CARBON INFLUENCE ON THE FRACTURE TOUGHNESS OF TRANSITION METAL CARBIDES

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The group VB transition metal carbides (TMCs) comprise a class of ultra-high temperature ceramics (UHTCs) that display excellent stability in extreme environments with a melting point above 3000°C. TMCs have remarkable mechanical properties such as high hardness, high strength and wear resistance. As a result, these materials are commonly used in applications such as bearings, cutting tools, and thermal protection systems, yet their broader utility is often limited due to their inherent brittleness. The bulk fracture behavior of UHTCs has been shown to be driven by the crystal structure of carbide phase, which is influenced by the carbon-to-metal ratio. Previous research has suggested that lath-like ζ-Ta_4C_3 phase increased the fracture toughness of tantalum carbide, yielding a K_{IC} of nearly 15 MPa-$m^{1/}2$ [1]; yet relatively little research has been performed systematically examining the microstructure-to-fracture properties. Consequently, we investigate the fracture behavior of a series of tantalum carbide and niobium carbide under both quasi-static and dynamic loading conditions. For this study, two materials systems are focused on, tantalum carbides with C/Ta ratio between 0.5 to 1.0 and niobium carbides with C/Nb ratio between 0.5 to 1.0. X-ray diffraction (XRD) is used to identify the phase content and scanning electron microscopy (SEM) is used to characterize the initial microstructures. The surface crack in flexure (SCF) method is used to evaluate the fracture toughness of various tantalum carbide and niobium carbide under quasi-static loading [2], and a unique long-bar apparatus with digital image correlation (DIC) and high-speed imaging is used to investigate the dynamic fracture behavior in Mode I (opening). The influence of microstructure, carbon concentration, and rate effects on fracture toughness will be discussed.

[1] K. Hackett, S. Verhoef, R. Culter, D. Shetty, Phase Constitution and Mechanical Properties of Carbides in the Ta-C System, Journal of the American Ceramic Society, Volume 92, No. 10, 2009, 2402-2407.
[2] X. Zhao, M. Togaru, Q. Guo, C. Weinberger, L. Lamberson, G. B. Thompson, Carbon influence on fracture toughness of niobium carbides, Journal of the European Ceramic Society, Volume 39, Issue 16, 2019, 5167-5173.