A CRITICAL REVIEW OF MECHANICAL PROPERTIES OF POWDER METALLURGY TITANIUM

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Mechanical properties are the primary concern in the development and application of powder metallurgy (PM) titanium and its alloys. Their mechanical properties are reviewed by comparing PM with ingot metallurgy (IM) and by examining the dependence of the mechanical properties on the microstructures that are unique to PM titanium. The effects of the most critical factors (porosity, oxygen content, and microstructure) on mechanical properties are discussed. Throughout this review, PM Ti refers generically to PM titanium and titanium alloys. IM Ti embraces ingot metallurgy titanium and titanium alloys. Static and dynamic properties are examined to illustrate the challenges as well as the opportunities for PM Ti. Selected recent PM Ti technologies and attendant mechanical properties are also assessed.

INTRODUCTION

Titanium is an excellent material for many applications in light of its combined properties of high strength, light weight, and corrosion resistance. However, practical applications have been severely limited due to its high intrinsic cost, particularly in cost-sensitive civilian applications such as automobiles. Therefore, cost reduction is a major driving force in R&D on particulate titanium production and processing.

PM provides a viable approach for reducing the cost of titanium parts because of its near-net-shape capability. It has therefore been the focus of R&D worldwide in the past three decades. An extensive body of data has been reported and accumulated on the mechanical properties of PM Ti, especially during the 1980s and '90s, which demonstrated that PM is indeed a viable approach for manufacturing low-cost high-performance products. A series of comprehensive reviews by Eylon, Froes, and Donachie on the mechanical properties of PM Ti and their dependence on processing are available.[1–3] Notwithstanding long-term efforts and the data that are available, concerns over the mechanical properties of PM Ti persist, especially for aerospace applications in which parts are required to have mechanical properties and performance comparable to IM parts. Critical properties such as fatigue strength are not allowed to deviate from those of IM Ti.

As a convention, PM Ti is classified into two groups based on the processing route: blended elemental (BE) and prealloy (PA).[2,4] BE parts possess the attribute of low cost, but their mechanical properties are, in general, lower than those of IM parts.[1,2] In contrast, PA parts usually have satisfactory properties,[1,2] while the cost is significantly higher than that of BE parts, reducing competitiveness with respect to cost reduction. Therefore, the challenge is the trade-off between cost and performance. The opportunity is to either reduce the cost of PA parts or increase the performance of BE parts. Based on recent developments, the latter may hold the more promise.

This review provides an update and a critical assessment of the mechanical properties of PM Ti, focusing on the factors that affect these properties. In addition, developments over the last decade with respect

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