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Ratcheting behavior of zirconium alloy tubes under combined cyclic axial load and internal pressure at 350 °C

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ABSTRACT

Zirconium alloy is used as nuclear fuel cladding in nuclear reactors because it offers the merits of low neutron absorption cross-section, high corrosion resistance, excellent mechanical properties, and satisfactory creep resistance under operating conditions. However, the cladding experiences uniaxial and multiaxial stresses, which can lead to material failure due to the ratcheting effect. In this context, in this study, a series of uniaxial and multiaxial ratcheting tests were conducted on zirconium alloy tubes at 350 °C. The experimental results show that the temperature significantly affects the properties of zirconium alloy, and its ductility at 350 °C is poorer than that at room temperature. The axial ratcheting strain rate greatly increases with increase in the mean stress, stress amplitude, and peak stress holding time. In addition, the loading history also greatly affects the uniaxial and multiaxial ratcheting of zirconium tubes. A lower stress level after a loading history with higher stress level leads to shakedown of the ratcheting, while a higher mean stress after a loading history with lower mean stress brings down the ratcheting strain rate. The existence of a constant internal pressure significantly retards the failure of the zirconium tubes.

KEYWORDS: Ratcheting; Zirconium alloy; Multiaxial loading; Loading history; High temperature

1. Introduction

Zirconium alloys, which are solid solutions of zirconium with the other metals (e.g., Zr–Sn–Nb alloys), are widely used as nuclear fuel cladding in nuclear reactors [1] because of their outstanding properties of low neutron absorption cross-section [2, 3], high corrosion resistance [4], excellent mechanical properties [1, 5], and satisfactory creep resistance under operating conditions. During nuclear reactor operation, the nuclear fuel cladding generally experiences uniaxial or