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Expansion of BISON Capabilities to Predict the Dynamic Response of Irradiated Fuel Rods

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ABSTRACT:

The main goal of the proposed research is to expand the capabilities of BISON and MOOSE (Multi-physics Object Oriented Simulation Environment) to simulate the structural dynamic response of fuel rods and fuel assemblies during handling (wet and dry storage) and transportation. Expanding the capabilities of BISON and MOOSE to facilitate the evaluation of the dynamic response of fuel rods and assemblies is important to conduct a more reliable risk assessment of fuel assemblies, as well as storage and transportation casks. To date, a single computational environment able to simulate the condition of the cladding and pellets after irradiation, their deterioration, and their dynamic response during handling and transportation does not exist. The proposed work will address this current gap.

The study will focus on modeling issues useful to assess fuel rod dynamic responses that account for: the interaction between pellets and cladding, as well as between pellets, using models of a full-length fuel rod with robust cyclic contact algorithms; the effect of support conditions (i.e. spacer grids) on the dynamic response of a fuel rod via the incorporation of new nonlinear support/spring elements; the effect of pinching on the cladding; the contribution of frequency-independent damping; and the dynamic response of fuel rods in the assembly by taking into account their boundary conditions and the geometric constraints imposed by adjacent fuel rods. This work will complement existing efforts to couple BISON with dynamic analysis solvers in MOOSE.

The study will be divided into five major phases: (i) development and validation of the coupling between MOOSE and BISON to simulate the dynamic response of fuel rods, (ii) validation of the MOOSE Contact modulus (using both Dirac and Constraint options) utilizing experimental results and the incorporation of a robust cyclic contact algorithm to appropriately represent the interaction between cladding and pellets, (iii) development and incorporation of nonlinear spring models into the Tensors Mechanics module in MOOSE to simulate the effect of spacer grids on the degree of restraint of the fuel rods; (iv) expansion of the capabilities of the MOOSE Tensor Mechanics module to model frequency-independent damping, (v) validation studies and holistic evaluation of the dynamic response of fuel rods and fuel assemblies.

The proposed work will provide support for programmatic interests associated with engineering-scale fuel performance validation of BISON and the PCI challenge problem. Validation studies are proposed to further develop and expand the capabilities of BISON. Data from experiments to be used for validation purposes will incorporate the effect of PCI (bonding and/or contact) on the dynamic response of fuel rods. The sensitivity of dynamic responses that account for the uncertainty in the most important modeling parameters associated with will also be evaluated.