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Experimental characterisation of Lamb wave propagation through thermoplastic composite ultrasonic welds

Pedro Ochôa¹, Irene Fernandez Villegas², Roger M. Groves¹, Rinze Benedictus²

¹*Aerospace Non-Destructive Testing Laboratory, Faculty of Aerospace Engineering, Delft University of Technology, Delft, The Netherlands*

²*Structural Integrity and Composites Group, Faculty of Aerospace Engineering, Delft University of Technology, Delft, The Netherlands*

Abstract

Ultrasonic welding is a very promising technique for joining thermoplastic composite (TpC) components in aircraft primary structures [1, 2]. The potential introduction of new lightweight structures in civil aviation has been driving the change towards condition-based maintenance (CBM) as an alternative to the regular inspection interval approach [3]. In turn, CBM has been pushing forward the development of structural health monitoring (SHM) technology capable of reliably assessing the structural integrity of a component during flight or at pre-flight checks. Among all of them, Lamb wave techniques are widely recognised as some of the most promising approaches for SHM of composite structures [4].

Accurate quantitative damage assessment can only be performed if ultrasonic response changes can be unambiguously correlated to specific damages. That correlation requires the distinction of benign features from damaging ones. Therefore, before designing an SHM system for any component it is first necessary to understand the influence of several intrinsic characteristics of the undamaged joints on Lamb wave propagation. In the case of TpC ultrasonically welded (UW) joints, the cross-section is characterised by a very thin (~ 0.05 mm) polymeric weld-line between the laminated adherends, and a region within the two laminate layers adjacent to the weld-line which is affected by partial fusion of the matrix during the welding process [1, 2]. Although this heat-affected zone does not have a separation surface as the weld-line, it is expected to have different elastic properties to the rest of laminate.

Despite several computational and experimental investigations about Lamb-wave-based SHM of different types of composite structures, the interaction of Lamb waves with the unique properties of TpCUW joints has not been addressed yet. This paper presents the first experimental study about the influence of weld quality and adherend edge tapering on the propagation of Lamb waves through TpCUW single-lap joints. The main aim of this research is to understand how the guided wave interactions with the internal structure of TpC ultrasonic welds influence the scattering at a single-lap geometry. The conclusions can later be used to develop a model which will assist the design of a Lamb-wave-based SHM system for a TpC structure. The results from this study are also expected to provide some reverse-engineering insight on different weld qualities, ultimately contributing to the improvement of the manufacturing process of TpCUW joints.

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