



PROBING MATTER WITH ELECTROMAGNETIC WAVES

SVR-Based Inversion of Eddy Current Probe Impedance Data for Crack Reconstruction Within Complex Structures

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Mots-clefs: NDE, Eddy Current Testing, Learning-by-Examples, Support Vector Regression

Abstract

In the last decades, great efforts have been devoted towards the development of efficient algorithms for the qualitative imaging (i.e., localization and shape retrieval) of small defects in large-scale structures. The detection and characterization of cracks, voids, corrosion and other damages that can represent a risk for the mechanical and safety integrity of the inspected structure is of fundamental importance in many scenarios involving aeronautic and nuclear engineering [1]-[3]. Among all the proposed techniques, many rely on the use of Eddy Current Testing (ECT), thanks to its portability, flexibility and low cost [3]. As a matter of fact, the signal variations produced on the inspecting probe in proximity of a detectable discontinuity can be profitably exploited in order to recover information on the defect itself.

In order to achieve such a goal, tomographic approaches based on deterministic or stochastic optimization can be exploited to retrieve high resolution images of the investigated domain [4],[5]. However, their intrinsic high computational load prevents their use in applications requiring very fast analysis, even when the use of mathematical approximations (e.g., Born or Rytov) is possible. Efficient reconstruction algorithms based on Compressive Sensing (CS) [6],[7] can also be applied, but unfortunately their applicability is limited to those scenarios where some prior knowledge on the sparseness of the unknown scatterers is at disposal [6].

Following a different approach, Learning-by-Examples (LBE) techniques [8]-[10] are able to predict almost in real-time the characteristics of the unknown scatterers, without requiring the evaluation of computationally-expensive models during the on-line testing phase. Within this framework, Support Vector Regression (SVR) benefits from a solid mathematical background, showing strong generalization capabilities and excellent computational efficiency [8].

This work is then aimed at presenting an innovative method for the localization and characterization of anomalies in complex structures by exploiting eddy current data and SVR. In the following, a short description of the technique is given. Let be given a planar structure lying on the (x, y) plane of thickness H affected by a flaw located at position (x_f, y_f, z_f) having length l_f , depth d_f and width w_f [Fig. 1(b)]. The complex-valued ECT signal is collected at Q points from an inspecting coil working at a predefined frequency and lift-off (i.e., $\xi = [\text{Re}(\xi_q), \text{Im}(\xi_q)]$, $q = 1, \dots, Q$). During an initial off-line phase, a set of N measurements is generated by considering N different configurations of the flaw. Then, denoting with α_j the j -th parameter to be retrieved ($\{j = 1, \dots, J = 6\}$), the known input-output pairs $\{\xi^{(n)}, \alpha_j^{(n)}, n = 1, \dots, N, j = 1, \dots, J\}$ are used to train J SVR in parallel. After this phase, previously-unseen measurements can then be inputted to the j -th estimator in order to get an estimate of the j -th parameters of the defect.

The proposed inversion technique has been applied to a numerical set-up where a plate structure of thickness $H=1.55$ [mm] [Fig. 1(a)] is inspected by a coil working at a frequency of 300 [kHz]. An average relative error below 2% has been computed when estimating the x and y coordinates of a flaw affecting the inspected domain, for a Signal-To-Noise Ratio (SNR) of 20 [dB] on test data. Good results have been also obtained in estimating its dimensions, with a relative error lower than 2% for the prediction of its length [Fig. 1(b)].

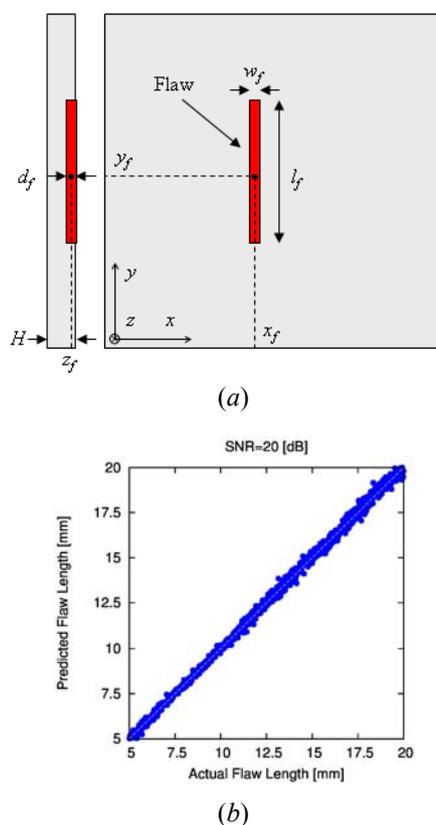


Fig. 1. (a) Geometry of the planar inspected structure and (b) actual vs. predicted length of the flaw (l_f), when $SNR = 20$ [dB] on test *ECT* measurements.

Future work will be devoted to assess the effectiveness of this approach against real experimental data.

Acknowledgment

This work has been partially supported by the SIRENA project (2014-2017) funded by DIGITEO (France) under the "Call for Chairs 2014".

Citations

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