Corrosion Detection for Steel Wires in Bridge Cables Using Magnetic Method

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Summary

Steel Cables are major load-carrying components in cable-supported bridges. The magnetic flux testing method is believed to be feasible to detect steel wire corrosion in bridge cables by evaluating loss of metallic cross section area (LMA). Variations in the length, width and depth of the corrosion zone will cause disturbance in the output of the LMA-measuring sensors. Main purpose of this fundamental research is to clarify the influence of corrosion size on LMA signals during the steel wire magnetic detection. Finite element method (FEM) is used to simulate the magnetic flux testing for steel wires with LMA defects. Variable parameters considered in the FE model include: sizes and locations of LMA defects, air gap between the cable and the magnets, and diameter of the cable under test. Model experiments are conducted in our lab for comparison with the FEM simulation. A defect-length factor is suggested to describe the influence of the defect length on the LMA signal and a calibrating method is proposed to eliminate the effect of flaw sizes in LMA quantitative evaluation.

Keywords: magnetic testing, LMA, flaw size, bridge cable, FEM, model experiment

1. Introduction

A great number of cable-supported bridges have been constructed in the world during the past thirty years. However, the cables often incur rust and even break within their design lives. The magnetic flux method has shown high potential to detect steel wire corrosion and broken wires, and has been used in the non-destructive testing of cable-supported bridges. Previous research indicates that the defect signals will be influenced by defect length and that quantitative evaluation will be given if the defect-length effect can be eliminated.

Main purpose of this paper is to clarify the influence of defect length on defect signals during the steel wire magnetic detection. Finite element method (FEM) was used to simulate the magnetic flux testing for steel wires with LMA defects, and model experiments were conducted in our lab for comparison with the FEM simulation. A calibrating method was proposed to eliminate the defect-length effect in LMA (loss of metallic cross section area) quantitative evaluation.

2. FEM simulation

Finite element models were established to simulate a bridge cable composed of 61ϕ7mm steel wires and to conduct parametric analysis. Influences on the defect-length effect from three parameters were studied: the defect location, the air gap distance between the magnets and the cable surface, and the diameter of the cable under test.

The LMA signal character can be described by the curves in Fig 1, in which the horizontal axis refers to the relative length of the defect and the vertical axis refers to the relative peak value of the LMA signal. These two curves are also proposed to describe the defect-length effect in bridge cable evaluation. In Fig 1, L refers to the length of the defect, L_{yo} refers to the length of the magnetic yoke, and L_{cr} refers to the axial clearance between the two magnets. Curve 1 shows the signal character of long uniform corrosion, especially the superficial corrosion of cables, which will cause

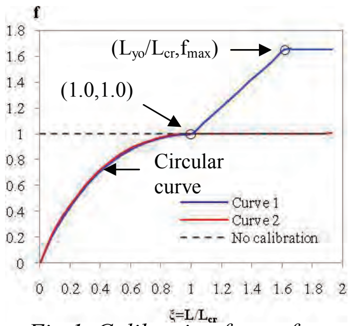

Fig.1. Calibrating factor for two types of defects

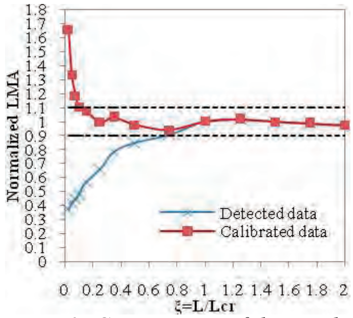

Fig. 2. Comparison of detected and calibrated data

an increase in the air gap distance, thus exerting obvious influence on the magnetizing performance. Curve 2 shows the signal character of local corrosion and broken wires. After a series of analysis and comparison, the circular curve is selected to fit the curve part of curve 1 and curve 2 because it is convenient for engineers to build the curves and it also has a high accuracy.

The curves in Fig 1 can be used for data calibrating to eliminate the defect-length effect in bridge cable evaluation. The factor f on the calibrating curve 1 and curve 2 is a function of ξ, i.e., f(ξ). Suppose that the LMA of one cable section is A_0, the LMA after calibration will be $A=A_0/ f(\xi)$.

3. Experiment investigation

A cable model made of 66ϕ7mm steel wires and 7 aluminium tubes, 4m in length, was built in the lab. A series of defects at various locations were set in the cable. The relative area of the defects was set to be 3.03%. The detected data of several tests were averaged into one to eliminate random errors during tests. The average data was calibrated by the calibrating curve 2 in Fig 1. Both of the average data and the calibrated data are shown in Fig 2. It can be seen that when the detected data is used directly for defect evaluation without calibration, which is a common practice in traditional NDE process, the error is significantly large and gives an underestimation of real LMA when the defect is shorter than L_{cr}. The calibrated data gives a much better evaluation for the short defects.

4. Conclusion

Main conclusions of this paper are as follows: (1) Traditional quantitative detection of LMA defects gives an obvious underestimation for the evaluation of inner defects, especially for the short defects. (2)When detecting superficial defects, overestimation for long defects and underestimation for short defects will be given if no calibration is conducted, and cables with a larger diameter will give larger errors if the same device is used for all cables. (3)Evaluating errors caused by the defect-length effect can be reduced significantly by the calibrating method proposed in this paper. The proposed calibrating curve has a good coincidence with the experimental results. (4)The defect-length effect is mainly based on the ratio between the defect length and the parameter $L_{cr}=L_{yo}-2L_{mag}$, rather than the absolute value of the defect length. For defects longer than $0.1L_{cr}$, the calibrating method shows good performance. With the calibrating method proposed here, defects larger than $0.1L_{cr}$ can be evaluated with the return flux signal no matter the defect is a uniform corrosion defect or a wire broken defect.

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