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PROCEEDINGS

Modeling and Simulation of Irradiation Hardening and Creep in Multi Principal Component Alloys

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ABSTRACT

Nuclear energy demands radiation-resistant metal materials. Multi-principal element alloys (MPEAs) show superior radiation resistance over traditional alloys due to lattice distortion, promising for advanced reactors. However, damage evolution and mechanical performance of irradiated MPEAs under loading are unclear, limiting long-term application. We investigated hardening behavior induced by irradiation defects like dislocation loops and voids in MPEAs using crystal plasticity models and experiments. Here, we developed i) a stochastic field theory-based discrete dislocation dynamics simulation. A novel cross-slip mechanism in irradiated crystals was unveiled through co-linear reactions between dislocations and diamond perfect loops [1]; ii) With the continuous loading process, the damage transformation shows an abnormal trend of decreasing to increasing, which is attributed to the competition between dislocation ring annihilation and dislocation proliferation. The combined effect of lattice distortion and oxide particles can promote the annihilation of radiation damage in the early stages of deformation [2]; iii) Based on the framework of crystal plasticity theory, the three-dimensional geometric structure influence of irradiation defects was considered, and an irradiation hardening and creep model was established. Predict the shape dependent radiation hardening and creep behavior of voids in face centered cubic metals at different irradiation doses, times, and temperatures [3,4]. This work not only provides an effective theoretical approach for enhancing yield strength but also elucidates the fundamental behavior of irradiation damage at the mesoscale, guiding the development of advanced radiation-resistant MPEA by manipulating heterogeneous lattice strains.

KEYWORDS

Multi-principal element alloy; irradiation hardening; irradiation creep; discrete dislocation dynamics

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