US NRC Workshop on Advanced Manufacturing

Westinghouse AM Thimble Plugging Device / Advanced Debris Filtering Bottom Nozzle Implementation Process

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Agenda

- Westinghouse AM Objectives
- Advanced AM Components
- Reactor Ready Component
- Licensing of AM TPD
- Advanced AM Debris Filter Bottom Nozzle

Westinghouse AM Objective

- Westinghouse is using the AM process to produce high quality / high performance fuel products for use in commercial nuclear reactors.
- Westinghouse has performed significant testing, designing, prototype building, verifying design characteristics, validating material properties, etc. to ensure that the AM process is fully understood and thus can be safely used for producing fuel components for use in commercial reactors.

AM Provides Significant Benefits Relative to Existing Manufacturing Methods

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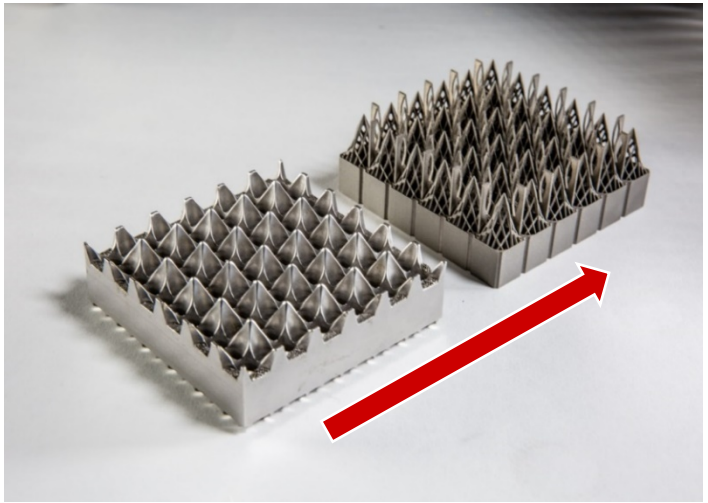
Advanced AM Components - Bottom Nozzles

Numerous Advanced AM Component designs have been developed and tested by Westinghouse and are close to being implemented via Lead Test Assembly Programs

- Advanced AM debris filtering bottom nozzle created
  - Low Pressure drop
  - Improved filtering performance
  - Improved structural support via use of Alloy 718



AM Optimizes performance

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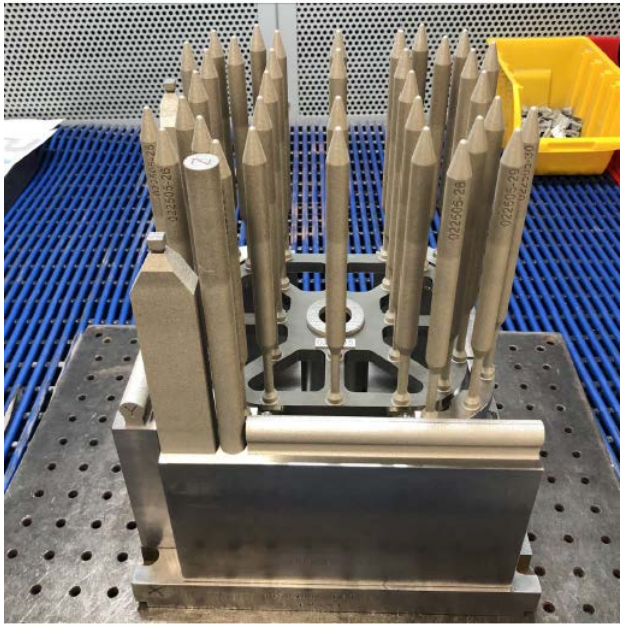
Reactor Ready Component Project

- **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**



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Westinghouse AM Testing and Analyses Summary

- **Westinghouse performed significant work to support the AM components, including for the first application of the AM TPD.**
  - 2015-2017: Mech. Testing of AM test specimens irradiated in MIT reactor
  - 2016-2018: Autoclave Testing of AM Type 316L SS and AM Alloy 718
  - 2015-2019: AM Thimble Plugging Device (TPD) testing
    - Extensive testing of the AM TPD including in comparison to the current TPD design
    - Density Evaluation of AM Type 316L SS
    - Defect evaluation via dye penetrant testing for AM TPD
    - Microstructure Evaluation for presence of voids or porosity
  - 2019: US NRC Issues Action Plan for AMTs including request for a candidate AM component for which W offered the AM TPD.
  - May 2019: Westinghouse met with NRC at W Rockville offices and covered all aspects of the development, design, manufacture, quality assurance/control, licensing, etc. of the AM TPD.

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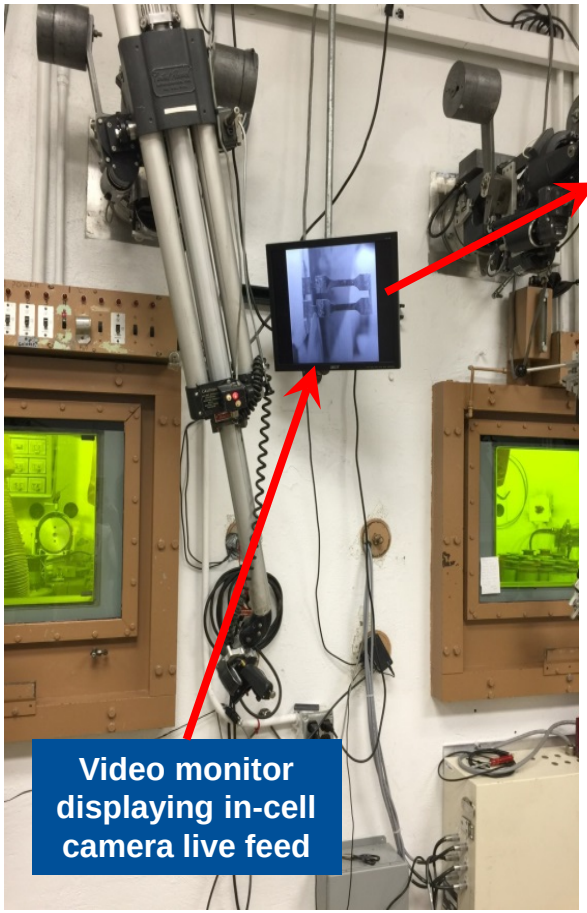
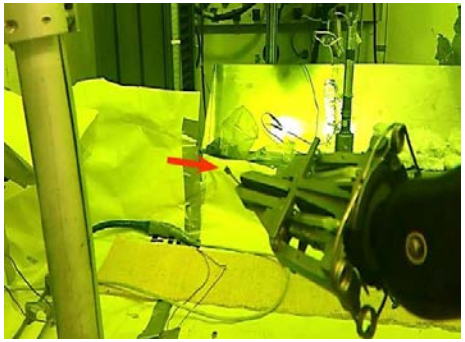
Mechanical Testing Irradiated AM Specimens

- **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.**



Intact irradiated quad held with hot cell grips prior to separation into 4 individual miniature tensile specimens



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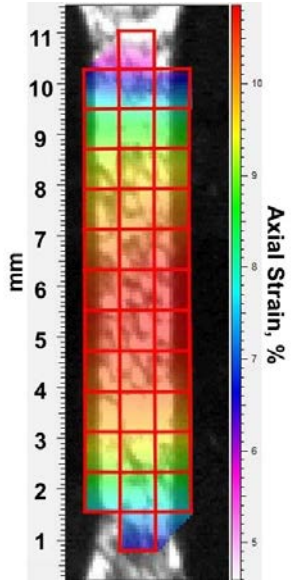
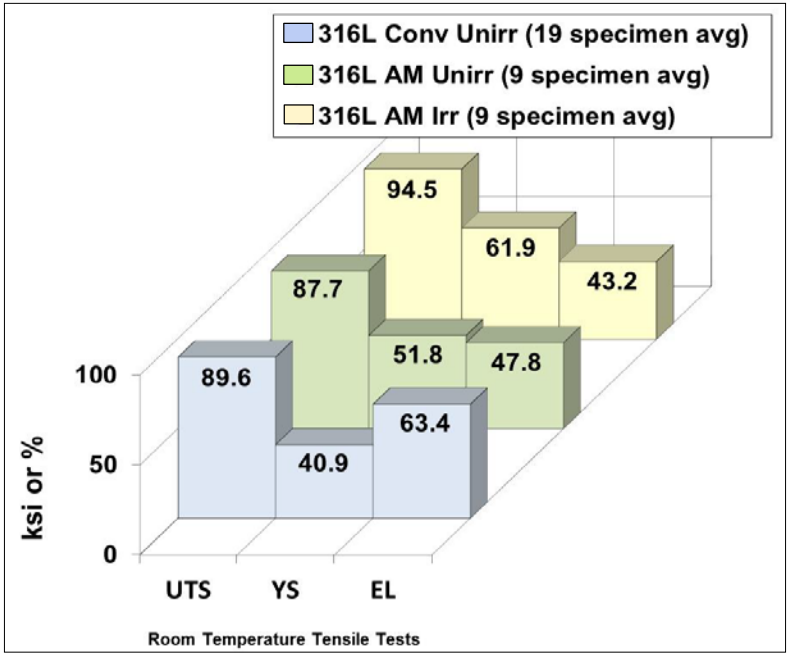
Mechanical Testing - AM 316 SS Performance

Irradiated AM Specimen SX51





US NRC AMT Action Plan:

- Testing performed to assess irradiation and aqueous environment effects on the performance of AMTs.

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Manufacturing Validation Process

- Three confirmatory AM TPD builds were created utilizing the same AM machine, same lot of material and same process parameters. Each of these builds included witness specimens and tensile bars.
- Two builds were destructively tested along with the witness specimens to establish consistency of the witness specimen results.

US NRC AMT Action Plan:

- Discusses the need to investigate state-of-the-art modeling and simulation tools being developed to predict AM microstructure and properties of AMT materials, to provide a path for validating the acceptability of AMT components similar to the use of witness specimens and lot testing.

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Westinghouse AM TPD Testing

Mechanical Testing of AM TPDs:

- Mechanical testing was performed for the existing and the AM TPDs. Testing included axial pull tests, lateral bending tests and baseplate weld integrity tests.
- Performance of the AM TPD was consistent with the existing TPD.
- All TPD mechanical design criteria satisfied.

NRC AMT Action Plan:

– Testing should address differences between AMTs and traditional manufacturing processes from a performance-based perspective. Focus should be on those performance characteristics pertinent to safety that deviate from traditional manufacturing requirements.

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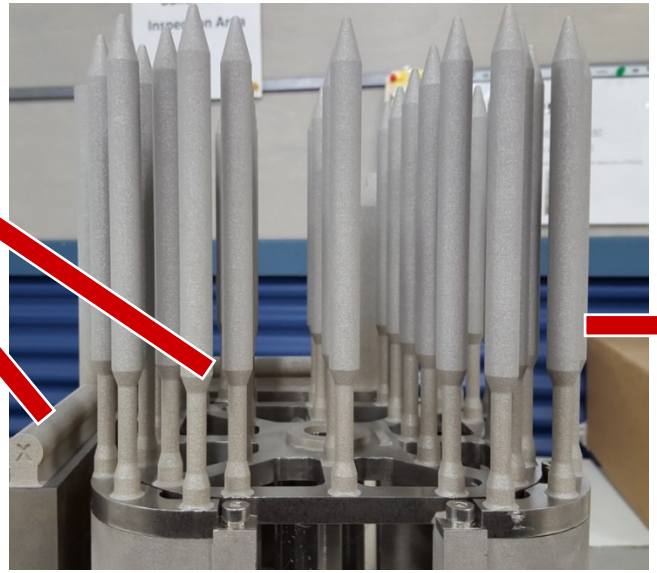
ASTM E-8 Tensile Specimen Testing

- ASTM E-8 Tensile specimens cut from AM TPD
- Tensile testing performed on resulting ASTM E-8 Tensile specimens.

ASTM specimens from X and Y cylinders



Z Specimens from Z cylinder and from select AM rodlets

US NRC AMT Action Plan:

- Performance criteria for the AMT component may include physical properties, mechanical properties, dimensionality, functionality, and reliability.

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Westinghouse AM TPD Testing

Additional Testing and Evaluation:

Dye Penetration Testing:

- Dye penetrant testing was performed on the complete AM TPD and there were no observed defects.

Microstructure Evaluation:

- Cylinders were created from the AM Rodlets and were cut in half and polished and examined at 50x magnification and found to be free of voids or porosity.

Density Evaluation:

- Cylinders were created from the AM Rodlets and were evaluated for density and were determined to be consistent with wrought 316L Stainless Steel material.

- **US NRC AMT Action Plan:**

  Adequate information to demonstrate whether inspection and non-destructive examination (NDE) techniques are sufficient to assess the condition of AMT-fabricated components, and in particular for the types of defects that can compromise the safe performance of the component and can accelerate degradation of the component during service.

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Manufacturing Verification Process

- ASME NQA-1-2008: Requirement 3 - 300 Design Process states the following:
  - "(2) specify required inspections and tests and include or reference appropriate acceptance criteria"
- Westinghouse Product Spec. (PDTPAM00) for AM TPD
  - Process Plan, Manufacturing Qualification, Safety related Properties
    - Product identification, Chemical composition, mechanical properties, grain structure density, etc.

Design is controlled consistent with 10 CFR 50 Appendix B

- **US NRC AMT Action Plan:**

Consistent with 10 CFR Part 50 Appendix B requirements, each processing step is to be performed using a quality assurance procedure with appropriate documentation. Critical processing parameters will be identified along with the parameter values and a technical basis for the values. The compliance with requirements of the pertinent processing standard shall be confirmed in an appropriate manner, such as process logs, inspection, and testing.

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AM TPD Implemented using 50.59 Process

- Equivalent in form, fit, and function with minor changes which "screen out" – no adverse impact on the design function
- No changes to design and safety criteria
- The AM process does not adversely affect the manner in which any plant design function is performed or controlled.
- There are no system design or operation changes.
- This activity does not involve a safety analysis methodology change.
- This activity does not involve a test or experiment.
- This activity does not require any Technical Specification (TS) changes.

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Post Irradiation Evaluation of AM TPD

- **Post Irradiation Examination (PIE)**
  - Westinghouse currently plans on performing inspections of the AM TPD which will include detailed visual inspections with a high-resolution camera system as well as performing drag tests.
- **US NRC AMT Action Plan:**

  Although there is nothing specific regarding PIEs, Subtask 2C: AMT Guidance Document mentions that a report will be created to be used as a resource for staff reviews of AMTs and includes the topic of "In-Service Inspection"

AM Advanced Debris Filter Bottom Nozzle

- Full size AM Advanced Debris Filter Bottom Nozzle
  - Reduced pressure drop
  - Improved Filtering capability
- Pursuing the licensing of Lead Test Assembly AM Bottom Nozzles (4 to 8) using the 50.59 process.
- Coordinating with the NRC to ensure licensing approach is acceptable.
- Licensing support will include GSI-191 testing to demonstrate acceptability of design

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Summary

- Westinghouse has invested significant time and effort thoroughly evaluating the Additively Manufactured process for application to fuel components for a commercial reactor.
- Material and Mechanical Property Testing concluded that AM Properties are consistent with conventional wrought material.
- First reactor ready component (AM TPD) installed in Byron Unit 1 in the spring of 2020.
- Westinghouse continues to pursue through testing and development of advanced AM components following guidance provided in the US NRC Action Plan on AMTs.

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Questions

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