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DISPERSION MONITORING ANALYSIS AND OPTIMISATION FOR EPOXY NANOREINFORCEMENT

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ABSTRACT

The scope of this work is to monitor and analyse the reinforcement effect of carbon nanotubes in typical epoxy systems. This is performed via the parametric analysis of the dispersion effects on mechanical properties and toughness. Ultrasonic dispersion of carbon nanotubes is related to the parallel processes of de-agglomeration and aspect ratio reduction which adversely affect the nanocomposite properties. This effect is studied with well-established models to predict composite properties and is monitored in real time using a novel methodology based on dielectric spectroscopy.

Keywords: carbon nanotubes, dispersion, toughness, dielectric spectroscopy.

INTRODUCTION

During the past decade, carbon nanotubes (CNTs), and nano-fibres have been in the forefront of material research as filler material to epoxies for the production of high performance composite structures with enhanced properties. It is however doubtful that this potential is achieved until now, as the incorporation of the nano-scale involves a series of technical challenges which often act in a antagonistic way. For example, CNTs have huge surface area and as a result are perfect for instigating all the mechanisms at the interface which form the basis of the remarkable properties of composites. This very surface area is by definition the reason of their tendency to agglomerate and as a result they end up being more like a defect (of a higher order of magnitude) rather than reinforcement at the nano-scale. It is also important to consider that the nano-reinforcement also intervenes in the epoxy network causing adverse behaviour during the curing process.

Concluding, efficient dispersion is the key issue to the attainment of properties such as would be expected by the properties of the nano-graphitic reinforcement. To this end this work presents a total approach which involves the parametric study of the dispersion process, the analysis and comparison with well-known models regarding mechanical and fracture properties and finally a novel monitoring methodology based on the evolution of the dynamic electrical properties of the epoxy/ CNT mixture during the dispersion process.

RESULTS AND CONCLUSIONS

Dispersio usually involves two stages i.e. (i) the deagglomeration of the nanotubes and (ii) the breakage of the CNTs with the corresponding reduction of the CNT aspect ratio. Obviously, the desirable result is the maximum deagglomeration together with the minimum reduction in the aspect ratio. As has been shown in a previous study, the simultaneous control of the amplitude of the ultrasonic pulse and the total energy input may result to the optimisation of the dispersion process as is manifested by the increased fracture toughness of the final nano-composite [1]. More than a twofold increase may be achieved via a simple optimisation process (Figure 1). The fracture properties of the composite are governed by a number of terms which relate to fibre debonding and pull out as well as the crack path within the composite as dictated by the fracture toughness of the interface (together with the size of the damage/ plasticity zone). The parametric solution of the governing equations leads to the estimation of the optimum aspect ratio for the CNT reinforcement.

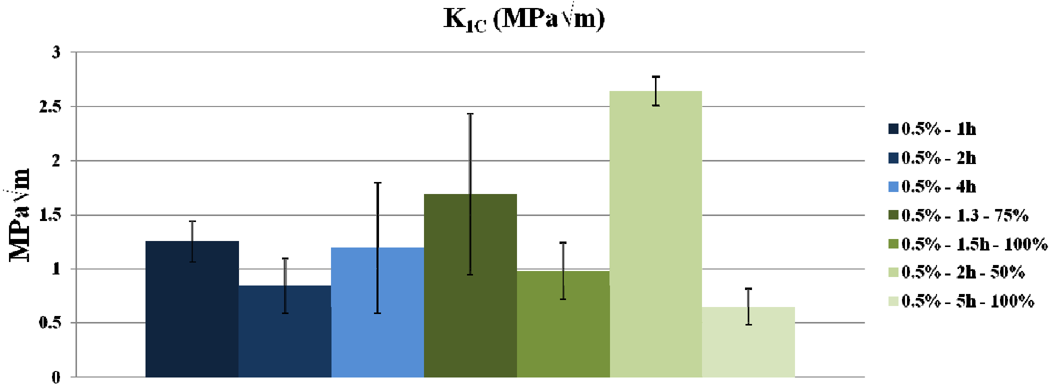

Fig. 1 - Dispersion protocol optimization for CNTs in epoxies

In parallel, the dispersion process leads to the formation of a conductive percolation network which is radically changing the impedance of the composite. Using a simple equivalent circuit model [2], the dispersion may be followed as the inductance of the composite reaches asymptotically a minimum value with sonication time (Figure 2).

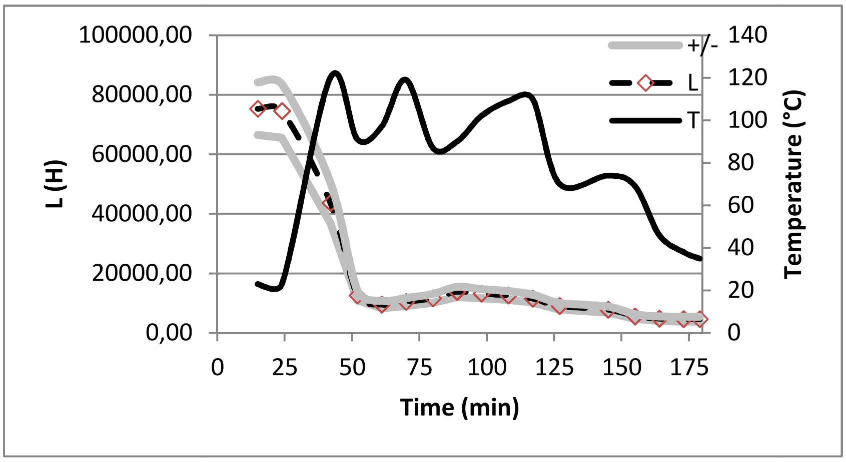

Fig. 2 - Inductance L for the CNT phase and temperature T vs. sonication time

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