Through thickness thermal conductivity prediction study on carbon reinforced composites

F. Petropoulos, C. Kostagiannakopoulou, G. Sotiriadis, P. Kelverkloglou and V. Kostopoulos*

Applied Mechanics Laboratory, Department of Mechanical Engineering and Aeronautics,
University of Patras University Campus, 26500, Patras, Greece
*Corresponding author: e-*mail address:* kostopoulos@upatras.gr

Abstract

Thermally conductive Polymeric Matrix Composites (PMCs) offer new possibilities for replacing metal parts in applications where good heat dissipation and light weight structures are needed. Since, polymers typically have intrinsic thermal conductivity much lower than those of metals or ceramic materials, there is a tendency to incorporate conductive nano-fillers (of ceramic, metallic and carbon nature) into the insulating polymer, to develop thermally conductive PMCs [1]. During the past decade, Carbon Nano Tubes (CNTs) and Graphene Nano Platelets (GNPs), offer a new generation of very promising nano-scaled conductive fillers, since they exhibit outstanding electrical and thermal properties, together with their high aspect ratio and specific surface area characteristics.

The objective of the present work is to investigate the influence of dimensional characteristics of few layered Graphene Nano-Platelets (GNPs) and Carbon Nano Tubes (CNTs) on the thermal conductivity of nano-reinforced epoxy polymers, using validated numerical models of continuum nature.

The results showed that the incorporation of both carbon fillers improved the thermal conductivity of the reference polymer. Furthermore, thermal conductivity of the epoxy system was significantly increased by increasing the filler content. The highest achieved increase of thermal conductivity (~176%) appeared in the case of 15 %wt. of GNP reinforced epoxy. This limit was kept, since for higher GNP %wt. content it is not possible to homogeneously mix the GNPs into the epoxy matrix. It is worth to say that the addition of GNPs enhanced more efficiently the thermal conductivity of polymer in comparison to the MWCNTs (that in any case have a much lower threshold %wt. of homogeneously mixing in the host epoxy material (close o 2 %wt.)).

The existed analytical models for the calculation of thermal conductivity of nano-modifies polymers exhibit significant dissensions when used for fillers at the nano-scale level, when compared agaist experimental results [2]. Thermal conductivity is a phonon-based mechanism effect that it is affected by many factors, such as the geometry of the nano-fillers, their orientation, the used %wt. fraction and the quality of dispersion into the host matrix material. All these parameters affect the phonons free mean path and the phonons scattering. Further to the above-mentioned parameters, phenomena such as clustering/agglomeration of nano-fillers and the quality of the formed interface, present detrimental influence in the thermal conductivity, and must carefully been considered.

This work focuses in the development of numerical models for the calculation of thermal conductivity of epoxy nano-composites based on the utilization of the Asymptotic Homogenization Theory (ATH). Using a Representative Volume Element (RVE), modeling and analysis of different level of complex structures was achieved and the calculation of their effective thermal conductivity properties was concluded. In the most of the cases the numerical results were successfully compared against existed experimental data.

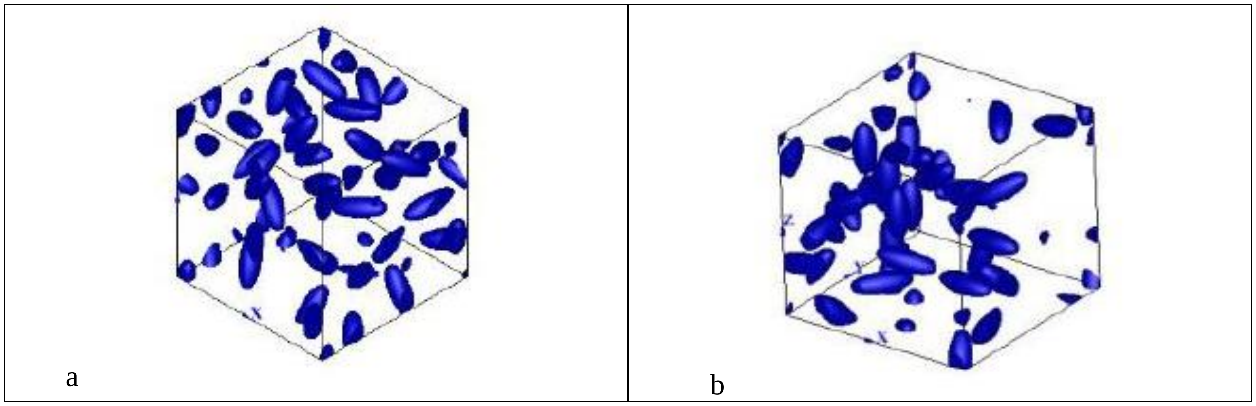

Figure 1: RVEs with GNPs used as fillers in the polymer randomly dispersed in Figure 1a and with clustering effect in Figure 1b.

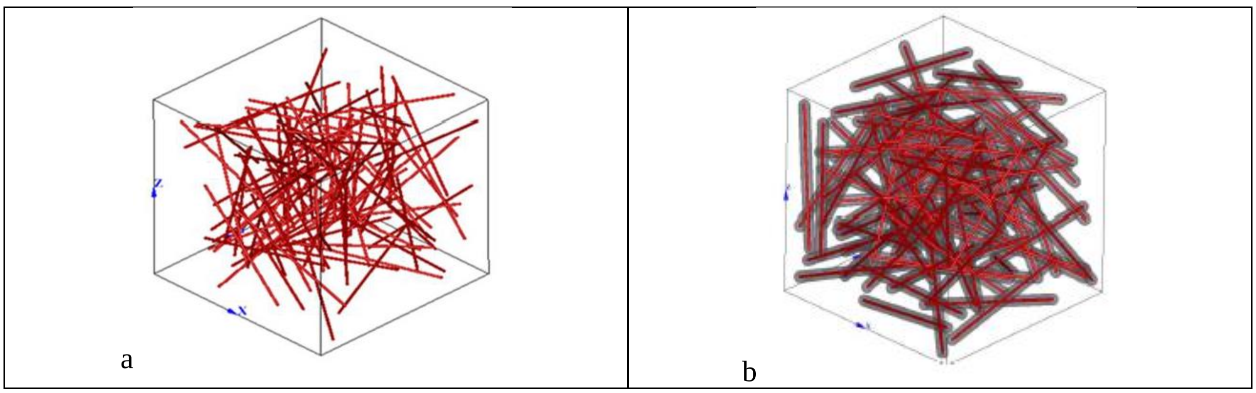

Figure 2: RVEs with CNTs used as fillers in the polymer randomly dispersed in Figure 2a and with clustering effect in Figure 2b.

Keywords

Thermal conductivity, nano-composites, graphene nano-platelets, carbon nanotubes nano-scaled conductive fillers, clustering effects, Asymptotic Homogenization Theory (AHT), Representative Volume Element (RVE), Multiscale

References

1. Burger N., Laachachi A., Ferriol M., Lutz M., Toniazzo V., Ruch D. Review of thermal conductivity in composites: Mechanisms, parameters and theory. Progress in Polymer Science 2016; 61:1-28.

2. Kostagiannakopoulou C., Fiamegkou E., Sotiriadis G., Kostopoulos V. Thermal Conductivity of Carbon Nano-reinforcced Epoxy Composites, Journal of Nanomaterials 2016; p12