Topology optimization of components through LPBF manufacturing

Laser powder bed fusion (LPBF) can be used to produce complex and topology-optimized components cost- and resource efficiently. Each volume increment of the component is created in the manufacturing process as the metal powder is selectively melted and solidifies. The thermal history in LPBF can differ significantly, especially for large cross-sectional changes due to different thermal conduction conditions. Process parameters and mechanical properties are generally determined using simple test geometries and are, therefore, only conditionally applicable to complex components.

In cooperation with the DLR Institute for Materials Research, Fraunhofer ILT is investigating how component geometry influences the metal structure on behalf of the German Federation of Industrial Research Associations (IGF Project No.:22135 N) and the German Federal Ministry of Economics and Climate Protection. The institutes aim to simulate the above-mentioned effects in order to predict the actual mechanical properties of topology-optimized components. Furthermore, they are investigating how the downstream heat treatment could influence the microstructure

Investigations on the material Ti6Al4V

Since titanium has low thermal conductivity, the institutes are examining the effect of the thermal history on the material Ti6Al4V. For this purpose, they are analyzing topology-optimized LPBF components and classifying them with respect to angular and cross-sectional area changes in the build direction. From the results, test shapes have been derived (Fig. 2) and manufactured using LPBF for static and dynamic tests. Subsequently, the specimens are being tested "as-built" or after hot isostatic pressing. The data obtained are documented in a component geometry catalog.

Resource-efficient production

The results show that irradiated energy is dissipated so slowly – when the exposure area suddenly increases – that an influence on the metallic microstructure can be detected. At corresponding points in the component, a mixture of α- and β-phase forms instead of the α-structure usual for Ti6Al4V. The cooling rate also has an effect on the lamella shape and size. Figure 1 shows local overheating based on tarnish colors.

The component geometry catalog developed in the project is intended to simplify the practical applicability of topology optimization and LPBF manufacturing in the aerospace, medical technology and mobility sectors. Moreover, it can accelerate innovative product development and enable companies to manufacture while using fewer resources.

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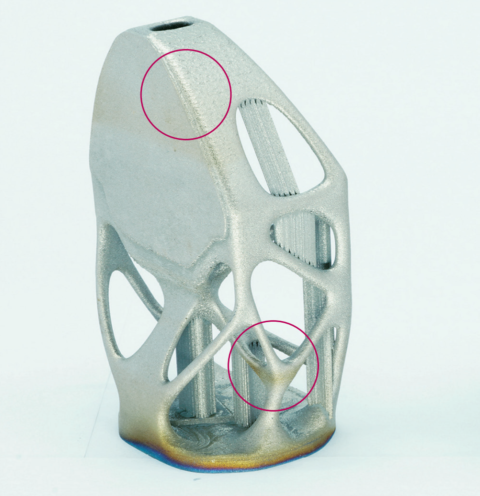

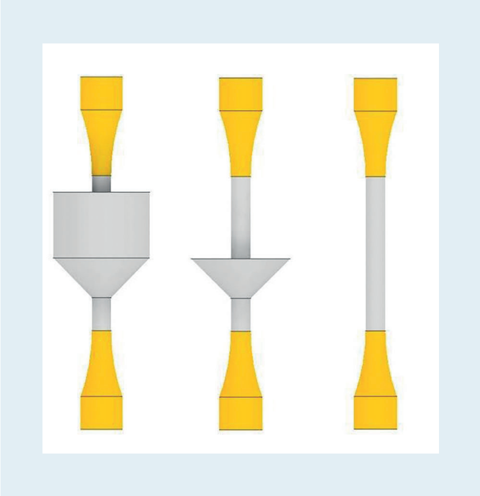

1 Demonstrator with local overheating (highlighted in red).
2 Test geometries for static tests.