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Materials Letters 59 (2005) 3656 – 3659

materials letters

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Diagnostics of stress corrosion and fatigue cracks using benchmark signals

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Received 13 April 2005; accepted 23 June 2005
Available online 20 July 2005

Abstract

On the basis of the background that most studies for quasi-static, low-frequency electromagnetic nondestructive methods consider artificial notches that are, in reality, not always similar to real cracks such as stress corrosion and fatigue cracks, this paper introduces original eddy current inspection data in order to make it available to other researchers in the field. The authors expect this data to be helpful to those who are interested in the application of quasi-static low-frequency electromagnetic field simulations to practical eddy current testing problems. Stress corrosion and fatigue cracks are fabricated into nickel–chromium alloy plates, and eddy current inspections of the plates are performed using four eddy current probes. Signals of four specimens with stress corrosion cracking and another four with fatigue cracks are presented together with profiles of the cracks revealed through destructive testing.

Keywords: Nondestructive testing; Eddy current testing; Natural crack; Benchmark problem; Numerical modeling; Alloy 600

1. Introduction

Numerical simulations of quasi-static, low-frequency electromagnetic fields have advanced significantly in recent years, enabling one to compute eddy currents induced in linear conductive media with high accuracy. One of the practical applications of such numerical simulations is the simulation of eddy current inspection signals. Many computational methods have been developed, and quite a few have demonstrated their efficiencies [1].

However, a large problem still remains regarding the establishment of computational strategies for eddy current inspections from a practical point of view. Although the discrepancy between real cracks and artificial notches has already been noted by a few studies [2–4], the computational model of real cracks, namely how induced eddy currents flow near real cracks, has not been adequately studied, and most studies of the simulation of eddy current inspections have heretofore only considered artificial notches. Whereas eddy current inspections are considered to be complementary to the diagnostics of metal alloys using the existing sophisticated methods such as photoinduced non-linear optical methods, this hampers the application of numerical simulations to real problems.

The most plausible reason why the consideration of real cracks is still avoided in the literature is the difficulty of fabricating cracks, particularly stress corrosion cracking. Whereas some research groups have started to consider real cracks [5,6], most studies still utilize notches to model cracks in their studies of eddy current inspections because it is not always possible to obtain experimental data. Accurate experimental data that anybody can access and utilize for their own research purposes is indispensable for the further development of electromagnetic field simulation techniques applicable to practical eddy current issues.

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0167-577X/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.matlet.2005.06.038

Such circumstances motivated the authors to collect and provide experimental data measured in their laboratory. The data contains eddy current inspection signals of artificial stress corrosion cracking and fatigue cracks. The true profiles of the defects are also provided with the signals. A brief explanation of the experiments and some of the results are presented in this paper.

2. Eddy current inspections

2.1. Specimens

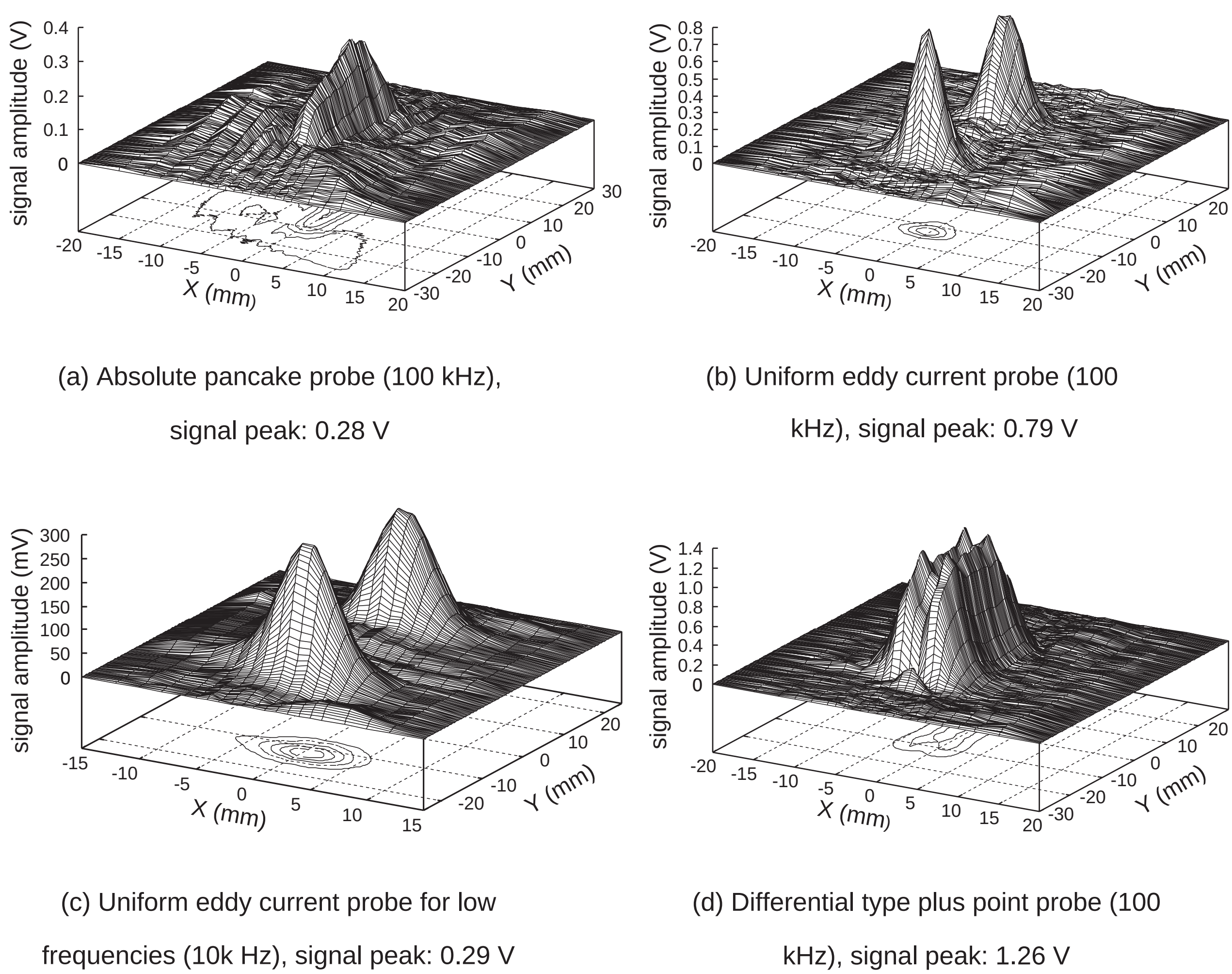
Stress corrosion cracking and fatigue cracks were artificially introduced into Alloy 600 plates. After a notch was machined into a plate to locate the initialization of cracking, the plate was loaded with three-point bending and dipped into polythionic acid solution to introduce stress corrosion cracking. Fatigue cracks were fabricated with cyclic three-point bending. The notch was removed after a crack was introduced. The specimens measured 100 mm in length, 200 mm in width, and 8 mm in thickness. Penetrant testing was then performed to confirm the presence of cracks and also to evaluate their length. Four specimens with stress corrosion cracking and four specimens with a fatigue crack were prepared.

2.2. Experimental results

To obtain as much information as possible, eddy current inspections were performed using the following four probes:

- Absolute pancake probe (100, 400 kHz);
- Uniform eddy current probe (100, 400 kHz);
- Uniform eddy current probe for low frequencies (10, 40 kHz);
- Differential type plus point probe (100, 400 kHz).

Values in the brackets indicate frequencies utilized in the inspections. Eddy current inspections were performed using a commercial eddy current inspection instrument, the aect2000s by Aswan ECT Co. Ltd. For an inspection, an eddy current probe was precisely positioned using an XYZ



(a) Absolute pancake probe (100 kHz), signal peak: 0.28 V

(b) Uniform eddy current probe (100 kHz), signal peak: 0.79 V

(c) Uniform eddy current probe for low frequencies (10k Hz), signal peak: 0.29 V

(d) Differential type plus point probe (100 kHz), signal peak: 1.26 V

Fig. 1. Eddy current signals caused by the largest stress corrosion cracking.