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SIMULATION-BASED PROCESS QUALIFICATION FOR CRITICAL AM COMPONENTS

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ABSTRACT

Additive manufacturing enables significant weight reduction, improved performances and part consolidation by integration of functionality. These opportunities are especially beneficial for the aerospace market. Alongside the high potential, applications in aerospace also come with some major challenges. Fatigue is the predominant failure mode, which may lead to the an accident or worse an aircraft crash. Hence, authorities demand that safety is essentially guaranteed. This makes the qualification and certification process of critical components for aviation challenging, time-consuming and costly.

Qualification and certification of critical components is fundamentally reshaped by the application of metal additive manufacturing, where complex physics of the process determine the microstructure development and defect populations. This results in heterogenous microstructures and defect populations that differ markedly from conventional processes. In this session we wish to discuss how model-based process parameter generation and integrated computational materials engineering (ICME) frameworks should connect material processing, thermal cycles and microstructural evolution to predict local properties and fatigue performance. Particular emphasis is placed on processing strategies resulting in a homogeneous microstructure with predictable material properties alongside minimising material defects, such as lack-of-fusion pores, keyhole porosity and surface roughness. To ensure compliance, material defects, being dominant fatigue initiators depending on size, morphology and spatial distribution, must remain within (a priori established) acceptable limits.

Contrasts between damage tolerance and safe-life methods are recognised in fatigue design, in particular for aerospace industries, highlighting limitations when applied to conventional additively manufactured parts with heterogeneous microstructures. We project that for the qualification and certification of critical components the material processing strategies must evolve towards a homogeneous microstructure with predictable (and tolerable) defect sizes alongside the development of inline process monitoring techniques capable of assessing process stability and detecting crucial anomalies.

Through this session we wish to advocate for a shift toward process-based certification, in which qualification is built upon traceable links among model-based process parameters, supported by ICME-enabled digital threads, and inline process monitoring systems, rather than solely on component-level testing.