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MECHANICS AND CHEMO-THERMO-MECHANICAL MODELLING FOR METAL ADDITIVE MANUFACTURING

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ABSTRACT

Metal additive manufacturing couples rapid melting and solidification with repeated thermal cycling, solute redistribution and mechanical constraint. These interactions determine microstructural evolution, residual stresses, distortion and susceptibility to cracking, and influence the mechanical performance of the finished component. Predicting this behaviour requires models that describe the coupling between temperature, composition, phase transformations and deformation, while connecting local mechanisms to the response of an entire build.

This invited session covers the mechanical, thermo-mechanical and chemo-mechanical modelling of metal additive manufacturing, with emphasis on their consistent coupling. Particular attention will be given to thermal contraction, plastic deformation, stress-assisted diffusion, transformation strains and evolving interfaces, and to how these mechanisms affect stress development and mechanical behaviour under repeated thermal cycling. Contributions may address powder bed fusion, directed energy deposition and subsequent heat treatment, ranging from fundamental formulations to simulations validated against experiments. Topics of interest include:

- Thermodynamically consistent constitutive formulations for coupled chemical, thermal and mechanical processes.
- Phase-field modelling of solidification, segregation, precipitation and solid-state transformations, including interactions with stress, diffusion and deformation as well as interfacial mechanics.
- Multiscale approaches connecting melt-pool dynamics, microstructure evolution, crystal plasticity and component mechanics.
- Prediction of residual stresses, distortion, hot cracking and damage during fabrication and post-processing.
- Microstructure-sensitive modelling of anisotropy, plasticity, fatigue and fracture in additively manufactured alloys.
- Model calibration, validation and uncertainty quantification using in situ monitoring, microstructural characterisation and mechanical testing.
- Reduced-order models and physics-informed machine learning for efficient simulation and process optimisation.