Multi-scale statistical approach of the elastic and thermal behavior of a thermoplastic Polyamid-glass fiber composite

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Objectives

Determination of the RVE for elastic (shear and bulk moduli) and thermal (thermal conductivity) behavior, by a statistical approach and a numerical homogenization method in the aiming of predicting the macroscopic behavior of the composite.

Multi-scale heterogeneity
Image analysis

The influence of the area fraction and fibers spatial arrangement on physical properties

For each property, finite element calculations (Zebulum) are performed on 100 different images of the composite’s microstructure by assuming plane strain condition. The sizes vary from 50 x 50 pixels (122 x 122 µm²) to 600 x 600 pixels (1464 x 1464 µm²).

The thermal conductivity and the bulk modulus are related to the fibers area fraction. These properties are improved by increasing the area fraction. However, the shear modulus is strongly dependent on the fibers spatial arrangement than the area fraction. It is fundamental to know the minimum size of the RVE of these properties for this material.

Thermal conductivity’s RVE

Thermal conductivity is homogeneous if the gradient of temperature is perpendicular to the fibers axis, but lower than if the gradient is parallel to the fibers axis.

By a statistical method, the RVE is obtained according to the relative error (table 1).

Finally, the RVE of all these properties is higher of RVE: 854 x 854 µm². The effective properties of this RVE are 0.34 W.m.K⁻¹ (for the thermal conductivity), 2.01 GPa (for the shear moduli) and 5.95 GPa (for the bulk modulus).

Experimental results

In this study, experimental test is not performed for the thermal conductivity.

Conclusion

- The fibers local area fraction and fibers spatial arrangement have not the same influence on physical properties of the composite.
- A studied size should be higher than the smallest RVE to be well estimated by Hashin-Shtrikman bounds.
- Prediction of macroscopic behavior knowing local fluctuations of the microstructure.
- The slight difference between the experimental and numerical results is probably due to the are fraction diminution through the segmentation process.