NON-DESTRUCTIVE TESTING FOR COMPOSITES PRODUCED BY FUSED DEPOSITION MODELLING ADDITIVE MANUFACTURING

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Abstract

Additive manufacturing (AM) using 3D printing is one of the most promising manufacturing technologies nowadays. However, the development of reliable Non-Destructive Testing (NDT) techniques for AM products is a big challenge. In fact, AM introduces new defect morphologies, dimensions and locations demanding customized and more suitable NDT techniques. These issue is even more pronounced in the case of AM of composites. Considering the Fused Deposition Modelling (FDM) AM process, possible defects that may arise include: delamination between matrix layers, lack of bonding between matrix and reinforcements, porosities (inter-filament discontinuity and path discontinuity), trapped support material between internal surfaces, misalignment of reinforcements or excessive surface roughness (staircase defect). Detecting such defects with existing standard NDT techniques presents major limitations as these general-purpose NDT techniques were developed for other requirements and operational conditions.

This paper focuses on one of the most difficult challenges in NDT: the challenge of detecting defects in composite materials produced by Additive Manufacturing (AM), in particular, using continuous fibre reinforcement thermoplastics (FRTP). For those FRTP products produced by AM, structural applications and safety requirements are envisaged, increasing the demand for NDT. In fact, there are many FDM AM products without special safety requirements, which is not the case for the target products in this article.

Four different NDT techniques were studied and critically compared: active thermography, eddy currents, digital X-ray and ultrasound. Tests were performed in composite samples produced by Fused Deposition Modelling (FDM) AM containing different artificial defects, using polymeric matrix (PLA, ABS, Polyamide and PEEK) and continuous reinforcement fibres introduced externally (carbon and glass fibres and NiTi wires).

Active thermography with customized heat sources were shown to be adequate for detecting voids and delaminations parallel to the surface, while X-ray and eddy currents...
with customized probes allow the identification of the NiTi wires and their arrangement inside polymeric matrix. Ultrasonic inspection presents major limitations due to the high acoustic attenuation of polymers (not so intense for PEEK) and due to high surface roughness when a 3D printing nozzle of 1.4 mm was used.

![Image](image.png)

**Figure 1 – Production of samples with artificial defects.**

a) Sample with 150×150×6 mm with the following artificial defects: 1, 2 and 3 – 0.1 mm thickness teflon insert with 30, 15 and 10 mm side, respectively; 4 – lithium grease between layers; 5 - petroleum jelly between layers to induce delamination defects. b) Sample with 80×80×5 mm with an artificial defect at the half thickness (word “FIBR3D”). c) Sample with 150×150×6 mm with the following inserted materials: 1, 2 and 3 – 0.2 mm NiTi wires; 4 and 7 – 0.3 mm Kevlar fibres; 5 – 0.22 mm cupper wire; 6 – 0.2 mm iron wire; 8 – 0.2 mm glass fibre

![Image](image.png)

**Figure 2 – Inspection result using active thermography in samples produced by FDM AM with artificial defects.**

a) Sample with 50×50×5 mm with an artificial defects at the half thickness with 15×15×2 mm, simulating a delamination defect; b) Sample with 80×80×5 mm with an artificial defects at the half thickness with the word “FIBR3D”

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