RHEOLOGY OF ACRYLONITRILE BUTADIENE STYRENE WITH HOLLOW GLASS MICROSPHERES FOR EXTRUSION PROCESS

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Abstract

The influence of hollow glass microspheres (HGM) on the rheological properties of a commercially available Acrylonitrile-butadiene-styrene (ABS) polymer was investigated. ABS/HGM composites were prepared with various HGM contents. The rheology of the ABS/HGM composites was characterized to provide insight into the influence of the temperature and sphere concentration on the flow behavior under shear. Linear viscoelastic measurements show that both complex viscosity and storage moduli exhibit about 4 orders of magnitude increase with increasing HGM concentration from 40 vol% to 50 vol%. The viscosity increase is more pronounced at low frequency shear rates.

Introduction

Polymer based low density materials possess great potential in various applications. Demands for tailoring their functionalities have grown rapidly in recent years. Very few fillers or additives have lower density than a typical polymer resin [1,2]. Hollow glass microspheres are found to be one of the most attractive functional fillers for composites because of their unique properties [3]. One of the interesting and potential applications of such microspheres is the forming of light weight syntactic foams [4]. However, the introduction of solid fillers increases the viscosity of a composite and the processability is often decreased [5-7]. The present work examines the rheological behavior of ABS containing hollow particles for extrusion through 25.4 mm diameter 24 L/D single-screw extruder. The working pressure inside the extruder barrel was estimated to not exceed 34 MPa (5000 psi). The HGM was selected based on the criteria that it is capable of withstanding the maximum hydrostatic pressure inside the barrel.

Experimental

Materials

The material used in this study was prepared by mechanical blending ABS (melt flow rate 7.5g/10 min at 230°C/3.8-kg load) with HGM (0.46 g/cm³, average diameter 20 µm). The HGM contents studied were 0 (neat ABS), 10, 20, 30, 40, 50 percent by volume.

Characterization

Rheological characterization was carried out on a Discovery Hybrid rheometer (TA Instruments). Rheological measurements were performed using 25 mm parallel plates. Isothermal frequency sweeps were performed between 1 rad/s and 100 rad/s with strain amplitude of 0.5% maintained within the linear viscoelastic region (LVR). Isothermal frequency sweeps were collected over a temperature range from 210 C to 270 C for ABS containing 50 vol% HGMs. A soak time of 120 seconds were introduced to ensure the thermal equilibrium is reached prior to proceeding with the test at a different temperature.

Results and Discussion

Effects of HGM concentration

Dynamic frequency sweep tests in LVR were used to explore network formation and microstructures of the ABS containing HGMs. Figure 1 shows the angular frequency dependence of the linear viscoelastic modulus G’ (a) and G” (b) for the filled ABS with various HGM concentrations. The dynamic modulus of the HGM filled ABS increases with increasing HGM concentration. For the ABS/HGM with HGM concentration ≥ 40 vol%, their storage modulus decrease more slowly than the modulus of the less HGM concentrated systems as the angular frequency is reduced below 10 rad/s. This behavior reflects the elastic character of the agglomerated network under small strain [8]. The systems possess high HGM concentration undergo a slow relaxation process. The complex shear viscosity of ABS and ABS containing HGM show strong shear thinning behavior. The magnitude of η” increases with increasing HGM content.
Effects of temperature

Figure 3 shows (a) the storage modulus and (b) the loss modulus as a function of angular frequency for ABS with 50 vol% HGM concentration at various temperatures. As is evident from these figures, the dynamic modulus decreases as the temperature increases. The impact of the elevated temperature on the dynamic modulus weakens as the temperature increases. The curves of the dynamic modulus tend to level off and merge at the low frequency range. The observation suggests the formation of a continuous agglomerated network of the HGMs in the ABS matrix, which results in special relaxation mechanisms manifesting longer relaxation times [9]. However, the aforementioned effect diminishes at the high frequency range, at which the relaxation behavior is dominated the ABS matrix.

Like before, the complex viscosity of the 50 vol% HGM concentrations was calculated from the storage modulus and the loss modulus using the standard methods. The complex viscosity at the selected temperatures are shown in Figure 4 as a function of angular frequency. As expected,
the complex viscosity decreased with increasing temperature.

![Figure 4](image_url)

**Figure 4.** Frequency dependence of the complex viscosity of ABS containing 50 vol% HGMs at various temperatures.

**Conclusions**

This work has investigated the evolution of rheological and viscoelastic responses of ABS containing HGMs. The rheological behavior of the ABS/HGM composite showed strong rate-dependent behavior. The dynamic modulus and complex viscosity increased significantly with increasing the HGM content. The study established the fundamentals for viscoelastic and related properties of HGMs filled ABS and provided useful information that can improve the processing of commercial polymeric materials.

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**References**