The Shear Creep Stress and Loss Factor of Polystyrene/ Waste Tires Composites

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Abstract— *Polystyrene/waste tires composites were prepared in this study by incorporating shredded waste tires into polydisperse polystyrene in a melt-mixing method. The dynamic mechanical properties of PS and PS/composite have been evaluated and compared. These properties were studied using ARES-Rheometer under nitrogen atmosphere in parallel plate geometry with diameter 8 mm. The measurements are carried out over a wide range of temperatures ranged from 120°C to 220°C and frequencies from 100 to 0.1 radians per second. The shear creep stress J(t) and loss factor were studied and compared with those of unfilled PS. The dynamic mechanical properties and stability at elevated temperatures were found to increase with the addition of waste tires to PS as confirmed by the results.*
From the results, the value of J(t) modulus for PS/waste tire is higher than this for the original material of PS. The incorporation of the rubber to the PS changes the value of J(t) at 0.001 second from 5.6×10-6 to 3.7×10-6 Pa-1 for PS and PS/waste tire, respectively and this difference increases with time. This confirmed that PS/waste tire composite exhibits higher stability at 180°C for a long time than the original unfilled PS. At frequency ω = 6.7×102 radians/s , the value of tanδ increases about 20% by the incorporation of the rubber filler, due to the increase in the G" modulus particularly at low frequencies in the flow regime.

Keywords: Polystyrene/waste tires composites, Shear creep stress, Loss factor.

1. INTRODUCTION

Disposal of waste rubber material is a global problem, and used tires constitute the largest volume of scrap rubber. Recycling of waste tires is essential due to economic and environmental reasons. Utilization of ground waste rubber has been reviewed recently. Finely ground waste tire rubber has been used as filler in rubbers and in thermoplastics [1]. Physical properties and processability are reported to be adversely affected when large volumes of waste rubber is added to a rubber compound.

Dynamic mechanical analysis over a wide range of temperature and frequencies permits the determination of the viscoelastic behavior of molten polymers and, in particular, the study the glass transition of reinforced composites. Therefore, the investigations of the polymer composites using the mechanical and the dynamic mechanical analysis are becoming of great interesting [2-17].
The main objective of this work was to study in details the shear creep stress and loss factor of polystyrene/waste tire composites compared to the original material of unfilled polystyrene.

2. EXPERIMENTAL PART

2.1 Samples preparation and characterization
PS/waste tires composite was prepared by introducing waste tires into commercial PS with molecular weight about 2×107 g/mol. The waste tires were shredded into small particles sizes of about 2 mm. The mixture of PS and 12 wt % shredded tires are dry mixed by hand-mixing for around half an hour and heated at 300°C for 2 hours. Followed by preparation the samples of filled and unfilled PS for the rheological measurements under compression-mold at 190°C for 3 hours and 15 bars in a disc form with diameter 8 mm and thickness 2.2 mm.

2.2 Measurements
The dynamic mechanical measurements were performed for PS and PS composite by using an ARES-Rheometer (Rheometric Scientific). The rheometer was operated in the dynamic mode on the plate-plate geometry of 8mm diameter and about 2 mm gap. The gap size changes with the temperatures and is read electronically and allows absolute moduli to be determined. The measurements were performed in this study for the samples under nitrogen atmosphere, strain amplitude 1%, over temperature ranged from 120 to 220°C and angular frequency (ω) varied from 10^2 to10^{-1} radian/s.

3. RESULTS AND DISCUSSION

In this study the experiments data which measured over a wide range of the temperature are shifted into a single log -log curve at a reference temperature T_0 by using of the time-temperature superposition principle which described by Williams-Landel-Ferry [19] as, log a_T = -C_1 (T-T_0) /(C_2+(T-T_0)).Where a_T is the horizontal shift factor and constants C_1 and C_2 are material specific. a_T shifts the data obtained at different temperatures along the log frequency, ω axis and in vertical direction is given purely by b_T ($b_T = \rho T / \rho_0 T_0$ [20]). Where ρ is the material density.

The shear creep stress J(t) is plotted as a function of time in Figure 1. As shown in this Figure J(t) increases with time by a slop about 0.4 up to 0.01 second followed by a deviation in the slop to be about 0.6 in the case of filled PS and about 0.9 in the case of unfilled PS. This due to the relaxation of the polymer molecules with time at 180°C. This difference in the slop between filled and unfilled PS at long time means PS composite is more stable at high temperature for a long time than unfilled PS. At long time zone, the value of J(t) modulus for PS/waste tire is higher than this for the original material of PS as shown in Figure 1. In this Figure, the incorporation of the rubber to the PS changes the value of J(t) at 0.001 second from 5.6×10^{-6} to 3.7×10^{-6} Pa^{-1} for PS and PS/waste tire, respectively and this difference increases with time as shown in Figure 1. This confirmed that PS/waste tire composite exhibits higher stability at 180°C for a long time than the original unfilled PS.

The relative degree of viscous to elastic dissipation of the material is indicated by tan δ (Fig.2). Tanδ is plotted in Figure 2 versus frequency for PS and PS/rubber. tan δ is related to the loss modulus by , tan δ = G''/G' , therefore, tan δ is called the loss factor. Figure 8 shows decreases of tanδ at the intermediate frequencies-branch and reach the minimum value at about $\omega = 8.6 \times 10^2$ radians/s, then increases again. This minimum in tan δ is against to the entanglements zone in G'' and G' and it is associated to the high elasticity of the material at this regime which leads to a minimum in the loss energy per a cycle of the deformations. Again Figure 8 shows an increase in tanδ for filled PS compared to unfilled PS at low frequency. At $\omega = 6.7 \times 10^2$ radians/s , the value of tanδ increases about 20% by the incorporation of the rubber filler, due to the increase in the G'' modulus particularly at low frequencies in the flow regime.

4. CONCLUSION

In this study the PS/waste tires composite were prepared. The dynamic mechanical properties for PS composite are evaluated and compared to those of the original material of unfilled PS. These properties are determined by ARES Rheometer under nitrogen atmosphere in parallel plate geometry with diameter 8 mm. The measurements are carried out over a wide range of temperatures, ranged from 120°C to 220°C and frequencies from 100 to 0.1 radians per second.

From the results, the value of J(t) modulus for PS/waste tire is higher than this for the original material of PS. The incorporation of the rubber to the PS changes the value of J(t) at 0.001 second from 5.6×10^{-6} to 3.7×10^{-6} Pa^{-1} for PS and PS/waste tire, respectively and this difference increases with time. This confirmed that PS/waste tire composite exhibits higher stability at 180°C for a long time than the original unfilled PS. At frequency $\omega = 6.7 \times 10^2$ radians/s , the value of tanδ increases about 20% by the incorporation of the rubber filler, due to the increase in the G'' modulus particularly at low frequencies in the flow regime.

5. ACKNOWLEDGMENTS

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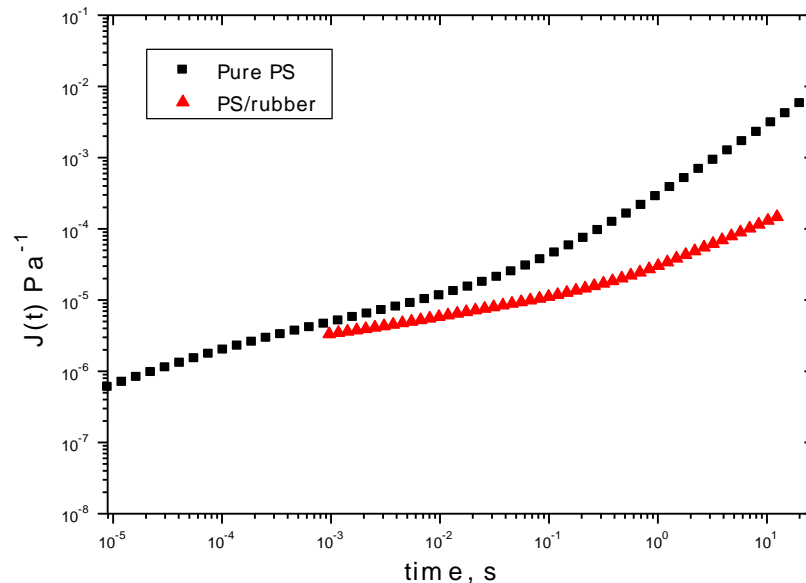
Figure 1: Master curve of J(t) versus time for PS and PS composite at $T_0 = 180°C$.

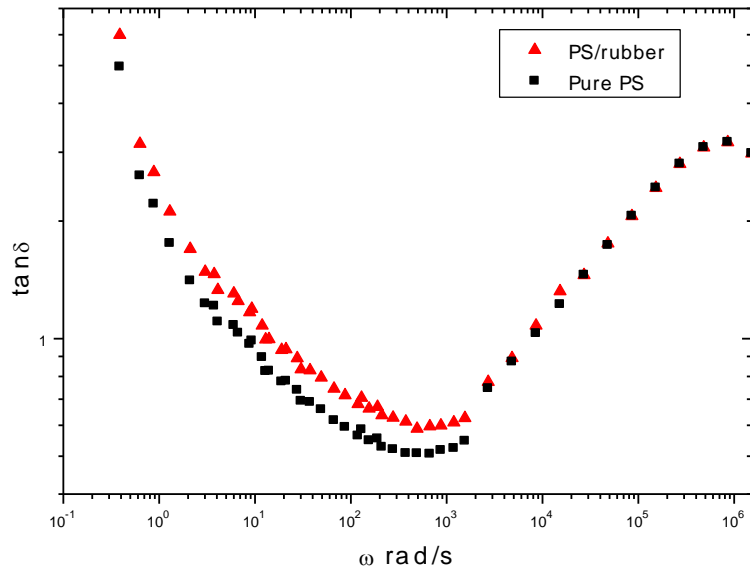*Figure 2: Master curve of tan δ as a function of ω for PS and PS composite at $T_0 = 180°C$.*