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DECONVOLUTION ALGORITHMS AND THEIR APPLICATIONS IN ULTRASONIC INSPECTION OF CFRP MATERIAL

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ABSTRACT

With rapidly increasing demand of composite materials, the adaptable non-destructive detection of flaws in materials and evaluation of the structure health is under urgent requirement to be developed. Many signal processing algorithms for the detection of delaminations in thin multilayered composite plates have been developed in the past decade. The choosing a suitable algorithm is a key for success.

In this work, we address the recent accomplishments of deconvolution for processing ultrasonic signals. The advantages and limitations of deconvolution algorithms widely-used in ultrasonic NDT applications are explored. Computer simulation has been performed to verify the best detection of delamination. This improvement is also experimentally verified using ultrasonic traces acquired from a carbon fibre reinforced plastic material.

Keywords: ultrasonic signal, Deconvolution, CFRP material.

INTRODUCTION

Technological innovation applied in the aeronautical sectors prefers the use of structures that are in able to have great advantages in terms of performance with a significant weight reduction. This involves research and development of new materials, in which composite materials have an high importance in the study of new concept structural architecture. For example, carbon fibre reinforced polymer multi-layered composite materials (CFRP) are widely used in aeronautical due to their high tensile and compressive strength, and corrosion resistance properties. However, composite structures can encounter damage under mechanical loading and temperature degradation. Typical failure modes in a laminated composite are delamination, matrix cracks and fibre fracture [1][2]. The defect that is most commonly found in composites is delamination that occurs parallel to the surface of the structure [3].

The received ultrasonic signal is modelled as a convolution between the waveform emitted by the transducer and a reflectivity function. The problem of ultrasonic scan consists in reconstructing as accurately as possible the reflectivity sequence. Given the definition of the direct model, the inverse problem specifically treated in this work is the deconvolution. The resolution of this class of problems encounters to two difficulties related to the presence of noise and to the loss of information due to the convolution. The deconvolution problem is thus to return to the "best" solution, i.e. which is physically significant. In this work, the deconvolution methods applied are divided in three main categories: determinist, semi-blind and blind, were studied, implemented, adapted to ultrasonic signals and applied to composite materials testing.

RESULTS AND CONCLUSIONS

Thickness of the part and depth of defect with precision in %:

	Determinist Deconvolution	Semi-blind Deconvolution		Blind Deconvolution		Real value (mm)
	Regularisation method	L^2 norme	BG	DRN	EM Deconvolution	
Thickness of the part	2.75mm 2.99%	2.75mm 2.99%	2.73mm 2.24%	2.68mm 0.37%	2.66mm 0.3%	2.7
Position of the delamination 1 (delamination close to the front surface)	0.89mm 41%	1.16mm 84%	0.9mm 42%	0.84mm 33%	0.66mm 6%	0.63
Position of the Delamination 2 (delamination close to the back wall)	2.5mm 12.6%	2.24mm 0.9%	2.53mm 13.9%	2.26mm 1.8%	2.5mm 12.6%	2.22

In this work, we presented a summary of the deconvolution problems and their applications to ultrasonic signals. These problems have been studied from a synthetic signal representing a real case of ultrasonic testing and experimental signals. The methods studied should achieve automatic analysis of ultrasound acquisition (or a portion of the acquisition) to detect the echoes of defects and locate their positions immediately. The approach to these problems has been made from an original angle with two key points:

- Measure thickness of multilayer composite materials.
- Detection of delamination defects in multilayer composite materials.

It should be noted that current techniques for the characterization of defects is based on manual procedures cumbersome and ill-suited to the large amount of information contained in an ultrasound acquisition. This study showed that adaptation of deconvolution methods applied in signal processing can provide effective solutions to the problem of expertise automatic ultrasonic data. These encouraging results open interesting perspectives.

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