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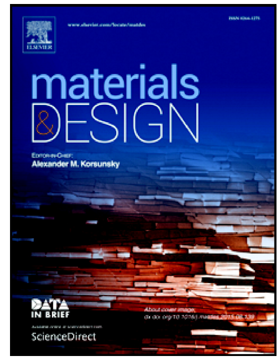

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Characterisation of epoxy powders for processing thick-section composite structures

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Abstract

Epoxy powders were investigated as a processing route for fast, low-cost manufacturing of thick-section fibre reinforced polymer parts. Thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), and parallel-plate rheometry were used to characterise the material for realistic processing conditions. The epoxy powders contained heat-activated curing agents and exhibited good thermal stability at and above typical processing temperatures (160-180°C). The exothermic heat produced during curing was found to be small when compared to some conventional epoxies. Similarly, it was shown that epoxy powders can be melted between 45 and 120°C to achieve low viscosities for fibre tow impregnation, without inducing significant cure. Semi-empirical cure kinetics and chemorheological models were presented, which can be used to predict the epoxy's behaviour during part consolidation and curing. Modifications were made to an existing cure kinetics model to better represent the behaviour of the epoxy at lower temperatures. The relationship between glass transition temperature and the degree-of-cure was described using the DiBenedetto equation and was implemented in an existing chemorheological model. The chemorheological model was applied to a standard process cycle to assess the accuracy of the model and the effectiveness of the process cycle.

Keywords

Polymer composites; Epoxy powder; Characterisation; Composite processing; Thick-section

1. Introduction

The composite materials industry continues to grow as demand increases for more lightweight, high strength products. In recent years, the composites manufacturing industry has looked towards out-of-autoclave (OOA) materials and processes as a more cost-effective way of producing high quality composite components. Examples include: high-pressure resin transfer moulding (HP-RTM), which has gained attention for its use by BMW in the iSeries production [1]; vacuum infusion processing (VIP), a commonly used technique in manufacturing wind turbine blades [2]; and vacuum-bag-only (VBO) prepregs, which have evolved from conventional autoclave prepregs and have been the topic of much research in the aerospace industry [3]. In the latter case, it has been shown that the latest generation of VBO prepregs can be used to manufacture autoclave-quality products without the need for expensive infrastructure and tooling. VBO prepregs typically consist of a fibre reinforcement that is *partially* impregnated with a thermoset resin matrix, whereas conventional autoclave prepregs are fully impregnated with resin. This leaves dry-fibre pathways in the VBO prepregs which allow air and vaporised moisture to be evacuated under vacuum conditions, thus reducing the likelihood of void formation [3]. Full consolidation of a part is achieved by applying sufficient heat to reduce the resin viscosity so that it can flow into the dry fibre tows (< 100 Pa.s [4]), as illustrated in Fig. 1. The plies of prepreg are consolidated by atmospheric pressure acting through the flexible vacuum bag. Heating the material can be achieved in numerous ways including large ovens and integrally heated tooling [5]. Commonly, carbon fibres are the reinforcement used in these VBO prepregs; however, the