Asociación Argentina
de Mecánica Computacional

Mecánica Computacional Vol XL, págs. 871-871 (resumen)
F.A. Avid, L.C. Bessone, P. Gamazo, J.J. Penco, M.A. Pucheta, M.A. Storti (Eds.)
Concordia, 6-9 Noviembre 2023

MICROMECHANICAL DESCRIPTIONS OF STEADY-STATE CREEP IN COARSE-GRAINED ZIRCONIUM ALLOYS UNDER IRRADIATION

Juan E. Ramos Nervi[a,c], Javier W. Signorelli[b] and Martin I. Idiart[c]

[a] *Departamento de Materiales y Diseño de Combustibles, Nucleoeléctrica Argentina S.A., Francisco N. de Laprida 3125, Villa Martelli, Provincia de Buenos Aires, Argentina, jnervi@na-sa.com.ar, https://www.na-sa.com.ar/*

[b]*Grupo de Física y Micromecánica de Sólidos Heterogéneos, Facultad de Ciencias Exactas, Ingeniería y Agrimensura, Universidad Nacional de Rosario, Argentina, signorelli@ifir-conicet.gov.ar, https://www.ifir-conicet.gov.ar/*

[c]*Centro Tecnológico Aeroespacial, Departamento de Aeronáutica, Universidad Nacional de La Plata, Argentina, signorelli@ifir-conicet.gov.ar, http://www.cta.ing.unlp.edu.ar/*

Keywords: Irradiation; creep; growth; thermodynamics; micromechanics; constitutive models; microstructure; edge and helical dislocations; climb.

Abstract. In view of their low capture cross-section for thermal neutrons and their adequate mechanical properties, zirconium alloys are employed for primary structural elements in nuclear power reactors. During normal operating conditions, the structural elements undergo continuous dimensional changes whose quantification is of importance for the purposes of plant life management. This has motivated a multitude of engineering models for describing steady-state creep in zirconium with varying degrees of complexity. The simplest models rely on purely phenomenological descriptions while the more sophisticated models rely on multiscale continuum descriptions explicitly accounting for the microscopic physical processes producing deformation. In all cases, however, the creep rate is invariably assumed to be additively composed of a thermal creep rate produced solely by stress, an irradiation growth rate produced solely by radiation, and an irradiation creep rate produced by stress and radiation concomitantly. In this presentation we expound a rigorous constitutive framework for coarse-grained zirconium alloys under irradiation that exposes the essential structure of constitutive laws conducing to additive creep rates. The framework combines a two-scale description with internal variables. Thus, the structure of local constitutive laws within individual grains follows from a thermodynamical formulation accounting for point defects nucleated by radiation and for deformation produced by dislocation glide and climb, while the structure of the overall constitutive relations for the polycrystalline aggregate follows from homogenization. Consequently, the resulting description is thermodynamically consistent and conforms to the generalized standard material model. A special class of constitutive laws is generated by means of convex dissipation potentials reproducing mean-field reaction rate theory.