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Cure modelling of polyester thermosets in a glass mould

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ABSTRACT

The curing of unsaturated polyester was studied experimentally and using a model of the process. The kinetic parameters were calculated from the heat flow–time curves obtained by differential scanning calorimetry (Mettler Toledo DSC 823), operating in a non-isothermal mode. The temperature–time histories were studied in a cylindrical glass mould. A potential use of glass as a mould for polymer curing is found in the production of optical sensors. Here, glass was selected as a mould material because it is UV transparent, chemically inert and easy to clean. The thermal properties of glass moulds coupled with the intrinsic curing kinetics are of a significant interest in such investigations. Taking into account the heat transferred by the convection from the air to the mould surface and the conduction through the mould wall and resin, as well as the kinetics of the heat generated in the cure reaction, a numerical model has been constructed. The contributions to the rise in temperature from the heat conduction and chemical reaction are different in different parts of the composite, which can explain the temperature–time histories. The introduction of a carbonate based filler reduced the amount of heat released in the composite and, as a result, lowered the temperatures through the resin. A good agreement between experimental data and the predicted mathematical model of the curing process in the mould has been observed.

Keywords: Thermoset; Curing; Kinetic model; Inert filler; Glass mould; Heat transfer; Boundary conditions

1. Introduction

Thermosets are generally supplied as relatively low molecular weight, unsaturated linear polyesters dissolved in a monomer such as styrene, providing crosslinking units by reacting with the unsaturated resin in a radical addition reaction (Lawrence, 1962; Parkyn et al., 1967). Inert and reinforcing fillers thickening agents, low profile additives are added to the compound in order to modify the performance of the product. Also, initiators, inhibitors, and other additives are added to control the reaction kinetics.

Polyester resins are the most commonly used matrix in the marine and composite industry. Nowadays, polyester resin based composites are applicable in many other areas, such as medicine (bone cement – filling the gap between the bone and a metal prosthesis) and architecture (artificial marble) (Nzihou et al., 1999).

The cure performance of the unsaturated polyester resins is characterized by a complex mechanism involving a copolymerization of the polyester and styrene molecules induced by the decomposition of an initiator. The interaction of chemical kinetics with certain physical processes that take place during the curing, such as the phenomena of the gelation and vitrification (the change from chemical kinetic control to diffusion control) and the possibility of forming different morphological or chemical structures increase the difficulty of the study of the curing (Lee, 1981).

The energy balance forms the main structure of the master model of the curing in a mould, and takes into account several factors: the accumulation of heat in the composite, the heat generated by the chemical reaction, the heat conduction in the material and the heat dissipation at the composite skin. The energy balance equation is coupled with a suitable expression for kinetic behaviour of the chemical reaction which can account for the diffusion control effect. The solution of the complete mathematical system gives both the temperature and the degree of curing as a function of time and position, from experimental results obtained by the thermocalorimetric experiments in moulds (Vergnaud and Bouzon, 1992; Kosar and Gomzi, 2004).

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