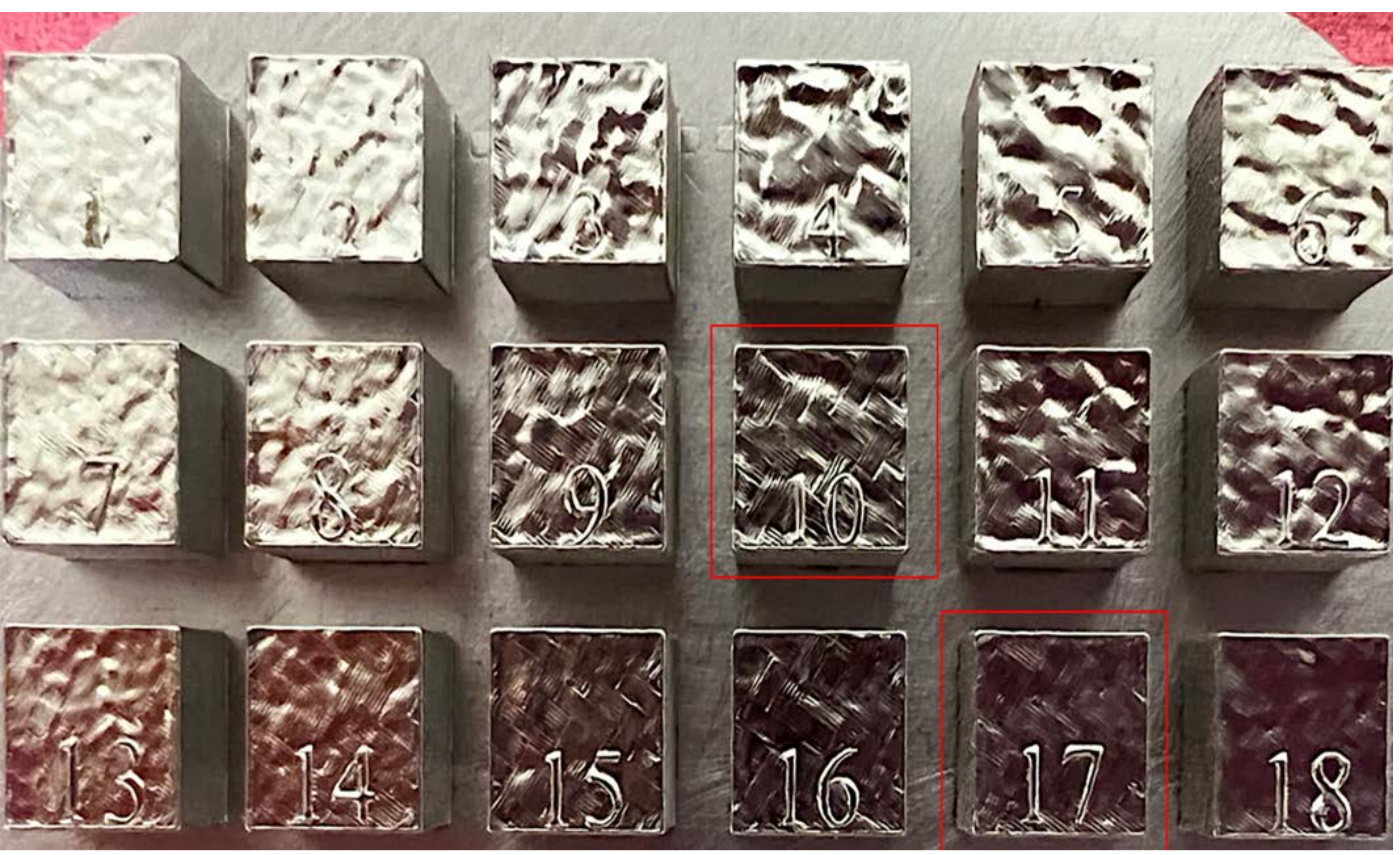
ARCS
AUTONOMY RESEARCH CENTER FOR STEAHM

Autonomy for Manufacturing and Construction

Additive Manufacturing of Aerospace Heat Exchanger



Synopsis

- Crack-free HAYNES® 282®, a superalloy developed for high temperature structural applications, was fabricated using the Renishaw AM400 machine with optimized parameters. The reduction of porosity in as-printed alloys is related to laser parameters, including laser speed, hatch distance, and other factors.
- The typical structure of L-PBF-fabricated HAYNES® 282® consists of columnar structures, equiaxed grains, and ultrafine grains. Processing parameters play a crucial role in the precipitation of the strengthening phase, with spherical and cubic strengthening phases observed in alloys printed using chessboard and meander patterns, respectively.
- L-PBF-fabricated HAYNES® 282® exhibited excellent mechanical properties in both as-printed and heat-treated states, with high yield strength and ultimate tensile strength (UTS).

Research Objective

- The Autonomy Research Center for STEAHM (ARCS), in partnership with NASA JPL, academia and private industry partners, will create a Consortium for High-Volume Additive Manufacturing of Aerospace Heat Exchanger and Talent Development.
- The project will leverage ARCS's unique student talent and its access to JPL personnel and facilities, plus its strong partners, to conduct convergence.

Research Approach

- Develop robust superalloys by nanoparticles self-dispersion to improve the performance of heat exchanger
- Identify best practices of the generative design for additive manufacturing (AM)
- Cut the sample, observe it with micro CT, detect the roughness after corrosion precipitation, and finally summarize it through Transmission Electron Microscopy (TEM) for fusion in Laser Powder Bed Fusion (LPBF) additive manufacturing

Research Results and Products

- Cracks-free HAYNES® 282® was successfully fabricated with chess board printing patterns, and combination of optimized hatch distance and VED was selected to achieve low porosity and smooth surface in as-printed HAYNES® 282®.
- Sub-grain was observed in as-printed HAYNES® with fine γ' phase, equiaxed and elongated grain were observed in X-Y and Y-Z planes of heat-treated specimen, respectively. The 2-step aging heat treatment contributes to finer γ' phase and precipitation of carbides along grain boundaries.
- In as-printed status, specimen has higher yield stress (YS) and ultimate tensile stress (UTS) in the X-Y plane, while higher engineering strain of 43.8% was observed in Y-Z plane.

Commercialization and/or Societal Impact Opportunities

- **Application:** High-performance materials
- **Key Values:** Improved mechanical properties, reduced porosity and crack-free components
- **Potential Customer:** Aerospace industry

Team Names & Collaborators

ARCS Students: Changyu Ma, PostDoc Material Science and Engineering; Jianhao Zhu, MS Manufacturing Systems Engineering; Marshall Doyle, MS Mechanical Engineering; Zachary Liu, student at Sierra Canyon School

ARCS Faculty: Dr. Bingbing Li, Professor Manufacturing Systems Engineering; Dr. Christoph Schaal, Associate Professor Mechanical Engineering

Collaborators:

NASA JPL: Dr. Ryan Watkins; **NASA Goddard:** Mr. Ryan McClelland; **UCLA:** Prof. Xiaochun Li, Prof. Morris Wang; **Honeywell:** Mr. Gregory Colvin; Rafael, Maldonado Comas; Natalie Campos, Natalie; **Castheon Inc.:** Dr. Youping Gao; **ASTM AM COE:** Mr. Shane Collins; **SimInsights Inc.:** Mr. Rajesh Jha; **El Camino College:** Mr. Jose Anaya

External Advisory Committee: Mrs. Marilee J. Wheaton (The Aerospace Corporation); Mr. Dale Turner, DOE CESMII

Citations

Changyu Ma, Tianqi Zheng, Yu-Keng Lin, Philip Mallory, Xiaochun Li, Y. Morris Wang, Bruce Kang, Bingbing Li, 2018,, "Achieving Uniform Distribution of Nanoparticles in Oxide Dispersion Strengthened (ODS) SS316L through Laser Powder Bed Fusion (L-PBF)", Manufacturing Letters (JCR 2024 Impact Factor: 1.9), 41, pp. 766-771.
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Changyu Ma, Manikanta Grandhi, Philip Mallory, Zhichao Liu, Bingbing Li, Bruce Kang, 2024,"Directed Energy Deposited SS316L with Nano-Y2O3 Additions: Powder Processing, Microstructure, and Mechanical Properties", Progress in Additive Manufacturing (JCR 2024 Impact Factor: 4.4).
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