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MODELLING OF CLOSED-CELL FOAMS INCORPORATING CELL SIZE AND CELL WALL THICKNESS VARIATIONS

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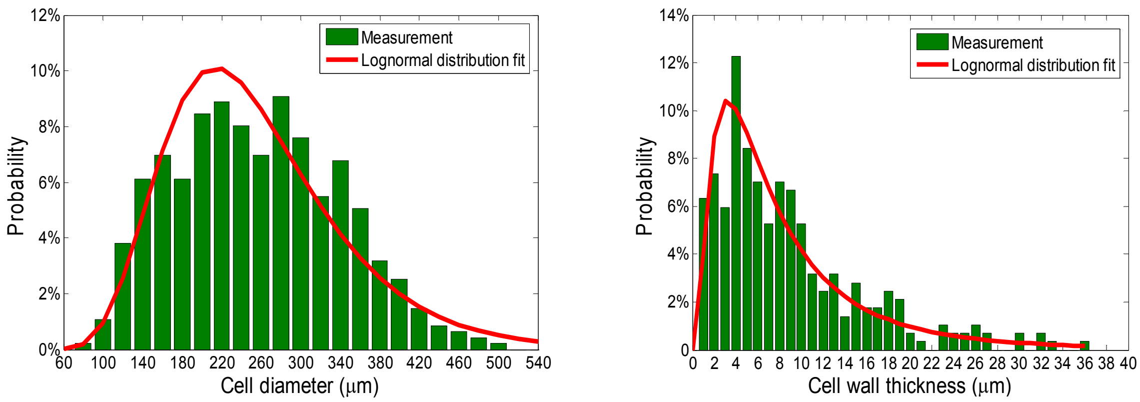
The study concerns with the micromechanical modelling of polymeric closed-cell foams (M130) incorporating realistic cell size and cell wall thickness variations. Firstly, the characterization of the foam was conducted. Uniaxial compressive tests and block shear tests were employed to evaluate the Young's modulus and shear modulus of the foam, which serve to validate the subsequent simulation results. Because the properties of cell walls of a polymeric foam may differ from those of the bulk material from which the foam is made [1], the Young's modulus of cell wall material of the foam was characterized using nanoindentation tests [2]. Cell size and cell wall thickness distributions of the foam were measured from the micrographs of microstructure of the foam, as shown in Figure 1.

Secondly, Laguerre models of the measured cell size distribution of the foam were generated. To create Laguerre tessellations with a prescribed cell size distribution, random close packing of spheres having the prescribed size distribution needs to be accomplished [3] (see Figure 1b). Taking the centres and diameters of the spheres as the seed points and weights of Laguerre tessellations, respectively, Laguerre tessellations that have cell size distribution close to the diameter distribution of the spheres can be generated (Figure 2b).

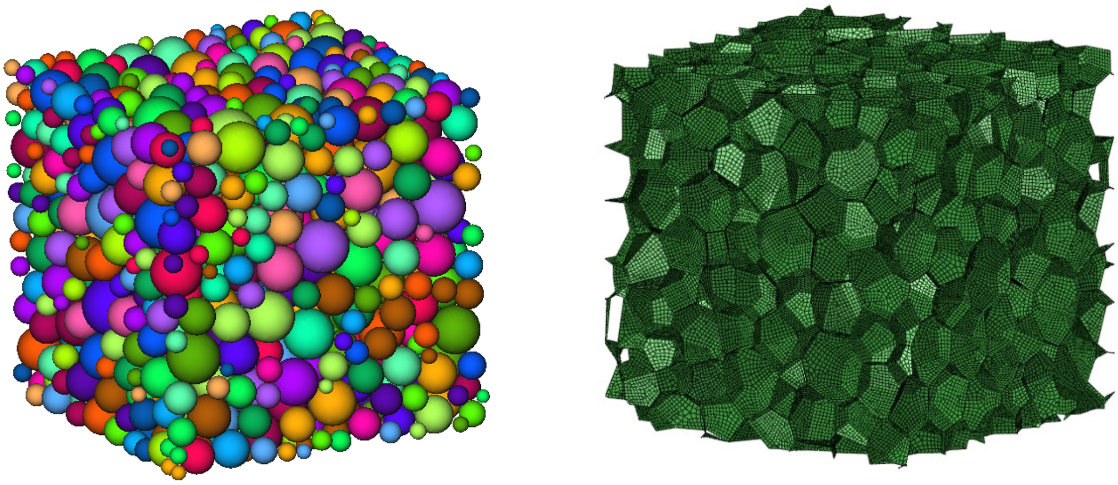
After assigning the measured cell wall thickness and the Young's modulus of cell wall material, the Laguerre models were subjected to compressive uniaxial and biaxial tests numerically to predict the Young's modulus and shear modulus of the foam. The predicted Young's modulus and shear modulus agree well with the experimental data. In contrast, it is found that the Kelvin model, Weaire-Phelan model and Laguerre model with uniform cell size and cell wall thickness over predict the stiffness of the foam. This emphasizes the importance of integrating realistic cell wall and cell size variation for micromechanical modelling of closed-cell foams.

Keeping the relative density of the models constant, the effects of cell size and cell wall thickness variations on the stiffness were investigated. Results show that the Young's modulus and shear modulus decrease with increasing variation of cell size and cell wall thickness. The effects of cell size and cell wall thickness variation on the fractional reduction in stiffness of closed-cell foams are independent on relative density. The effect of cell size variation on stiffness reduction is comparable to that of cell wall thickness variation. Lastly, the combined effect of cell size and cell wall thickness was studied. It is found that there is little interaction between the effect of cell size variation and the effect of cell wall thickness variation on the stiffness of foams, and thus the combined effect of them can be determined by simply multiplying the individual effects. Expressions for predicting the stiffness of closed-cell foams which accounts for cell size and cell wall thickness variations are formulated based on the simulation results.



(a) (b)

Figure 1: Measured cell size (a) and cell wall thickness (b) distributions and their lognormal distribution fits.



(a) (b)

Figure 2: Random close packing of spheres (a) and meshed Laguerre foam model (b)

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