High performance Aluminum alloys by Additive Manufacturing

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Abstract

The recent developments additive manufacturing equipment, process software and metal powders have enabled consistent processing of high performance aluminum alloys. Most of these materials are difficult or impossible process in conventional manufacturing methods to include thin walled sections, internal cavities or abrupt changes in cross-sectional areas. Additive manufacturing (AM) provides several beneficial properties for metallic materials. Fast solidifying rates result in a fine microstructure, enabling higher mechanical properties when compared to traditional methods. AM method may however also lead to anisotropy of some properties. A high temperature solution annealing (SA) heat treatment is the traditional way to homogenize the microstructure and to distribute alloying elements into the aluminium matrix. Mechanical properties can be further enhanced with ageing treatments. The breakup of the fine lamellar AM microstructure is observed in the very early stages of SA heat treatments. Further coarsening of the microstructure happens when SA is continued, which can have undesirable effects on mechanical properties. A novel heat treatment cycle including a shortened SA step is proposed in order to retain the benefits of the fine AM structure. The dependence of tensile properties on build direction can also be diminished by said heat treatment.

Keywords:
Additive manufacturing, Ageing, Aluminium alloys, EOS AlSi10Mg, EOS F357, Aluminium, Heat treatment, Anisotropy, Microstructure, Porosity, Solution annealing

1. Introduction

The direct metal laser sintering (DMLS) of aluminium is being adopted rapidly by machine building, automotive and aerospace industries. The unique characteristics of layer by layer AM microstructure provide equal or even enhanced properties, when compared to conventional manufacturing methods, such as casting. In this research, EOS AlSi10Mg and EOS F357 aluminium-silicon (AlSi) alloys, manufactured by DMLS, were studied. Their AM microstructure can be characterized by finely dispersed alternating phases of aluminum cell-like structures, surrounded by a silicon-rich eutectic network. Melt pools, i.e. laser scan tracks, make slight variations across the microstructure. The heat affected zones along melt pool lines show slight coarsening of the otherwise homogenous microstructure. Build orientation can be observed from the tendency of the alloy to form more elongated cells along the direction of the heat flow (from top to bottom in figure 1 of EOS F357 alloy).

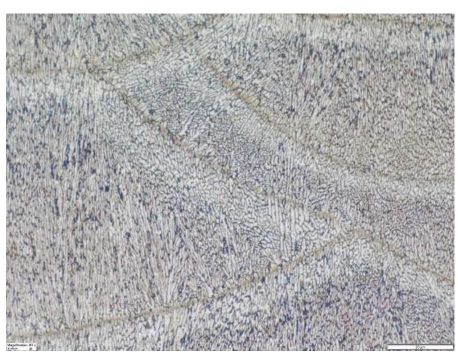

Figure 1. Optical micrograph of as-built EOS F357 sample, showing melt pool lines crossing fine alternating aluminium-silicon cell structure. The growth direction of lighter gray Al dendrites is revealed by elongated cells/grains in the vertical orientation. Scale bar is 20 µm. Etched with Weck's reagent.

Heat treatment of aluminium alloys has traditionally been used for strengthening as well as for improving the thermal stability of the alloys [1] [2]. The response to heat treatments is dependent on