SURFACE PROPERTIES AND FATIGUE RESISTANCE OF AM-STRUCTURES

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INTRODUCTION

In recent years, additive manufacturing (AM) has developed into a promising manufacturing technology with revolutionary possibilities such as "complexity for free". In contrast, the physical properties of these components are often neither known nor assessable. This entails new risks and challenges with regard to the quality and reliability of such products, especially for applications in medical technology.

Acetabular cups from Renishaw (left) and Arcam (right)

METHODS

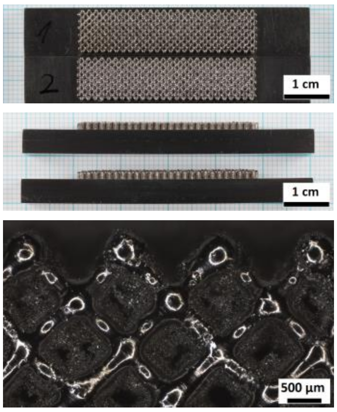
Laser metal deposition

(Abbreviation: LMD) Grid structures made of titanium alloy Ti6Al4V were deposited on 10 bars made of the same alloy.

Dimension: 1.9 mm high grid structure on 60 x 10 x 5 mm bars

Device: LMD „OFH" at Fraunhofer Institute for Laser Technology ILT, Aachen, Germany.

LMD Device at Fraunhofer institute for Laser Technology ILT



TAV-bars with AM-structure. Internal stress led to a bending of the bars.

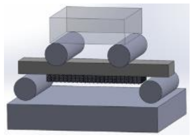
Surface analysis

Confocal microscopy & Scanning electron microscopy (SEM).

Fatigue tests

4-Point bending test:

- 270 - 637 MPa
- 10 Hz.



Fracture analysis

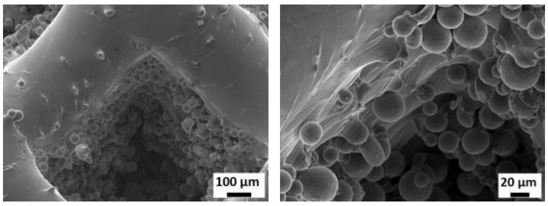
SEM with energy dispersive X-ray analysis (EDX)

Metallography with Micro-hardness measurements

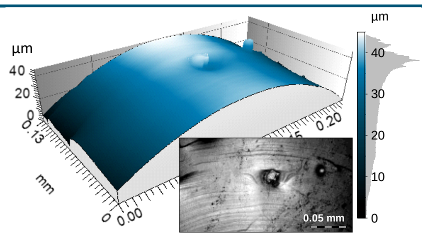
RESULTS

Surface analysis

- Overspray
- Small metallic droplets
- Roughness Ra of the structures ranged from 0.11 to 1.2 µm



SEM-images of AM Structure with overspray and droplets

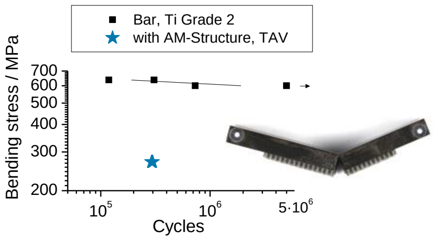


Topography measured with confocal microscopy

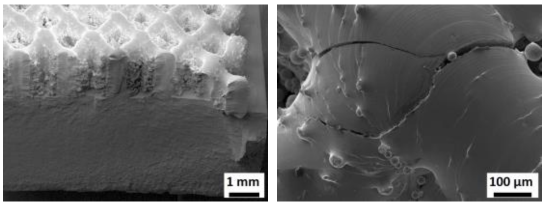
Fatigue tests

There was an early failure of the bars with the AM-structures in the 4-point bending test!

The SEM-investigation showed that there was a multiple crack initiation within the AM-structure.



Early fracture of the bars with AM-structures

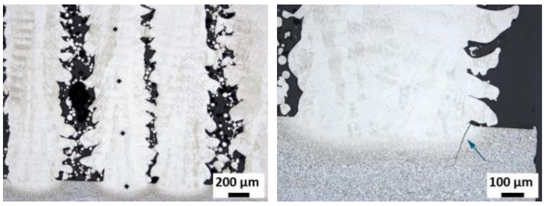


SEM-images of the fracture surface (left) and of the AM-structure with secondary cracks (right).

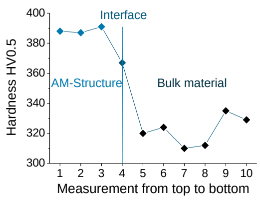
Metallographic examination

The broken samples showed additional secondary cracks that start at the interface. The microstructure of the AM-structure and of the heat affected zone at the interface was dendritic, while the bar exhibited small grains.

The AM-structures were harder than the bulk. This was related to a higher oxygen content in the AM-structure (EDX-measurements).



Etched cross-section with hardness indents (left) and detailed view with a secondary crack at the interface (right)



Micro-hardness of the AM-structure and the bulk

DISCUSSION & CONCLUSIONS

The reason for the failure was the higher hardness due to the dendritic grains and a higher oxygen content of the AM-structures compared to the bulk material. Thus, the upper part was more brittle than the bulk. This led to cracks in the AM-structure and at the interface, and finally to the early failure of the components due to the cyclic bending stress and notch sensitivity.

This example shows that application specific testing and analysis can be crucial for product failure prevention.