Modeling of cellular structures under static and fatigue loads

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ABSTRACT

The design of lightweight components for additive manufacturing processes of metals includes lattice structures with optimized topology and dimensions. Lattice structures have the potential to provide high strength/weight ratios, however they are characterized by severe issues about their practical application, especially regarding the evaluation of stress-strain distribution and the prediction of fatigue-related lifetime.

The complex shape of lattice structures requires the use of detailed 3D finite element (FE) models to correctly predict stress and strain fields, thus implying a high computational cost. To overcome this issue alternative modelling strategies are needed. The homogenization method based on strain energy equivalency is used to calculate the 3D stress and strain fields in the region of mechanical components made of lattice material. The described calculation is applicable to hybrid structures too, where bulk material regions are also present.

On the other hand, fatigue behaviour of engineered cellular structures is of outstanding interest due to local stress intensifications associated to notches with small connection radii. The number of notches in lattices is dramatically high, as well as the local points of potential cracks initiation. Fatigue of metals investigation methods are applied to the lattice structure, with special focus to the Crossland's criterion. After identifying the most loaded homogenized cell, under the hypothesis of constant strain energy, the loading state of the real-shape octahedral cell is calculated. The inverse homogenization process applied to the equivalent homogeneous medium allows identifying the most critical cell of the region of the component made of lattice material. Finally, the fatigue strength at 10^6 cycles is evaluated on the High diagram and the failure requirement related to the Crossland's criterion checked.

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