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Laser Re-Melt Technique for Laser Additive Repair of Narrow Rectangular Cracks in Grade 5 Titanium Alloy (Ti-6Al-4V)

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Abstract. Groove inaccessibility, top groove powder impedance, irregular sidewall powder delivery and lack of sidewall vertical irradiation have been reported as major limitations for the use of Laser Additive Technology (LAT) for narrow rectangular crack repair applications. As a result, most reported repair attempts were concluded unsuccessful. In the present work, a multi-track laser re-melt technique was developed for the repair of narrow rectangular cracks of sizes 2 and 3 mm, both 5 mm deep on 7 mm thick Ti-6Al-4V plates. The laser re-melt technique was carried out at controlled laser power, focal length, spot size, powder feed rate, gas flow rate and scanning speed. The repaired substrates were evaluated for defects through optical microscopy (OM) and scanning electron microscopy (SEM). The obtained results showed densely fused defect-free repaired substrates with good evolving microstructure.

Introduction

LAT is a solid-freeform-fabrication that produces solid components from Computer Aided Design (CAD) files [1, 2] by using a laser beam to locally melt gas shielded powder and the substrate [3] in a layer-by-layer fashion [4, 5, 6] leaving them to bond together upon cooling and solidification [7]. The technology produces small heat affected zone (HAZ) and a small weld dilution zone (WDZ) which both protect the mechanical and metallurgical integrities of the built components [8]. LAT is used for building intricate parts, materials processing, manufacturing, maintenance, repair of worn-out components [9, 10, 11, 12], developing Functionally Graded Materials (FGM) and post-powder-deposition re-melting [13], usually in the biomedical and aerospace industries. These industries extensively consume titanium and its alloys, particularly Ti-6Al-4V [14]. However, most of these applications are of crack-free form while very few focused on repair of cracks. LAT crack repair applications in Ti-6Al-4V has been hardly studied [13, 15]. Graf et al [16] investigated LAT repair of V-grooves, U-grooves and inclined open top U-grooves in stainless steel and titanium alloys. V-grooves and inclined U-grooves enabled better powder delivery and groove accessibility. The V-grooves exhibited good side-wall fusion but were not well fused at bottom tip and had unmelted powders. Top groove powder impedance, groove inaccessibility, irregular sidewall powder delivery, and lack of sidewall vertical laser irradiation, and consequently, lack of (sidewall, interlayer, and intralayer) fusion, porosity, cracks and unmelted powder defects were cited as the main challenges for the LAT repaired narrow U-grooves. Narrow U-grooves could therefore not be successfully repaired. Rottwinkel et al [15] made unsuccessful attempts to repair cracks using preheated LAT. Most researchers have classified narrow U or rectangular cracks as unrepairable by LAT. This work therefore experimentally develops a re-melt LAT procedure for the repair of narrow rectangular cracks in Ti-6Al-4V components.