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FROM MICROSTRUCTURE AND DEFECTS TO MECHANICAL BEHAVIOUR: MODELLING AND TESTING OF ADDITIVELY MANUFACTURED MATERIALS AND STRUCTURES

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ABSTRACT

The mechanical behaviour of additively manufactured (AM) materials and components is governed by the microstructure and possible defects, which originate from steep thermal gradients, repeated thermal cycling, and the local processing conditions at the melt pool and layer scale. Although process simulation, microstructure modelling, and mechanical testing have each advanced considerably, they are frequently pursued in isolation. This limits the predictive capability needed for control and optimization of mechanical properties, in particular at the part scale. The stochastic nature of some influencing factors in AM, e.g. powder characteristics and local defects, makes empirical model validation indispensable.

This invited session brings together modelling and experimental researchers who establish quantitative links between process, microstructure, defects, and the mechanical response of AM materials and structures, including size effects and spanning different length scales. The emphasis is on the interplay of modelling and testing: in-situ monitoring at the melt pool and layer scale is employed to calibrate and validate thermal models, including the influence of the powder bed and support structures, whereas temperature and toughness measurements underpin constitutive and microstructure models. Besides established alloys, the session addresses emerging material systems, such as bulk metallic glasses and medium-/high-entropy alloys, for which microstructure-dependent strength and toughness remain open challenges. The session also considers filigree lattice structures and thin-walled components, where mechanical performance depends on process-induced geometric imperfections.

Topics include, but are not limited to: (i) microstructure–property relationships, phase transformations, micromechanics, homogenization, and constitutive modelling of AM alloys; (ii) defect formation and its influence on strength and ductility; (iii) mechanical and thermal testing, including scale and size effects; (iv) in-situ monitoring and melt pool-scale measurements for model calibration and validation; (v) thermal history, interlayer temperature, and scan strategies tailored to mechanical properties; (vi) data-driven and hybrid prediction and optimization of mechanical properties.

By combining academic and industrial perspectives, the session promotes validated, transferable strategies for predicting and controlling the mechanical behaviour of AM materials and structures.