Radiation testing of AM materials

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AMMT program motivation for irradiated AM materials properties

• AM is a new enabling technology
• New fabrication method means there is a large need for new data
• AMMT will provide new, valuable data for irradiation behavior of materials with engineering importance for nuclear reactors
Using the right tool for the job

• AMMT uses its expertise to select the right tool for the job
  • High level conceptualization of radiation testing for design achievement
  • Timelines to obtain data (accelerated vs prototypical)

Data needs
PIE needs
Radiation type and facility

Microstructure
Swelling
Hardening
RIS
Phase formation

Ion irradiation
IASCC
Embrittlement
Creep
Fracture toughness

Neutron irradiation

U.S. DEPARTMENT OF ENERGY
Office of NUCLEAR ENERGY
Using ion irradiations for screening and regulatory purposes

- Many advanced reactor designs aim for 100+ dpa
  - Materials test reactors will provide ~1-10 dpa/year
- Ion irradiations can:
  - Provide rapid screening of materials evolution
  - Link to prototypical neutron irradiation conditions by generating microstructure data
  - Modeling predicts microstructure evolution and links microstructure to properties to predict the effect of different irradiation conditions (temperature, fluence, energy)
Providing data and science to aid with NRC licensing

- A new fabrication method means a lot of data is needed to understand process-structure-properties-performance links to support licensing applications to the NRC
  - Case-by-case basis
  - Materials information to support safety case
- Looking for equivalencies or major differences from conventionally made materials
  - Impact of microstructure
  - Build variability
  - Post-build heat treatments

“The NRC licenses and regulates the Nation’s civilian use of radioactive materials, to provide reasonable assurance of adequate protection of public health and safety, to promote the common defense and security, and to protect the environment.”
AMMT program strategy for irradiated AM materials properties

• Consistent test plan of to deliver data and science

• AMMT is also working on a framework to promote the regulatory acceptance of combined neutron irradiations, ion irradiations, and modeling

• Looking for industry input on parameter spaces of interest
Neutron irradiation test plan development for AM316H

- Two-level testing strategy
  - HFIR@ORNL will provide baseline engineering information to higher doses
  - ATR@INL will provide novel advanced PIE for new reactor technologies
  - Leveraging standard capsule designs to make neutron irradiations faster and cheaper
- Looking for industry input on parameter spaces of interest

Current irradiation capabilities summary

- Mechanical specimens
  - INL (ISHA):
    - SSJ tensile bars (16mm x 4mm x 0.5–1mm) - max 48 specimens per capsule
    - Round compact-tension - max 13 specimens per capsule
    - Bend bars - max 24 specimens per capsule
    - TEM specimens (3mm diameter)
  - ORNL (Rabbit):
    - SSJ tensile bars (16mm x 4mm x .5mm-0.75mm) – max 36 specimens per capsule
    - Bend Bars (14.8 mm x 3 mm x 4.5 mm) – 6 specimens per capsule
    - Pressurized tubes

- Irradiation temperature: 200 – 1200°C

- Post-irradiation examination (PIE)
  - Elevated testing up to 800°C
  - Uniaxial tensile testing
  - Microstructural characterization
  - Hardness testing
  - Fracture toughness
  - 3- and 4-point bend
  - ...
INL Future Rad Mechanical Testing

- SPL facility opening start of FY26
- Max testing temperature 1200°C
- Creep testing
- Creep crack growth
- Fatigue
- Automated Charpy impact testing
- Additional capacity for tensile compression testing
- Nanoindentation and micromechanical testing
## Delivering data and insights for AM316L and AM718

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Case study: delivering data and insights for AM316L

- Test strain rate of $5 \times 10^{-4} \text{ s}^{-1}$ (displacement rate = 0.15 mm/min)
- Strength increased and ductility decreased with irradiation dose
- All specimens showed prompt necking at yield at 10 dpa
- Effect of AM build thickness and location is not evident