

Adaptive Spatial Lattice Manufacturing (ASLM): Scale effects for aluminum alloys.

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Abstract

In the light of the prevailing environmental challenges, developing innovative manufacturing solutions is essential, particularly within the aerospace and aeronautics sectors, where weight reduction is crucial. Among existing approaches, lattice structures offer a promising solution while preserving mechanical properties. However, their current additive manufacturing methods face limitations, both in terms of environmental concerns and constraints on the dimensions of the resultant parts and struts. Adaptive Spatial Lattice Manufacturing (ASLM) provides an innovative alternative. This process relies on a six-axis robot equipped with a laser to weld and cut metallic struts. Until now, ASLM has only been limited to stainless steel. However, aluminum alloys, whose density is nearly three times lower than that of steel, represent a significant asset for mass reduction. The aim of this study is to adapt ASLM to aluminum alloys and to understand the underlying mechanisms governing weld formation and mechanical behavior at different scales. The first step is to identify welding parameters that yield optimal microstructures and local mechanical properties. Unlike bulk laser welding, ASLM involves the formation of micro-joints that undergo rapid cooling. As a result, the influence of the strut cross-section on thermal dissipation, and consequently on microstructural evolution, must be thoroughly characterized. This initial phase therefore focuses on individual

weld points. Two aluminum alloys with markedly different softening behaviors in the weld zone were selected: drawn 5183, which strengthens through work hardening, and 6063, which relies on precipitation hardening. For the latter, post-weld heat treatments are applied to recover the appropriate mechanical properties. However, adapting ASLM to aluminum also raises several well-known metallurgical challenges. The high solubility of hydrogen in liquid aluminum has been demonstrated to promote significant porosity formation, while the low vapor pressure of magnesium has been shown to lead to its vaporization, further increasing porosity and, in the case of the 6063 alloy, reducing the amount of strengthening precipitates. Furthermore, the collapse of the melt pool is frequently observed during ASLM welding of aluminum struts. As the ultimate goal is to manufacture representative lattice topologies such as body centered cubic (BCC) or face centered cubic (FCC), potentially combining dissimilar alloys, this process necessitates repeated remelting at the same locations. This operation is made particularly challenging by the rapid formation of oxide layers during aluminum laser welding. The microstructure and mechanical properties of these multi-fusion joints are therefore characterized. To capture deformation processes at the local scale, in-situ X-Ray tomography mechanical testing followed by Digital Volume Correlation (DVC) is performed. This technique provides three-dimensional fields of local strain, making it possible to identify crucial strain concentration zones.

Keywords:

Lattice structures Aluminum alloys Laser spot welding