

NUMERICAL MODELING OF THERMAL FATIGUE CRACK FROM VIEW POINT OF EDDY CURRENT TESTING

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Abstract

Eddy current testing (ECT) is one of electromagnetic nondestructive method. It was initially regarded as one kind of qualitative measurement during the inspection of natural cracks, such as stress corrosion crack (SCC), thermal fatigue crack (TFC) et al. On the other hand, ultrasonic testing (UT) is widely used for quantitatively detecting cracks. However performance of UT is inevitably affected by complexity of natural cracks, e.g. fracture surface roughness and so on [1]. Therefore, enhancement of inspecting natural cracks by other non-destructive method is demanded. ECT has become a favorable candidate for the aim with the aid of great progress of electromagnetic computational technology [2]. In fact quite a few studies have been reported success in quantitative evaluation of SCC and also they pointed out that modeling of crack is the issue for the accuracy measurement [3,4,5]. Based on this, modeling of TFC should be emphasized for the accurate eddy current inspection. However, only few studies have been discussed on the matter [6,7]. Further researches by more specimens are needed.

The present study discusses numerical modeling of thermal fatigue crack (TFC) from view point of eddy current testing. Four TFCs artificially introduced into type SUS316 stainless steel plates are prepared for the study. Eddy current signal are gathered by a differential type plus point probe with three frequencies of 100 kHz, 200 kHz and 400 kHz. Subsequent destructive test is carried out to reveal the profile of cracks. TFCs are modeled as a region with constant width, uniform conductivity and real profile in numerical simulation by software Comsol Multiphysics 4.4. The basic geometry of simulation is shown as figure.1. With consideration on previous studies [6,7], numerical modeling of TFC in type SUS304 stainless steel and Inconel 600 plates, results of the study demonstrate that TFC should be modeled as an almost nonconductive region in general no matter how the frequency is used.

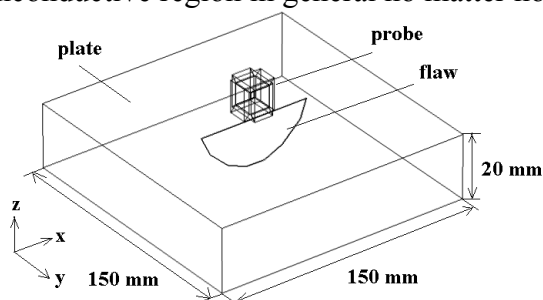


Figure 1. Basic geometry of simulation

References

- [1] M. Kemppainen, I. Virkkunen, Crack characteristics and their importance to NDE, *Journal of Nondestructive Evaluation* 30(3)(2011), 143-157.

- [2] BA. Auld, JC. Moulder, Review of advances in quantitative eddy current nondestructive evaluation, *Journal of Nondestructive Evaluation* 18(1)(1999), 3-36.
- [3] N. Yusa, Z. Chen and K. Miya, Sizing of stress corrosion cracking on austenitic stainless piping in a nuclear power plant from eddy current NDT signals, *Nondestructive Testing and Evaluation* 20(2)(2005), 103-114.
- [4] N. Yusa, Z. Chen, K. Miya, T. Uchimoto and T. Takagi, Large-scale parallel computation for the reconstruction of natural stress corrosion cracks from eddy current testing signals. *NDT&E International* 36 (2003), 449-459.
- [5] Z. Badics, Y. Matsumoto, K. Aoki, F. Nakayasu and A. Kurokawa, Finite element models of stress corrosion cracks (SCC) in 3-D eddy current NDE problem. *Nondestructive testing of materials*. IOS Press (1995), 21-29.
- [6] J. Wang, N. Yusa, H. L. Pan, M. Kemppainen, I. Virkkunen and H. Hashizume, Discussion on modeling of thermal fatigue cracks in numerical simulation based on eddy current signals, *NDT&E International* 55 (2013), 96-101.
- [7] J. Wang, N. Yusa, H. Pan, M. Kemppainen, I. Virkkunen and H. Hashizume, Modeling of thermal fatigue crack for enhancement of electromagnetic nondestructive evaluation of nuclear power plant, The 21st International Conference on Nuclear Engineering. (2013).

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