In-Situ Formation of Particle Reinforced Aluminium Matrix Composites by Laser Powder Bed Fusion of Fe_2O_3/AlSi12 Powder Mixture Using Consecutive Laser Melting+Remelting Strategy

Authors : Qimin Shi, Yi Sun, Constantinus Politis, Shoufeng Yang

Abstract : In-situ preparation of particle-reinforced aluminium matrix composites (PRAMCs) by laser powder bed fusion (LPBF) additive manufacturing is a promising strategy to strengthen traditional Al-based alloys. The laser-driven thermite reaction can be a practical mechanism to in-situ synthesize PRAMCs. However, introducing oxygen elements through adding Fe_2O_3 makes the powder mixture highly sensitive to form porosity and Al_2O_3 film during LPBF, bringing challenges to producing dense Al-based materials. Therefore, this work develops a processing strategy combined with consecutive high-energy laser melting scanning and low-energy laser remelting scanning to prepare PRAMCs from a Fe_2O_3/AlSi12 powder mixture. The powder mixture consists of 5 wt% Fe_2O_3 and the remainder AlSi12 powder. The addition of 5 wt% Fe_2O_3 aims to achieve balanced strength and ductility. A high relative density (98.2 ± 0.55 %) was successfully obtained by optimizing laser melting (Emelting) and laser remelting surface energy density (Eremelting) to Emelting = 35 J/mm² and Eremelting = 5 J/mm². Results further reveal the necessity of increasing Emelting, to improve metal liquid's spreading/wetting by breaking up the Al_2O_3 films surrounding the molten pools; however, the high-energy laser melting produced much porosity, including H_2–, O_2– and keyhole-induced pores. The subsequent low-energy laser remelting could close the resulting internal pores, backfill open gaps and smoothen solidified surfaces. As a result, the material was densified by repeating laser melting and laser remelting layer by layer. Although with two-times laser scanning, the microstructure still shows fine cellular Si networks with Al grains inside (grain size of about 370 nm) and in-situ nano-precipitates (Al_2O_3, Si, and Al-Fe(-Si) intermetallics). Finally, the fine microstructure, nano-structured dispersion strengthening, and high-level densification strengthened the in-situ PRAMCs, reaching yield strength of 426 ± 4 MPa and tensile strength of 473 ± 6 MPa. Furthermore, the results can expect to provide valuable information to process other powder mixtures with severe porosity/oxide-film formation potential, considering the evidenced contribution of laser melting/remelting strategy to densify material and obtain good mechanical properties during LPBF.

Keywords : densification, laser powder bed fusion, metal matrix composites, microstructures, mechanical properties
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