ADDITIVE MANUFACTURING OF HIGH STRENGTH NIOBIUM ALLOYS

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ABSTRACT

Niobium (Nb) alloys such as Nb-1Zr and C-103 have been used for various high temperature components due to their combination of good formability at room temperature and improved strength as compared to pure niobium. However, at elevated temperatures, the strength of these alloys decreases significantly. Higher strength Nb alloys have been developed, but these alloys lack the formability of C-103 and Nb-1Zr. Recently, Additive Manufacture (AM) of Nb and C-103 has been demonstrated. However, AM of Nb and C-103 results in elongated, columnar grains, which reduce mechanical properties as compared to a cold worked material. Therefore, the potential exists to develop and fabricate a higher strength Nb alloy by taking advantage of the net-shape forming capability of AM to circumvent the lack of formability of these alloys using conventional processing. During this investigation, high strength Nb alloys based on solid solution and stable high temperature precipitation strengthening were evaluated. To produce the Nb alloy feedstock, an innovative Plasma Alloying and Spheroidization (PAS) technique was used that resulted in spherical, highly flowable powder, which is essential for AM processing. The PAS Nb alloys were then successfully AM processed using Electron Beam – Powder Bed Fusion (EB-PBF). Improvements in microstructure and mechanical properties as a result of the solid solution and precipitation strengthening alloy additions were observed, which resulted in tensile strengths that exceeded wrought C-103 with equivalent ductility. These results will be discussed in this paper.

INTRODUCTION

A niobium alloy (C-103) is the baseline material used for radiatively cooled Reaction Control System (RCS) chambers, and niobium based RCSs have been used on missions from the Apollo and Shuttle Programs to numerous satellites/vehicles for positioning and station-keeping. Examples of niobium alloy thrusters are shown in Figure 1. Niobium is ideally suited for these applications due to its high melting temperature, low density, and excellent forming/welding characteristics.[1,2] To improve the mechanical properties of niobium, several alloys were developed in the 1960s based on solid solution and precipitation strengthening.[3,4] As a result of this work, the C-103 niobium alloy was developed. This alloy possesses a combination of improved mechanical properties as compared to pure niobium and still maintains good formability using conventional forming methods. However, other niobium alloys were produced that had superior elevated temperature properties to C-103, but these alloys lacked the deep drawing and spin-forming ability of C-103.