

# Dynamic and Complex Viscosity of Polystyrene/ Waste Tires Composites

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**Abstract:** In this work, polystyrene/waste tires composites were prepared using the melt-mixing method. The viscoelastic 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 dynamic and complex viscosity of the PS composites were studied and compared with those of unfilled PS.

The results showed that the frequency,  $\omega$  is shifted from 0.46 to 0.072 radians/s and the value of dynamic viscosity increases from  $5.0 \times 10^4$  to  $1.3 \times 10^5$  Pa.s by the addition of the rubber for PS. Zero-shear viscosity,  $\eta_0$  was found to be increased from  $9.5 \times 10^4$  for PS/waste tire composite to  $4.5 \times 10^4$  for PS.

The flow activation energy is calculated from  $\eta_0$  by using the rheometric software to be  $1.063 \times 10^5$  and  $1.46 \times 10^5$  J/mol.K for PS and PS composite, respectively.

**Keywords:** Polystyrene/ waste tires composites, Dynamic and Complex Viscosity.

## 1. INTRODUCTION

The growth rate of the use of particulate filled polymers is very fast in all fields of application Household articles and automotive parts are equally prepared from them. In the early stages, the sole reason for the introduction of fillers was to decrease the price of the polymer. However, as a result of filling all properties of the polymer change, a new polymer is in fact created. Some characteristics improve, while others deteriorate, and properties must be optimised to utilize all potentials of particulate filling. Optimization must include all aspects of the composites from component properties, through structure and especially interactions [1].

Composite materials are created by combining two or more components to achieve desired properties, which could not be obtained with the separate components. The use of reinforcing fillers, which can reduce material costs and improve certain properties, is increasing in thermoplastic polymer composites. The advantages of polymer composites on performance, economy, or ecology have accelerated the research activities in the field of polymer composites in terms of academic and industrial interests [2-18].

The motivation for this work was to evaluate in details the dynamic and complex viscosity for rubber filled polystyrene compared to the original material of unfilled polystyrene.

## 2. EXPERIMENTAL PART

### Samples preparation and characterization

PS/waste tires composite was prepared by introducing waste tires into commercial PS with molecular weight about  $2 \times 10^7$  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.

## 3. 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 ( $\omega$ ) varied from  $10^2$  to  $10^{-1}$  radian/s.

#### 4. 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,  $\omega$  axis and in vertical direction is given purely by  $b_T$  ( $b_T = \rho T / \rho_0 T_0$  [20]). Where  $\rho$  is the material density.

The complex viscosity  $\eta^*$  is plotted as a function of frequency,  $\omega$  in Figure 1 for PS and PS/waste tire.  $\eta^*$  falls rapidly with increasing  $\omega$  as shown in Figure 1. At very low shear rates  $\eta^*$  is called the melt viscosity,  $\eta_0$  ( zero-shear viscosity), at which the viscosity is independent on the frequency. The flow activation energy is calculated from  $\eta_0$  by using the rheometric software to be  $1.063 \times 10^5$  and  $1.46 \times 10^5$  J/mol.K for Ps and PS composite, respectively. The addition of the rubber alters the beginning of the plateau in the viscosity as shown in Figure 1 . Since it is shifted from 0.46 to 0.072 radians/s as shown in Figure 1 and the value of  $\eta_0$  increases from  $5.0 \times 10^4$  to  $1.3 \times 10^5$  Pa.s by the addition of the rubber for PS. This because the increase in the compaction due to the introduction of the rubber.

These values of  $\eta_0$  are again tested and evaluated from the modeling of the experiments data (Fig.2) of the viscosity by using Winter theory. This theoretical model is a spectrum was empirically expressed by Winter et al. [39] and it depends on the transition zone ,entanglement and flow regime as explained earlier in details in the theoretical part. It is clear from Figure 2 the plateau of the viscosity at low frequencies and the difference between  $\eta_0$  for PS/waste tire and the original material of PS is more significant. Where  $\eta_0$  for PS/waste tire is  $9.5 \times 10^4$  compared to  $4.5 \times 10^4$  of PS as shown in Figure 2.

#### 5. CONCLUSION

Polystyrene/waste tires composites were prepared in this study by incorporating small particles of waste tires into polydisperse commercial polystyrene (PS) in a melt-mixing method. The dynamic and complex viscosity of PS composites were 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.

The results showed that the frequency,  $\omega$  is shifted from 0.46 to 0.072 radians/s and the value of dynamic viscosity increases from  $5.0 \times 10^4$  to  $1.3 \times 10^5$  Pa.s by the addition of the rubber for PS.

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#### 6. ACKNOWLEDGMENTS

The financial support by the International Bureau in Germany, helpful discussions of Dr. W.Pyckhout –Hintzen at research center Juelich, Germany are greatly acknowledged.

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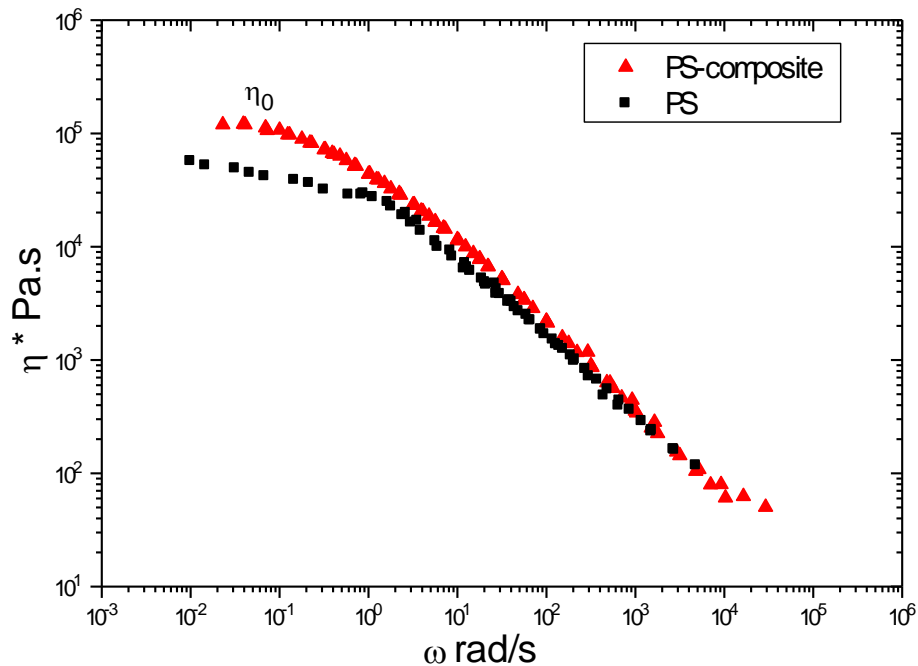


Figure 1: Master curve of  $\eta^*$  as a function of  $\omega$  for PS and PS composite at  $T_0 = 180^\circ\text{C}$ .

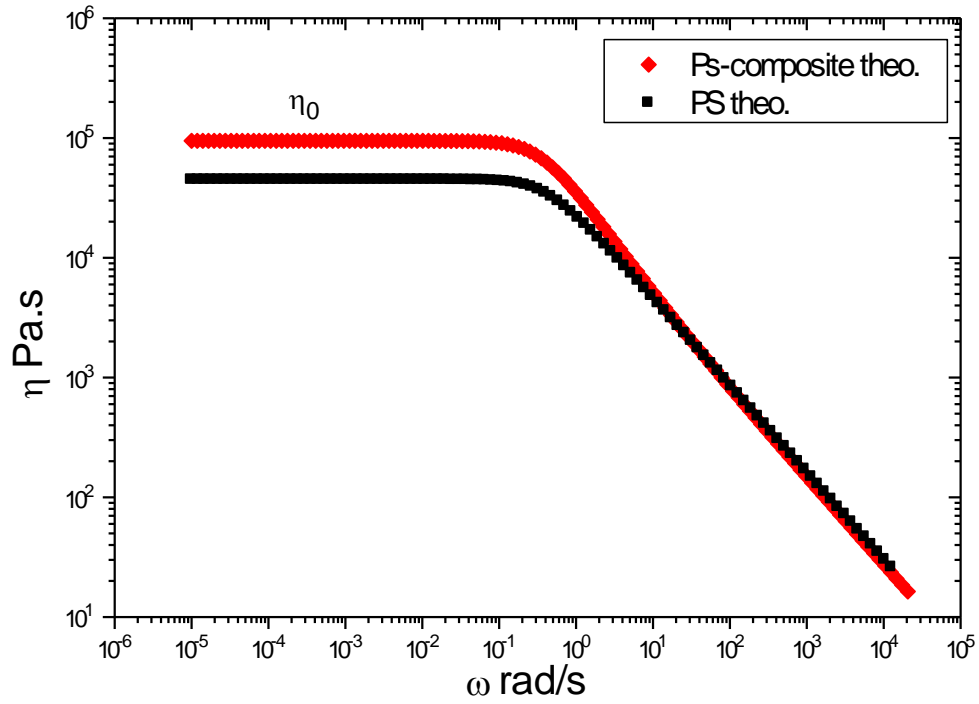


Figure 2: Determination of  $\eta_0$  theoretically for PS and PS composite at  $T_0 = 180^\circ$