In-situ Mechanical Neutron Diffraction Loading Characteristics of GRCop-84 Fabricated by SLM


Background

GRCop-84 is a precipitation strengthened alloy composed of Cu-8 Cr-4 Nb at% with Cr2Nb precipitates that provide dispersion and precipitation strengthening characteristics and limited solubility in the Cu matrix. The particle role of Cr2Nb (C15 Laves) is unusual only contributing 1/3 of strengthening at high temperatures while the matrix provides the remainder. The particles mechanically and thermally stabilize the matrix retaining purity and preventing coarsening and loss of strength. At high temperatures (50-85%, TmCu), GRCop-84 provides the best thermal and mechanical properties of available alloys.

GRCop-84 is currently in development for reusable launch vehicles including the Space Launch System (SLS) with a focus on fabrication with additive manufacturing (AM) techniques. GRCop-84 is an optimal material for consolidating with AM. The base material is costly, the production times are long, and more geometry control can considerably improve cooling efficiency. Development of AM GRCop-84 with selective laser melting (SLM) has rapidly progressed due to ease of printing and limited operator adjustment between builds, but the necessary knowledge-based form fabrication history and stress state during builds is still under development.

Motivation

Previous neutron diffraction experiments on MRNSF-2 revealed high residual individual stress in the Cu matrix (311) of as-built SLM GRCop-84. Higher even than reported yield stress values. However, GRCop-84 is a two-phased alloy, and almost no literature exists to explain stress evolution in SLM GRCop-84. It is critical to understand stress partitioning behavior between the two phases to accurately assess previous and future neutron results on a single peak, and the future of the alloy. Literature suggests 1/3 Crollan strengthening and 2/3 Hall-Petch for traditionally fabricated GRCop-84, but this might not be the case with SLM as its grain structure would be significantly different.

Stress/Strain Estimates/Assumptions

- Young's modulus, E, 111-130 GPa
- Poisson's ratio, ν, 0.29
- Initial strain, ε0 = δ0 / L0 = 0.00152 Å
- Initial Cu volume fraction, fCu = (1 - δ0 / L0)

Phase Partitioning

- δ0 = (ε0 / ν) 1 + 2ν (1 - ε0 / ν)
- fCu = ε0 / (ε0 + ν) (1 + ε0 / ν)
- fNi = 1 - fCu

Previous strain mapping showed evidence of strong compressive and tensile Cu matrix strain in the (311) which as the primary matrix component led to the assumption that the macro-stress behavior was similar; however, the stress partitioning behavior shown in this in-situ experiment requires re-evaluation of the strain mapping data. Wherever there is residual thermal strain in the matrix, there is likely balancing strain in the Cr2Nb phase that reduces the overall stress in these areas.

The as-built Cr2Nb particles are significantly smaller and less uniformly distributed than the HIP condition and exhibits more brittle behavior. These could be accounted for by the Cr2Nb being in a more unstable or less crystalline form than after it has been HIPed, or there could be a significant fraction of dissolved Cr2Nb in the Cu matrix.

Future work includes analysis of EBSD on primary samples, further metallurgy, in-situ HXRD, and in-situ mechanical EBSD to observe grain interactions in collaboration with current neutron data.

Conclusions

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References


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