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Microstructure evolution during fusion welding of rheocast AA7075 alloy

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Abstract

The microstructural evolution during varying thermal gradients of rheocast AA7075 aluminium alloy was investigated. To perform this study, semi-solid billets of non-dendritic microstructure were produced using Linear Electro Magnetic Stirrer (LEMS). Gas Tungsten arc welding (GTAW) was conducted to simulate varying thermal gradients near fusion zone. Welding simulations were performed using SYSWELD®. Quantitative metallography was used to aid the analysis. Numerical simulations and quantitative results show that the width of the partially melted zone (PMZ) plays a vital role in the nucleation mechanism and dendritic microstructure formation in this class of alloys.

Keywords: Semi-solid processing; Thermal gradient; Partially melted zone; Globular; Dendritic; SYSWELD®

1. Introduction

AA 7075 wrought aluminum alloys are extensively used in aerospace industry due their light weight and high specific strength to weight ratio. Generally, wrought alloys are hot and/or cold worked mechanically, to achieve dense parts with higher strength. However, few of them are processed through casting routes without casting flaws. Semi-solid processed alloys is a class of that lies between wrought (dilute alloys) and cast (near eutectic) alloys. In these alloys, the alloy in the mushy state is subjected to vigorous stirring during solidification. Strong convective forces shear the liquid metal and increase mobility of solute in the liquid to alter the dendritic

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morphology of the solid into globular/spherical microstructure [Flemings (1974)]. It also addresses some of the deficiencies of conventional casting process by producing low porosities or porosity free castings, which improves weldability of semi-solid formed components [Govender et al. (2007)].

This work is motivated by the need to study weldability of any alloy class that needs to mature towards fabrication of complex parts. Semi-solid processing has emerged as a route to produce alloys that are otherwise not readily diecastable. Large freezing range alloys could be produced with globular microstructure using semi-solid processing (SSP), so that they could be easily die-cast in semi-solid state. Similarly, wrought alloys which face solidification cracking or hot cracking issues could be made diecastable by modifying the microstructure as globular. With the semisolid processed & globular microstructure emerging as a new class of materials, it is important to probe weldability of these alloys as welding is an important fabrication technique to produce complex parts from individual parts. In this study, we explore the role of thermal gradient near the fusion boundary on the microstructure formation in the weldment of rheocasted wrought aluminium 7075 alloy.

Nomenclature

G_T	Thermal Gradient
W_P	Width of partially melted zone
h	Convective heat transfer co-efficient
A	Area of primary α-Al
P	Perimeter of primary α-Al

2. Experiment procedure

7075 aluminium alloy was semi-solid processed by rheocasting in a graphite mould placed inside Linear Electro Magnetic Stirrer (LEMS) [Kumar (2008)]. Cast plates of thickness 8 mm were machined from the billets. Bead on plate autogenous GTAW was performed. To simulate varying thermal gradients near fusion zone, GTAW experiments were performed by providing copper backing plate with and without water cooling condition at the bottom of weld coupons. Transverse cross-section of the samples were taken at the centre of the weld to examine the weld profile and microstructure in the fusion zone. To characterize the metallography, initially the surface of the samples were well polished using various grades of emery paper followed by diamond polishing. Then they were etched by Keller's reagent containing 2.5 % HNO_3, 1.5 % HCl, 0.5 % HF and remaining H_2O for optical microscopy. Quantitative metallography provided shape factor as measure of globularity of primary α-Al grains using the equation $(4\pi A)/P^2$, where the cross sectional area is (A) and perimeter is (P) of the primary α-Al grains are determined using image processing.

3. Numerical simulation

Finite element method (FEM) has matured with increase in the number of commercially available codes that make use of computational power and quickly provide realistic simulations of computational welding mechanics to aid in the understanding of the role of thermal, mechanical and material properties on welding. A 3-D model of the semisolid cast plate was created with visual weld pre-processor using eight node cube elements, in order to understand the weld pool geometry and thermal distribution influenced by heat transfer. The finite element mesh shown in Fig. 1 is modelled with adaptive meshing. The thermal gradient near the FZ and PMZ are high hence, mesh with finer elements are modelled along these zones in order to have better aspect ratio. Beyond the weld zones the gradient is less and so mesh with coarser elements are made to reduce the computational time. Pentagonal elements shown in Fig. 2 are used to have smooth transition between higher (finer mesh) and lower (coarser mesh) thermal gradients. Temperature dependent material properties such as thermal conductivity and specific heat as a function of temperature as specified in the literature [Feulvarch et al. (2006)] are given as input parameters to the 3-D model.