

PhD Defense by Deborah Kaschube

Title: **“Fatigue Analysis of Ti-6Al-4V Components Manufactured by Cold Metal Fusion”**

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Fatigue Analysis of Ti-6Al-4V Components Manufactured by Cold Metal Fusion

Deborah Kaschube

This PhD thesis investigates the fatigue behaviour of Ti-6Al-4V components manufactured by cold metal fusion (CMF) and assesses how fatigue life can be predicted for fatigue-critical applications. CMF is a sinter-based additive manufacturing (AM) route that combines polymer powder bed processing with subsequent debinding and sintering, offering design freedom and resource efficiency while introducing process-specific defects, surface conditions, and microstructures that influence fatigue performance.

The thesis begins by establishing the fundamental fatigue response of CMF Ti-6Al-4V at the specimen level. Cyclic stress-strain behaviour, strain-life parameters, and fracture mechanisms are determined to provide a material basis for later studies. These results show that fatigue performance is governed by the combined influence of surface roughness, porosity, microstructure, and cyclic softening rather than by a single dominant factor.

The work then examines how build orientation affects the fatigue response of CMF Ti-6Al-4V and benchmarks the CMF results against metal injection moulding (MIM). The orientation study reveals clear differences in surface roughness, porosity, and grain size, which are reflected in the fatigue results. Among the CMF variants, the horizontal build orientation performs best, followed by the 45° inclined and then the vertical build orientation. The MIM tests additionally show that powder recycling is feasible, as recycled powder leads only to a slight reduction in fatigue performance compared with virgin powder.

In a further step, the thesis transfers the specimen-based description to a real component by assessing a CMF manufactured drive wheel. The analysis predicts the critical failure location accurately and provides conservative life estimates, indicating that component-level effects such as residual stresses may contribute to the higher measured performance. The thesis then extends the investigation to asymmetric loading by studying mean-stress and mean-strain effects under fully reversed, compression-release, and tension-release loading. The results show a pronounced mean-strain dependency: tensile mean strain reduces fatigue life across the investigated range, whereas compressive mean strain improves life in the high-cycle fatigue regime but becomes detrimental in the very low-cycle fatigue regime. When several correction concepts are compared, the modified Smith-Watson-Topper approach shows the best overall agreement with the experiments.

Taken together, this thesis delivers a coherent progression from fundamental material characterisation to application-oriented fatigue assessment. It shows that the fatigue response of CMF Ti-6Al-4V is controlled by process conditions, build orientation, defect structure, component effects, and mean-strain influences, and that reliable life prediction requires all of these aspects to be considered together. The thesis therefore connects specimen-level testing with

component-level assessment and provides a framework for fatigue assessment that is directly relevant for the design and qualification of CMF titanium parts.