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Physical mechanisms of irradiation creep in metals at cryogenic temperatures

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Metal and alloys used in cryogenic applications and additionally subjected to irradiation and constant stress amplitude during operation in the pre-yield regime may undergo time-dependent deformations that affect the intended performance. Contrary to popular belief, the creep phenomenon that leads to nonrecoverable deformation during a material lifetime might cause significant problems for applications. For this reason, the creep mechanism in irradiated and unirradiated materials at extremely low temperatures (liquid nitrogen 77 K, liquid helium, 4.2 K) should be explained.
For the problem of creep at cryogenic temperature, classical creep models for elevated temperatures range are not enough. The present work proposes a physically-based constitutive model which allows to describe the effects of creep of irradiated materials at cryogenic temperatures and the physics of defect generation. The quantum tunneling as the mechanism responsible for creep deformations at sufficiently low temperatures and relatively high-stress levels is adopted. Dislocations that are locally pinned can escape from their pinning points more rapidly via tunneling than by means of thermal activation. Peierls lattice resistance mechanism is used to explain creep produced by the elastic interaction of a radiation induced point defects with existing dislocations in materials. This mechanism is based on the hypothesis that dislocation can pass through barriers (interstitials atoms and cavities) when corresponding Peierls energy is reached. Thus, in this case, the activation energy may be reduced in the presence of interstitial atom to a value much smaller than activation energy of creep at intermediate temperatures. Furthermore, assuming the quantum tunneling mechanism the kinetic law for the evolution of irradiation induced dislocation loops is proposed. Predicted creep rate behaviour as a function of stresses and *dpa* are presented.

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