Development of Accident Tolerant Fuel Options For Near Term Applications

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The objective of this proposed integrated research project (IRP) is to develop computational tools to evaluate accident tolerant fuel (ATF) options for near term applications. The computational tools will be predominantly developed under the framework of the Nuclear Energy Advanced Modeling and Simulation (NEAMS). The NEAMS tools: RattleSnake (neutronics), MARMOT (meso-scale fuel performance), BISON (engineering scale fuel performance) and RELAP-7 (thermal-hydraulic system analysis) will be further enhanced in order to model ATF options. The newly developed models will be evaluated on the core level under both steady state and transient conditions, including severe accidents, where time to melt of the fuel and core components is estimated. The selected NEAMS tools, while at an advanced state, require further validation and verification (V&V), especially for transient simulation of conventional LWR fuel and ATF concepts. For proper validation, existing experimental data will be utilized and new low-cost experimental data will be generated within this IRP. For verification, industry standard and licensing tools for neutronics, thermal hydraulics and fuel performance will be used for model development of conventional fuel and to provide cross-code checking of ATF performance.

All of ATF concepts involve some changes to the conventional fuel that is made of UO_2 pellets and Zircaloy cladding. Any type of change to the current fuel system is more costly from the point of view of manufacturing and initial regulatory burden. The "near term" focus of this IRP is motivated by minimizing such economic penalty through deploying ATF concepts for use in current light water reactors (LWRs) within the next 10 years. Therefore, computational tools to simulate near term ATF options need to be ready now. The near term options to increase the fuel/cladding accident tolerance under steady and transient response at a minimal economic cost that are considered in this IRP are:

- Thin ceramic/MAX phase coatings: Ti-Al-C, Ti-Si-C, Zr-Al-C,
- Thin metallic coatings: FeCrAl and Cr and
- Small additives to the UO_2 fuel: BeO and SiC.

The IRP combines strong university capabilities of Massachusetts Institute of Technology (MIT) with its experience in reactor and fuel design, neutronics and thermo-mechanical performance and safety analysis, University of Wisconsin (UW) with its experience in severe accident modeling and development of cladding coatings for the ATF industrial campaign, Texas A&M University (TAMU) with its material ion irradiation capability and experience in atomistic scale simulations and Pennsylvania State University (PSU) with its meso-scale fuel performance modeling to address the development of computational tools necessary for evaluation of ATF concepts. Since the selected NEAMS tools are currently being developed predominantly at Idaho National Laboratory (INL), INL is a member of the team to allow for efficient implementation and integration of models. The largest challenge of this IRP is development of the capability for simulation of integral fuel performance under accident conditions. This is addressed

through close collaboration of the university partners with ANATECH Corporation, which has developed such models for conventional LWR fuel system and AREVA, which is leading one of the industrial efforts in the current ATF campaign of DOE and one of the three nuclear fuel suppliers in the US.