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Effect of Co-monomer Content on Rheological Property of Sawdust/ABS Composites

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Abstract. Effect of co-monomer content in Acrylonitrile-Butadiene-Styrene copolymer (ABS) on the rheological property of sawdust reinforced ABS composites was investigated using capillary die rheometer. Three grades of commercial ABS resin were used. Sawdust from Para rubber tree treated with N-2(aminoethyl) 3-aminopropyl trimethoxy silane was blended with ABS by melt blending process using twin-screw extruder. From the results, shear thinning behavior was found for all of composites in the same shear rate ranges for testing that were investigated. At the low shear rate, the composites which contain higher acrylonitrile content, showed higher viscosity. At high shear rate, the viscosity of each co-monomer dependent composites tends to come close to each other on the curves. In this study, Carreau's model was used for curve fitting and those parameters were also determined. Die swell ratio of the composites tended to increase at the initial ranges of shear rate of 10-500 s^{-1}, and then the swelling ratio value decreased dramatically once the shear rate were further applied. The molecular weight has more effects than comonomer content on the die swell behavior i.e., at the same molecular weight, composites with higher butadiene content show higher swelling ratio.

Introduction

Wood-plastic composites (WPCs) are materials produced by adding the wood sawdust as reinforcement in plastic matrix. They are used to replace natural wood in many applications such as building materials, gardening and landscaping etc. WPCs have several advantages over natural wood, especially, environmental resistant property.

Acrylonitrile-butadiene-styrene terpolymer (ABS) plastics possess several prominent properties strength, rigidity, and toughness. In addition, it has resistance to chemical substance and endurance for wide range of temperature usage. Each component has different effect on the properties of ABS. Acrylonitrile contributes to heat and chemical resistance. Butadiene provides impact properties due to its rubbery phase. Styrene has its function on processability and surface properties. Therefore, outstanding properties of ABS plastics could be tailored-made by adjusting the proportion of its components. The main objective of this work is to investigate composites originated from wood sawdust and varied ABS grades. However, wood and ABS are incompatible molecules because of the difference in molecular polarity. Surface modification is thus required.

In previous work[1], it was found that silane coupling agent, N-2-(aminoethtl)-3-(aminopropyl) trimethoxysilane, can improve interfacial adhesion and good dispersion of sawdust in ABS matrix.

Optimum mechanical properties were discovered with the amount of silane 0.5%wt of sawdust. Thus silane with the mentioned amount was used in this work.

Rheological property of sawdust/ABS composites is an important factor for determining the processing parameters. This study purposively focused on the effects of co-monomer contents on the rheological properties of sawdust/ABS composites.

Experimental

Materials Three grades of ABS are supplied by IRPC PLC. There are included high flow (HF-ABS), medium impact (MI-ABS) and super high impact (SI-ABS) grades. They were characterized using H-NMR and elemental analysis for the determination of co-monomer content as shown in Table 1. Wood sawdust particles are supplied by V.P. Wood Co., Ltd. and their average size used in this work was in the range of 100–300 microns. The contents of wood sawdust particles added into ABS was 10 and 50 parts per hundred (phr). N-2(aminoethyl) 3-aminopropyl trimethoxy silane from Sigma-Aldrich Inc. (Germany) was used as coupling agent for enhancing interfacial strength between sawdust and ABS and the amount of silane is 0.5 percent weight of wood sawdust.

Table 1 Co-monomer content of ABS plastics

ABS	% Acrylonitrile	%Butadiene	%Styrene	MFI(g/min)
HF (GA300)	18.9	9.5	71.5	30
MI (MH-1)	20.7	8.6	70.7	18
SI (SP200)	21.4	12.5	66.2	17

Compounding and composite characterizations Sawdust surface was treated by silane coupling agent with 0.5%wt of sawdust. Treatment procedure was detailed as in previous work [2]. Treated sawdust and ABS were dried in oven for 24 hours before blending process. And then, they were dry-blended by high speed mixer for 2 min. After that, ABS and sawdust were compounded by twin screw extruder. The blending temperature profiles on the extruder were 170-190 ^{0}C from hopper to die zone. The screw speed was 80 rpm. The extrudates were then passed a pelletizer and then held in an oven for 24 h at 80 ^{0}C ready for characterization.

Rheological and die swell measurement of composites was performed on capillary die rheometer (CEAST Rheologic 5000) with the length-to-inner diameter (L/D) of the circular die was 20/1. Studies were done at three test temperatures of 180, 190, and 200 ^{0}C and the range of shear rates varied from 5 to 1500 s^{-1}.

Results and discussions

Figure 1 and 2 show the effect of temperature and shear rate on viscosity of neat ABS and wood-ABS composites and found that they all showed the shear-thinning behavior. Moreover, the effect of sawdust content was also shown in these figures. The melt viscosity of wood-plastics composites typically increases with wood filler amount because chain mobility of tough phase is restricted by wood particles.

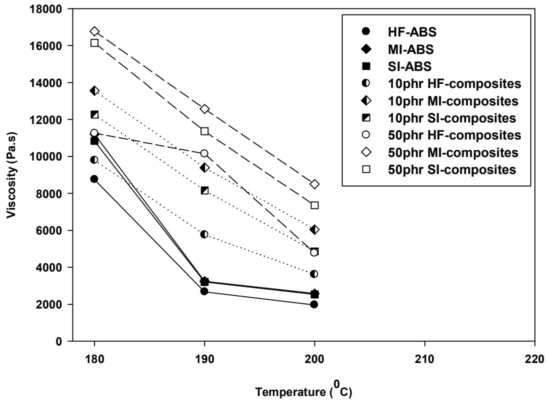

Fig.1 Effect of temperature on viscosity of ABS and wood-ABS composites at shear rate 10 s^{-1}

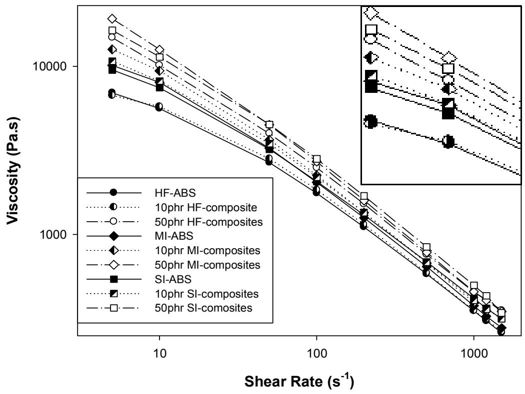

Fig.2 Viscosity of neat ABS and wood-ABS composites as a function of shear rate at 190 ^{0}C

For neat ABS and wood composites, their viscosities are strongly influenced by acrylonitrile monomers because of their secondary intermolecular bonds resulting in their high melt viscosities. Therefore, HF-ABS which has the lowest acrylonitrile content would show relatively low viscosity compared with MI and SI-ABS.

Table 2 Carreau's parameter

Carreau's parameter		λ			n		
		Sawdust content			Sawdust content		
T(^{0}C)	ABS	0	10	50	0	10	50
180	HF	0.14	0.14	0.18	0.31	0.29	0.28
	MI	0.20	0.24	0.30	0.29	0.27	0.24
	SI	0.20	0.19	0.24	0.30	0.29	0.26
190	HF	0.08	0.08	0.15	0.33	0.33	0.29
	MI	0.13	0.17	0.20	0.30	0.29	0.25
	SI	0.12	0.14	0.19	0.34	0.32	0.28
200	HF	0.06	0.05	0.09	0.34	0.30	0.33
	MI	0.08	0.09	0.17	0.30	0.28	0.28
	SI	0.08	0.09	0.16	0.32	0.32	0.32

The viscosity and shear rate curves were obtained and fitted by Carreau-Yasuda model [3] which is expressed as equation (1).

$$\frac{\eta-\eta_\infty}{\eta_0-\eta_\infty}\approx\frac{\eta}{\eta_0}\approx\frac{1}{\left[1+(\lambda\dot{\gamma})^2\right]^{\frac{1-n}{2}}} \quad \text{Eq.1}$$

Where n is power law index; λ is characteristic time as well as η_∞ and η_o are the viscosity at infinite and zero shear rate, respectively.

Carreau's parameter, λ and n, were calculated and listed in Table 2. Power law index (n) indicated shear rate sensitivity of materials, those of MI samples (neat and composites) are lowest at any given temperature. That means their viscosity rapidly decrease with an increase in shear rate. That maybe caused by the low content of butadiene phase which acts as the high entropy molecules, and then results in the rearrangement of MI-ABS molecules, following the flow direction. Characteristic time (λ) associates with the fluid's elasticity and generally known as relaxation time which refers to the time it takes the polymer chains to the equilibrium state after being disturbed by external stress. MI-ABS samples show the highest value for λ and the lowest value belong to HF-ABS and its composites.

For die swell measurement, generally, the die swell ratio of melt polymer tends to be directly proportional with shear rate, but not with the temperature. This die swell as mentioned was found in neat system as shown in fig. 3 and 4. In case of composites, they show the die swell under the influence of temperature similar to the neat samples. Whereas the unprecedented behavior was observed as per the effect of shear rate i.e., swelling ratio tended to increase at the initial ranges of shear rate (10-500 s^{-1}), and then the swelling ratio value decreased dramatically once the shear rate were further applied. The decline of the swell ratio at higher shear rate was probably influenced by more pronounced shear heating effect[3, 4].

The effect of co-monomer content on swelling ratio can be considered from figure 4. For neat ABS, MI-ABS shows the highest in swelling ratio. Although MI-ABS has the lowest content in elastic phase, butadiene, their swelling is highest at any given temperature due to its high degree of chain disentanglement during molten polymer passing through a die. Entanglement effect require a relative longer time for stress relaxation and result in the highest level of swelling ratio for MI-ABS. This result was supported by λ parameter which is calculated from Carreau's model in Table 2, show highest relaxation time in MI-ABS. And the same tendency was observed in all composites. From the results, the molecular weight has more effects than co-monomer content on die swell behavior.

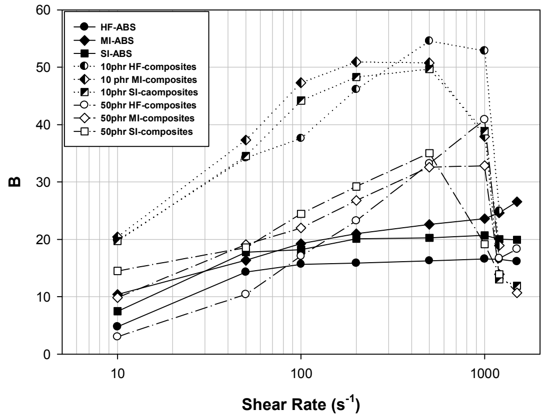

Fig.3 Effect of shear rate on die swell at 190 ^{0}C

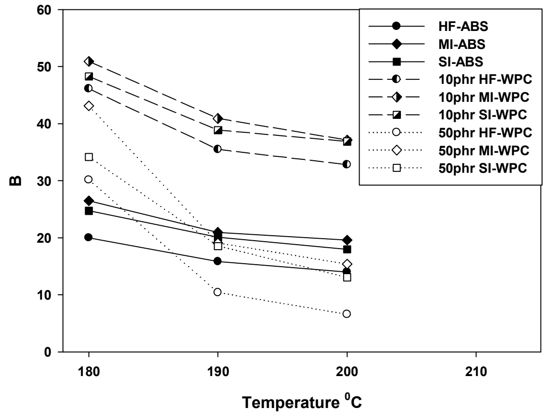

Fig.4 Effect of temperature on die swells of neat ABS and wood sawdust ABS composites at shear rate 200 s^{-1}

Conclusions

The shear thinning behavior can be observed in all composites. The secondary bonding at acrylonitrile is the important factor for an increase in viscosity for both neat and composites system. The molecular weight has more effects than comonomer content on die swell ratio. For the same molecular weight (comparing between SI and HF), butadiene monomer plays an important role in die swell phenomena. These effects can also be observed in both low and high sawdust content composites.

Acknowledgements

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