Flexural Properties of Fly Ash filled (0-80%) Polypropylene Composite

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Abstract— **Fly ash (FA) is an industrial waste that is obtained from thermal power plant. Fly ash helps to improve the mechanical properties of base polymer matrices as fillers. The purpose of this study is to conduct the composite consisting of PP and FA and also to test the flexural properties of the composites. In this research, the concentration of fly ash was varied from 0 to 80% by weight. All the composites were prepared using twin screw extruder machine and then test specimens were prepared using injection molding machine. A Universal Testing Machine (UTM) will be used to conduct flexural test. Based on this experiment, the flexural strength and flexural modulus are decreasing as the filler concentration increases due to the agglomeration of particles at the higher concentration of filler and the particle has lower chances to interact with the matrix in the high concentration of filler.**

Keywords— fly ash, flexural test, polypropylene

I. Introduction

The use of fly ash as filler for polymer matrix has gained interest in the recent years due to the low cost of production of product. It is a cheap material, always available and also cut the overall cost [1]. However, fly ash and base polymer matrix does not easily blend due to the dissimilarity in surface chemistry as the fly ash filled thermoplastics are often weak than the unfilled matrix. Various studies have showed the excellent compatibility of fly ash and polymers [2]. Other research has found that the consumption of resin can be reduced by the use of cenosphere [3]. Cenosphere also leads to cut the cost of products based on the polymers composites [4]. Das and Satapathy (2011) have investigated the structural, thermal, mechanical and dynamic mechanical properties of cenosphere filled polypropylene composites. It was observed that the composites are undergoing different modes of damage or fracture at the microscopic level under uni-axial tensile loading conditions when cenosphere was added to polypropylene. The Young Modulus is increased due to the rigid filler-matrix interface predominate and the decreased in tensile strength theoretically is because of the poor state of filler-matrix interfacial adhesion and also the presence of voids in the composites [5]. Gumandi *et al.* had conducted the evaluation of flexural properties of fly ash filled polypropylene composites. It was found that the larger particle size of fly ash can decrease the rate of flexural strength while the smaller particles showed higher value of flexural strength. For the flexural modulus, it shows that the smaller filler loading increases and decreases of flexural modulus for larger filler loading. The amount of fly ash different sizes added to the polypropylene and the percentage elongation at break is also decreases on addition on filler. Therefore, fly ash added to the polypropylene can improve the flexural strength and flexural modulus, but dramatically decreases percentage elongation at break [6]. The objectives of this research is to conduct the composite consist of PP and FA and to test the flexural properties of the sample composites using UTM.

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II. Methodology

A. Materials

Homo-polymer of polypropylene was supplied by Total Petrochemical and Refining USA with the density of 0.91 kg/m^3. Fly ash was supplied by Kapar Power Plant, Kapar, Selangor, Malaysia. Table 1 shows the general chemical composition of fly ash.

Table 1: General chemical composition of fly ash [2]

Cenosphere constituents	Composition (wt%)
SiO_3	56 – 60
Al_2O_3	25 - 35
Fe_2O_3	1 – 6
CaO	0.2 – 0.6
MgO	0.5 – 2
Na_2O	0.5 – 2
K_2O	1 - 2

B. Sample Preparation

Fly ash was washed in a tray with distilled water to remove any impurities. Then, the wet fly ash was dried and passed through sieve shaker Model Endecotts Octagon 2000 digital. The particle size was selected as the particle passed through sieve with cell diameter of 125 microns with the ASTM No 120.

Figure 1: The sieve shaker Model Endecotts Octagon 2000 digital

Next, Fly ash particles then dried at room temperature for 24 hours to reduce the moisture content. On the next day, the fly ash was kept in the oven for 15 minutes at 120^{0}C to remove the remaining moisture content of the fly ash.

C. *Composites*

PP-FA composites were prepared with different concentration of fly ash of 20, 40, 60 and 80% by weight using co-rotating twin-screw extruder to blend the fly ash and polymer. The total weight of FA/PP is 20g. The temperature when using screw extruder has several range of temperature around 180^{0}C to 250^{0}C. By doing try and error, the optimization temperature for PP was set to 220^{0}C, 220^{0}C, 220^{0}C, 220^{0}C, 220^{0}C and 200^{0}C from feed zone to die zone respectively. The revolutions per minute (RPM) were set around 50 for the unfilled and filled composites. Feed rate was around 25 g/min. The extruders were cooled at room temperature and then granulated.

Figure 2: Co-rotating twin screw extruder

D. *Test Specimens*

The granulated then were fed into the Injection Molding Machine (IMM) model BOY22A to prepare test specimen. Barrel temperature of rear zone, middle zone and nozzle zone were set to 200^{0}C, 200^{0}C and 210^{0}C respectively. According to the manual, this is the suitable temperature to melt PP/FA in the molding machine. The injection pressure were applied for 4s and varied from 90 kg/cm^2 for unfilled and filled PP. Screw speed set to 240 rpm and injection speed was 1m/s. The samples of PP composites prepared were kept at room temperature for 24 hours to promote relaxation of stress.

Figure 3: Injection Molding Machine (IMM)

E. *Measurements*

Flexural properties were tested using Universal Testing Machine with per ASTM D790. Flexural properties were speed of 50 mm/min. Load cell of 5kN was used to sense the load. Width and depth of specimen were 12.5 and 6.5 mm respectively, support span length of 100mm was selected and rate of crosshead motion was at 2.8 mm/min.

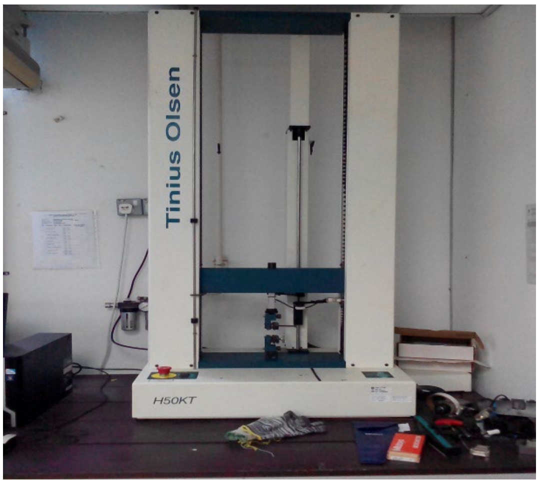

Figure 4: Universal Testing Machine (UTM)

III. RESULTS AND DISCUSSION

(A) Composite consist of PP and FA

Figure 5 shows the test specimens that had been mold using IMM. From the figure, we can see that the light color is the pure PP used. The darker the color of test specimens, it is means that the concentration of FA is higher.

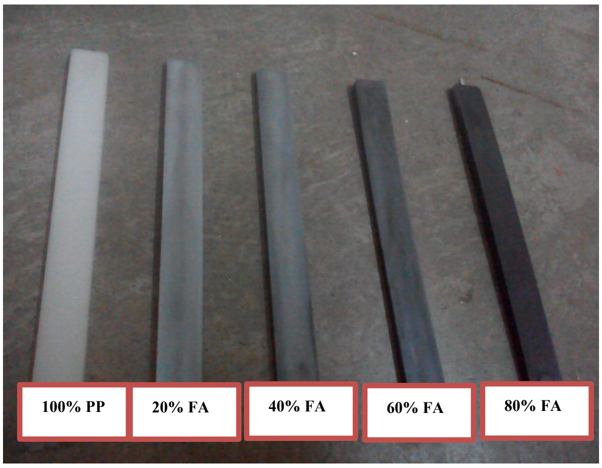

Figure 5: Test Specimens.

(B) Flexural properties of the sample composites

By using rotating screw extruder, the percentage of fly ash and polypropylene granule had been mixed together to get the granule of fly ash filled polypropylene. Table 2 shows the flexural strength and Flexural Modulus of the composites. From Figure 6, it was observed that as the addition of filler increases, the flexural strength is decreasing.

From Figure 3.1, it was observed that rate of flexural strength. This is because of the particle agglomeration at higher filler contents. Particle agglomeration can reduce the strength a material due to the weak point in material of agglomerates. When stress or force is applied to them, it can be easily break. These points then acts as stress concentrator. Agglomerations resulting from larger sized filler particles will produce weaker materials than composites having well dispersion of small sized particles. The rate of decrease of flexural strength is higher in the case of larger particle size of fly ash.

Table 2: Flexural strength and Flexural Modulus

Fly Ash Concentration (%)	Force (N)	Deflection of center of test specimen (mm)	Flexural Strength (MPa)	Flexural Modulus (MPa)
0	34.315	8.945	35.74	701.25
20	33.594	15.260	34.99	684.61
40	29.688	18.083	30.92	534.43
60	30.469	16.860	31.74	649.95
80	16.406	15.929	17.09	594.04

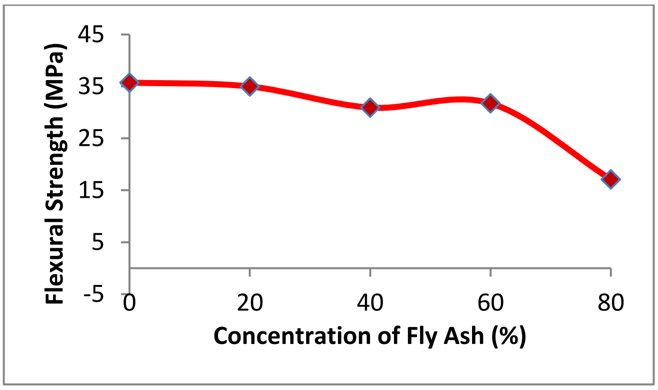

Figure 6: Flexural strength with percentage of fly ash added to the polypropylene composite

Table 3 shows the flexural modulus of PP-FA. Figure 6, shows the variation of flexural modulus of fly ash composite with filler content. Flexural modulus is not stable. Some of the value is increasing and some of it decreasing. Rate of increase is because of the surface area contact which can make the particle having higher interaction with matrix at the lower concentration. If agglomeration is present, the apparent volume occupied by the filler is increased and agglomeration results which void space is generated, which can be responsible for strain propagation. The increase in the flexural modulus of PP fly ash composite is due to the increase in the crystalline of composites by addition of fly ash.

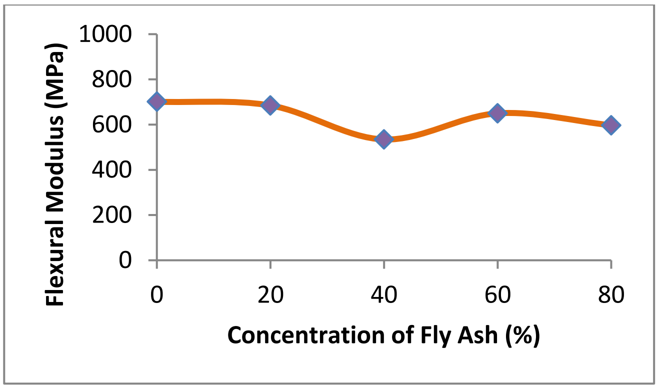

Figure 7: Flexural modulus with percentage of fly ash added to the polypropylene composite

IV. Conclusion

The flexural properties of fly ash filled polypropylene composites were evaluated in the present research work. Fly ash is found to be good filler for polypropylene matrix composites. With fly ash added to the polypropylene, it can improve the flexural strength and flexural modulus. Spherical shaped filler, such as fly ash gives significant improvement in stiffness due to better surface area for interaction. It is concluded that composites with fly ash showed significant improvement mechanical properties of composite.

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