Understanding Constituent Redistribution, Thermal Transport, and Fission Gas Behavior in U-Zr Annular Fuel Without a Sodium Bond

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ABSTRACT:

Uranium-zirconium (U-Zr) metallic fuels are candidates for Generation IV nuclear reactors and are proposed for use in TerraPower's Natrium^{TM} advanced reactor (selected for the Advanced Reactor Demonstration Program) and the US Department of Energy's (DOE) Versatile Test Reactor (VTR). Historical, metallic fuel slugs were designed with a large sodium-bonded gap to accommodate fuel swelling and would use a closed fuel cycle. However, an open fuel cycle may be required for new commercial reactor designs, which precludes the use of a sodium bond. Room for swelling is provided by changing the slug geometry, i.e., to an annular design. Recent work by the DOE Advanced Fuels Campaign suggests that the constituent redistribution and microstructure evolution in annular fuel is different than in non-annular fuel slugs with a sodium bond. This results in the fission gas behavior and thermal conductivity being different as well. The goal of this proposed project is to answer the question of why constituent redistribution in annular U-Zr fuel slugs without a sodium bond differs from that in non-annular fuel with a sodium bond and how it changes the fission gas and thermal conductivity behavior.

We hypothesize that Zr redistribution and swelling contribute to the shrinking of the center annulus, and that the high porosity in the outer region results in a low thermal conductivity and thus higher fuel temperatures that cause more Zr redistribution and swelling. We will test this hypothesis using structure and property data from annular fuel and multiscale modeling and simulation using the BISON and MARMOT fuel performance codes.

This project will reveal the cause of the unique constituent redistribution in the AFC annular U-Zr fuel and how it changes the fission gas behavior and thermal conductivity. It will also provide a ***validated and predictive capability in BISON for open-cycle annular U-Zr fuel performance*** for various burnup and temperature conditions. This will include three improved and validated BISON models:

- A constituent redistribution model for U-Zr that can include mass transport into a center anulus.
- A mechanistic fission gas release model for U-Zr that couples to the constituent redistribution model and is a function of Zr concentration and phase fractions.
- A thermal conductivity model for U-Zr that couples to the constituent redistribution model and the fission gas model.