Contribution ID: **111** Type: **Oral 20 Minutes**

Influence of RVE generation method on effective heat conduction modeling in open-cell ceramic foams: Review and recent advances

Wednesday, 16 May 2018 11:35 (15 minutes)

Ceramic foams play a crucial role in thermal engineering, as their porosity confers interesting properties which, combined with their high-temperature stability, allows them to meet both heat exchange and heat insulation demands. To facilitate optimization of the pore-scale morphology, numerous techniques have been developed to generate periodic representative volume elements (RVEs) of the foam mesostructure. As a fascinating variety of morphologies has been observed in ceramic foams, the choice of RVE generation method remains an open problem. In the present work, a review of available methods is performed to identify those most capable of reproducing the morphologies of real foams. Through a case study of conductive heat transfer modeling in an open-cell ceramic foam, the influence of RVE generation method is then analyzed.

In the context of heat transfer modeling, developments in RVE generation techniques are driven mainly by studies on radiative or convective transfer, where the effect of morphology is pronounced. Two main approaches to generate RVEs are distinguishable from the literature:

- The first treats the foam as a subtraction of elementary objects, usually spheres, from a solid phase. Early works assume regular packing (such as in face-centered cubic lattices), while recent developments introduce dispersity and contact laws to simulate bubble physics.
- The second approach partitions the volume into cells with minimum surface energy, then grows the solid phase from the cell faces (walls) and edges (struts). As with the first approach, regular partitions (such as the Kelvin cell) are increasingly being superseded by Voronoi-based structures that reflect the disorder in real foams.

In both approaches, physics-based techniques (bubble simulation or Voronoi-based tessellation) currently give the most realistic foam representations, often with predetermined cell size distributions as input. For open-cell structures, the key differences in the resulting geometries lie in the void phase connectivity and the range of pore and strut shapes possible. The Voronoi-based approach seems well suited to distinctively polyhedral pores. However, when the pores appear spherical (as is the case for many ceramic foams), both approaches have been successfully used to reproduce key morphological parameters of real foams. It is thus interesting to quantify the influence of the choice of RVE generation approach on the modeled effective thermal conductivity.

Indico rendering error

`Could not include image: [403] Error fetching image`

A case study is performed on an open-cell alumina foam with 80% porosity, with morphological parameters extracted from micro-tomographic images. Two periodic RVEs are then generated with state-of-the-art approaches, starting with random packing of non-overlapping, polydisperse spheres in a cubic volume. The first inflates the spheres before subtracting them from a solid matrix. The second uses the spheres as seeding points for a Voronoi-Laguerre diagram, to which polygonal struts of non-constant section are added. Both RVEs are geometrically validated with the morphological parameters of the real foam. Finite element modeling is used to obtain the effective thermal conductivity of the real foam mesostructure and the two RVEs. The RVEs may then be used to perform parametric studies on the foam morphology. The results highlight the influence of RVE generation technique, and provide modeling guidelines for future work.

References

H.X. Peng, Z. Fan, J.R.G. Evans, J.J.C. Busfield, Microstructure of ceramic foams, In Journal of the European Ceramic Society, Volume 20, Issue 7, 2000, Pages 807-813, ISSN 0955-2219, https://doi.org/10.1016/S0955-2219(99)00229-0 ; Salvatore Cunsolo, Rémi Coquard, Dominique Baillis, Wilson K.S. Chiu, Nicola Bianco, Radiative properties of irregular open cell solid foams, In International Journal of Thermal Sciences, Volume 117, 2017, Pages 77-89, ISSN 1290-0729, https://doi.org/10.1016/j.ijthermalsci.2017.03.007 ; Nolan J. Dyck, Anthony G. Straatman, A new approach to digital generation of spherical void phase porous media microstructures, In International Journal of Heat and Mass Transfer, Volume 81, 2015, Pages 470-477, ISSN 0017-9310, https://doi.org/10.1016/j.ijheatmasstransfer.2014.10.017.

Acceptance of Terms and Conditions

Click here to agree

Primary author: LOW, Zi Kang (Université de Lyon, INSA Lyon, LaMCoS CNRS UMR5259 ; Saint-Gobain C.R.E.E.)

Co-authors: CUNSOLO, Salvatore (Université de Lyon, INSA Lyon, LaMCoS CNRS UMR5259); BLAL, Nawfal (Université de Lyon, INSA Lyon, LaMCoS CNRS UMR5259); NAOUAR, Naim (Université de Lyon, INSA Lyon, LaMCoS CNRS UMR5259); SAN MIGUEL, Laurie (Saint-Gobain C.R.E.E.); BAILLIS, Dominique (Université de Lyon, INSA Lyon, LaMCoS CNRS UMR5259)

Presenter: LOW, Zi Kang (Université de Lyon, INSA Lyon, LaMCoS CNRS UMR5259 ; Saint-Gobain C.R.E.E.)

Session Classification: Parallel 7-B

Track Classification: MS 2.07: Prediction of the thermal conductivity of porous materials