Accelerated Creep Testing of Laser Powder Bed Fusion Ti6Al4V

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Abstract.

Reliable characterisation of high-temperature creep behaviour is essential for the development and calibration of constitutive models used in thermo-mechanical simulations of structural components. Conventional constant-load creep testing is time-intensive, motivating the use of accelerated methods capable of rapidly assessing creep properties, which can accurately reflect the findings of longer-term tests.

In this study, the high-temperature uniaxial creep response of laser powder bed fusion (LPBF) Ti6Al4V (Ti64) at 800 °C is examined using displacement-controlled stress relaxation tests and stepped creep experiments. The aim is to evaluate the ability of these techniques to extract meaningful creep parameters, identify stress-dependent deformation regimes, and assess consistency between accelerated and conventional testing approaches.

Stress relaxation tests were conducted under displacement control. All experiments exhibited a two-stage relaxation response, characterised by an initial rapid stress decay followed by a slower, quasi-steady regime. Differentiation of the stress relaxation data enabled the extraction of strain-rate evolution as a function of stress. The resulting effective stress exponents exhibit a pronounced stress dependence, increasing from values close to unity at low stresses (< 10 MPa) to values exceeding four at higher stresses. This transition is consistent with a change in the dominant deformation mechanism from diffusion-controlled creep at low stresses to dislocation-controlled processes such as climb and glide at higher stresses.

Stepped creep tests were performed to efficiently generate creep strain-rate data over a wide stress range within a single specimen. These tests produced steady-state creep rates in a fraction of the time required for individual constant-load creep experiments. Comparison of stepped creep results with stress relaxation-derived strain rates and available uniaxial creep data shows good agreement in both absolute values and stress exponent trends, supporting the validity of accelerated testing methodologies for constitutive parameter identification.

Pre-test microstructural characterisation using scanning electron microscopy (SEM) and electron backscatter diffraction (EBSD) was undertaken on heat-treated material to provide context for the observed deformation behaviour. Overall, the results demonstrate that stress relaxation and stepped creep methods provide a robust and time-efficient framework for characterising the high-temperature creep response of LPBF Ti64, with relevance to constitutive modelling and long-term performance assessment.