Study of Thermal Behaviour of Thermoset Polymer Matrix Filled with Micro and Nanoparticles

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Abstract

Introduction: Most of composites researches have been conducted on weight loss on structural equipments. However, other applications lead to researches focused on on-board equipments which are in contact with electrical components and need to be thermally conductive. This work is a part of our on-going research in the frame of the THEOREM project. This project leaded by THALES Systèmes Aéroportés aims to develop a hybrid composite material made of a polymeric matrix filled with micro and nanoparticles and reinforced with long carbon fibers. This material should exhibit high thermal conductive properties. The first step of this collaborative project studies the improvement of thermal conductivity in a thermoset matrix system. Various kinds of candidate fillers are examined on the basis of the thermal conductivity in order to determine the mass fraction to be introduced in the matrix to get the desired thermal conductivity. Use of COMSOL Multiphysics: As already said, the ultimate aim of this research program is to get a model enabling to understand the thermo-mechanical and the thermal behaviors of carbon fibers composites with a macro or nanoparticles-filled matrix. The very first step of this work consisted in modeling the behavior of a representative volume element (RVE) of the filled epoxy matrix. The main challenge was to get a spatial distribution of doping particles in the RVE. For this goal, we noticed that COMSOL Multiphysics is based on Java language, therefore a program was developed enabling to use the Java random function to generate points considered as the center of particles. Particles were modeled as spheres and their volume was determined by the RVE and the fillers volume fraction. We determined a non-penetration parameter which allows only contacts between spheres. Heat equation was applied in the model in order to get the conductivity of these isotropic doped matrices (Figure 1). Results: The model was tested to see the impact on the thermal conductivity of different settings such as: the RVE size, the mesh size, the particles radius or the particles volume fraction. Numerical results were compared to the analytical model (Hamilton model) and experimental results (Figure 2). The divergence between experimental and theoretical results is attributed to errors on physical properties measurements. Cp values given by Nanoflash do not seem to be as precise as expected. This means that new measurements with DSC (Differential Scanning Calorimetry) are required. Conclusion: We noticed that increasing the particles volume fraction (vp) in the RVE results in an exponential increase in the number of elements and in the calculation time (i.e. vpMAXI (maximal volume fraction) ~ 20%). Nevertheless, from a physical point of view this is not a problem. The ultimate aim of this application is to use filled matrix to produce composites reinforced with long fibers. This means that this filled matrix's viscosity has to be maintained as low

as possible. To improve thermal behavior of matrix, more experiments are in progress with other types of fillers. In consequence we will develop another program for other particles shape, based on the present one.

Reference

1. R. L. Hamilton and O. K. Crosser. Thermal conductivity of heterogeneous two-component systems. Industrial & Engineering Chemistry Fundamentals, 1(3), pp.187-191 (1962).

Figures used in the abstract

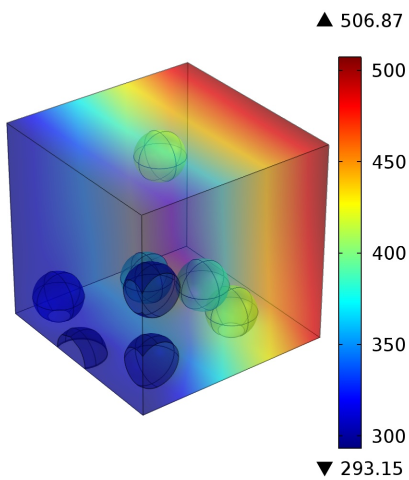

Figure 3: Temperature (K) distribution for vp = 5% and R = 3 microns.

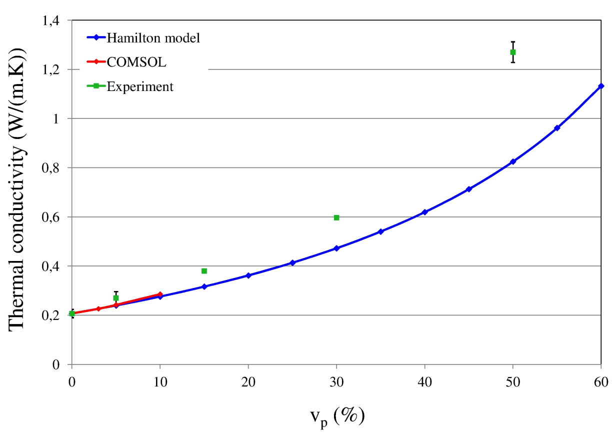

Figure 4: Comparison between analytical, experimental and numerical results.