Chapter 8

Advanced Signal Processing Techniques in Non-Destructive Testing

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ABSTRACT

Non-destructive testing (NDT) is commonly used to monitor the quantitative safety critical aspects of manufactured components and forms one part of quality assurance (QA) procedures. The strategic trend in the development of NDT has changed towards the issue of safety in the broadest sense, to the protection of the population and the environment against man-made and natural disasters. Industrial NDT of manufactured items is usually undertaken when a product is likely to be placed under extreme or long periods of stress or wear, or if any component failure is liable to result in a major incident. While the emphasis in NDT has long been on the hardware technology, there has been an increased realisation of the potential benefits of applying advanced signal processing techniques to the signals resulting from an NDT examination.

This chapter describes some recent advances in signal processing as applied to NDT problems. This is an area that has made progress for over twenty years and its importance is gaining attention gradually, especially since the new advanced techniques in signal processing and pattern recognition.

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INTRODUCTION

NDT is a technique widely used in industry to detect, size, classify and evaluate different types of defects in materials, and it plays an important role whenever the integrity and safe operation of engineered components and structures are critical. Efficient and reliable NDT techniques are essential to ensure the safe operation of complex parts and construction in an industrial environment for evaluating service life, acceptability, verification and validation and risk. Automating the evaluation and inspection process can potentially lead to a reduction or elimination of the impact of human error, thus making the inspection process more reliable, reproducible, and faster. The most widely used conventional NDT techniques are ultrasonics, radiography, infrared thermography and computed tomography (CT) techniques.

NDT is not a direct measurement method, thus the nature and size of defects must be obtained through analysis of the signals obtained from inspection. Signal processing has provided powerful techniques to elicit information on defect detection, sizing, positioning and characterisation. Inspection signals were in general 1-D, utilising the very basic signal processing techniques. In case of 2-D inspection signals (images), the main processing methods include operations like image restoration and enhancement, morphological operators, Wavelet transforms, image segmentation, as well as object and pattern recognition. These methods facilitate the extraction of special information from the original images, which would not, otherwise, be obtainable. Moreover, 3-D image processing can provide advance information if an image sequence is available. Currently, NDT techniques have developed greatly due to recent advances in microelectronic systems and signal and image processing and analysis. Many image processing and analysis techniques can now be readily applied at standard video rates, in particular, to methods that generate image sequence (TV-type), such as real-time radiography, ultrasonic-phased array, laser ultrasonics, pulse-video thermography and shearography.

Signal processing for NDT has many different approaches that may not be well correlated. The role of computational intelligence (CI) methodologies for NDT applications is vital and is expected to receive more attention in the future. Advanced signal processing techniques, such as Wavelet transform and independent component analysis (ICA), can be used in solving NDT problems such as feature extraction, de-noising and the identification of defects. Perhaps the most influential signal processing development for NDT is split spectrum processing (SSP), which is one of the important and powerful treatments to automatically detect multiple flaws embedded in non-stationary grain noise. The non-linearities of the SSP algorithm effectively change the flaw and grain echo distribution to enhance the separation of their amplitudes beyond that of simple envelope detection technique. Ultrasonic non-destructive characterisation of thin layered composite materials or structures can be difficult because the reflected signals are highly overlapped. The classical signal processing approach would have difficulty separating the layers and determining the thickness of each layer, necessitating the need for advanced approaches (Cacciola, Morabito & Versaci, 2007).

Advanced signal processing techniques allow extracting of information not easily available from the NDT measurements and thus essentially extend the resolution of the measurement beyond what is offered by the physical system. These techniques are expected to address the main problems in NDT when performing the inspection or examination. Mainly, these problems are: high levels of noise, high reflectivity of the material under test, defects orientation, high attenuations and/or low amplitudes of the received inspection signals, cladding thickness effect, grain structure of the material under test and the low accuracy of sizing, positioning and characterisation of flaws, among others.