e-Journal of Nondestructive Testing - ISSN 1435-4934 - www.ndt.net
14th European Conference on Non-Destructive Testing, Verona, Italy (ECNDT 2026)

Towards non-destructive prediction of porosity-induced mechanical property variations in L-PBF AlSi10Mg via pulsed laser thermography

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Abstract

Additive manufacturing of aluminium alloys by Laser Powder Bed Fusion (L-PBF) enables the fabrication of lightweight and highly integrated components. However, residual porosity still represents a critical limitation for structural applications. Internal voids affect stiffness, strength, and fatigue behaviour, and simultaneously modify the thermal transport properties of the material. This work investigates the use of pulsed laser thermography as a quantitative non-destructive approach to relate porosity to variations in mechanical properties in additively manufactured AlSi10Mg.

The study is based on bi-layer specimens composed of a nearly dense surface thin layer and a porous substrate, obtained by systematically varying the hatch spacing during L-PBF. A pulsed laser spot thermography setup in reflection mode is employed to record the transient thermal response. Inverse analysis is used to estimate the in-depth thermal diffusivity of the surface layer and the thermal reflection coefficient at the coating–substrate interface.

The results show that the reconstructed thermal parameters, particularly the substrate effusivity, exhibit a clear dependence on porosity. By exploiting established relationships between porosity and mechanical properties for AlSi10Mg, the thermographically estimated effusivity enables a non-destructive prediction of porosity-induced variations in mechanical performance. The proposed methodology represents a step towards fast and scalable NDT-based assessment of additively manufactured aluminium components.

Keywords: Pulsed laser thermography; additive manufacturing; AlSi10Mg; porosity; thermal diffusivity.

1 Introduction

Porosity is one of the main factors limiting the structural performance and certification of L-PBF aluminium components [1]. While conventional techniques, such as X-ray computed tomography, provide accurate information, they are not suitable for rapid or large-scale inspections. Active infrared thermography offers a non-destructive alternative, as porosity alters heat diffusion. This work focuses on pulsed laser thermography as a means to indirectly assess porosity-induced variations in the mechanical properties of L-PBF AlSi10Mg.

2 Materials and experimental methods

Bi-layer AlSi10Mg specimens were produced by L-PBF, combining a nearly dense surface thin layer with a porous substrate obtained by varying the hatch spacing. Pulsed laser thermography tests were performed in reflection mode using a focused laser spot and an infrared camera. A thin graphite coating ensured uniform absorptivity. Literature's previous work supported the selection of post-processing parameters[2].

Thermal diffusivity in-depth, along with the thermal reflection coefficient at the coating–substrate interface, was estimated by inverse analysis of the transient thermal response in a double-logarithmic representation [3]. The substrate effusivity was then derived and adopted as a compact indicator of porosity. The procedure has been resumed in Fig. 1.

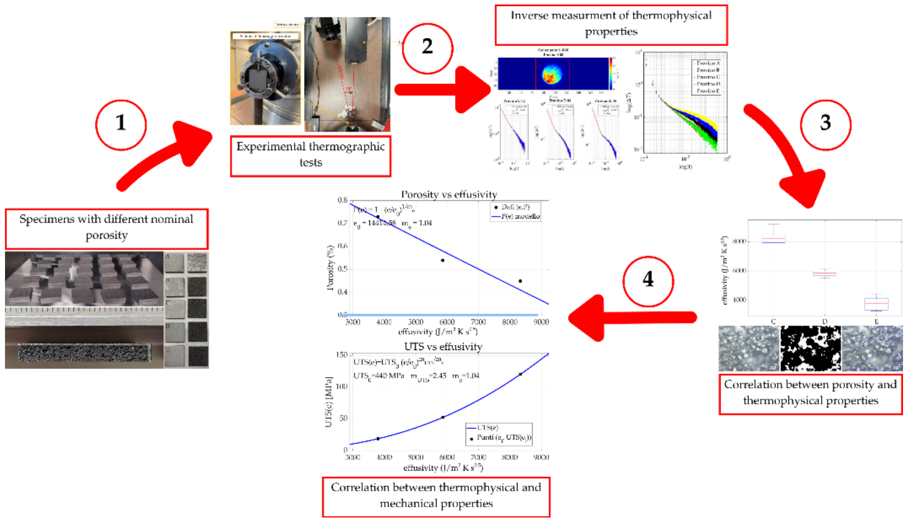

Fig. 1. Workflow of the pulsed laser thermography approach adopted to estimate substrate effusivity in bi-layer L-PBF AlSi10Mg specimens and to indirectly predict porosity-induced mechanical property variations.

3 Results and discussion

The reconstructed thermal parameters show a systematic dependence on porosity. In particular, substrate effusivity decreases monotonically with increasing porosity, while the diffusivity of the dense surface layer remains nearly constant. By combining the thermographically estimated effusivity with established porosity–property relationships for AlSi10Mg, porosity-induced variations in elastic modulus, yield strength, and ultimate tensile strength can be indirectly estimated [4].

4 Conclusions

A compact pulsed laser thermography-based procedure for the non-destructive evaluation of porosity effects in L-PBF AlSi10Mg has been presented. The approach allows an indirect estimation of porosity-induced variations in mechanical properties through thermally derived parameters. The results support the potential of this method as a fast and scalable NDT tool for assessing mechanical performance in additively manufactured aluminium components.

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