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Low Frequency Ultrasonic Degassing to Reduce Void Formation in Epoxy Resin and Its Effect on the Thermo-Mechanical Properties of the Cured Polymer

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Abstract : The demand for multi-functional lightweight materials in sectors such as automotive, aerospace, electronics is growing, and for this reason fibre-reinforced, epoxy polymer composites are being widely utilized. The fibre reinforcing material is mainly responsible for the strength and stiffness of the composites whilst the main role of the epoxy polymer matrix is to enhance the load distribution applied on the fibres as well as to protect the fibres from the effect of harmful environmental conditions. The superior properties of the fibre-reinforced composites are achieved by the best properties of both of the constituents. Although factors such as the chemical nature of the epoxy and how it is cured will have a strong influence on the properties of the epoxy matrix, the method of mixing and degassing of the resin can also have a significant impact. The production of a fibre-reinforced epoxy polymer composite will usually begin with the mixing of the epoxy pre-polymer with a hardener and accelerator. Mechanical methods of mixing are often employed for this stage but such processes naturally introduce air into the mixture, which, if it becomes entrapped, will lead to voids in the subsequent cured polymer. Therefore, degassing is normally utilised after mixing and this is often achieved by placing the epoxy resin mixture in a vacuum chamber. Although this is reasonably effective, it is another process stage and if a method of mixing could be found that, at the same time, degassed the resin mixture this would lead to shorter production times, more effective degassing and less voids in the final polymer. In this study the effect of four different methods for mixing and degassing of the pre-polymer with hardener and accelerator were investigated. The first two methods were manual stirring and magnetic stirring which were both followed by vacuum degassing. The other two techniques were ultrasonic mixing/degassing using a 40 kHz ultrasonic bath and a 20 kHz ultrasonic probe. The cured cast resin samples were examined under scanning electron microscope (SEM), optical microscope, and Image J analysis software to study morphological changes, void content and void distribution. Three point bending test and differential scanning calorimetry (DSC) were also performed to determine the thermal and mechanical properties of the cured resin. It was found that the use of the 20 kHz ultrasonic probe for mixing/degassing gave the lowest percentage voids of all the mixing methods in the study. In addition, the percentage voids found when employing a 40 kHz ultrasonic bath to mix/degas the epoxy polymer mixture was only slightly higher than when magnetic stirrer mixing followed by vacuum degassing was utilized. The effect of ultrasonic mixing/degassing on the thermal and mechanical properties of the cured resin will also be reported. The results suggest that low frequency ultrasound is an effective means of mixing/degassing a pre-polymer mixture and could enable a significant reduction in production times.

Keywords : degassing, low frequency ultrasound, polymer composites, voids
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