

Novel Testing Methods for Mechanical Assessment of Additively Manufactured Materials in Aerospace Relevant Contexts – Experience and Development at the University of Nottingham

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Keywords: Constitutive Behaviour, Failure, Additive Manufacture, Elevated Temperature, Representative Loading

Abstract. In order for the revolutionary design and manufacturing freedom offered by additive manufacturing to be implemented in industry, notably in high value manufacturing sectors such as aerospace, confidence must be generated in how additive materials will perform when applied in harsh engineering environments. This means developing robust predictive models, supported by good experimental observations, that capture material deformation and failure behaviours and allow these to be applied in structural simulations. There are many examples in the literature illustrating how additively manufactured materials/structures can exhibit significant levels of anisotropy and heterogeneity (a result of the complex thermo-mechanical conditions imposed in most welding based additive processes). Subtle asymmetries in the build volume also give rise to notable stochastic effects that are not as pronounced as in wrought material counterparts. In addition, constitutive and failure properties can be heavily length scale dependent. Given the drive to adopt structures which make good use of the load carrying potential of a material (thereby optimising for weight), complex design tools like topology optimisation are often seen as an attractive way to generate the efficient designs that additive manufacture can enable. The challenge is how to both furnish these design tools with appropriate predictive models, such that the complex physics can be represented in the optimisation process, and how to demonstrate the consistent ability for additively manufactured materials to perform as required in demanding engineering systems. This presentation reviews research conducted by the team at the University of Nottingham in this field and comments on where future work should be directed. The use of novel specimen geometries, notably those which induce multiaxial load states or “small specimen” methods, to generate elastic and plastic flow data are explored and demonstrated for case study alloys including Ti-6Al-4V and Inconel 939. The use of small specimen methods is particularly exciting as it allows for the generation of a large amount of data (enabling the building of statistical material representations) for little source material and tests materials at length scales relevant to additively manufactured components. The importance of detailed material characterisation is demonstrated in this work through a topology optimisation exercise performed on the General Electric “Jet Engine Bracket” case study geometry. Using ABAQUS TOSCA, a 42.4% variance in optimised part volume is demonstrated. This variance is driven entirely by the choice of material representation, meaning that a naive choice of material data for a design problem can lead to a potentially large discrepancy in the final output. Such results illustrate the need for determining application representative material models for additive manufacturing design problems and motivates future developments in this area.

