Microstructural computational modeling of the mechanical behaviour of closed-cell foams: from tessellation-based to CT scan-based modeling

Summary

The mechanical behavior of closed cell metallic foams strongly depends on their geometry at the scale of cells and cell walls. Two approaches are proposed in this work to address this computationally:

(i) a controlled geometrical description of foam morphology features by exploiting an advanced tessellation-based procedure, allowing to generate realistic microstructural geometry,

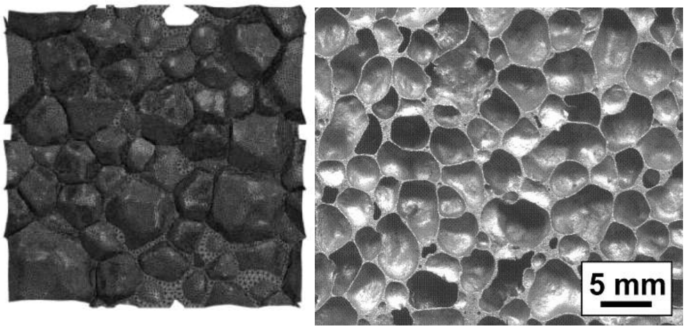
(ii) a procedure allowing to extract geometrical features of a foam morphology based on image-based modelling using CT scans.

The first approach proposes a methodology that allows the automated generation of RVEs with a detailed control of the microstructure, including of cell geometries. It is primarily based on an inclusions packing algorithm assisted by distance fields control. Such distance fields can subsequently be used to morph inclusions, producing generalized tessellations with the possibility of incorporating curved and irregular boundaries. 3D morphologies of closed cell foams are produced by extracting the geometry from a proper combination of distance field functions. The procedure allows controlling the cell size distribution, spatial cell wall thickness distribution (correlated or not with the cell size distribution), wall curvatures and/or defects. An automated 3D meshing tool for implicit geometries was exploited to produce high quality tetrahedral meshes from the generated implicit foam geometries.

Representative volume element based simulations were performed using this approach to assess the different morphological features relative importance on the mechanical behaviour of ALPORAS. An original extension of this tool was incorporating the transformation of 3D geometry into a shell-based finite element model. This resulted in a significant gain in computation time and allowed for simulating compression test up to densification (being out of reach with 3D solid finite element models) showing a good qualitative match with experimental results from the literature. The second approach proposes a robust methodology for the automated generation of shell-based finite element models directly from X-ray Computed Tomography (CT) scans. An in situ X-ray CT compression test of the sample was performed to serve as basis of comparison to the computations. As first steps, raw CT images are segmented using various image processing techniques and an implicit 3D geometry is reconstructed for each cell by using a Euclidean distance field computation technique. An automated geometrical procedure is used next to extract a (surface) shell geometry from this implicit 3D geometry, followed by subsequent meshing step. A direct comparison of the performed simulations with raw experimental data is performed. The detailed deformation and failure mechanisms of closed-cell foams under quasi static uniaxial compressive loading are investigated numerically and compared directly with the result of the in situ experimental measurement.

Keywords

Closed-cell metallic foam, computational homogenization, RVE generation, automated meshing, morphological indicators, shell geometry, closed-cell foam, computed tomography scan.



The computationaly generated RVE (Left) based on real closed cell foam (Right).

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