Varestraint Weldability Testing of Nickel-Based Alloys Built with Laser Blown Powder Directed Energy Deposition Additive Manufacturing

William Evans 1*, Eric Brizes 2, Jhoan Guzman 3, Antonio Ramirez 3

1 Metallic Materials and Processes Branch, NASA Marshall Space Flight Center, Huntsville, AL, 35812, USA
2 High Temperature and Smart Alloys Branch, NASA Glenn Research Center, Cleveland, OH, 44135, USA
3 Materials Science & Engineering Department, Welding Engineering Program, The Ohio State University, Columbus, OH, USA

*Corresponding author: william.c.evans-1@nasa.gov

Keywords: Nickel-based Superalloys, Varestraint Weldability, Additive Manufacturing, Laser Powder Bed Fusion (L-PBF), Laser Blown Powder Directed Energy Deposition (LP-DED)

Abstract

In this investigation, varestraint weldability testing was conducted on two nickel-based alloys used by NASA for rocket engine applications. The purpose of varestraint weldability testing is to compare the susceptibility of different alloys to hot cracking during welding operations. The alloys investigated were Ni 625 and Ni 718 which are both heavily utilized by the aerospace industry for their corrosion resistance and strength at elevated temperatures. The goal of this study was to compare weldability properties between conventionally manufactured material and additively manufactured material. Three forms of each alloy were investigated during this study: conventional rolled plate, laser powder bed fusion (L-PBF), and laser blown powder directed energy deposition (LP-DED) printed plates. Each set of materials underwent transverse varestraint weldability testing to isolate the fusion zone solidification cracking phenomena. Then, images of the crack evolution were recorded for each sample to measure the total crack length, maximum crack distance, and overall number of cracks in each sample. Distinct differences in total crack susceptibility arising from the different alloys' chemical composition and their respective manufacturing route were analyzed.

Introduction

Nickel-based alloys have been the subject of welding and weldability related research for many years and are highly utilized in industry for their range of physical and mechanical properties [1, 2]. This family of alloys is normally regarded as being highly corrosion-resistant and exhibiting moderate to high strength, even at elevated temperatures. In general, these alloys contain more than 50 wt% Ni and are classified into two categories based on strengthening mechanisms [1, 2]. The first category being solution-strengthened alloys, these alloys often include additions of Fe, Mo, Cr, Nb, W, and C for strengthening and corrosion resistance [1]. The second group is precipitation-strengthened alloys which are strengthened by the gamma prime (γ') and gamma double prime (γ'') phases [1, 2]. They are often referred to as super alloys as they retain moderate to high strength at elevated temperatures. Moreover, these alloys contain additions of Fe, Mo, Ti, Al, and Nb for strengthening and high levels of Cr for corrosion resistance [1, 2]. Nickel-based alloys are commonly utilized across several industries but are heavily utilized in the aerospace industry in jet turbine engines and liquid rocket engines [3].

This study focuses on the weldability characteristics of two Ni alloys commonly utilized by the aerospace industry, solution-strengthened Ni 625 and precipitation-strengthened Ni 718 [3]. The weldability of both alloys has been studied for decades [1, 2, 4, 5]. A popular method for examining the