Control of AISI 4340 As-Printed Hardness via LPBF Parameter Selection

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ABSTRACT

Water atomized (WA) low alloy steels have potential for adoption in laser powder bed fusion (LPBF) due to their high mechanical performance and relatively low cost. For complex shapes, where LPBF provides the greatest benefit, it is beneficial if as-printed properties are as close to service requirements as possible. This study proposes a combined physics-based modeling and empirical strategy to control the as-printed hardness of WA AISI 4340 steel, while maintaining high as-printed density. A meaningful variation in part properties can be achieved using parameters such as laser spot size, power, effective velocity and hatch spacing to control heat dissipation, melt pool geometry and melt pool stitching. Control of heat dissipation was found to be particularly important if similar mechanical properties are to be achieved across a wide range of part geometries. Hardness values achieved range from HV 364 to HV 407 while maintaining a relative density of 99.5±0.2%.

INTRODUCTION

Additive manufacturing (AM) is revolutionizing the global economy across multiple sectors, with its efficiency in use of raw materials and ability to reduce supply chain complexity highlighted as key advantages [1]. Recent reports such as the 2023 Research and Markets “Metal 3D Printing Market Size…” [2] corroborate this statement, with a global Metal 3D Printing market of $6.4 billion in 2022, and a forecast of $35 billion by 2030, with a compound annual growth of 24% between 2022-2030. LPBF having the highest rate of technology adoption for metal AM part production [3] and has been deployed toward functional part production in numerous well-established industrial sectors ranging from healthcare, energy, aerospace, marine, automotive, to consumer product sectors [4]. The popularity of this class of technologies is attributed to the high degree of achievable geometric complexity [5], owing to the fine resolution imparted by the beam spot diameters generally being between 50-100 μm [6]. In addition, there is an increased number of materials being adopted for production using this technology [7].