Effect of Heat Treatments on Mechanical Properties of Ultra-High-Strength Maraging Steels Fabricated by Additive Manufacturing

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ABSTRACT

In Metal Additive Manufacturing (metal AM) processes, especially laser powder bed fusion (L-PBF), there are many parameters that affect the microstructural development and consequently mechanical properties of built parts, such as thermal history, non-equilibrium solidification structure and meta-stable phase formation. These microstructural features can have a remarkable influence on the mechanical properties of parts after post-processing heat treatments. Generally, rapid solidification enhances the strength as a result of sub-structure refinement and increased dislocation density in martensitic steels. More importantly, rapid solidification might result in suppression of unwanted phase precipitation. However, intercellular micro segregation accompanied by fast, non-equilibrium solidification might result in the formation of retained austenite, preferentially located at the cellular boundaries, which can affect the strength of maraging steel. Moreover, the presence of these phases might influence the ageing (tempering) behavior. In this work, we report on the effects of adapting different heat treatment strategies on the hardness, tensile strength, impact toughness and fatigue behavior of two different classes of ultra-high strength AM maraging steels aimed at achieving 54 and 60 HRC hardness levels.

INTRODUCTION

Maraging steels are characterized by very low carbon content and the presence of substitutional alloying elements which trigger age-hardening in iron-nickel martensite by the precipitation of nanosized intermetallic particles [1,2]. The metallurgical principles of maraging steels might be ascribed to the "martensite" formation in Fe-Ni alloys on cooling and "martensite to austenite reversion "upon heating [3]. In Fe-18Ni-Co-Mo grades with Ti as supplementary hardener, more than half of the overall contribution to strengthening is due to the martensitic microstructure while the rest is provided by the precipitation of intermetallic particles (e.g., Ni_3Ti and Ni_3Mo) during age-hardening of martensite. This class of high strength steels shows enhanced resistance to hydrogen embrittlement and stress-corrosion cracking compared to high-strength low-alloy steels. Moreover, a distinctly improved toughness can be achieved at high strength levels in these steels [4]. Maraging steels are therefore considered as viable materials for