Mechanical Properties of Semi-Expanded Hollow Sphere Structures

T. Daxner[1], R.W. Tomas

Institute of Lightweight Design and Structural Biomechanics
Vienna University of Technology, A-1040 Vienna, Austria.

Because suitable technologies are available for the production of cellular structures, that are hybrids between densely packed hollow spheres and polyhedra with nearly flat cell walls, we investigate whether these hybrids can be expected to have better mechanical properties than either of the aforementioned topologies.

By coating polymer spheres with a metal powder slurry and subsequent sintering it is possible to produce a wide range of different cellular structures: Hollow metal sphere aggregates are the end product if no significant expansion of the polymer spheres takes place, and sintered polyhedra are the result if the coated polymer spheres are subjected to a high degree of confined expansion prior to sintering. With suitable process parameters, tailored intermediate configurations can be produced. The question arises, which degree of expansion is best with regard to achieving advantageous effective mechanical properties such as high effective stiffness or high effective strength.

This question can be addressed with idealized micro-mechanical models which allow for an investigation of the influence of the degree of expansion on the mechanical properties. Using idealized models offers the possibility of studying this influence without the result being also affected by imperfections, boundary conditions, and so on, which tend to make the determination of the mentioned influence difficult in experiments.

Specifically, finite element unit cell models are employed as idealized mechanical models for the real micro-structure. These models are generated from densely packed hollow sphere arrangements by a simulation of the actual expansion process of the polymer spheres and their coating. This way, realistic geometries and wall thickness distributions are obtained for the subsequent study of the sintered end products. The expansion simulations are highly nonlinear because the local strains can become considerable as the coated spheres expand into the vertices formed by planes of symmetry of the sphere arrangement. Correspondingly, the thickness reduction in these regions has to be accounted for in detail.

The mechanical properties are predicted in dependence on the initial thickness of the coating and the degree of confined expansion; the effective elastic constants are extracted. The macroscopic yield behavior is predicted for different load cases. Depending on the design requirements, the proposed methodology allows for the determination of an optimal degree of expansion for the considered route of production.

[1] Corresponding author: Email: daxner@ilsb.tuwien.ac.at. Address: Vienna University of Technology, Gusshausstr. 27-29 (E317), A-1040 Vienna, Austria.