# 198 Non-destructive evaluation of isotropic plate structures by means of mode filtering in the frequency-wavenumber domain

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## Introduction

Light weight structures that require regular inspection are increasingly common. From the aerospace to automotive industry the use of advanced materials as well as complex geometries is ever increasing and placing new demands on Non-Destructive Evaluation (NDE) techniques. Thickness reduction can be key for identifying corrosion defects, de-lamination defects and supports and ribs separating from structures. This work focuses on identifying thickness reductions in plate like structures with a view of using the same technique for identifying de-lamination defects in composites. Current techniques commonly used to identify and quantify these types of defect are based around contact ultrasound such as C-scan or A-scan. While these techniques are reliable and robust and can offer good spatial and depth resolution, they can be slow and costly to complete as well as requiring contact between the probe and structure. Wavenumber, the spatial frequency, of a guided Lamb wave can be correlated to material thickness, bulk material properties, temporal frequency and wave mode. Changes in wavenumber can therefore be used to identify thickness changes [1–3].

## Experimental Procedure

This work proposes a novel method of bandpass mode filtering to a specific guided wave mode centred around a particular thickness. By finding the instantaneous amplitude post filtering, to a given mode, a thickness map can be found by assigning the thickness of the filter that maximises energy at each point. Unlike previous techniques this enables broad band multi frequency excitation to be used and analysed into a single result. Broadband excitation allows parts of larger thickness ranges, than previously achievable, to be imaged in greater detail. Fig. 1, shows a flow chart of the steps in the proposed algorithm.

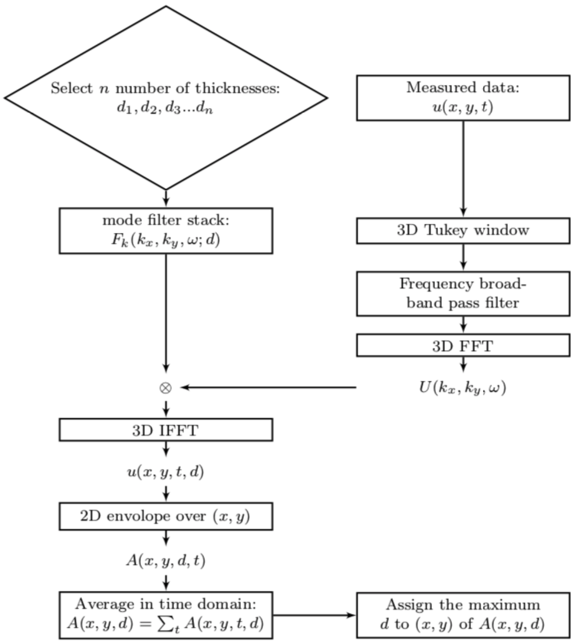


**Figure 1:** Mode filtering algorithm

To test this approach a phantom aluminium plate was created with a thickness range from 0.5mm to 8mm with circular thickness reductions at various thicknesses. A calculated thickness map showing the actual plate thicknesses is shown in Fig. 2. The map was calculated to the same spatial sampling frequency as the measurement data.

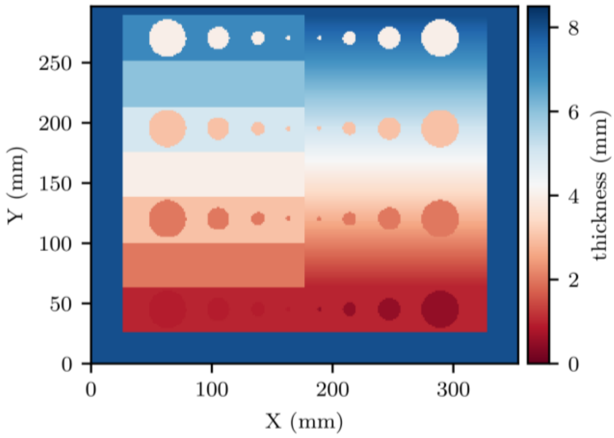


**Figure 2:** Phantom true thickness map

Using a PZT based ultrasonic sensor attached to the phantom plate a Frequency Modulated (FM) sine wave ranging from 75kHz to 400kHz was driven into the plate continually to create a steady state excitation. The plates response was measured using a 3D Scanning Laser Dopler Vibrometer (SLDV) with a spatial sampling frequency of 808m$^{-1}$ and a temporal sampling frequency of 2.56MHz with a sample length of 1024. Fig. 3 shows a thickness map calculated using the described algorithm.

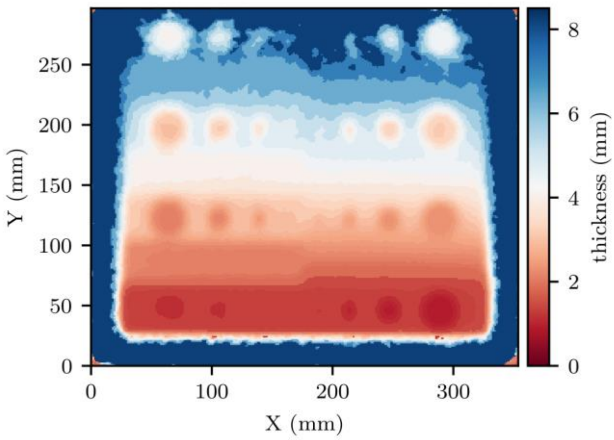


**Figure 3:** Calculated thickness map

## Conclusions

A good representation of the phantom was achieved. As expected, clarity reduced with increased thickness, but the two largest thickness changes were still clearly resolvable even at a plate thickness of 7mm. As further analysis the phantom was also driven with single frequency excitation at frequencies with in the FM range used. Results from FM excitation out performed all single frequency excitation. The use of the 3D SLDV in this work allows to further expand to parts with more complex geometries.

## References

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[3] M. D. Rogge and C. A. C. Leckey, “Characterization of impact damage in composite laminates using guided wavefield imaging and local wavenumber domain analysis,” *Ultrasonics*, vol. 53, no. 7, pp. 1217–1226, 2013.