Contribution ID: **35** Type: **Oral Presentation - a full paper will be submitted**

Fatigue strength in Additive Toolmaking: A study of Metal Binder Jetting and Electron Beam Melting for processing carbide-rich cold-work tool steels

Tuesday, 25 March 2025 16:50 (20 minutes)

Additive Manufacturing (AM) offers numerous possibilities for toolmaking, such as the integration of internal cooling structures, easy fabrication of complex tool geometries or hybrid manufacturing. Another important aspect is the minimization of necessary post-processing steps through near-net-shape manufacturing, which enables considerable cost and effort savings, especially for difficult-to-machine, carbide-rich tool steels. Previous studies have investigated laser-based processes (LPBF). Due to locally high cooling rates and associated high residual stresses, hot cracking often occurs in laser-based AM of ultra-high-strength tool steels. In particular, steels with high carbon, vanadium or cobalt contents are difficult or not processible. This hot cracking tendencies are removed with Metal Binder Jetting (MBJ), as this process is cold and uses debinding / sintering. AM processing is also possible via Electron Beam Melting (EBM) with optimized printing parameters.
In this study AISI A11 (V10, X245VCrMo10-5-1) was successfully processed using MBJ and EBM. The resulting carbide and microstructures were characterized depending on the AM process and optional HIP application. Mechanical investigations enable appropriate microstructure-property-correlations for fatigue performances. For additively manufactured A11 with / without HIP (A11 AM) the High Cycle Fatigue (HCF, NG = 107) strengths are statistically evaluated under rotation bending tests (RBT). Those results are compared to conventional material (A11 PM) produced via HIP and subsequent Hot Working (HW). The critical defect types and sizes are exemplarily compared for each process.
The results show that AM toolmaking of high vanadium alloyed, carbide-rich tool steels is a promising alternative to conventional steelmaking. Emerging defect types and sizes are manufacturing-dependent, whereby fatigue strength is primarily determined by microstructural defect sizes. AM toolmaking obtains similar HCF strengths as conventional steelmaking when applying suitable HIP treatments, but without HIP fatigue strengths are clearly below those of conventional A11 PM due to increased porosity or lack of fusion.

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Session Classification: Fatigue

Track Classification: Processing: Additive manufacturing of tools