Simulation of fuel rod fragmentation, relocation and ballooning through peridynamics in MOOSE framework

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ABSTRACT:

The proposed project focuses on the development of a methodology that includes the appropriate governing physical fields within the realm of peridynamics (PD) to investigate fuel cracking, fragmentation, relocation, ballooning and PCI, cladding rupture and dispersion. The proposed work consists of (1) Integration of PD multi-physics modeling tool into the NEAMS/ToolKit and INL/MOOSE framework, (2) Validation and verification of the PD multi-physics as a modeling tool. Qualitative evaluation of the predictions against available experimental data concerning metallic fuels will be performed in collaboration with INL and LANL. The need for a realistic, multiphysics predictive modeling and analysis capability for advanced and ATF response is of paramount importance because of difficulty in obtaining empirical data on new Accident Tolerant Fuels (ATF) fuels. Currently, a truly predictive all-inclusive analysis and simulation tool that couples neutron and heat diffusion with mechanical material interaction in conjunction with realistic fracture mechanics, critical for the success of ATF concepts and future reactor designs, does not exist. Even the fuel performance codes such as FRAPCON/FALCON rely on empirically driven models for thermal conductivity and fission gas transport and release. The current integral system codes do not have the ability to be coupled to advanced tools such as BISON that trace fuel/clad swelling properly during startup. In addition, the BISON fuel code does not have the capability to adequately predict crack formation and propagation. These difficulties can be overcome by incorporating multiple physical phenomena under one computational framework, peridynamics, which directly and fully couples the distinct physics involving mechanics of deformation and swelling, diffusion of temperature, species and neutrons. The effects of material failure/damage will immediately influence local material properties governing the fields of diffusion. Once validated and integrated into the MOOSE framework, this approach will lead to a comprehensive and realistic prediction of nuclear fuel/pellet behavior. Such data will also be available to validate BISON fracture predictions; thus, leading to possible improvement of fracture models required in BISON applications. Furthermore, comparison of PD and BISON predictions will establish the fidelity of the proposed method.