Processability studies on PVC/LLDPE blends

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ABSTRACT

The rheological and morphological properties for the blends of polyvinyl chloride (PVC) and linear low density polyethylene (LLDPE) were investigated. The effect of shear rate, blend composition and chemical modification of the blends by chlorinated polyethylene (CPE) addition were studied and the results were compared with non compatibilised blends. A decrease in the melt viscosity is observed with increase of shear rate, indicating pseudoplastic behavior. The incorporation of CPE to the binary blend increases the melt viscosity. The morphology of the blends was modified by compatibilisation. The rheological and morphological variations could be related to the interfacial tension and the size of the dispersed phase particles.   © 2008 Trade Science Inc. - INDIA

INTRODUCTION

The reprocessing of mixed plastic waste is nowadays becoming more popular in view of the economic benefits and also as a solution to the major problem created by the non-biodegradability of plastics. Several researchers have studied the blends of PVC with PS, PP, HDPE etc.[1-4].This method of reutilization of solid plastic waste is used as a base for producing secondary products. Earlier studies reported that the blends of PVC and PE are not likely to yield products with expected mechanical properties because of the poor adhesion of phases due to thermodynamic incompatibility[5,6]. The ability of CPE to improve the mechanical properties of blends of PE and PVC has previously been reported[5-8].

The rheological properties of polymer mixtures are also studied extensively due to its practical relevance.

Investigation of the rheological properties of the mixtures will make it possible to assess their behavior during their processing, so as to design processing variables. Rheology of PVC blends is particularly important due to the fusion behavior of PVC. The mechanical strength of PVC blends is critically dependant upon the fusion state of PVC and hence study of the processing characteristics of PVC blends is of great importance. Several researchers have pointed out the significance of rheological studies in predicting the flow behavior of polymeric systems under various conditions[9-15].

The melt processability studies on the blends of PVC and LLDPE is described in this paper. The effects of shear rate, blend composition and chemical modification on the blends have been studied, with a view to understand the processing behavior of blends of PVC and LLDPE. The variation in the morphological behav-

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ior of the blends by CPE modification is examined by optical microscope.

EXPERIMENTAL

Polymers used are

PVC: - Powder,Suspension polymer; K value=65; LLDPE: - Ladene: 218 W, Melt index (g/10min.)=2.0, Density (g/cm^3) =0.918; CPE: - 38% Chlorine content, Mooney Viscosity [ML (1+4)/120ºC] =51; TBLS: Commercial Grade

Capillary rheometer is widely used for determing the rheological properties of polymer melts since they cover a wide shear rate range of interest in practical processing upto(10,000s^{-1}) with good reproducibility. In this study, the rheological properties of PVC/LLDPE blends were measured using a Goettfert Viscotester model 1500 as per ASTM D 3835-79 over a wide range of shear rates ranging from 23.0 s^{-1} to 2880.0 s^{-1} at temperatures of 160º, 180º and 200⁰C. Typical formulation for a 20/80 PVC /LLDPE blend is given below.

PVC: 20

LLDPE: 80

TBLS (stabilizer): 2.5 phr of PVC

CPE: 10 phr of total weight

Apparent shear stress(τ) and shear rate(γ) were calculated according to Poiseuille law. Then apparent viscosity η is given by τ/γ. Rabinowitsch correction (correction due to non- Newtonian behavior of the melts) and Bagley correction (correction due to end pressure drop) were applied in order to get true values of shear stress, shear rate and viscosity.

The temperature dependence of the viscosity of the polymer blends can be expressed by the flow activation energy, calculated from the Arrhenius type equation

$$\eta = A.e^{E/RT}$$

Where E is the activation energy for viscous flow, R,the gas constant, T the absolute temperature and A is a constant. The activation energy can be taken from the plot of η against 1/T.

The morphology of the polymer blends was investigated using an optical microscope (Versamet-2 Union 7596). For optical microscopy, a compression set test piece was cut to a convenient size and mounted on a microscope slide. The photographs were taken at a magnification of 330.

RESULTS AND DISCUSSION

Figure 1 gives a comparison of apparent and true viscosities against shear rate for 40/60 PVC/LLDPE blend. The true viscosity values are only slightly displaced from the apparent values probably because the apparent values were taken with a capillary of fairly high L/D ratio[16]. Again since the evaluations in the present study are of a comparative nature, Bagley and Rabinowitsch corrections were not employed for further studies. The effects of shear rates and blend composition on the melt viscosity of PVC/LLDPE binary blends are presented in figure 2. It may be concluded from the figure that, there is no substantial change in the viscosity and hence in the structure of the melt for the composition range studied. The strong non-Newtonian behavior of the blends at higher shear rates is evident from the figure. The melt viscosity decreases with shear rate, which is an indication of the pseudoplastic nature of the blend system. As low shear rate increases, the polymer molecules disentangle and get oriented, as a
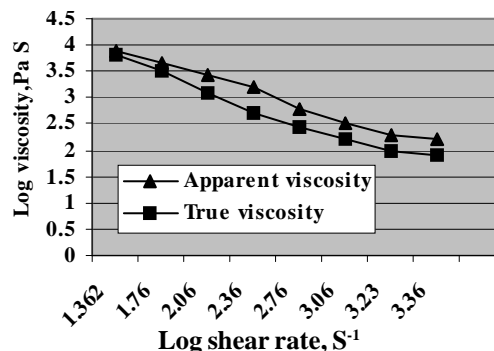

Figure 1: Comparison of apparent and true viscosities with shear rate for 40/60 PVC/LLDPE blend
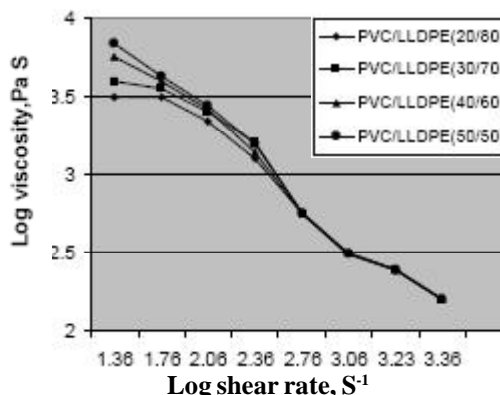

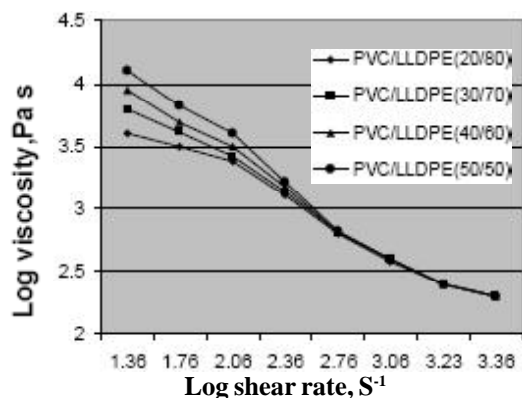**Figure 2: Viscosity- shear rate curves of PVC/LLDPE blends at 170⁰C**

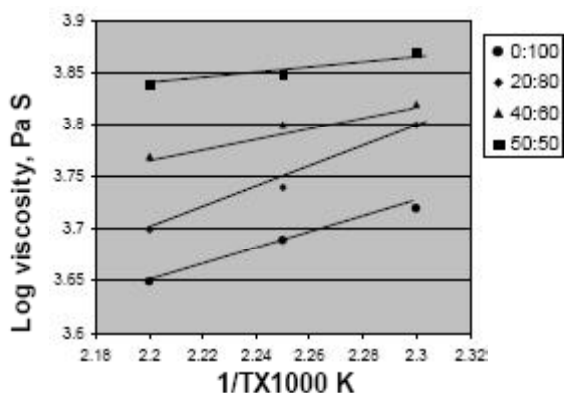**Figure 3: Viscosity-shear rate curves of CPE modified PVC/LLDPE blends at 170⁰C**

Figure 4 : Variation of viscosity with temperature of PVC/ LLDPE blends with blend composition at a shear rate of 23.0 s⁻¹
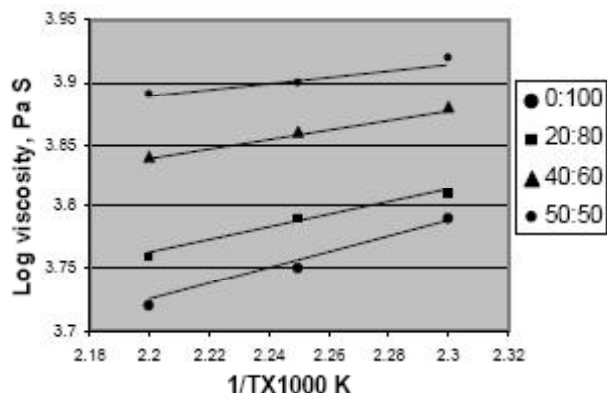

Figure 5 : Variation of viscosity with temperature of CPE modified PVC/LLDPE blends with blend composition at a shear rate of 23.0 s⁻¹

TABLE 1: Variation of activation energy of PVC/LLDPE blend with blend composition

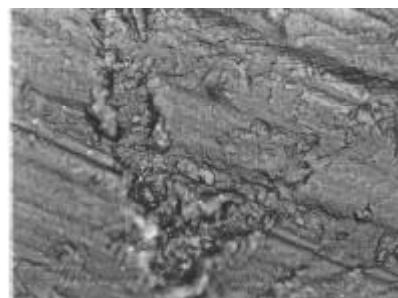| % Composition of PVC/LLDPE	Activation energy at a shear rate of 23 .0 s⁻¹	
	Unmodified (KJ/mole)	CPE modified (KJ/mole)
0 /100	23.94	19.15
20 /80	19.14	17.23
40 /60	17.42	15.11
50 /50	13.40	10.44

Figure 6: 20/80 PVC/LLDPE blend (Unmodified)

Figure 7: 20/80 PVC/LLDPE blend (CPE modified)

result of which the viscosity decreases. The addition of a compatibiliser to polymer blends affects the flow behavior because it changes the interaction of the components at their interface. Figure 3 gives the viscosity - shear rate plot of CPE modified blends. When CPE is added it enhances the viscosity of the system, particularly at low shear rates. This effect may be due to the interactions which contribute towards increasing the strength of the blends. At higher shear rates this effect is not so pronounced suggesting that better properties can be obtained by mechanical compatibilisation of the blends at high shear.

Figures 4 and 5 show the plots of log viscosity against 1/T for the unmodified and modified blends at a shear of 23.0 s⁻¹. The slopes of these curves are proportional to activation energy for viscous flow. The activation energy has considerable practical importance because it expresses the temperature dependence of viscosity of the material. The activation energy calculated from the slope of the straight lines is shown in TABLE 1. It can be observed that, the flow activation energy decreases with increase in PVC content. Also CPE modification reduces the flow activation energy of the blends in all cases. The lower activation energy obtained from the modified blends show that CPE is an active flow improver.

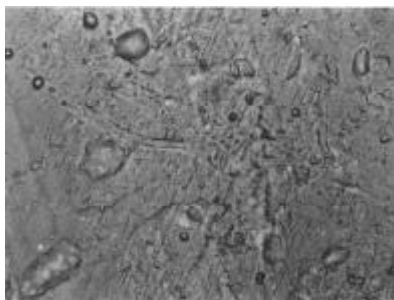This observation was further confirmed by mor-

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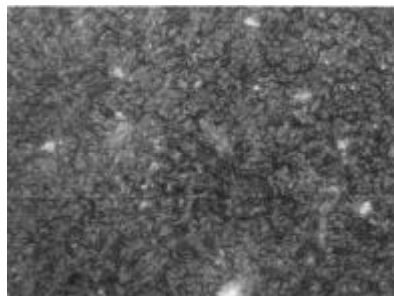**Figure 8: 40/60 PVC/LLDPE blend (Unmodified)**

Figure 9: 40/60 PVC/LLDPE blend (CPE modified)

phological analysis. The morphology of the blends observed with the optical microscope is shown in figures from 6 to 9. As is evident from the photographs, the morphology of the different systems varies with composition. In order for the blends to exhibit superior mechanical properties, the dispersed phase should be uniformly and finely dispersed in the major continuous phase. From the photographs it is clear that, CPE modification makes a more regular and homogeneous distribution of the dispersed phase. All the morphological observations are in accordance with the earlier observation that CPE improves the fusion behavior of PVC particles. Thus the rheological and morphological variations by CPE modification could be related to the reduction of interfacial tension and the size of the dispersed phase.

CONCLUSIONS

The melt viscosity of PVC/LLDPE blend system decreases with increase in shear rate, indicating pseudo plastic behavior. The viscosity is found to increase by CPE modification, which may be improved interactions. The incorporation of CPE changes the flow activation energy of the blends. The low activation energies obtained from CPE modified blends show that, CPE is an active flow improver. The morphological analysis indicates that CPE modification makes a more regular and homogeneous distribution of dispersed phase of the PVC/LLDPE blends.

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