park [a], Hyoung Suk Choi [a]
[a] *KOCED Seismic Simulation Test Center, Pusan National University, Yangsan*
[*] *Corresponding author: swkim09@pusan.ac.kr*

1. Introduction

Maintaining the soundness of the main equipment of a nuclear power plant is recognized as a very important issue in relation to the safety of the structure, and the soundness of the piping is a very important issue related to the safety of the nuclear power plant. The piping of a nuclear power plant is designed, manufactured, installed, tested, and inspected according to strict standards and specifications, but many piping damage and breakage cases are reported in the isolated nuclear power plant. In this study, the ultimate state of the steel pipe elbow, which is a weak part of the isolated power plant piping system, is defined as rupture or leakage and in-plane cyclic loading test is performed. Also, it measured the failure strain and deformation angle of the steel pipe elbow using an image measurement system and measured the failure strain and deformation angle which were impossible to measure with a conventional sensor.

2. Methods

In this study, it applied the image measurement system to measure the failure strain and deformation angle of the steel pipe elbow under in-plane cyclic loading test. The image measurement system consists of CMOS camera, lens and notebook. The failure strain was measured using a 1D average strain measurement method using an image measuring system. The deformation angle was measured by line recognition using image filter processing.

2.1 Average Strain Measurement

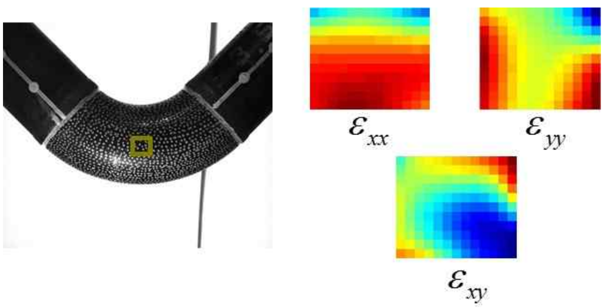

Fig. 1. Strain measurement using image signal

Displacement is obtained by tracking motion from image information of any speckle pattern before and after deformation of the object. The image of the region to be measured is shown before and after the deformation, and the position information of the pixel can be expressed using the normalized cross correlation [1-2]. The average strain of a structure can be determined by using the image measurement system. When the axial displacement against the reference point along the axis is plotted to the pixels of each image and lines are plotted using the linear function, its slope is the average strain. Fig. 1 shows the contour analysis of the average strain.

2.2 Deformation Angle Measurement

Fig. 2 shows the algorithm for measuring the deformation angle of piping using image filter processing, and is classified into 6 steps. Region The ROI (Region of Interest) window is extracted for the region where the failure strain measurement is desired in the steel pipe elbow. In order to reduce the noise of the illumination when acquiring the image, the median filter is used and the shape of the piping is enhanced by using a sharpening filter. The boundary of the steel pipe elbow is extracted by using Sobel operators on the enhanced shape, and Dilation structure is applied to extend the outermost pixel to facilitate line recognition. The deformation angle of the steel pipe elbow is also measured by recognizing the line through the Hough transform [3].

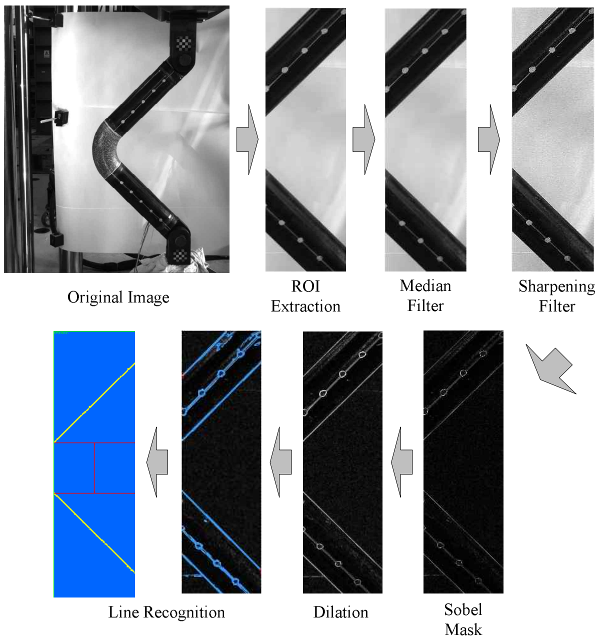

Fig. 2. Deformation angle measurement using image signal

3. In-plane Cyclic Loading Test

The test was performed to verify the failure strain and deformation angle measurement algorithm using image signal. In this study, failure mode of piping was defined as penetration crack and in-plane cyclic test was performed until penetration crack occurred [4].

Fig. 3. Installed sensor (Targets and strain gage)

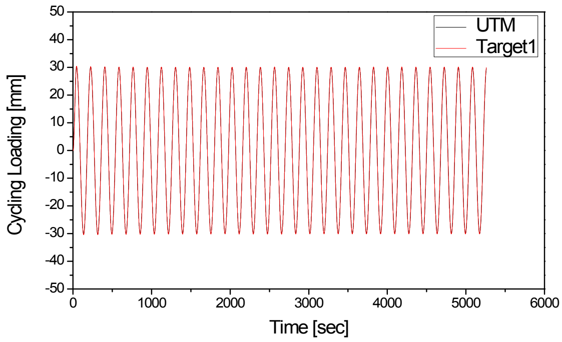

Fig. 3. Comparison of response measured from UTM

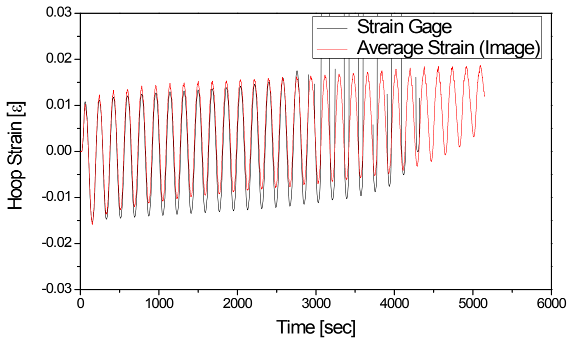

Fig. 4. Comparison of response measured by strain gage

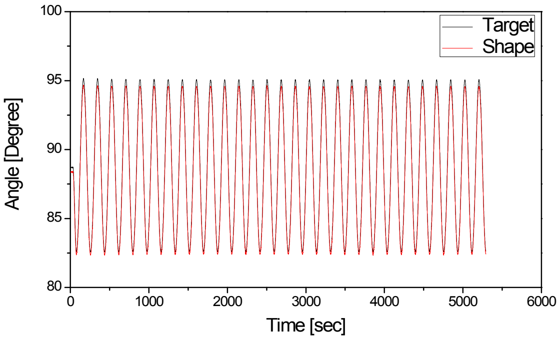

Fig. 5. Comparison of measured deformation angle

Fig. 3 shows the installed position of the sensor. Fig. 4 compares the response measured by the LVDT of UTM (Universal Testing Machine) with the image signal (Target 1) under the in-plane cyclic loading test and confirms that they are in good agreement. Also, the error rate [5] for the percent error is less than 1% and the RMS error is less than 0.5 mm. Therefore, it is shown that the reliability of the displacement response estimated using the image signal processing is good. Fig. 5 compares the average strain estimated using image signal (Target 6) and the response measured by the strain gage. The strain measured by image signal is estimated to be less than 5% of the percent error and less than 3% of the RMS error, but the strain gage is installed at a symmetrical location and is considered to be an error due to local problems Fig. 5 compares the deformation angles measured with arbitrary targets (Targets 2 ~ 5) drawn on the piping and the images applied with image signal to the deformation angles measured using the line recognition. In Fig. 5, it can be seen that the phase difference occurs at the starting point. This is because it is not located at the center of the steel pipe elbow exactly when drawing any target in the steel pipe elbow, so it is showed that the phase difference occurs.

4. Conclusions

In this study, it suggests a non-contact measurement method based on image signal based on image measurement system, which is a suitable method for measurement of failure strain and deformation angle under in-plane cyclic loading test of steel pipe elbow.

ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (NRF-2015R1C1A1A01054962).

REFERENCES

[1] H. A. Bruk, S. R. McNeil, M. A. Sutton, and W. H. Perter, Digital image correlation using Newton-Raphson method of partial differential correlation, Experimental Mechanics, Vol.29, No.3, pp.261-268, 1986.
[2] J.P. Lewis, Fast normalized cross-correlation, Vision Interface, pp.120-123, 1995.
[3] Zhou S, Jiang Y, Xi J, Gong J, Xiong G, Chen H. A novel lane detection based on geometrical model and Gabor filter. Intelligent Vehicle Symposium, pp. 59-64, 2010.
[4] B.G. Jeon, S.W. Kim, D.U. Park, H.S. Choi, A Failure Estimation Method of Steel Pipe Elbows under In-plane Cyclic Loading, Nuclear Engineering and Technology, Vol. 49, pp. 245-253, 2017.
[5] S. W. Kim, S. S. Lee, N. S. Kim, and D. J. Kim, Numerical Model Validation for a Prestressed Concrete Girder Bridge by Using Image Signals, KSCE Journal of Civil Engineering, Vol. 17, No. 3, pp. 509-517. 2013.