Additive Manufacturing of FeCrAl + TiC Composite for High Temperature Applications

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Objective & Research Question:

This research explores enhancing **FeCrAl** alloys for high-temperature use by reinforcing them with titanium carbide (**TiC**) through laser powder bed fusion (**LPBF**). By addressing the issue of coarse TiC precipitates in conventional processing, we aim to produce fine, stable particles that strengthen the alloy at elevated temperatures. The study examines how laser scan speed affects TiC refinement and whether 5 wt.% TiC addition improves mechanical performance at 500 °C.

Research Methodology and Challenges:

FeCrAl samples were fabricated using a **Laser Powder Bed Fusion (LPBF)** machine to study how processing parameters affect print quality. The **dataset** defined variations in laser power, scan speed, hatch spacing, and layer thickness used as inputs for each print. The figure shows the **as-built FeCrAl cubes**, where each corresponds to a parameter set; defective samples marked with red "X" resulted from **insufficient melting or unstable melt pools**.

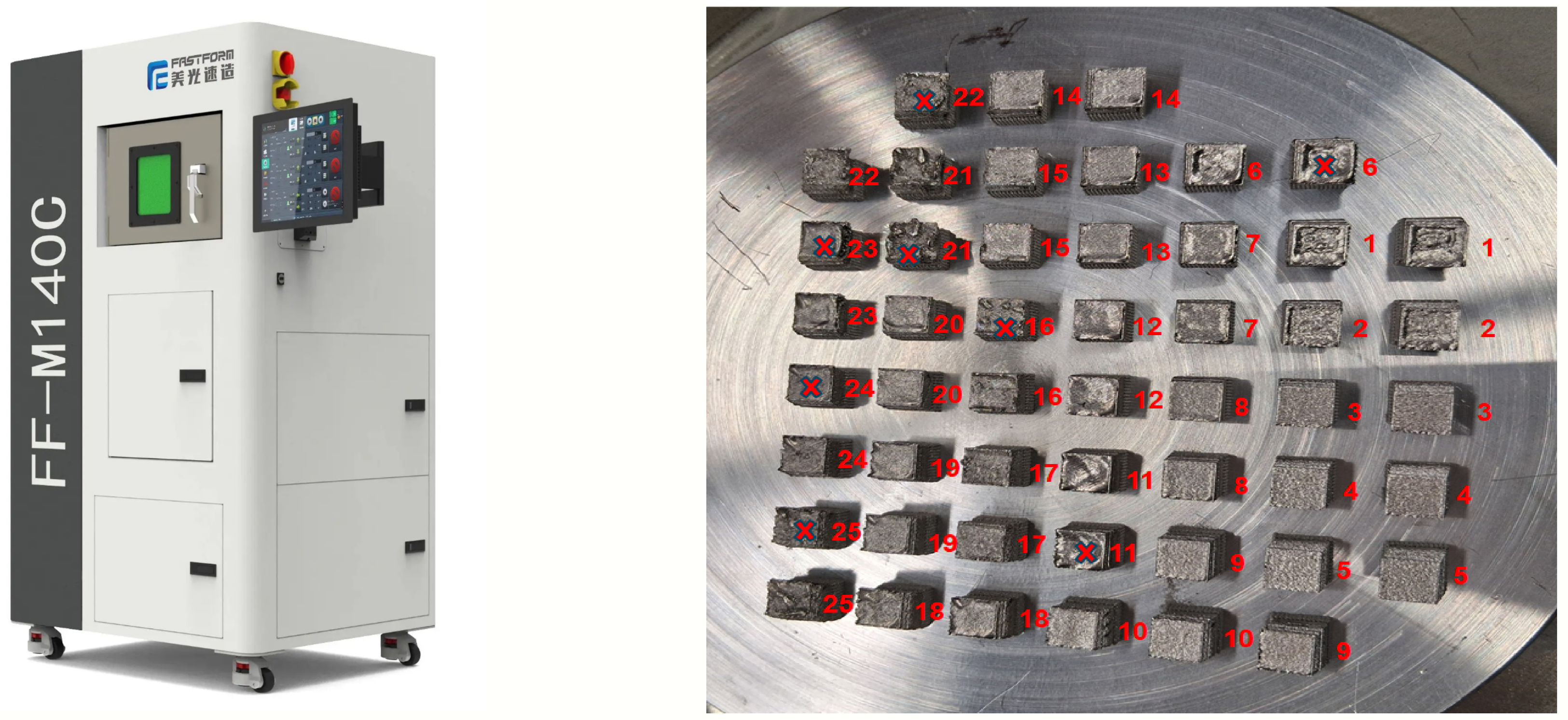

Fig.1. LPBF-printed FeCrAl cubes.

Key challenges included maintaining **uniform powder flow**, avoiding **porosity and warping**, and minimizing **oxidation** during high-temperature exposure. The results from the parameter matrix helped establish a **feasible LPBF window** for defect-free FeCrAl fabrication.

Results:

A representative volume element (RVE) of FeCrAl reinforced with 5% TiC was simulated using the **Johnson–Cook plasticity and damage model** in ABAQUS to analyze stress evolution under tensile loading. The simulation revealed that the **smaller TiC particles** carried a greater portion of the applied load compared to the central larger particle, resulting in localized stress concentrations along the FeCrAl–TiC interfaces. The contour map **(Fig. 2)** shows the von Mises stress distribution within the RVE, highlighting effective load transfer across the TiC reinforcement network.

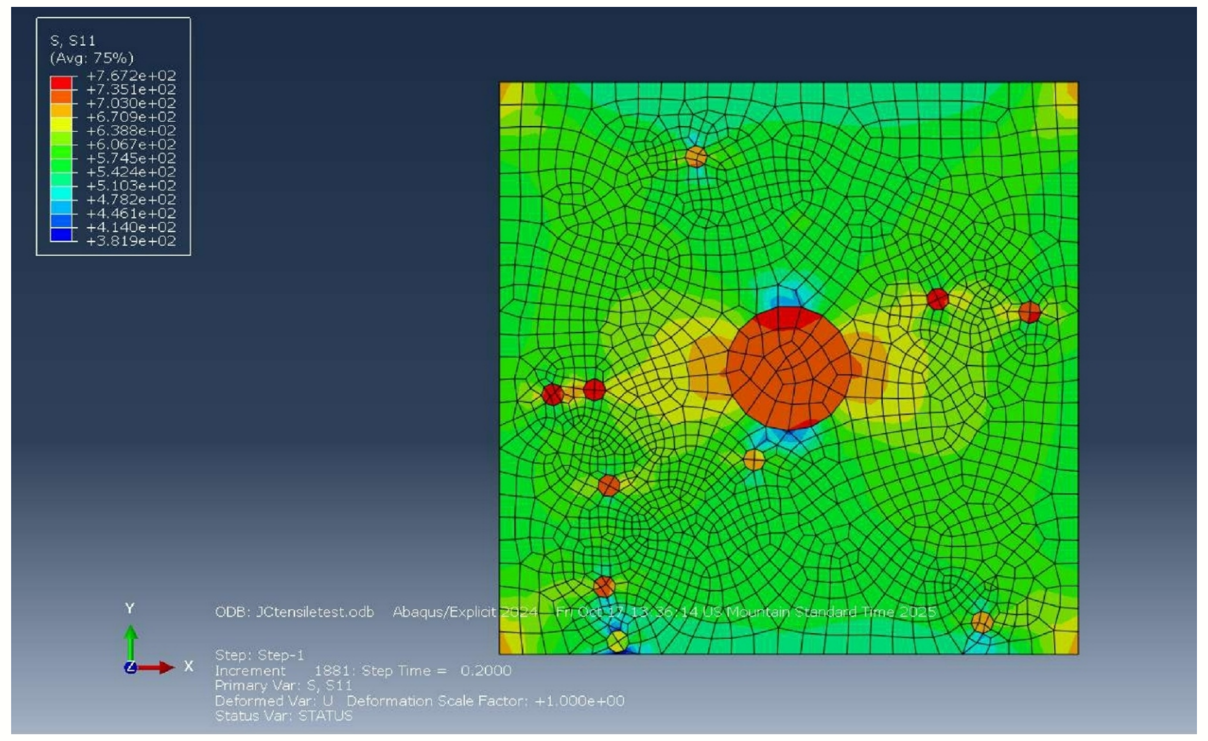

Fig.2. Simulated stress distribution in FeCrAl–5% TiC RVE.

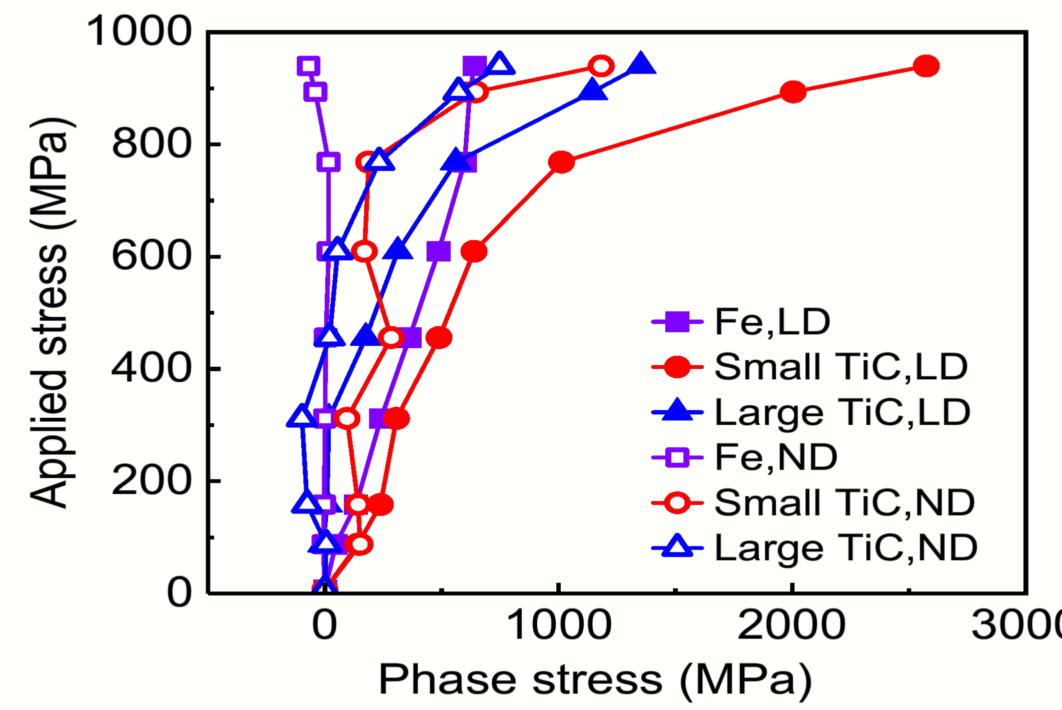

Fig.3. In-situ neutron diffraction of FeCrAl–TiC composite.

The **in-situ neutron diffraction measurements (Fig. 3)** corroborated the simulation results, displaying similar stress partition behavior in the FeCrAl matrix. Overall, these findings demonstrate improved stiffness and efficient load sharing in the TiC-reinforced FeCrAl composite.

References:

1. Selvamurugan Palaniappan et al., Additive Manufacturing of FeCrAl Alloys for Nuclear Applications – A Focused Review, Nuclear Materials and Energy, 40 (2024) 101702.
2. Shaimaa I. Gad et al., Predictive Computational Model for Damage Behavior of Metal-Matrix Composites, Materials, 14 (2021) 2143.

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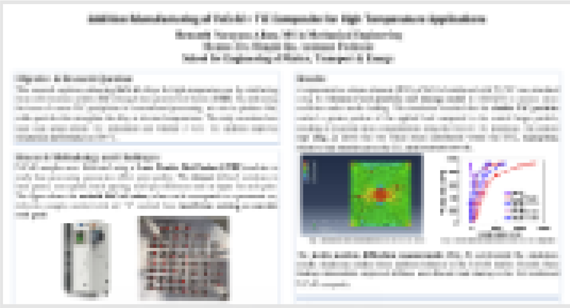

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Hemanth Narayana Allam <hallam1@asu.edu>
to Minglei

8:01 PM (2 minutes ago)

Hello professor,

Thank you, Professor, for the modifications. Can you approve it, from your side, for the sake of a screenshot?

Best,
Hemanth

•••

Minglei Qu
to me

8:03 PM (0 minutes ago)

Yes, I approve.

From: Hemanth Narayana Allam <hallam1@asu.edu>
Sent: Monday, November 3, 2025 8:01:52 PM
To: Minglei Qu <minglei.qu@asu.edu>
Subject: Re: Updated MORE poster

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