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RADIATION DAMAGE EVOLUTION IN DUCTILE MATERIALS

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The problem undertaken in the present work concerns the physical processes involved in radiation damage and its effects on mechanical properties. In this work we present a multiscale modeling of evolution of radiation induced micro-damage in ductile materials subjected to periodic stress states in the inelastic range. Exposure to high energy radiation (flux of particles) damages the microstructure of materials. Energetic particles penetrating a solid displace the lattice atoms from their original positions. In elastic collisions, that is initiated when a given atom is struck by a high-energy particle, an incident particle transfers recoil energy to lattice atom, the primary knock-on atom. The initial primary knock-on atom, will recoil with a given amount of kinetic energy that it dissipates in a sequence of collisions with other atoms. As a result of scattering of energetic particles, atoms in the solid can be displaced from their equilibrium lattice positions, creating a vacant lattice site and interstitials. This vacancy-interstitial pair is called Frenkel pairs. The vacancies of the Frenkel pairs often accumulate in clusters by means of diffusion. The resulting microstructural and damage evolutions cause profound macroscopic property changes that severely degrade the lifetime limits of the component subjected to irradiation. Based on the expected displacement damage (*dpa*), we then attempt to identify the critical radiation damage effects for structural materials.

The evolution of radiation induced damage is combined with the evolution of classical micro-damage of mechanical origin (micro-cracks and micro-voids) within the common framework of Continuum Damage Mechanics (CDM). A multi-scale constitutive model comprising the evolution of radiation induced damage under mechanical loads has been formulated.

Kinetics of radiation induced damage involves two laws for ductile rupture which introduces a strong coupling between deformation and damage: the Rice &Tracey laws and the extended type Gurson (ETG) laws for cyclic loads. Both models were extensively compared. The Rice & Tracey (R-T) law predicts the growth of an initially spherical void in an infinite, rigid - perfectly plastic material subjected to a uniform remote strain field. In order to compute the classical damage parameter, the volume or the surface density of voids has additionally to be known. On the other hand, ETG law is based on direct definition of the porosity parameter and the driving force of damage evolution is the accumulated plastic strain. Such a proposal is justified by the fact that for cyclic loads the cumulative effects are of primary importance. Both R-T and ETG kinetics may be conveniently applied to describe the evolution of radiation induced damage in the form of clusters of voids embedded in the metallic matrix.

Closed form analytical solutions for the problem of periodic irradiation combined with cyclic axial load, and corresponding to R-T and ETG laws were obtained.