Nuclear Fuel Behaviour Modelling at the Royal Military College of Canada

K. Shaheen*, G. Bruni, A. El-Jaby, M.J. Welland, B.J. Lewis, and W.T. Thompson
Royal Military College of Canada
17000 Station Forces
Kingston, Ontario, K7K 7B4

The behaviour of nuclear fuel elements under normal and defective conditions is being modelled at the Royal Military College of Canada (RMC). The simulated fuel behaviour involves highly coupled phenomena affecting the fuel pellets, sheath, and fuel-to-sheath gap.

Under normal operating conditions, a fuel performance model considers the interrelated effects of heat transport and fission gas diffusion in a physically evolving fuel element, including the effects of grain growth, gap closure, and pellet-sheath interaction. The model is developed using correlations employed by industry, as well as mechanistic-based considerations. The effects of defective fuel phenomena on the fuel performance are presently being considered through the introduction of a previously developed fuel oxidation model to the fuel performance model.

A separate, standalone code with a customised numerical solver is used to predict the fission product inventory and coolant activity concentration in the primary heat transport system resulting from the exposure of a defective element(s) based on an empirical diffusion coefficient. This model has been validated against coolant activity concentration data from operational power reactors. In addition, a mechanistic model for the prediction of sheath hydriding in defective elements is presently under development. In the event that the melting conditions of the fuel are exceeded, a phase-change model incorporates the effects of the non-congruent melting process with regards to the heat effect and the redistribution of oxygen.

These models are composed of systems of highly-coupled time-dependent partial differential equations, which are solved primarily using the finite element software package COMSOL Multiphysics. The developed models provide a platform for research and industrial applications, including the design of fuel behaviour experiments and prediction of safe operating margins.

* Corresponding author: shaheen-k@rmc.ca