

Radial Corrosion- and Pressure-Assisted Stress Buildup in High Temperature Pipes

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Abstract

The corrosion in the pressurized cooling pipeline of light water reactors is a catastrophic event leading to the fracture. We develop a real-time framework for the accumulation of compressive stress due to both elastic and corrosion events. In this regard, we quantify the infiltration of the oxygen in the zirconium matrix within the curved boundary during high temperature exposure. The rate of the oxide growth and consequently the is stoichiometrically computed versus the imposed internal/external imposed pressure values. In parallel, we quantify the augmentation in the volume and relate it to the stress build-up within the curved pipe. Finally, the onset of the failure is predicted based on the accumulated elastic and plastic (i.e. corrosion-based) stresses .

Keywords: Corrosion, Elastic Stress, Corrosion Stress, Curved Boundary.

1 Introduction

The oxidation of metallic pipelines is a crucial factor for the assessment and engineering of the corresponding structures [1, 2]. In nuclear reactors, the zirconium Zr has a substantial potential to withstand loads under highly oxidative regimes is paramount due to its limitation on the reactor's fuel energy extraction rate and its resistance on the oxidation [3, 4, 5, 6].

Indeed, one of the main failure mechanisms in the light water reactors (LWRs) pipes is the stress buildup and the formation of a metal oxide layer, interfacing with the underlying metal matrix [7]. In fact the corrosion succeeds the diffusion of oxygen solute from the water into the metal matrix. [8, 9, 10]. Such event follows a series of oxidative reactions which induces a weakened structure of the overall pipe surface, leading to the susceptibility to fracture [11, 12]. The kinetics of such reactions have already been explored previously, with the focus on the material composition and chemistry [13, 14, 15, 16].

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