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Abstract

Fatigue damage evolution of additively manufactured Ti6Al4V porous structures for medical implants

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The aim of the research group 5250 'Permanent and bioresorbable implants with customized functionality', funded by the German Research Foundation, is to develop and validate an integrated solution for the production, characterization and simulation-based design of additively manufactured implants in oral and maxillofacial surgery, taking into account the physiological conditions of the individual bone situation. Additive manufacturing using the PBF-LB/M process can be used to produce delicate TPMS (triply periodic minimal surface) lattice structures reducing the stiffness of the implant and minimizing stress shielding. The effect of stress shielding leads to bone loss and to a lower stiffness of the bone which is responsible for most of the issues after implant surgery [1]. Stress shielding can occur with different types of implants, the reduction in the stiffness of the implant can already be successfully demonstrated in previous studies by using additively manufactured and graded or porous structures [2–4]. In order to ensure a safe design of the patient-specific implant, the process-structure-property relationship hast to be understood. The specifications are based on DIN EN ISO 5832-3 for materials in medical applications with regard to microstructure and mechanical properties. Because of high cooling rates in the PBF-LB/M process, heat treatment (HT) is necessary to ensure compliance with these specifications, resulting in a uniform α-β mixed structure and released residual stresses. The effects of the manufacturing parameters can be analyzed using µ-computed tomography to ensure an optimized setting of the geometric fidelity and defect distribution within the structure. Material-specific characteristic values are generated as part of quasi-static and cyclic loadings using coupled measurement methods such as digital image correlation (DIC). Previous study showed, that local damage evolution can be detect using optical measurement systems [5]. This allows the local damage behavior to be observed and subsequently correlated with fractographic analyses using a scanning electron microscope (SEM), so that manufacturing-related influences and failure mechanisms can be integrated into the design of additively manufactured patient-specific implants.

AUTHOR'S STATEMENT

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