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Analysis of the sedimentation process in reactive polymeric suspensions

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Abstract

Sedimentation of particles can undermine the uniformity of the product in the manufacture of the particle-filled composites. An adequate mathematical description of the sedimentation process could be helpful for providing necessary information concerning the dominant parameters and can give an insight for the process designer to prevent such an undesirable phenomenon in composite production. The present article deals with the mathematical modeling of settling particles during curing of polymer matrix composites. The sedimentation process is described by the mass conservation law for particles. Since the viscosity of the suspending polymer increases as a result of curing process, a new model is presented for settling velocity of particles, combining the Stokes' law and an appropriate rheokinetics model for reactive polymers. In addition, to take into consideration the hindered settling phenomena in concentrated suspension, the fluid viscosity in Stokes' law is replaced by an adequate suspension viscosity model. The model developed in this study allows one to predict the particle concentration distribution along the height during the sedimentation of particles in reactive media and to investigate the role of molding temperature, catalyst content, initial particle concentration, and characteristics of particles. Such information provides a means for optimization of the composition of the suspension and molding process conditions to obtain a uniform product. The parameters of the rheokinetics model are determined by viscosity measurements at various levels of temperature and catalyst. Two sets of sedimentation experiments including nonreactive and reactive experiments are carried out based on hydroxyl terminated polybutadiene/aluminum (HTPB/Al) suspensions. In both cases, the simulated results agree well with experimental measurements, justifying the soundness of the model in predicting the sedimentation process for reactive suspensions. Numerical simulations are also performed to investigate the role of various molding conditions and materials characteristics on the sedimentation process in the actual reactive suspension system.

Keywords: Sedimentation; Composites; Curing; Mathematical modeling; Simulation; Rheokinetics

1. Introduction

Once a homogenous suspension of solid particles is placed inside a container, the particles settle out as a consequence of gravitational force. This phenomenon, sedimentation, is observed in various engineering fields such as chemical engineering, materials and pharmaceuticals processing, wastewater treatment and oceanography. Owing to the importance of the sedimentation process in such practical applications, it has been extensively studied by researchers for decades (Wallis, 1969; Khan and Richardson, 1989; Sharma et al., 1993; Concha and Burger, 2002; Xue et al., 2003; Berres et al., 2005) and significant steps have been taken to characterize the fundamentals of the process.

Sedimentation is also a basic physical phenomenon taking place during the manufacturing of particle reinforced composite material (Drenchev and Sobczak, 2000; Drenchev et al., 2002). Sedimentation of dispersed particles disturbs the uniform distribution of reinforcing particles in the final products. It appears that prediction of solid concentration distribution as a result of sedimentation can be of practical importance to achieve desirable processing conditions for controlling the settling of the solid particles in producing composite materials. A mathematical model can be an efficient predictive tool, because it is a cost effective manner for investigating the solid concentration and does not have the limitations encountered in experimental

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