The First Japanese-Australian Joint Seminar

under the theme:

Application of Electromagnetic Phenomena
in Electrical and Mechanical Systems

SEMINAR PROGRAM and ABSTRACTS

The University of South Australia
Adelaide, Australia

16 - 17 March 2000

Inverse analysis of magnetization from magnetic flux density for evaluation of fatigue degradation

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1. Introduction

Some non-magnetic structural steels used in power plants show presence of magnetic flux leakage at the stress concentrated parts[1]. This is due to the martensitic transformation inside the loaded material. Therefore, it is possible to estimate the fatigue degradation by inverse inference of the magnetization from magnetic flux density scanned outside the steel. The advantage of this new method compared with the usual methods is that we can evaluate the degradation by NDT before the outbreak of cracks. In this study, a method of reconstructing the magnetization from the magnetic flux density is developed. Furthermore, the magnetization of a sample with cracks introduced by a fatigue test is reconstructed by this method.

2. Simulation

An auto-adaptive feed-forward Neural Network (NN) is used to reconstruct the magnetization from the leakage magnetic flux density. Faster than a model-based approach and using additional regularization methods, this procedure is very effective to cope with the difficult inverse problem[2]. The magnetic flux density $\boldsymbol{B}$ due to the magnetization $\boldsymbol{M}$ is computed using *Biot-Savart* law,

$$\boldsymbol{B} = \frac{\mu_0}{4\pi} \int \frac{(\nabla \times \boldsymbol{M}) \times \boldsymbol{R}}{R^3} \, dv. \tag{1}$$

3. Results

After training the NN with simulated data, the validation mean absolute error is 0.0239. The result shows good quality of reconstruction. The magnetization of the sample with cracks introduced by a fatigue test was reconstructed by using this NN. The shape of the sample is shown in Fig.1. The sample was cut into this shape because x component of the magnetic flux density couldn't be measured.

Fig.2 is the reconstructed magnetization distribution. The slit and the crack are shown in this figure. We can confirm the region of the crack and a part of cutting plane are magnetized. The magnetic flux density were calculated from this magnetization to examine the accuracy of results, and the calculation results are in the agreement with the measurement results very well.

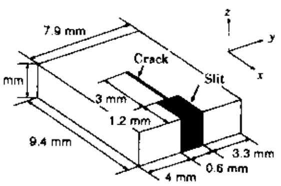

Fig.1 Shape of Sample

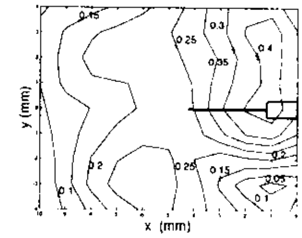

Fig.2 reconstructed magnetization distribution: $|M|$

4. Conclusion

In this study, we developed a method for reconstructing the magnetization distribution from the magnetic flux density. Using this method, we reconstructed the magnetization distribution of a sample with a crack. It is confirmed from the result the regions around a crack and a part of cutting plane are magnetized . This method will be applicable even to samples without cracks because the fatigue exposed parts in those sample are also magnetized.

References

[1] A. Gilanyi, Nondestructive Evaluation of Structural Steels based on Magnetic Property Change,*Ph.D.Thesis*, The University of Tokyo, 1997

[2] R. C. Popa and K. Miya, Approximate inverse mapping in ECT, based on aperture shifting and neural network regression, *J. Nondestr. Eval.*,Vol. 17,No. 4, 1998, pp. 209-221.