Rheological Studies of ABS Reinforced Carbon Black Blends

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***Abstract*— Nowadays, effort of combining conductive fillers into ABS making the blends antistatic has utilized plenty of potential applications with high demand on conductive polymer composite, which are not limited to electrical insulating materials any more. Carbon black (CB) is conductive fillers that can be added into ABS. The effects of added carbon black on the processability of Acrylonitrile–Butadiene–Styrene (ABS) thermoplastic polymers ~~have~~ was ~~been~~ investigated. Adding carbon black with ABS has been done by changing the weight percent which range from 10% to 50% and later analy~~i~~sis the trends. The flow properties of composite materials have been evaluated by Melt Flow Index. The rheological properties was calculated by result of Melt Flow Index. The processing flow decreases as the carbon black content increases. Next, the rheological properties of ABS reinforced carbon black blends has shown that flow rate in a polymer is related inversely to viscosity. High carbon black content in ABS will increases the resistance to flow. Thus will slow the flow rates.**

I. Introduction

Acrylonitrile butadiene styrene (ABS) is common thermoplastic polymer whose commercialization began in the 1940's (Halonen, 2016). ABS is well-known in thermoplastic industries because it has good chemical and mechanical properties. One of the characteristics is smooth surface finish and good processing characteristics (Patiño-Soto, Sánchez-Valdes, & Ramos-deValle, 2007).

Filler is introduced ~~because of the~~to enhance materials ~~enhance the~~ properties such as morphological, mechanical and others of the polymer blends. There ~~is~~ are many available fillers such as carbon nanotubes (CNTs), graphene, carbon black, clay, Multi walled carbon nanotubes (MWCNT) and glass fibers are used as filler in small size which is nano size. The filler materials can improve mechanical, electrical and thermal properties of polymer composite. At the present time, for polymer matrix carbon black (CB) proves as practical filler material. Among other filler materials that available in market now, carbon black has good properties and also lowest cost (Lohar & Jogi, 2018).

Nowadays, effort of combining conductive fillers into ABS making the blends antistatic has utilized plenty of potential applications with high demand on conductive polymer composite, which are not limited to electrical insulating materials any more. Carbon black (CB), carbon nanotube (CNT) and carbon fiber (CF) are conductive fillers that can be added into ABS, despite the fact that these fillers are electrically ideal, the basic performance remains keeping several defects. For instance, CNT is the best in electrical conductivity but it is high-priced and CB's addition may critically influence the mechanical property which will be the substantial for getting the similar conductivity. In relation to increasing addition of CB into poly-matrix, it is well-known that the electrical conductivity will rise. It is also definitely increase after reaching the percolation threshold. Percolation threshold value is affected by various factors (Wang, Hong, Feng, Badami, & Zeng, 2014). By adding conductive CB/CF in composite will make the materials easy to break off. Various studies had been pursued in order to understand polymer mixing with high toughness.

One of the physics discipline that concerns with the deformation and flow of matter under stress is a rheology. When a mechanical force is exerted on it, it is certainly concerned with the features of matter that determine its behaviour. It is interested with the three traditional states of matters instead of only gases and liquid. Rheological properties have various applications and vital implications in general. Usually, to convey the desired flow behavior, the usage of an additive is introduced. Rheology applications are important in various areas of industries involving plastic, metal and many other materials. From rheological researches, the outcome provide the mathematical description of the viscoelasticity behaviour of matter. It is important to understand the rheology of a material especially in the processing of composites, even if the process is designing an injection molded part or determining the cure cycle for a polymer (Sadiku-Agboola, Sadiku, Adegbola, & Biotidara, 2011). Based on previous research, it shows that with more structured CB samples during mixing, it will resulted an increasing in viscosity, showing that higher particle–polymer interactions, it is also influence the CB dispersion in the matrix (Mallette, Quej, Marquez, & Manero, 2001).

Acrylonitrile Butadiene Styrene (ABS) is a thermoplastic polymer. But, it is lacks of conductivity. Carbon Black (CB) is good conductor, because of that it is introduce to act as filler. Hence, this will change the properties of the new composite (ABS+CB) especially in rheological properties. Rheology is the study of flow of matter, primarily in a liquid state, but also as "soft solids" or solids under conditions in which they respond with plastic flow rather than deforming elastically in response to an applied force. Rheology studies is important when it comes to processing, the change in rheology will affect the processing parameters. Next, it is because of insufficient data on rheological studies of ABS reinforced with carbon black blends.

This study focus mainly on the effect of the new composite which is combination of (ABS+CB), with (10-50%) range of carbon black is act as a fillers on ABS. Next, this study also focus on rheological properties which is also can be defined as flow properties of Acrylonitrile Butadiene Styrene (ABS) reinforced carbon black blends. Melt Flow Index (MFI), and then comparing them in order to evaluate which useful information are given from the protocol.

The aim of this study was to analyze the effect of carbon black fillers on ABS and to measure the rheological properties of ABS reinforced carbon black blends.

II. METHODOLOGY

A. *Materials*

ABS that have been used for this research have been obtained from the Universiti Teknologi Mara (UiTM) laboratory.

CB is used as a filler for this research. CB was used in a range of 10, 20, 30, 40 and 50wt%.

B. *Preparation of composites*

Prior to mixing, ABS were pre-dried for 16 hours in a hot air oven at 80°C to remove moisture content. The ABS/CB batches at prearranged compositions were dry-mixed, and then melt blended in an internal mixer with a temperature of 210°C at a screw speed of 5 rpm for 3 minutes. Afterwards, CB was inserted by varying wt% of CB from 0-50wt%. at 220°C with a screw speed of 100rpm for 10min.

~~The ABS/CB composites were then compression moulded using a hot press at 220°C with 150 kg/m2 pressure. The duration for the heat press as follows; pre-heat time 6 minutes, compress 8 minutes and cooling time 6 minutes.~~

C. *Rheological testing*

Melt Flow Rate (MFR) is other alternative name besides Melt Flow Index MFI, it measures the flow properties (measured in g/10 min) of a substance at a particular shear stress (related to applied load) and temperature. An extrusion plastometer, also known as a melt indexer, is used to determine the MFI of pure, compounded, and post-processed thermoplastics.

Firstly, make sure that the machine on by plugging the main socket into 3 pin 15 amp socket. Next, SV value should be set on PID controller and the test duration are display on digital timer. After setting the timer and temperature, turn on the heater by pressing on the switch. Wait for the reading in PV display in PID controller to reach the SV display. Later, when the required temperature has been attained, place the plastics granules in the barrel for testing. After fill in the granules inside the barrel, poke the granules with the plunger to ensure close packing and to eliminate air between the granules. The PV value on PID monitor will slightly decrease when the granules are inserted into the barrel. Wait for to reach SV value. Next, SV and PV value are the same, place the plunger along with the dead weight (4.9kg) on it into the barrel. Then, melted plastic comes out of the barrel. When the time is completes, the cutter will automatically cut the sample. Weigh the melted sample using digital balance. This weight will be used for calculating the Melt Flow Index of the sample.

The formula to calculate MFI:
MFI = Weight of sample (grams) x F (grams/10 min).
F= 20 (grams/10 min).

F- Factor for obtaining flow rate in (grams/10 min).
PV - Process Variable
SV- Set point Variable =220°C

III. RESULTS AND DISCUSSION

A. *The effects of carbon black fillers on ABS*

Table 1: Result of MFI testing: 10%-50% of carbon black.

Weight percent of carbon black	No of sample	Sample weight (g)	Flow rate (g/10 min)	Average flow rate:
10%	1	0.43	8.6	8.33 g/10 min
	2	0.40	8.0	
	3	0.42	8.4	
20%	1	0.36	7.2	6.53 g/10 min
	2	0.30	6.0	
	3	0.32	6.4	
30%	1	0.26	5.2	5.13 g/10 min
	2	0.26	5.2	
	3	0.25	5.0	
40%	1	0.17	3.4	3.4 g/10 min
	2	0.18	3.6	
	3	0.15	3.0	
50%	1	0.06	1.2	1.2 g/10 min
	2	0.07	1.4	
	3	0.05	1.0	

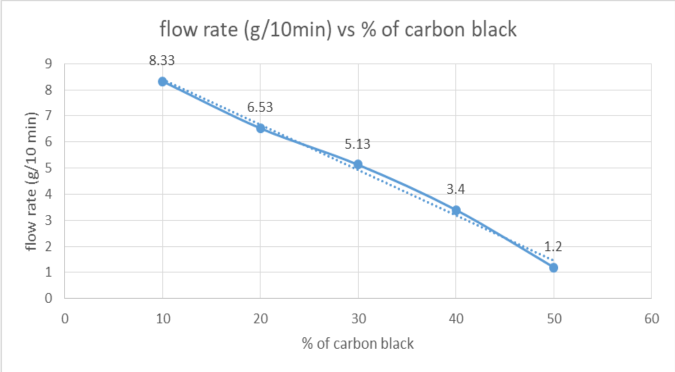

Figure 1: flow rate (g/10min) vs percent of carbon black

The measurement of rheological properties of any polymeric material in the molten state is crucial in order to gain fundamental understanding of the processability of that material (Sadiku-Agboola, 2011). This is because rheological behaviours are strongly influenced by the material structure and the interfacial characteristics. The rheology of polymer melt is crucially essential for two reasons. Firstly, it has helped to resolve many polymer problems, such as wide gauge variations in films, poor optical quality of sheet and films, slow production rates, dimensional instability and poor mechanical properties. Secondly, it has been employed for the analysis of parameters, such as: molecular structures.

Based on the results above, addition of carbon black to ABS will result higher flow rate (g/10min) of the new composite. The effect of carbon black particles was as expected by causing a relative increase in the polymer's melt viscosity and reduction the output. This is in agreement with Rahim et al. (2011) founding. At 10 (wt%) of carbon black, it shows that the flow rates is 8.33g/10min. Next, at 20 (wt%) of carbon black, the flow rates is lower than before which is 6.53g/10min. Subsequently, at 30 (wt%) of carbon black, the flow rates is 5.13g/10min. Following that, at 40 (wt%) of carbon black, the flow rates is 3.4g/10min. As the weight percent is increase at 50 (wt%), the flow rates obtained is 1.2g/10min. From the tabulated data above, percent of carbon black vs flow rate (g/10min) graph has been plotted. From the graph, the result shows decreasing trend. It can be said that, percent of carbon black is inversely proportional to the flow rates. The hypothesis of this experiment is flow rates (g/10min) is decreases as the percent of carbon black increases. Based on the result above it proves that the hypothesis is accepted.

The rheological properties can be seen from behavior of material viscosity. Viscosity is a measurement of resistance to flow. Flow rate in a polymer is related inversely to viscosity. High-viscosity materials flow with greater resistance and therefore more slowly under any particular set of conditions than low-viscosity materials do. This is due to high viscosity will result high internal friction. In such a way that the shear stresses will be higher in a more viscous environment at a given shear rate. Carbon black aggregates may be dispersed and broken to a larger extent with higher shear stresses based on Mallette et al (2001) founding. Based on data above, high carbon black content in ABS will increases the resistance to flow. It can be said that, 50 (wt%) of carbon black has higher viscosity than 10 (wt%) of carbon black.

The amount of internal friction depends on the type of particles and the amount of attraction they have for each other. High internal friction of the composite is because of carbon black possess smaller particle diameter that gives rise to higher surface area and strength. High surface area is usually associated with higher conductivity, improved hardness, and higher viscosity (Mallette, 2001). The structure level of a carbon black ultimately determines its effects on several important in ABS properties. Increasing carbon black structure increases hardness, electrical conductivity and increases compound viscosity.

Temperature showed little dependency on carbon black content (Zhang, 2002). In polymeric materials, viscosity is affected by the temperature. The temperature for MFI testing was operating at 220°C. During the cleaning of MFI, the temperature need to be increase in order to ease the cleaning of the remaining composite. The temperature was increase up to 240°C. As temperature increases, more energy creates more kinetic motion of particles means more collisions and the particles spread out further. Particles can slide past each other easier now since internal friction has decreased and viscosity decreased. Particles slide past each other easier now so they flow easier and faster. That is why heating up a thick gooey will allow it to be “thinner” or “runny”.

Based on the data obtained, the optimum value for processing flow is 10 (wt%) of carbon black blends. It shown that, beyond 10 (wt%) of carbon black it is difficult to flow due to high viscosity of composite as the (wt%) of carbon increases.

IV. Conclusion

From the collected data and discussion, it can be conclude that processing flow was affected by addition of carbon black to ABS. The research objective was achieved by demonstrate the effect of carbon black fillers on ABS. The processing flow decreases as the carbon black content increases. Next, the rheological properties of ABS reinforced carbon black blends has shown that flow rate in a polymer is related inversely to viscosity. High carbon black content in ABS will increases the resistance to flow. Thus will slow the flow rates. This will affect the processability of the composite, which will make it difficult to flow during processing of this material.

Acknowledgment

Thank you to my supervisor and Universiti Teknologi Mara.

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