Niobium (Nb) Base Alloy Powders for High-Temperature Additive Manufacturing Applications

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ABSTRACT

The development of commercially available Niobium (Nb) base alloy powders for additive manufacturing (AM) opens up completely new opportunities for the production of high-temperature, high-performance components that are particularly interesting for aerospace applications. It is crucial to comprehend the entire workflow, which ranges from powder production and characterization to the determination of optimal process parameters. In a detailed publication, TANIOBIS GmbH, in collaboration with Alloyed Ltd., provides insights into the preparation, characterization, and processing of Nb base alloy powders using metal AM techniques. Nb base alloys such as C-103 and FS-85 are emerging as promising candidates to improve the capabilities of 3D printing, particularly in aerospace applications. What sets Nb base alloys apart from common materials are their exceptional properties - remarkably low density combined with high thermal conductivity, and outstanding mechanical strength at high temperatures. These properties make such alloys a superior alternative to traditional Ni and Co base materials, particularly in environments with temperatures surpassing 1050°C. While C-103 has become firmly established in conventional manufacturing, there is still no experience with conventional molding for FS-85, which is currently the focus of interest due to its extraordinary strength at elevated temperatures. The commercial availability of FS-85 alloy powders for additive manufacturing opens up exciting possibilities for producing high-performance components with complex geometries.

INTRODUCTION

Refractory metals are characterized by very high melting temperatures and therefore have the potential to be used in future aerospace applications. The maximum operating temperature of Ni- or Co-based superalloys currently applied in engines is approx. 1050 °C. Above this temperature, these materials are no longer structurally stable due to the onset of creep.

In contrast, high temperature refractory metals, i.e., Hf, Nb, Ta, Mo, and W possess melting temperatures in the range of 2200 °C (Hf) and 3400 °C (W) and thus have the potential to perform at temperatures exceeding 1050 °C by far. The pure metals as well as their alloys are accordingly outperforming even the most advanced Ni- and Co-based superalloys. Among the refractory metals, Nb is the most attractive candidate for application in structurally and thermally loaded parts because of its favorable combination of high melting point (2477 °C), low density (8,57 g/cm³), good thermal conductivity (54 $W \cdot m^{-1} \cdot K^{-1}$) and ductility.

Intensive studies on Nb base alloys already started in the 1960's and 1970's, mostly triggered by the search of Boeing and NASA for new aircraft and aerospace alloys, i.e., for use in turbine and propulsion systems. In most cases, Nb was alloyed with other refractory metals, such as the metals mentioned above, to improve high-temperature properties and allow higher operation temperatures of the manufactured parts. The most prominent alloys to mention in this regard are (in alphabetical order) C-103 (Nb-10Hf-1Ti), [1] Cb-129Y (Nb-10W-10Hf-0.1Y), [2] Cb-752 (Nb-10W-2.5Zr), [3] FS-85 (Nb-28Ta-10W-1Zr), [4] Nb-1Zr, [5] and WC-3009 (Nb-30Hf-9W). [6] In addition, several reviews appeared comparing room and high-temperature properties of the Nb base alloys. [7,8,9,10]