A New Approach to Evaluate Defects in Metallic Plates Based on Computing with Words and Fuzzy Entropy

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ABSTRACT

Eddy-Current Techniques for non-destructive testing and evaluation of conducting material are one of the most known application oriented field in electromagnetics research. According to the Italian PRIN Project (proj. 2009TCLKNF_002), the Authors, in this work, propose a novel approach based on soft computing domain to characterize defects in metallic plates in terms of depth and shape starting from a set of experimental measurements. The problem is solved by means of a classification system based on computation with words and fuzzy entropy extracting information on the specimen under test from the measurements carried out in Non Destructive Tests Laboratory of “Mediterranea” University. Whereas, fuzzy entropy minimization module is based on traditional fuzzy inference system due to intrinsic characteristics of data the main advantage of the proposed approach is the introduction of computation with words in order to improve the data characterization.

Keywords: Computation with Words, Fuzzy Entropy and Interference, Natural Languages, Non-Destructive Testing/Evaluation (NDT/NDE), Signal Processing

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1. INTRODUCTION

Non-Destructive Testing/Evaluation (NDT/NDE) and quality measurement of specimens are a strategic activity in industry, especially for the electronics, aeronautics and telecommunications companies. Methodologies and techniques are related to different frameworks: safety management of industrial equipment, energy production, mechanical engineering and aerospace, biomedical, and so forth. They involve different academic scientific areas. In manufacturing and maintenance of highly expensive research and/or technological facilities, it is necessary to minimize the invasiveness of inspection procedures, possibly by acquiring information on the integrity of a system through measures outside the object under analysis. Nevertheless, decisions starting from these “observations” are often so much critical that they can endanger the life of the system itself, or worse, the security of the personnel involved in special operations. It is understandable that it is highly important to develop reliable, reproducible and fast methodologies, which can infer conclusions, based on collected signals, about the state of a system without compromising its integrity and functionality. The applicative international research is also active within the field of quality assessment and it has major industrial implications that require a trade-off between ability to detect the presence of defects in specimens of various kinds (often in real-time) and cost and timing of these activities. In particular, non-destructive identification systems allow the detection of damages with sufficient precision but no further and useful information can be extracted about its shape (Yamada, Katou, Iwahara, Dawson, & Yamada, 1995; Tsuboi & Misaki, n.d.; Prakash, 2009; Azzerboni, Carpentieri, Finocchio, & La Foresta, 2004). As for on-line applications, it is imperative to exploit experimental procedure of detection of defectiveness characterized by a reduced computational complexity. These problems, of great interest for scientific research, can be summarized under the name of “inverse problems”, since they aim at characterizing defects starting from signals. In the past, the Authors have gained extensive experience in NDT/NDE domain for modeling and implementing solutions based on wavelet analysis, soft computing and data fusion (Cacciola, Calcagno, Morabito, Pellicanò, & Versaci, 2009; Cacciola, Calcagno, Morabito, & Versaci, 2008; Buonsanti et al., 2009). Advances in digital processing also made possible the development of tomographic techniques resulting in images of the inspected area by simultaneously processing several one-dimensional measurements inspecting complex geometries, increasing the possible information and reducing the problems related to the scanning, imaging systems, which are increasingly exploiting arrays of receiving and/or transmitting probes, and show advantages respect to the classical inspection techniques (high sensitivity to discontinuities, high reliability, fast analysis, deep scanning, thickness determination, detection of possible anomalies). Sometimes, the computational complexity can be heavy in terms of calculus time. So, soft computing techniques, can be mainly exploited in approach specific problems, where traditional analytical and/or numerical processing were unable to provide appropriate solutions with acceptable computational load and where the sampling and noising of sampled signals can be affected by imprecision and uncertainty. In addition, different defects can be characterized by similar signals. So, it appears natural to treat the classification and shape reconstruction problem as a sort of fuzzy procedure for which, thinking that signals with a kind of defect are affected by similar ranges of statistical values, they can be treated as elements of a particular class. So, the problem can be formulated by a fuzzy approach where each class of defects is considered as a particular fuzzy set. Conventional classification approaches, which assign a specific class for each defect, are often inadequate because each defect may embrace more than a single class. Fuzzy set theory, which has been developed to deal with the not precise information, can provide a more appropriate solution to our problems (Kosko, 1997). According to the Italian PRIN Project
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