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Model-based Probe State Estimation and Crack Inverse Methods Addressing Eddy Current Probe Variability

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Recent work on model-based inverse methods with eddy current inspections of surface breaking discontinuities has shown some sizing error due to variability in probes with the same design specifications [1]. This is an important challenge for model-based inversion crack sizing techniques, to be robust to the varying characteristics of eddy current probes found in the field [1-2]. In this paper, a model-based calibration process is introduced that estimates the state of the probe. First, a carefully designed surrogate model was built using VIC-3D® simulations covering the critical range of probe rotation angles, tilt in two directions, and probe offset (liftoff) for both tangential and longitudinal flaw orientations. Some approximations and numerical compromises in the model were made to represent tilt in two directions and reduce simulation time; however, this surrogate model was found to represent the key trends in the eddy current response for each of the four probe properties in experimental verification studies well. Next, this model was incorporated into an iterative inversion scheme during the calibration process, to estimate the probe state while also addressing the gain/phase fit and centering the calibration notch indication. Results are presented showing several examples of the blind estimation of tilt and rotation angle for known experimental cases with good agreement within +/- 2.5 degrees. The RMS error was found to be significantly reduced by fitting the probe state and, in many instances, probe state estimation addresses the previously un-modelled characteristics (model error) with real probe inversion studies. Additional studies are presented comparing the size of the calibration notch and the quality of the calibration fit, where calibrating with too small or too large a notch can produce poorer inversion results. Once the probe state is estimated, the final step is to transform the base crack inversion surrogate model and apply it for crack characterization. Because of the dimensionality of this problem, simulations were made at a limited set of select flaw sizes with varying length, depth and width, and an interpolation scheme was used to address the effect of the probe state at intermediate solution points. Using this process, results are presented demonstrating improved crack inversion performance for extreme probe states.

Acknowledgements:

This work is supported by the U.S. Air Force Research Laboratory (AFRL) through Research Initiatives for Materials State Sensing (RIMSS), Inversion of Received Electromagnetic Signals to Characterize Damage in Propulsion Systems, Contract No: FA8650-10-D-5210, Agreement No. 12-S7114-03-C1.

References:

1. Aldrin, J. C., Shell, E. B., Oneida, E. K., Sabbagh, H. A., Sabbagh, E., Murphy, R. K., Mazdiyasni, S., and Lindgren, E. A., "Model-based Inverse Methods for Sizing Surface-breaking Discontinuities with Eddy Current Probe Variability," *42nd Annual Review of Progress in QNDE, Incorporating the 6th European-American Workshop on Reliability of NDE*, Vol. 1706, p. 090002, AIP Publishing, 2016.
2. Mooers, R. D., and Aldrin, J. C., "Effects of Angular Variation on Split D Differential Eddy Current Probe Response," *Review of Progress in QNDE*, eds. D. E. Chimenti and L. J. Bond, (American Institute of Physics 1706, Melville, NY), 35, 090022-1 – 090022-9 (2016).