Advancements in High Pressure Heat Treatment for Additively Manufactured Parts

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ABSTRACT

The use of hot isostatic pressing (HIP) is of growing interest for additively manufactured (AM) parts with significant research efforts in place to mature and optimize these novel manufacturing techniques. Historically HIP has been used to eliminate internal cracks, voids, and pores with subsequent heat treatment performed using conventional technologies to obtain the desired microstructure and mechanical performance. Recently, it has been shown in literature and practice that it is possible to integrate HIP and heat treatments in the HIP furnace with the aid of high-pressure gas cooling or quenching, an approach known as High Pressure Heat Treatment (HPHT^{TM}). One recent development advancing the HPHT technology is controlled cooling. Controlled cooling enables the HIP system to now cool based on component temperature at a predefined rate for targeting desired material properties. This report will cover the most recent HPHT advancements and learnings, and review HPHT cast studies performed on AM alloys, highlighting both material performance and productivity improvement.

INTRODUCTION

HIP is commonly used in a wide range of industries from aerospace and space, power, advanced automotive, and medical for high demand and critical applications. The stringent requirements placed on the material properties and reliability for castings, metal injection moldings (MIM), and AM components rely on HIP to remove defects inherent to these manufacturing techniques. Defects such as shrinkage and gas porosity are common in castings. Residual sintered porosity is prevalent in MIM and binder jet components. Lack-of-fusion and keyhole defects can form in AM components from powder bed fusion processes. These defects negatively impact component fatigue, creep, and ductility performance as well as corrosion resistance. HIP is a well-proven technology that has shown the ability to remove such defects to further enhance the material properties with subsequent heat treatment performed using conventional heat treatment equipment. With advancements in HIP systems, it is possible to also achieve the desired microstructure and mechanical performance in the HIP cycle, with the aid of high-pressure gas cooling and quenching. This approach offers the freedom to consider a combined HIP and heat treatment cycle known as HPHT. HPHT leads to shorter process times, cost reductions, improved energy efficiency, and increased productivity while offering an opportunity to further improve material properties and reduce property scatter for more predictive performance.