A Study on the Experimental Errors of Strain-based Fault Detection of Bolted Truss Structures

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1. Introduction

Mechanical structures used to lift heavy objects are designed with safety and reliability in mind, but they are often damaged due to errors in materials and shapes, unexpected environments, and overloads. Accordingly, the field of structural health monitoring has been continuously developed to detect damages of structures and to understand their importance, impact, and progress. In this paper, experimental errors and methods for dealing with the strain measurement, which is mainly used in the static estimation method among the techniques for the monitoring structural damage during field operation, are analyzed.

A plurality of strain gauge signals attached to each element were obtained by applying a cyclic load perpendicularly to the ends of the multiple truss structure samples simulated on lab scale. Therefore, it is analyzed experimental errors such as scattering by sample, location and direction of strain gauge attachment, and suggested how to deal with them. The ultimately, we proposed fault detection method for each damage scenarios that are robust against these error factors.

2. Test specimen and conditions

The truss model is assembled with small size angles and C-type section steel, and the fastening part using high tension bolts is fastened with a constant torque value depends on hole size. And structural limitations of the test machine that apply the load on the same line, the specimen is connected top and bottom with the same shape model to give the moment. Prior to starting the main test, the pre-test confirmed the maximum load value, maximum displacement value, and maximum strain of the truss structure, and determined the test conditions and attachment locations under which the strain value changed significantly because of repeated loads. Strain was measured by attaching a quarter bridge type strain gauge to 24 spots in the truss structure.

In the experiment, the truss structure was mounted on the UTM as shown in the below figure, and the strain change in the attached strain gauge was recorded while repeatedly given the displacement value in the elastic region.

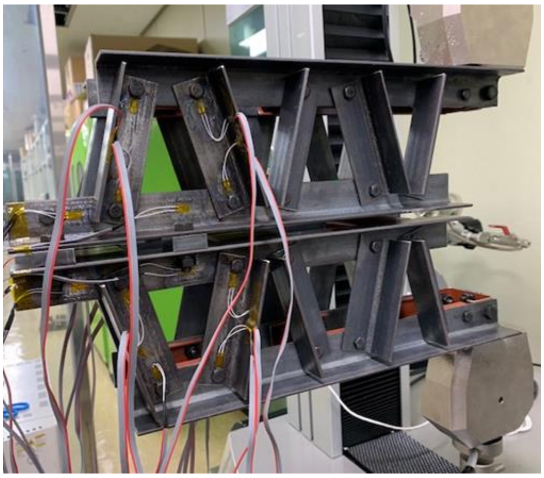


Fig.1 Truss model assembled with steel angles

After the repetition process was completed, the angles in the truss structure were replaced with artificial cracks, reassembled, and remounted in the UTM. The variation of the strain value of 24 points in the normal structure and the fault structure including cracks was analyzed. The table below shows the test conditions such as the repeated displacement value and the period applied to the truss model.

Table 1 Test conditions

Damage Scenario	Test Range (mm)	Frequency (Hz)	Crack Location
#1	1.5 ~ 2.5	0.2	F-6
#2	1.5 ~ 2.5	0.2	F-11
#3	1.5 ~ 2.5	0.2	R-11
#4	1.5 ~ 2.5	0.2	R-6
#5	1.5 ~ 2.5	0.1	F-6
#6	1.5 ~ 2.5	0.1	F-11
#7	1.5 ~ 2.5	0.1	R-11
#8	1.5 ~ 2.5	0.1	R-6

The crack is in the center of the equal angle and is machined into 1 mm width by 20 mm depth. As shown above the table, the strain was recorded in the truss model by replacing it with four spots of normal structure.

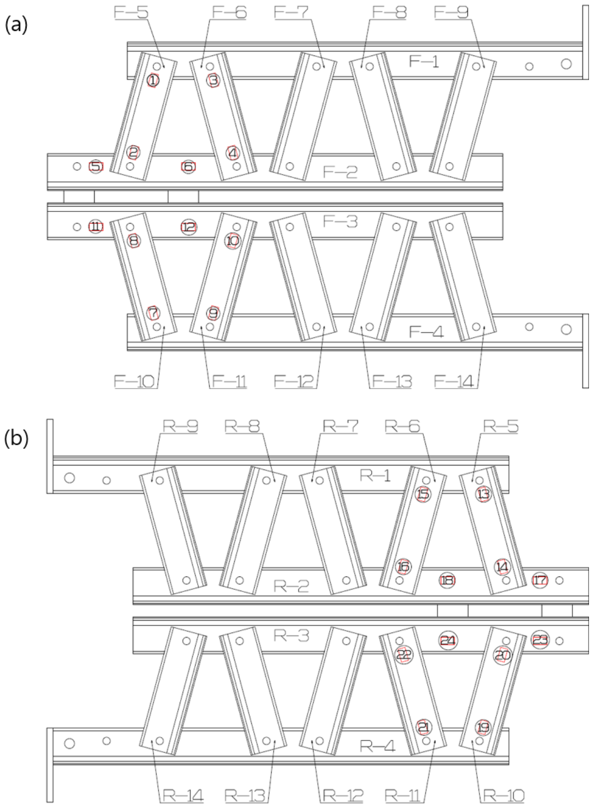
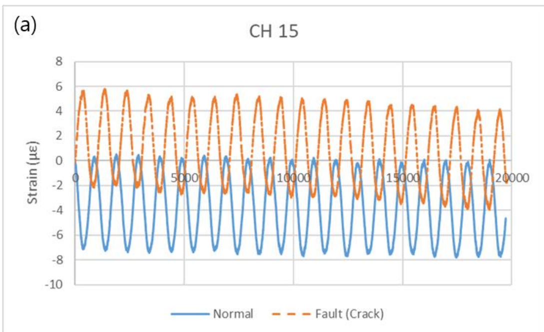


Fig.2 Attached strain gauge location and spots of replaced steel angle in the truss model as (a) front view and (b) rear view

3. Strain response of truss structure

In scenario 8, where the position of R-6 was changed among 8 conditions, strain signal of strain gauge number 15 was detected as the phase shifted by 180 degrees. As a result, the strain signal increased more at the maximum peak value and decreased more at the minimum peak value with respect to the repetitive displacement value at the symmetry strain gauge number 13 and the parallel strain gauge number 18 among the unchanged surrounding strain gauges.



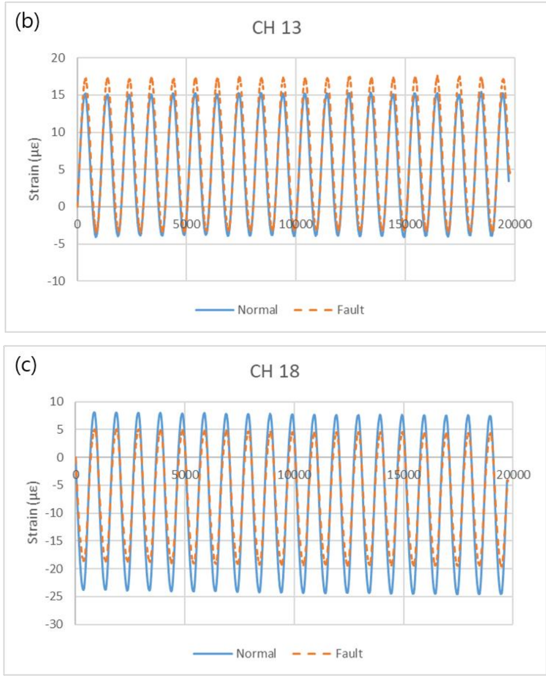


Fig.3 Strain signal comparison on different strain gauge channels

4. Conclusions

When the same truss model assembled top and bottom was repeatedly loaded in the elastic range, the variation of the strain signal in the normal structure and that of the fault structure including cracked member was compared.

The strain gauges were attached to the fixed end of the small truss made in the cantilever beam shape, and the change tendency of the strain response of the other part was confirmed when the damage was included in the specific part.

References

[1] S. H. Lee, J. H. Lee, Damage Detection in Truss Structures using Anti-Optimization, *Journal of Korean Society of Steel Construction,* 25 (4) (2013) 441-449.