Mechanical Studies of ABS Reinforced Carbon Black Blends

Nur Mayang Tirana Ahmad Khalid and Sakinah Mohd Alauddin

Faculty of Chemical Engineering, Universiti Teknologi MARA

***Abstract*—The usage of ABS has shown its potential in synthetic engineering plastics however many studies suggested that modifications should be made to assure the improvement on the mechanical properties of ABS. As the highlight of this research, carbon black blends were reinforcing into ABS and the mechanical properties of ABS reinforced carbon black blends are studied as the flexural modulus and impact strength are determined. The preparation for ABS/CB was carried out by using a Haake Rheomixer OS at melting point of 210 °C at 5 to 60 rpm. The flexural testing and impact testing are conducted according to standard methods ASTM D790 and ASTM D256 respectively. The maximum flexural modulus and flexural strength were exhibited by 50% CB blends as the values were 237.33 MPa and 10.01 MPa respectively. As the percentage of CB blends increased, ABS/CB composite become stiffer. At 20% CB, the maximum value for impact test was 0.00133 kJ/m^2 and on the other hand, 50% CB blends for ABS/CB composite showed the lowest strength for impact. Filler loading has been proven to improve the mechanical properties of ABS composites by increasing the interfacial bonding between ABS and CB blends.**

Keywords*—ABS, Reinforcing filler, Universal Testing Machine, Izod Impact Tester, Flexural modulus, Impact strength.

I. INTRODUCTION

Polymers play an important role in the development of engineering plastic industries. Their application spread widely in various areas of polymer as they can be used in automotive industry, building and construction, packaging, electronic industry, and agriculture. There are two types of polymer that have been commercialized in market which are thermoplastic polymer and thermoset polymer [1].Thermoplastics such as ABS have received more attention as polymer matrices due to their less requirement for treating process and low hazardous chemical compositions. Coming with the higher demand than thermoset resins, thermoplastics are more preferable as they are more environmental friendly in aspect of accessibility to recycle and capability to promote good mass production [2].

Due to its excellent properties such as impact resistant, resistant to heat, chemical resistant along with other splendid characteristics of easy to fabricate, stable in sizes and better surface glossiness, ABS is chosen as one of the most preferable thermoplastics that have been used in synthetic engineering industries [3]. Through a research of polymer composites structure-property relationships, optimal mechanical properties can be achieved [4]. According to K. Senthivel et al. [5], by adding fillers to thermoplastic polymers, some of the properties and cheaper compound will be produced. Fillers rely on thermal, magnetic and electrical properties along with the interaction of surface material [6].

As stated in a study by Huang and Schadler [7], in a diverse and heterogeneous system, the properties of filler and polymeric matrix interface and filler geometry/dispersion morphology are the biggest elements that can affect the composite ultimate properties. This statement can be strengthen as according to Weaver [8], the intermolecular interaction and dispersion of filler material are another two main factors that can bring some effect on mechanical properties of a given composite apart from the material properties itself. For example, in rubber industries carbon black and silica are the usual type of main reinforcing agents that have been widely used. By reinforcing carbon black into polymer composites such as ABS, it can help to improve the mechanical properties the ABS. It stated that the Young's modulus increased as it also depends on the amount of carbon black added [9]. When the polymer chains of ABS was interfered with carbon black, the combination of these two materials causing the composites become more rigid rather than ABS with no reinforcing filler. Carbon black helps in the developing mechanical properties of ABS by modifying the surface interaction between polymer matrix and added filler.

In the studies of mechanical properties of thermoplastics, basic mechanical parameters as tensile properties, flexural properties and impact strength of the material are determined by using several of methods. A clear understanding of the reinforcement should be focused in order to provide detailed perceptions into certain aspects of mechanical properties such as the increasing in tensile strength or modulus or the changes in stress or strain.

II. METHODOLOGY

A. Materials

Acrylonitrile-butadiene-styrene (ABS) resin was supplied by Laboratory of Polymer at Faculty of Chemical Engineering as in it comes in the form of resins. The carbon black powder was also supplied by the Laboratory of Polymer at Faculty of Chemical Engineering.

B. Composite preparation

The ABS/CB composite was prepared by melt blending components in an internal mixer (Haake Rheomixer OS) at temperature of 210 ºC. First of all, before melt blending process, ABS was dried in an oven at 80 ºC for at least 3 hours. Then, ABS resins were firstly added into the chamber of Haake Rheomixer OS at a temperature of 210 ºC and let to be grafted by a rotating speed of 5 rpm. After been mixing for 3 minutes, CB was instantly added into the rheomixer and then the mixer screw speed was allowed to rotate from 5 rpm to 60 rpm. The operating temperature for this mixing process is set up at constant which is at 210 ºC. The time taken for mixing process is estimated to be 10 minutes. Then, the steps are repeated by varying the weight percent (wt%) of CB from 0% to 50%. For overall process, the time taken was approximately 10 – 15 minutes of mixing.

After the mixing process, the ABS/CB composite must be moulded. Under the specific conditions, the moulding process was continued by using heat press machine. The suitable weight for the sample of ABS/CB must be determined by using this formula before it can be inserted into internal mixer.

$$W = V \times SG \times FF$$

W = Weight of sample, g
V = Volume of internal mixer, (69 cm^3)
SG = Specific gravity of mixed batch, g/cm^3 (1.04)
FF = Fill factor (70%)

Table 1: The weight of ABS and CB based in the wt%

Wt %	*Mass of ABS, g*	*Mass of CB,g*
0	50	0
10	45	5
20	40	10
30	35	15
40	30	20
50	25	25

As for the final step for the sample preparation, the ABS/CB composite was made into sheet samples accordingly to ASTM by hot-pressing it at 210 ºC and 150 kg/m^2 for approximately 15 minutes. It is required to take around 5 minutes for pre-heating process and 10 minutes to compress.

C. Mechanical testing

By taking at least 3 samples, flexural test was conducted according to the standard ASTM D790. A Universal Testing Machine was used to test the flexural properties of the samples in order to measure the force needed to bend tested sample under three loading point conditions. A loading noses and supports shall have cylindrical contact surfaces of radius 3.00mm is introduced to hold the sample as in the **Fig.1** below.

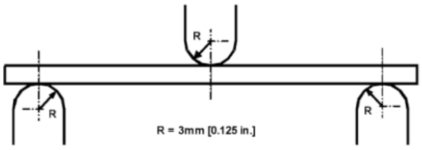

Figure 1: Three point loading configuration with fixed loading nose and supports.

For this test, it is required to terminate the test when the sample reaches 5% deflection respective to the maximum strain in the outer surface of the test sample or breaking occurs. But if the sample does not break, the test is continued as far as possible.

Three samples were also prepared to get the average value of the result. At first samples were notched by using Tinius Olsen model 899 Notcher in order to fit the size of impact testing machine. Izod Testing Machine Tinius Olsen 503 was used in testing the impact strength of ABS/CB composite according to standard ASTM D256. As for the standard for ASTM, the size of sample was 4 x 12.7 x 3.2 mm as noted that the preferred thickness of 3.2 mm due to its tendency not to bend or crush. A heavier hammer was used if there is no breakage until the failure occurs.

III. RESULTS AND DISCUSSION

A. The effect CB content on flexural modulus and flexural strength

The effect of CB blends content on the flexural properties was investigated throughout this research as the concentration of CB was varied until the ratio of ABS: CB is 1:1. For each set of concentration, the test was run for 3 times and average result is calculated in order to plot a graph.

According to the graph obtained **(Fig.2)**, both modulus of bending and bending strength were increased when the value of CB blends contents were increased. The highest value of flexural modulus is 237.33 MPa as the ratio of ABS: CB was 1:1 respectively, indicating as the amount of CB blends affected the ability of ABS/CB composite to resist bending or flexural deformation. Pure ABS exhibited the lowest modulus (25.27 MPa) as there was no modification had been made to the surface morphological of the specimen. By correlating the previous study with this research, filler loading can be one of the important aspects in determining the mechanical properties of composites [13].

The stiffness of the ABS/CB composites subsequently increased as the value of flexural modulus (modulus of bending) is higher. As it can be observed from **Fig.2**, the specimen of ABS/CB composite will be stiffer as the values of flexural modulus was increased resulting from the increment in percentage of CB blends. The reinforcement of ABS/CB proved that by adding corresponding fillers such as CB into polymeric composites, the stronger intermolecular bonding strength will be formed. The modification is made on the surface of ABS reinforced CB blends.

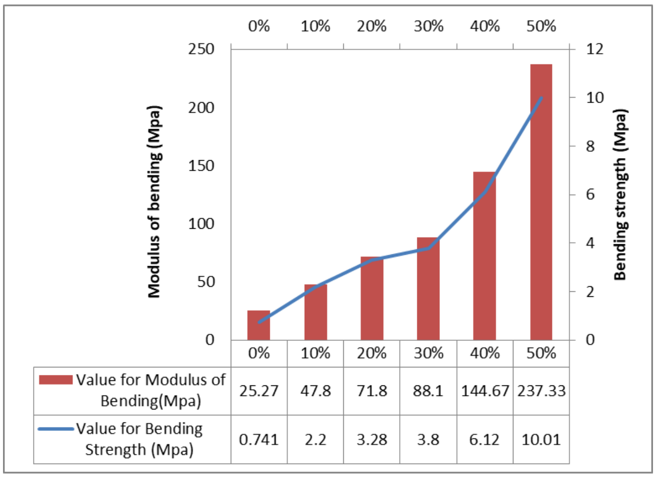

Figure 2: A graph of dependency of the bending strength and the bending modulus to the percentage of CB blends

Flexural strength (bending strength) is the maximum value of flexural stress sustained by any material during a bending test (flexural test). In this present research, the values of flexural strength were obtained from Universal Testing Machine (UTM) software. Same pattern as modulus of bending, the values of bending strength were increasing monotonically as the amount of CB blend contents increased as shown in **Fig.2**. The bending strength of pure ABS (0% CB) is 0.741 MPa and it increased gradually to maximum value of 10.01 MPa at 50% ABS (50%CB). The optimum value of flexural strength for this research is exhibited by the test sample with 30% of carbon black blends.

According to these data, it can be observed that the amount of CB contents enhanced the surface morphology of pure ABS composite. Comparison was made from a previous study where the effect of compositions of glass fiber reinforced nylon 6-polypropylene composites on the flexural strength. A remarkable improvement on the flexural strength can be observed as the composition of glass fiber increased [14]. Corresponding to flexural modulus, increment values in flexural strength also contributes to the stiffness of ABS/CB composites. Stiffness of the ABS/CB composite were increased gradually as the CB contents increased might be due to the improvement in interfacial bonding. A study explained that the improvement of interfacial bonding can be made when the higher compaction load is supplied [15].

B. The effect CB content on impact strength

Based on **Fig. 3**, the relationship between impact strength and percentage of CB blends was illustrated in the plotted graph

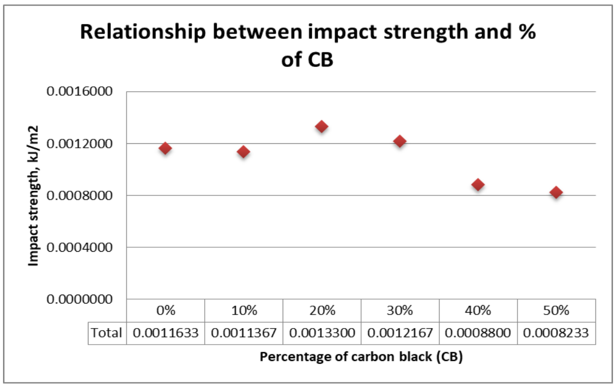

Figure 3: Impact strength at various concentration of CB (%)

From the data obtained, it can be observed that the data was inconsistently decreasing. The lowest value of impact strength was exhibited by reinforced ABS with 50% CB blends while at 20% CB; the material seemed to achieve the highest value of impact strength with a value of 0.00133kJ/m2. As for pure ABS (0% CB), it was denoted that the value of impact strength is lower than the value of impact strength for a ratio for ABS: CB of 4:1. It showed that specimen at 20% of CB blends has the highest ability to withstand the high rate of loading. At 50% of CB contents, sudden shock absorbed by the specimen was the lowest as less strength was needed for the specimen to break or deform.

These data for impact test showed that the results were slightly contradicting with to the previous studies done by Sahab et al.[10]. As stated by Saheb et al.[10],in the case of HNTs+CB reinforced ABS/PP the values of impact strength seemed to be decreased as compare to pure composite of ABS/PP. Almost similar outcomes from a study by Pustak et al.[4] can be used in order to strengthen the statement regarding on the relationship between filler contents and impact strength. The value of impact strength will decrease predictably according to its nature, with every addition of silica fillers into iPP/silica composites [4].

Supposedly, the impact strength will be decreased progressively with higher concentration of CB because the tendency of breakage should be higher for the ABS/CB composites with more CB contents when the load stroked the notched specimens. In **Fig. 3**, there were a slight deterioration in the value of impact strength for 0% and 10% of CB respectively. It can be speculated that it might have some errors during the tests were conducted due to several factors such as the aggregation tendency of the filler, at which condition the fillers will form into cluster. The aggregated filler or clumping filler can be a disturbance in the homogeneity of the composite material then leads to lower mechanical strength. The aggregated filler can interrupt the homogeneity of the composite which then leads to lower the mechanical strength

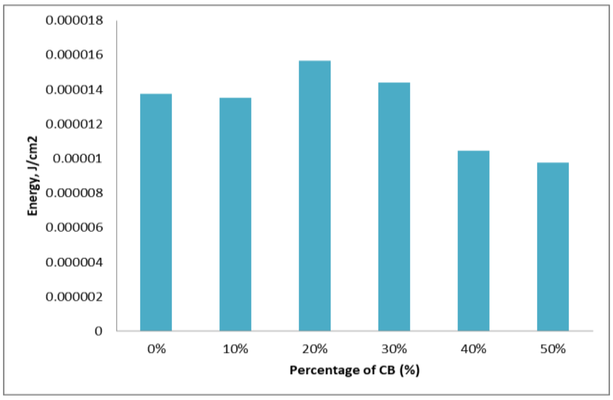

Figure 4: The amount of absorb energy to break the samples based on the percentage of CB

Fig. 4 indicates that the amount of energy absorbed by the ABS/CB composites in order to fracture or break. Same as the data for impact strength, the impact energy should be decreased as there is increment in percentage of CB. From the graph plotted in **Fig. 4**, ABS/CB composite with 20% of CB contents yields the highest value of impact energy where theoretically, the highest impact energy should exhibits by pure ABS compound. The increment in absorbed energy is an indication of extent of damage sustained on the surface of the specimens [11]. The more brittle the material, the lower the amount of absorbs energy to break the specimen hence will resultant to low impact strength [16].

This research studied that the effect for addition of filler contents can change the impact strength of a composite. In general, impact strength is the ability of material to absorb sudden shock from outer sources, and it is also called as material's toughness where a material with low toughness is a brittle material. Impact strength also can be affected by several factors such as the severe mixing process and uniform dispersion of impact modifiers [12].

IV. CONCLUSION

Reinforcement of ABS/CB was done through several steps of preparation and the mechanical properties for this composite were tested. Results showed that mechanical properties of the composites were related to their filler content. The effects on mechanical properties of the composite due to the homogeneous mixing of ABS and CB were studied. Compared to impact strength, the flexural modulus and flexural strength increased gradually when the percentage of CB blends increased. Other than that, the higher value of flexural modulus indicates the higher stiffness of ABS/CB composites. In this research, the data obtained for impact strength showed inconsistency as it should be decreased gradually with added amount of CB contents. It proved that filler loading can affect the mechanical properties for composite materials. The stronger interfacial bonding of ABS/CB will leads to the higher the values of flexural modulus and flexural strength. Hence, the material will be stiffer with the addition percentage of CB. The deterioration of analysis for impact strength may affected by other parameters such as temperature and morphology. It can be conclude that if the material is more brittle or easy to break; the impact strength will be lower as the amount of energy absorbed is limited. From this research, 50% of CB has the lowest amount of energy absorbed and impact strength and this statement is corresponding to the principle of flexural modulus.

As suggestions, additional studies should be carried out to investigate other factors that may effect on mechanical properties of ABS composite such as temperature and morphology analysis.

ACKNOWLEDGMENT

Thank you to my supervisor, Madam Sakinah binti Mohd Alauddin and Universiti Teknologi Mara for giving me chances to carry on with this research project. I would like to thank my fellow friends who helped me during carry on with this research.

References

[1] Witz, C & Sanchez Somolinos, Carlos & Bastiaansen, Cees & Broer, DJ. (2005). *Handbook of Polymer Reaction Engineering*, edited by T. Meyer and J. Keurentjes.

[2] Yao, S., Jin, F., Rhee, K. Y., Hui, D., & Park, S. (2018). Recent advances in carbon fiber-reinforced thermoplastic composites: A review. *Composites Part B: Engineering*, 142, 241-250. doi:10.1016/j.compositesb.2017.12.007

[3] Wang, F., Hong, R., Feng, W., Badami, D., & Zeng, K. (2014). Electrical and mechanical properties of ABS/EPDM composites filled with carbon black. *Materials Letters*, 125, 48-50. doi:10.1016/j.matlet.2014.03.136

[4] Pustak, A., Leskovac, M., Denac, M., Švab, I., Pohleven, J., Makarovič, M., Šmit, I. (2014). Interfacial and mechanical properties of polypropylene/silica nano- and microcomposites. *Journal of Reinforced Plastics and Composites*, 33(9), 851-861. doi:10.1177/0731684413518827

[5] Senthivel, K., Manikandan, K., & Prabu, B. (2015). Studies on the Mechanical Properties of Carbon Black/Halloysite Nanotube Hybrid Fillers in Nitrile Rubber Nanocomposites. *Materials Today: Proceeding*s, 2(4-5), 3627-3637. doi:10.1016/j.matpr.2015.07.118

[6] Wypych, G. (2016). *Handbook of fillers*. Toronto: Chemtec Publishing.

[7] Huang, Y., & Schadler, L. S. (2017). Understanding the strain-dependent dielectric behavior of carbon black reinforced natural rubber – An interfacial or bulk phenomenon? *Composites Science and Technology*, 142, 91-97. doi:10.1016/j.compscitech.2017.02.003

[8] Weaver, A. (2017). Mechanical and electrical properties of 3D-printed acrylonitrile butadiene styrene composites reinforced with carbon nanomaterials (Unpublished master's thesis).

[9] Lee, J., Lee, J., Pandey, J., Ahn, S., & Kang, Y. J. (2010). Mechanical Properties and Sound Insulation Effect of ABS/Carbon-black Composites. *Journal of Composite Materials*, 44(14), 1701-1716. doi:10.1177/0021998309357673

[10] Saheb, M., Tambe, P., & Malathi, M. (2017). Infleuence of Hybrid Fillers on Morphological, Mechanical and Thermal Properties of ABS/PP Blend. *International Journal of Chemical Sciences*,15(1), 111.

[11] Balan, R, et al.(2014) "Estimation of Residual Flexural Strength of Unidirectional Glass Fiber Reinforced Plastic Composite Laminates under Repeated Impact Load." *Journal of Composite Materials*, vol. 49, no. 6, May 2014, pp. 713–722., doi:10.1177/0021998314525484.

[12] Campo, E. Alfredo.(2008) "Mechanical Properties of Polymeric Materials." Selection of Polymeric Materials, 2008, pp. 41–101, doi:10.1016/b978-081551551-7.50004-8.

[13] Kim, Kyo-Han, et al., (2002) "The Effect of Filler Loading and Morphology on the Mechanical Properties of Contemporary Composites." *The Journal of Prosthetic Dentistry*, vol. 87, no. 6, 2002, pp. 642–649., doi:10.1067/mpr.2002.125179.

[14] Kusaseh, N. M. et al., (2018). Flexure and Impact Properties of Glass Fiber Reinforced Nylon 6-Polypropylene Composites. *IOP Conference Series: Materials Science and Engineering*, doi:10.1088/1757-899X/319/1/012045.

[15] Iqbal, AKM. & Amierah,N. (2017). Effect of reinforcement volume fraction on the mechanical properties of the Al-SiC nanocomposite materials. *IOP Conference Series: Materials Science and Engineering*. 226. 012168. 10.1088/1757-899X/226/1/012168.

[16] Amrishraj, D., and T. Senthilvelan. "Acrylonitrile Butadiene Styrene Composites Reinforced with Nanozirconia and PTFE: *Mechanical and Thermal Behavior." Polymer Composites*, vol. 39, no. S3, 2017, doi:10.1002/pc.24421.