Robust Simulation of Complex Loaded Cellular Structures

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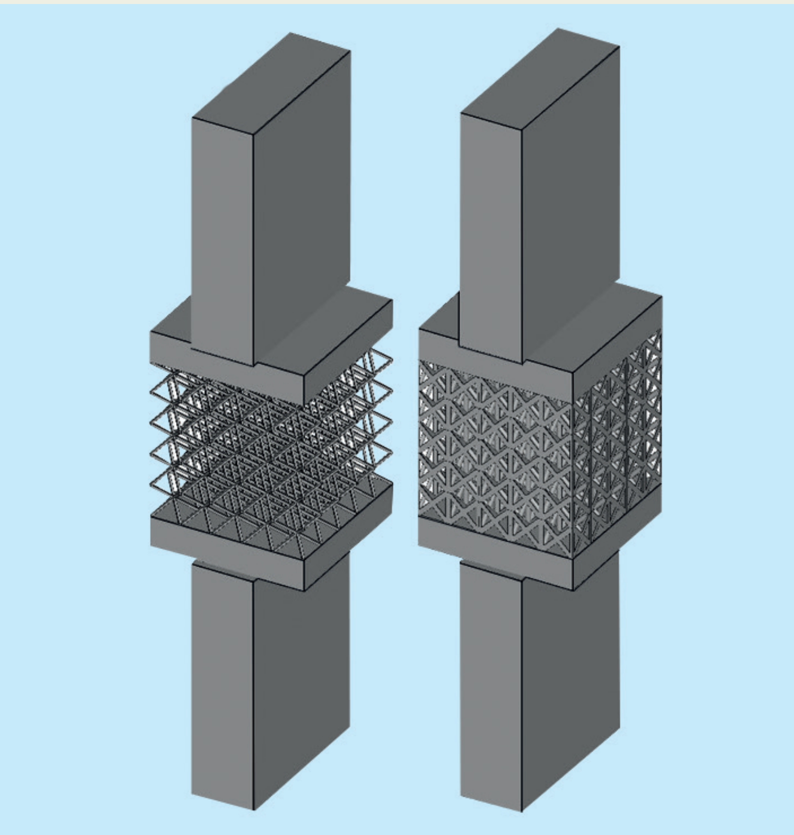
Currently, one of the main challenges in industry is the reduction of the energy consumption of moving parts as well as of the total amount of the material used. In order to meet the demand for optimized light-weight parts, the development of load adapted structures has begun to play a key role in today's research. One approach is the use of low density materials, such as the well-known aluminum foams. However, on small scale these foam structures are stochastic and therefore not load optimized. At this point additive manufacturing becomes highly beneficial as it enables for an unprecedented design freedom. By application of additively manufactured non-stochastic cellular structures, which can be locally adapted to the prevailing stresses, an optimized relative loading capacity becomes feasible.

Figure 1: Samples with a body-centered base cell (left) and face-centered base cell with additional struts in loading direction (right)



Objectives

The establishment of a finite element analysis (FEA) model for complex loaded cellular light-weight structures is the aim of the present project. Based on the findings of a preliminary linear-elastic simulation the examinations will be extended to linear-plastic deformation behavior including diverse material conditions by applying 316L stainless steel (ductile) and Ti-6Al-4V alloy (brittle). The main goal will be to achieve a solution for the simulation of different deformation effects depending on the cell geometry. This aspect is very important for reducing time-consuming experiments in order to establish the applications for energy absorbing light weight structures.

Furthermore, plastic cellular structures will be manufactured by Laser Sintering (LS) in order to verify the developed FEA model for a fundamentally different kind of material.

Preliminary Analysis

For characterizing the fundamental behavior of cellular structures the first project was drafted with a focus on the occurring deformation mechanisms of metallic samples under uniaxial and bending load. The deformation behavior was determined by using digital image correlation (DIC) and robust FEA. Figure 1 shows two samples with different base-cell designs. Based on theoretical analysis the body-centered base cell is bending dominated and the face-centered base cell is stretch domi-

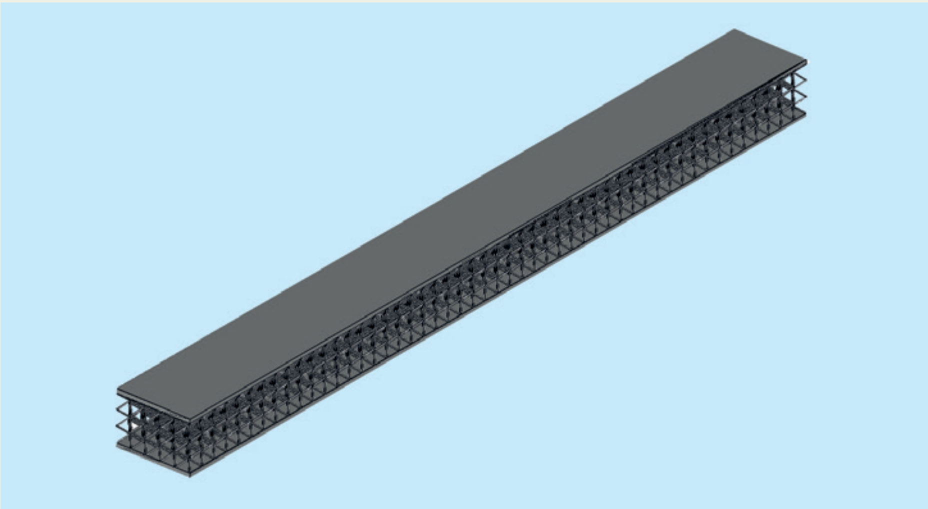


Figure 2: Design of a sample on basis of party load adapted sandwich structures

nated based on theoretical analysis. In this case the chemical composition of the materials is pivotal for the ductile or brittle behavior of the base cells. The results proved a good specific loading capacity but also a high influence of the cellular design on the resulting failure mechanisms. The results of simulation and mechanical tests for the face-centered base cell under uniaxial load showed good accordance between the observed and simulated local deformations. Considering to the deformation behavior of a body-centered base the results have been inconclusive. The linear-elastic model was incapable to emulate the mechanical properties. Therefore a linear-plastic deformation model is needed.

In the first work package of the current project the literature was screened for existing approaches for designing cellular structures. Different cell geometries were evaluated on basis of FEA with respect to several aspects, such as the spatial stiffness and the stress distribution of the base cells, as these certainly have a high impact on the resulting mechanical performance. In a next step the base cells will be examined by mechanical testing. The focus will be on the behavior under both uniaxial and bending load, whereby the latter will be contemplated for sandwich structures as shown in Figure 2.

Approach

The main activities to reach a robust FEA model include the following aspects. At first the base cells have to be analyzed by using FEA simulation. Thereby the elastic-plastic behavior must be implemented in the FE model. Because of different microstructural conditions of the material after post-treatments diverse FE models will be extended in order to cover this aspects. After that the verification of the FE model by mechanical testing including DIC will start. By doing this samples with diverse local microstructural conditions will be examined.