Opportunities in additive manufacturing for advanced nuclear energy systems

Kurt A. Terrani, Ph.D.
Director – Transformational Challenge Reactor

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TCR is bringing to bear additive manufacturing (AM) and artificial intelligence (AI) to deliver a new approach

Using AI to navigate an unconstrained design space and realize superior performance

Leveraging AM to arrive at high-performance materials in complex geometries

Exploiting AM to incorporate integrated and distributed sensing in critical locations

Using AI to assess critical component quality using in situ manufacturing signatures
Myriad additive manufacturing methods span a vast dimensional scale across a range of material systems.

**Powder bed techniques**

- Metal or ceramic powder or slurry sequentially spread and fused in 2D layers
- Fusion achieved via melting (e.g. laser or e-beam source) or binding (via binder jet or lithography)
- Ability to accommodate most complex geometry with best spatial resolution
- Limited to a single material system
- Build volumes usually < 0.05 m³ with some extending up to 0.3 m³

**Direct deposition techniques**

- Metal powder or wire or ceramic slurry directly deposited as continuous point on substrate
- Deposition via melting (e.g. laser or arc welding), drying, or curing
- Complex tool path design is needed, and less geometric complexity is accommodated
- Flexibility to accommodate multiple material systems
- Build volumes usually < 0.5 m³ with some extending up to 7 m³
Example of powder bed system: 3D printing of stainless steel via laser powder bed fusion technique
Example of large direct deposition system: Medusa wire arc additive

Coordinated control of 3 robots + rotary table

(2 m ø x 2 m)

Printed 316L block

(2.5” x 7” x 9”)

Transient layers (~18 mm, not stable heat profile)

L. Love, M. Noaks, Y. Yamamoto, A. Nycz (ORNL)
Using AI to assess critical component quality using in situ manufacturing signatures: Digital Platform for quality assurance
Augmented Intelligence for Advanced Manufacturing

- Data to features
- Deep Learning
- Machine Learning
- ML anomaly detection
- CV anomaly detection
- AI anomaly visualization
- ML performance prediction for specific geometry
- ML performance prediction for arbitrary geometries
- AI driven design

AI Complexity
- Descriptive
- Diagnostic
- Predictive
- Prescriptive

Year
- 2020
- 2025
Research Activities

Data management

Metadata search

Data viewer

In-situ quality control

Sensor development

Printer operator reviewing a Peregrine analysis

nuclear reactor manifold

Research Activities
Process Correlation Campaign

Standard Cluster

Location Specific Sample Extraction

Build 0.1 Layout

2,784 SS-J3 specimens

Data Correlation

Mechanical properties

Creep properties
Extensive neutron irradiation testing of additive and advanced manufactured materials was carried out to develop their irradiated properties database, facilitating their adoption.
Key outcomes are documented to coordinate and guide industrial application and deployment of additive technologies for nuclear energy.
Additive manufacturing of salt pump impeller for Kairos Power

As ORNL builds novel reactor, nuclear industry benefits from technology

Kairos Environmental Testing
Additive manufacturing of framatome fuel assembly components for Tennessee Valley Authority

Reconstruction of in situ manufacturing data