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M1Po3B-02: Characterizing niobium fatigue failure near 20 K

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Niobium plays a critical role in a range of cryogenic applications, including superconducting magnets, superconducting radio frequency (SRF) cavities, and cryogenic electronics, owing to its superior superconducting properties, high strength, and excellent resistance to embrittlement. Although tension, compression, and the shear behavior of niobium has been studied at cryogenic temperatures, research on fatigue failure, particularly near 20 K has remained sparse. Furthermore, the underlying mechanisms of damage and failure under fatigue in niobium are not well understood. To address this gap, this study utilizes a Cryogenic Accelerated Fatigue Tester (CRAFT) setup to characterize limits of failure under cyclic tension-tension loading. Our experimental setup consists of a PT415 GM cryocooler mounted on a custom vacuum chamber housed between the uprights of an MTS Acumen load frame with a dynamic load capacity of 12 kN and 100 Hz. Heat transfer is mitigated by an actively cooled copper shield and a multi-layer insulation blanket as well as pulling vacuum inside the test chamber. We characterize the fatigue life of pure niobium at different temperatures and frequencies to develop the stress-life cycle (S-N) curves and use a Scanning Electron Microscope (SEM) to identify the mechanisms of crack initiation and propagation. Findings of this study provide insights into the fatigue behavior of niobium at cryogenic temperatures and help identify the safety limits of niobium components.

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