Benchmarking of NDT for composites produced by Additive Manufacturing

Miguel Machado[1], Ana P. Martins[2], Maria I. S. Silva[3], Frederico Costa[4], Pedro Vieira[5], Marta S. Carvalho[2], Telmo G. Santos[6]

[1]DEMI, UNIDEMI, Portugal, [1]DEMI, Department of Mechanical and Industrial Engineering, Portugal, [1]DEMI, NOVA School of Science and Technology, Portugal, [1]Department of Physics, NOVA School of Science and Technology, Portugal, [1]Department of Physics, UNIDEMI, Portugal, [1]Department of Mechanical and Industrial Engineering, NOVA School of Science and Technology, Portugal

Continuous Fibre Reinforcement Thermoplastics (CFRTP) parts, produced by Fused Deposition Modelling (FDM) Additive Manufacturing (AM), are being studied and proposed for lightweight structures. These complex parts often have high safety requirements, needing reliable Non-Destructive Testing (NDT) methods for a full inspection. Desired NDT techniques must be reliable, fast and affordable, but in the context of Industry 4.0, NDT has also to be automated, non-contact and results are expected to be digital images, that can be further processed and easy understandable. In this paper we studied and critically compared different NDT techniques for the inspection of CFRTP parts produced by FDM AM, namely: air-coupled ultrasound (50 to 400 kHz), double active transient thermography (reflection and transmission modes), Micro Waves (2.45 GHz), Terahertz (0.1 THz), and low-intensity X-ray. The objective was to describe the influence of the different inspection conditions and parameters, to define its effectiveness, highlining the main advantages and limitations. Different delamination defects and continuous reinforcement fibres, including Shape Memory Alloys (SMA) NiTi wires, were introduced in different Polylactic Acid (PLA) parts produced by FDM AM. The influence of the curvature of the parts was analysed. The results of the experimental tests were also compared with the results of the numerical simulations using Finite Element Methods (FEM). It was shown that thermography reflection mode, is the fastest and expedite technique for detecting delamination defects in curved parts. Low-intensity X-ray presents a limitation in terms of non-metallic fibre location. C-Scan air-coupled ultrasound inspection detects delamination defects with good spatial resolution, despite being time-consuming. Experimental results were corroborated by the numerical simulation, which allowed a deeper insight into the physical phenomena involved.