Fabrication Process R&D to Support HFIR HALEU Silicide Conversion

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USHPRR Fuel Fabrication Pillar

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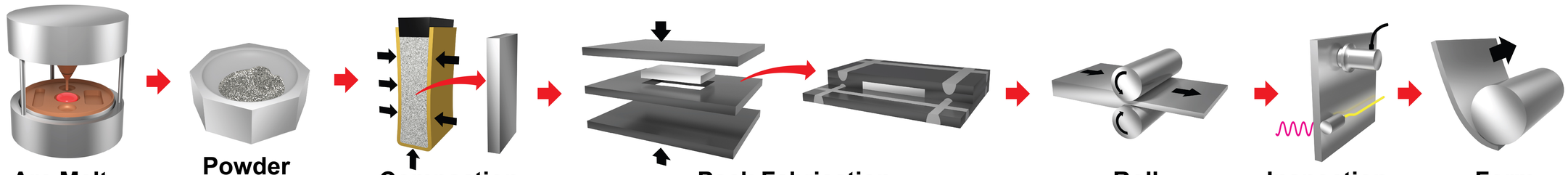
Objective

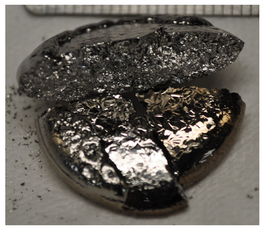
- U_3Si_2-Al dispersion fuel is proposed for converting the U.S. High Flux Isotope Reactor (HFIR) to a high assay low enriched uranium (HALEU) fuel.
- Conversion requires use of high volume fractions in excess of 45%. Complex fuel shape[1], volume loading, and homogeneity requirements present fabrication challenges.



Arc Melt

This step is critical to forming a phase pure U_3Si_2 fuel with minimal impurities.

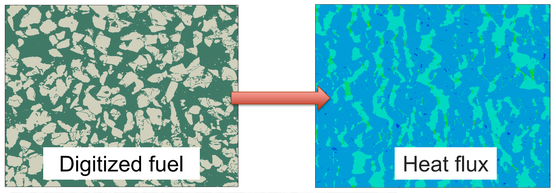
- Experimental work investigates phase purity, efficient measurement of impurities and fabrication practices.

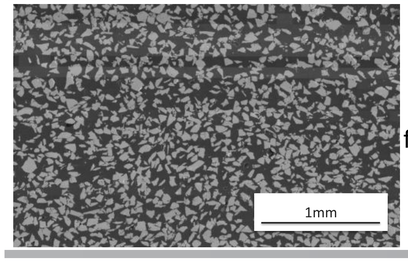


Powder Production

Grinding affects particle size distribution (PSD).

- Microstructure FEM model can predict thermal conductivity, heat flux, and temperature for multiple PSDs and morphologies.
- PSD affects fuel homogeneity.



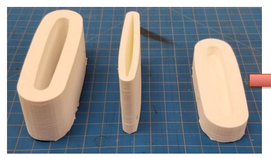


Homogeneous fuel made through controlled PSD

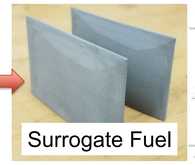
Compaction

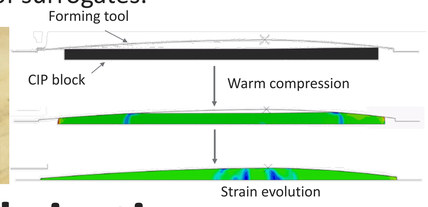
Cold Isostatic Pressing (CIP) provides uniform density and enables complex shape formation. Closed die forging ensures exact dimensions with mass control. Surrogates only currently.

- CIP studies inform hydrostatic pressures and mold requirements for both net shape and near net compaction of surrogates.
- FEM models inform CIP shapes for forging based on creep and plastic flow properties of surrogates.



CIP Mold

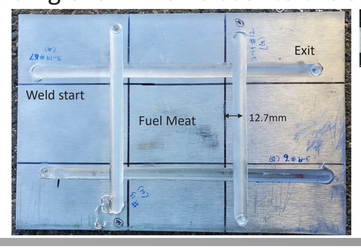


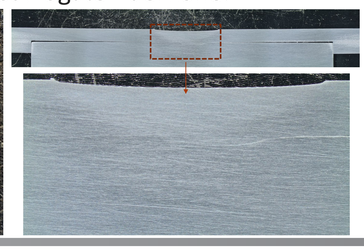


Pack Fabrication

Use of friction stir welding (FSW) allows for efficient pack sealing and provides multiple benefits over traditional weld methods

- Parametric studies have been undertaken to develop tool geometry, speed, and RPM's.
- Experiments measuring temperature show much lower temperatures than fusion welding even when closer to the surrogate fuel zone.

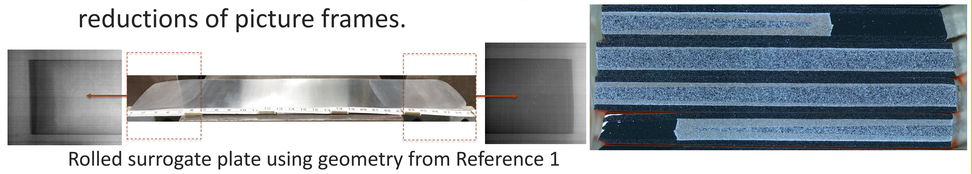




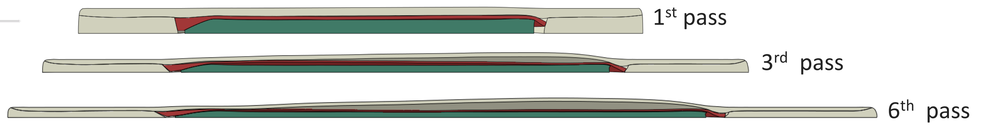
Rolling

Rolling forms the fuel pack into the desired fuel geometry.

- Parametric study determined the compact geometry needed to form desired fuel shape after rolling.
- Modeling showed taper and filler to fuel flow stress ratios needed to minimize dog bone.
- Experimental work validates the modeled surrogate fuel geometry.
- Experimental work investigates bonding with variable temperature and reductions of picture frames.



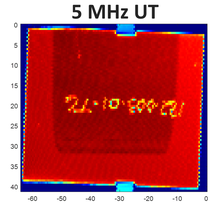
Rolled surrogate plate using geometry from Reference 1

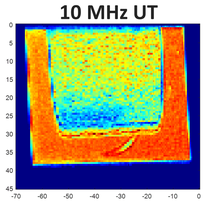


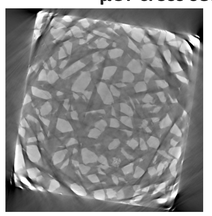
Inspection

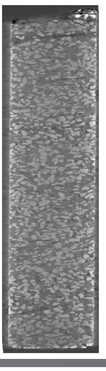
Inspection confirms geometry and fuel homogeneity requirements

- Investigated ultrasonic frequency on square fuel zones
- Radiography to determine fuel homogeneity









U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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References: [1]Betzler et al., 2021. *High Flux Isotope Reactor Low Enriched Uranium Low Density Silicide Fuel Design Parameters.* United States. https://doi.org/10.2172/1773657

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