
Investigation of the Combined Transient and Surface Effects on ATF Critical Heat Flux

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ABSTRACT:

The safe and reliable operation of light water reactors (LWRs) needs trustworthy prior knowledge on safety margin evaluation in anticipation of design basis accidents (DBAs). One important DBA is the reactivity-initiated accident (RIA), an accident that involves a sudden and rapid insertion of reactivity in the reactor core. Understanding RIA complex transient behavior requires high-fidelity experimental data and multiphysics-coupled modeling to mechanistically reflect the thermomechanical behavior of fuel-cladding-coolant interactions. As the deployment of accident tolerant fuel (ATF) technologies in LWR cores approaches, it has become increasingly important that long-term cladding concepts, such as FeCrAl, be comprehensively assessed for their thermal-hydraulics, thermo-mechanical, and oxidation performances under both steady-state and transient conditions.

In this work, we will generate a new database of flow boiling heat transfer to assess fuel cladding behavior during RIA events. Rigorous experimental and analytical investigations will be conducted using traditional Zircaloy-2 and two FeCrAl (APMT and C26M) claddings in boiling water reactor (BWR) conditions. The new database will push the development of theoretical bridging relationships from the steady-state to the non-equilibrium power-transient flow boiling to improve predictive models used in thermal safety margin analyses. The experimental results will be compared with the component-level simulations to quantify and elaborate the potential impacts on reactor core operational margins and safety under RIA impacts. Simulations will be centered around the theoretical modeling of power-transient boiling, thermo-mechanical, and oxidation responses of three cladding alloys.

Particularly, this study aims to (i) probe the mechanistic relationships from the steady-state flow boiling to the Fuchs-RIA driven power-transient flow boiling, (ii) facilitate the multiphysics modeling of conjugate boiling heat transfer coupled with thermo-mechanical and oxidation kinetics behaviors, and (iii) characterize power-transient induced flow boiling instability resulting in cladding failure. These goals will be achieved by the experimental investigations integrated with analytical and numerical modeling. The power transient pulses will be simulated by a DC programmable power supply to approximate three typical Fuchs-RIA cases, *i.e.*, hot zero power, cold zero power, and hot full power at their corresponding power elevations. Post-critical heat flux RIA destructive experiments will be conducted to quantify the transient film boiling heat transfer and the cladding structural integrity using a micro-CT scanner.