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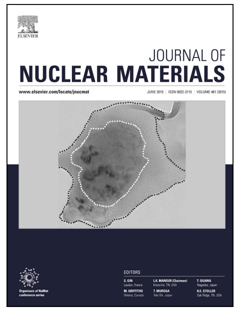

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Characterization and Mechanical Properties of Cladded Stainless Steel 316L with Nuclear Applications Fabricated Using Electron Beam Melting

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Abstract

The ability to fabricate or join components of 316L austenitic stainless steel using additive manufacturing (AM) processes such as laser and electron beam melting (EBM) offers several advantages including enhanced part complexity, narrow or absent heat affected zones, increased part precision, avoidance of filler materials (such as traditional welds), and the ability to create metallurgically sound bonds. These attributes can contribute to improved mechanical properties of the fabricated components and component repair in nuclear, aerospace, and chemical industries. In the present work, we report that austenitic 316L stainless steel additively manufactured by EBM exhibits a 76% increase in the yield strength and a corresponding increase of 29% in the ultimate tensile strength in contrast to the wrought substrate and commercial forged 316L stainless steel. The EBM clad 316L stainless steel elongation was 36%. The wrought substrate equiaxed grain size was ~30μm in contrast to elongated, columnar grains ~0.1mm wide and >1mm in length for the EBM cladding. TEM analysis revealed that these columnar grains, which exhibited very straight, and presumably special grain boundaries having a very high (100) texture, contained a variety of sub-grain microstructures consisting of low-angle sub- grain boundaries containing dislocation tangles and stacking-fault arrays, and homogeneously distributed $Cr_{23}C_6$ carbide precipitates, with no preferential carbide precipitation on either the straight, special columnar grain boundaries, or the very low-angle sub-grain boundaries. This observation and the formation of hierarchical microstructures which produce high strength and possibly corrosion resistance as a consequence of the absence of grain boundary carbide precipitation, illustrate the prospects for AM as a novel concept for achieving grain boundary engineering to promote high-strength and corrosion resistant alloys for high-temperature, corrosive environments, including elevated temperature nuclear reactor applications.

Keywords: additive manufacturing, electron beam melting, nuclear components, stainless steel 316L, welding, repair, cladding.

1. Introduction

Additive manufacturing (AM), colloquially known as 3D printing, refers to a group of technologies employed in the fabrication of components using a layer-by-layer method directly from computer-aided design (CAD) models [1, 2]. These manufacturing techniques offer several