Westinghouse Design for Additive Manufacturing (AM) and Development Needs

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Outline

• Advance Manufacturing Objectives

• Additive Manufacturing (AM) Implementation
  – Irradiation Testing of AM Materials
  – Thimble Plugging Device (Reactor Ready Component Project)

• Design for AM (DfAM) Examples
  – Fuel Components
  – Tooling Applications
  – Advanced Reactor Components and Replacement Parts

• M&S Development Needs
**Advanced Manufacturing Program Objectives**

*Improve industry competitiveness, through the development and implementation of advanced manufacturing technologies*

- Drive cost reductions in component manufacturing
- Enable new products and services that provide innovative customer solutions
- Leverage collaborative development and external funding sources
Additive Manufacturing Implementation

Exploiting the benefits of Additive Manufacturing

- Producing components with: Powder Bed Fusion, Binder Jetting, and Directed Energy Deposition AM technologies
- Complex components required for performance gains
- Obsolete and high value / lead-time components
- Advanced reactor components – eVinci™, LFR
- Prototypes, mockups, jigs / fixture, tooling

Enabling AM for Nuclear Component Manufacturing

- Leading material development & testing for in reactor use
- Supporting the development of ASTM and ASME codes and standards
- Submitted first ASME AM code case (August 2020)
Irradiation Testing of AM Materials
Westinghouse has funded material development and irradiation performance testing for 316L SS, Ni Alloy 718 and Zr

- Produced AM block and micro-tensile test specimens
- Irradiating materials in MIT’s test reactor (Oct. 2014 → 2018)
- Completing post-irradiation examination (PIE) at Westinghouse Churchill laboratory (316 and 718 completed, Zr PIE DOE funded)
- AM 316L irradiation performance consistent with wrought
Mechanical Testing Irradiated AM Specimens

- Unirradiated and irradiated tensile testing of AM 316 SS and Alloy 718 materials inside WEC hot cell

- Room Temp and elevated Temp (i.e., 572°F) tensile testing of ~50 AM 316SS specimens and ~50 AM Alloy 718 specimens

- Extensive unirradiated and irradiated materials evaluations completed
316L samples have been tested and evaluated for mechanical properties

- The absolute values for the AM material Ultimate Tensile Strength (UTS), 0.2% Offset Yield Strength (YS) and percent elongation (% EL) were as expected and consistent with conventional material
- Tensile strengths, both UTS and YS increased with irradiation as expected
- % EL went down with irradiation
AM Thimble Plugging Device
(Reactor Ready Component Project)
Kaizen Event Held to Select Demonstration Component – Dec 2014

- Thimble Plugging Device (TPD) selected as the first AM Fuels component to be placed in a commercial reactor as a demonstration component
- Low risk component, moderate complexity, fully contained in guide thimble tubes.
- AM TPD is equivalent in Form, Fit and Function as existing TPD.

Completed testing, analysis, quality assurance, manufacturing qualification, licensing, etc. to support one production AM TPD

Working with Exelon, the AM TPD was delivered for the Byron Unit 1 Spring 2020 Outage via 10CFR50.59
Fuel Components
AM Benefits

- Reduced pressure drop
- Improved debris filtration
- Multiple complex designs are enabled by AM, and prototypes can be built overnight
PWR Debris Filtering Bottom Nozzles

1. Single External Mesh
2. Single Internal Mesh
3. Double Internal Mesh
4. Optimized Double Internal Mesh
5. Optimized Double Internal Mesh with Inlet Features

AM allow for quick design iterations and performance testing
Pursuing advanced PWR Fuel Bottom Nozzle design through multi-physics topology optimization and DfAM to improving filtration and reduce pressure drop
Fuel Spacer Grids

**AM Benefits**
- Stronger support of fuel rods
- Improved mixing characteristics

**Designing AM thin-walled features to improve dimensional stability**
Fuel Spacer Grids

Traditional stamped, assembled and welded grid versus 1-piece AM grid
Tooling Applications
Control Rod Spider Gage

Gage used to measure the locations of the spider fingers after welding/brazing

- This gage weighs ~60 lbs, so inspectors are at risk of injury during gage movement
- Redesigned to a total weight of less than 35 lbs
Fuel Grid Strap Alignment Pins

Completed multiple design iterations to reduce build times and material usage / weight and increase part life

Optimized build layout to maximize alignment pins per build and minimize cost per alignment pin
Advanced Reactor Components and Replacement Parts
eVinci™ Microreactor Primary Heat Exchanger (PHX)

**eVinci PHX AM Design / Concepts**
- Developed lattice support structure for HX header plates
- Flexible supports allow tube movement during thermal cycle
Thermal Shield Flexure

**Topology Optimized AM Concept**
- Completed topology optimization, FEA and DfAM
- Additively manufactured optimized and traditional designs
- Complete fatigue testing of traditional wrought flexure and AM flexures
  - All 3 flexure successfully met fatigue testing cycle requirement
Modeling and Simulation Development Needs
M&S Development Needs

• Multi-physics optimization / generative design for AM structural and flow components
  – Topology optimization / FEA, CFD and DfAM constraints

• High-resolution, high-speed distortion simulation with the ability to auto-adjust input model and/or optimize layer / region parameters

• AM process and material performance simulation
  – AM parameters > grain size & structure > mechanical properties
  – Ability to optimize for parameters to minimum build time

• Irradiation performance modeling for AM materials