ASSESSMENT OF THE EFFECTS OF SCANNING VARIATIONS AND EDDY CURRENT PROBE TYPE ON CRACK DETECTION

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INTRODUCTION

Eddy current procedures are currently the most capable, of the nondestructive evaluation (NDE) techniques that are being applied in industry. The performance capability of an NDE procedure is that of the probability of detection as a function of flaw size. Prediction of the performance capability of a given procedure has been inexact, due to the lack of supporting theory, and has therefore been either validated experimentally or has been assumed to be applicable to a test problem by its similarity to a "time proven" application. Rigorous experimental validation of an NDE procedure is laborious and must be repeated for each new application and/or change in NDE parameters. Attention has been focused on this problem and much of the work described in this volume is directed toward the determination of critical characteristics of NDE applications and in the generation of supporting theory to facilitate predictive modeling of NDE performance capability. The experimental work described in this paper expands on previous work on the characterization of eddy current probes, as applied to flaw detection [1,2], and is directed to support the expansion of application theory [3].

Air core and ferrite core eddy current probes were fabricated to reduce the complexity of theory development. These probes are similar in construction to some probes that are used in industrial NDE applications but were not fabricated to optimize flaw detection. Indeed more complex probe forms are used in flaw detection and have been shown to provide improved detection and/or resolution than the simple forms used herein. The variety of probe configurations available has contributed to the problem of predicting the performance capability of specific eddy current procedure. Predictive performance has been further complicated by variations in the geometry and in the materials used in the fabrication of "identical" probes. X-radiographic inspection of "identical" probes (i.e. the same part number from various probe manufacturers) reveals a startling variety of geometries. Our objective in this work was that of NDE problem characterization and extra care was taken to fabricate "identical" probes for use at various facilities. Extra care in fabrication is evident but slight dimensional variations in probe geometry are revealed by X-radiography [4]. These variations are recognized as potential, contributing factors in the experimental work.

PROBE ELECTRICAL CHARACTERISTICS

Eddy current test instruments are designed to detect, amplify, display and quantify changes in the electrical properties of the test (sensor) probes. Measurement of the electrical characteristics of the probes was therefore made to assess inherent probe properties and differences in properties for "identical" probes. The test set up consisted of a Hewlett Packard (HP) 4192A Impedance Analyzer and a HP 2631G line printer, controlled by an HP 85 personal computer using an HPIB interface. The system was programmed to provide a stepped frequency scan from 0.1 KHz through 10 MHz. The HP4192A was programmed to provide a constant, 1 Volt rms, stimulus during the test sequence. The system voltage was recognized to be lower than the 4.24 Volt rms stimulus that is provided by the EM-3300 instrument that was used for flaw detection. The lower voltage was not judged to be significant since the characteristic operating point for the coils is well below the saturation level of the probe core material. Probe characterization, by this method, was performed in air, coupled to 6Al-4V titanium alloy plate material and at controlled lift-off distances from the titanium plate.

PROBE RESPONSE IN THE PRESENCE OF A FLAW

Support of the development of general theory and modeling required characterization of probe response in the presence of a flaw. Probe response, as sensed by the EM-3300 instrument, was used as a basis for plotting the relative output when the probe was scanned across the flaw. A 200 KHz, 235 turn (40 AWG), air core probe with a resonance frequency of 2141 KHz in air, was selected for the air core probe assessments. A 200 KHz, 50 turn (40 AWG), ferrite core probe with a resonance frequency of 2564 KHz in air was selected for the ferrite core probe assessments. The air core probe was a pancake type with a core diameter of 0.060 inches, an outside diameter of 0.120 inches, and a set-back of 0.022 inches from the probe face. The ferrite core probe was wound directly on a 0.0625 inch diameter by 0.375 inch long ferrite with a 0.064 inch set-back from the probe face. Both probes were initially characterized on 6Al-4V titanium alloy plate to ascertain response to lift-off. Minor changes in the electrical properties of the probes was observed over a lift-off range from 0.000 to 0.016 inches. Over this range, resistance and resonance frequency decreased slightly and impedance, inductance and phase angle increased slightly.

A 0.136 inch long by approximately 0.063 inch deep fatigue crack in a 0.250 inch think, 6Al-4V titanium alloy plate panel was selected for characterization of the response of the 200 KHz probes ($a/\delta = 1.24$). An Automation Industries, EM-3300, null balance (two phase/amplitude detectors) type instrument was used for all scanning. The instrument was initially nulled on the 6Al-4V titanium alloy panel. The phase angle of the detector was shifted to align lift-off response in the horizontal channel and thereby to minimize the contribution of the lift-off parameter in the vertical (defect) channel.

The panel was scanned (at 0.5 inch/minute) parallel to the axis of the fatigue crack and perpendicular to the axis of the fatigue crack, in the contact mode and at selected lift-off values to 0.0066 inches (see Figure 1). Scan line increments were set at 0.050 inches and data were recorded at 0.010 inch increments in both cases. The data were then

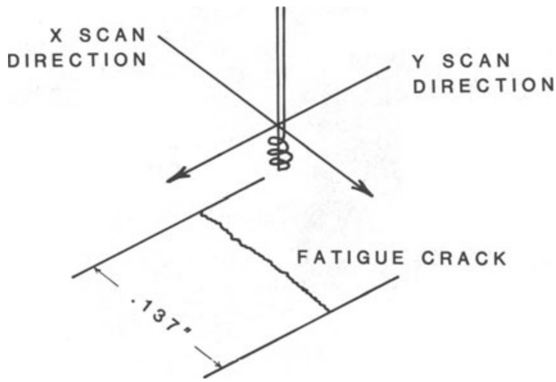

Figure 1. Probe scan paths

plotted to present an isometric view of the response as a function of proximity to the crack. Such plotting is a modification of an imaging method that was described by Copley [5]. In addition, plan view projections of the images were plotted and quantified with respect to the physical dimensions of the probes. This method supplements the direct measurement of probe fields [6] and provides a direct correlation of probe response to a flaw.

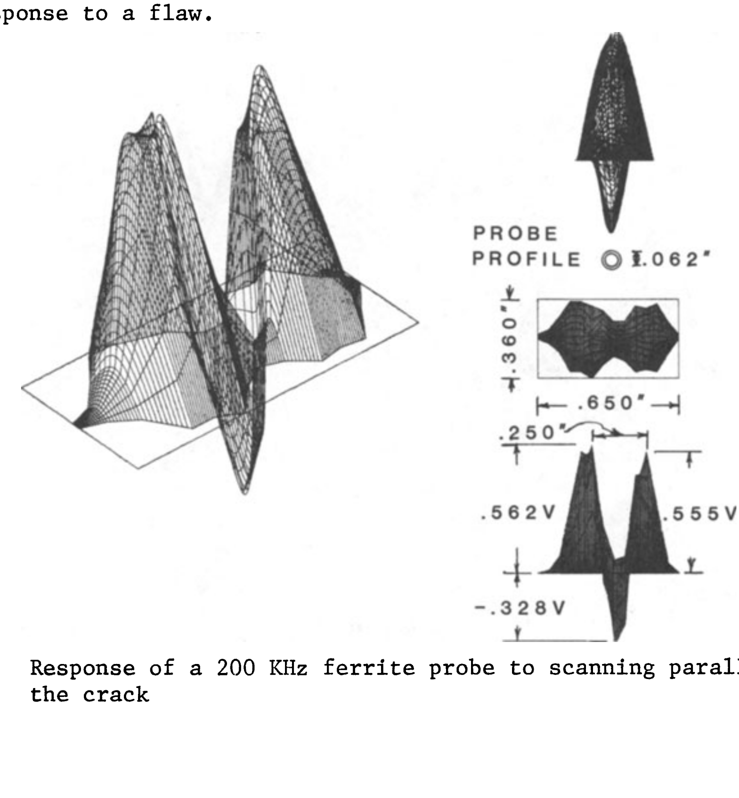

Figure 2. Response of a 200 KHz ferrite probe to scanning parallel to the crack

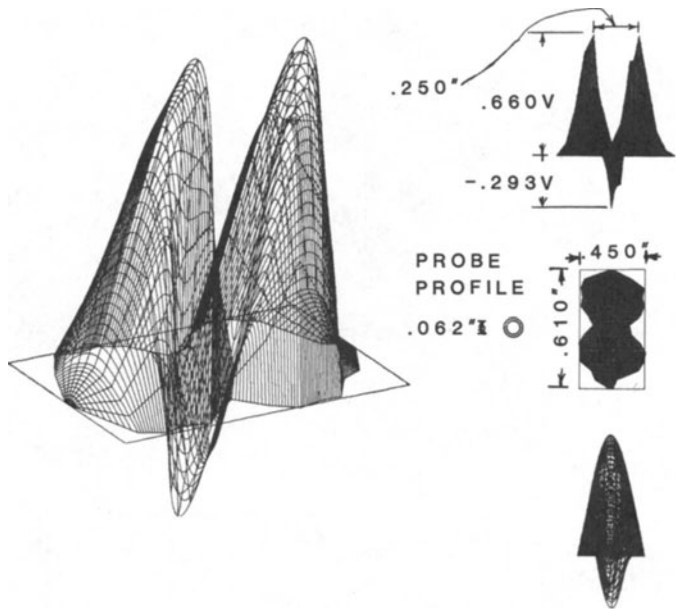

Figure 3. Response of a 300 KHz ferrite probe to scanning perpendicular to the crack

Figures 2 and 3 are plots of the response of the ferrite probe for the respective parallel and perpendicular (contact scans). Figure 4 shows the response of the air core probe. Figure 5 is a plot of the response of the ferrite core probe to a 0.013 inch diameter hole in a 6Al-4V titanium alloy panel (contact). Comparison of the responses reveals an increased sensitivity (magnitude of response) of the ferrite core probe

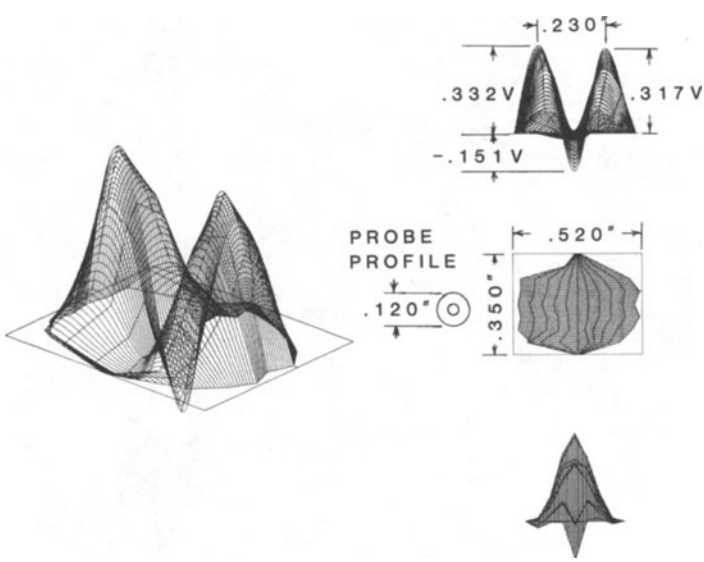

Figure 4. Response of a 200 KHz air core probe to scanning parallel to the crack

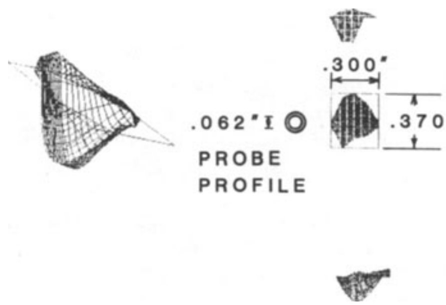

Figure 5. Response of a 200 KHz ferrite probe to scanning over a 0.013 inch diameter hole

and a response at a greater distance from the crack than that obtained with the air core probe. The shape of the responses to the crack is typical of that observed for those cases where the flaw is large with respect to the diameter of the probe. In like manner, the response to the hole is typical of responses for those cases where the flaw is small with respect to the diameter of the probe. Assymetric structural detail in one peak of the ferrite core scans is believed to be due to surface cracks in the ferrite core. Such surface cracks were observed in the Hall probe scans [6] and are common in ferrite core materials.

CONCLUSIONS

Systematic eddy current probe assessments offer new opportunities for improving the consistency of performance of the probes that are used in eddy current evaluations and for determining the suitability of a probe for continuing service in a critical NDE application. In addition, such assessments provide bases for extending the theoretical modeling procedures for use in engineering assessment and predictive analysis of eddy current performance and reliability in critical NDE applications.

Probe responses demonstrate the presence of eddy current field interaction beyond the limits of the probe diameter and the increased response obtained from ferrite core probes. The effect of the probe core diameter with respect to the flaw size is also clearly demonstrated in the form of the responses obtained.

ACKNOWLEDGEMENTS

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