American Journal of
Polymer Science & Engineering

American Journal of
Polymer Science & Engineering
http://www.ivyunion.org/index.php/ajpse/index
Vo2. 1, Article ID 201400366, 8 pages

Research Article

Mechanical Properties and Modeling of Fibreglass-reinforeced Epoxy Resin Wastes-filled Polypropylene

Francis N. Onuoha* and C.B.C Ohanuzue

Department of Polymer and Textile Engineering, Federal University of Technology Owerri, P.M.B. 1526, Owerri, Imo State, Nigeria

Abstract

The polymer composites were prepared from fiberglass reinforced polymer wastes obtained from cross-arm manufacturing and injection moulded after treating with latex and oven dried to reduce the itching nature of the fiberglass. The samples were size-classified as 150, 200, 250 and 300 microns. Tensile tests were later carried out on them. The mechanical properties determined include Tensile strength, Elongation at break, Hardness and Indentation. It is discovered that the tensile strength and indentation increased with increasing filler loadings while elongation and hardness decreased. The research was modelled to obtain higher filler weight percentage values that were not got in the laboratory after accurate and precise predictions were made with Matlab modelling software. The modeling was used to obtain the optimal and best results of the particle sizes.

Keywords: Polymer composites; Particle sizes; Filler Weights; Flammability Properties and Modeling
Academic Editor: Taihong Shi, PhD, PhD, Sun Yat-sen University, China
Received: April 16, 2014; **Accepted**: August 26, 2014; **Published**: September 13, 2014
Competing Interests: The authors have declared that no competing interests exist.

***Correspondence to**: Department of Polymer and Textile Engineering, Federal University of Technology Owerri, P.M.B. 1526, Owerri, Imo State, Nigeria; Email: francorev2007@yahoo.com

1. Introduction

The essential characteristic of reinforced thermoplastics materials is that they may be shaped by melt fabrication techniques, that is injection moulding and to a lesser extent, extrusion, blow moulding and thermoforming. In principle, the thermoplastic suffers no chemical alteration during the processing cycle and may thus be reprocessed several times. In practice, this ideal is seldom approached since the materials are affected by thermal, mechanical and oxidative degradation. Generally, the most serious limitation of thermoplastic based materials is their lower thermal stability.

In the related literature, it has been reported that most polymer composites involve fibers reinforcement, for instance, bamboo fibers (Chen et al, 1998), fibers from oil palm empty fruit bunch (Rozman et al, 2003), aspen fibers (Coutinho et al, 1997 and 1998). These composites bring about greater mechanical properties than those of polymers alone especially the Young's modulus and Flexural modulus (Chen et al, 1998; Rozman et al, 2003; Countinho et al,1997 and 1998; Marcovich,1999).

Furthermore, the application of coupling agents such as maleic-anhydride grafted polypropylene (MAPP) (Chen et al, 1998; Rozman et al, 2003; Countinho et al, 1997 and 1998; Marcovich et al, 1998) or Silane coupling agent (Countinho et al, 1997 and Malda and Kokta, 1991), have received much attention on the account of their effectiveness in intensifying phase compatibility between the polymer matrix and reinforcement loading to preferred mechanical properties of the composites.

In general, solid additives such as fillers and reinforcing agents improve impart strength, flexural strength, tensile strength and heat distortion temperature of polymers (Katchy, 2000).
Thus polyester with a modulus of 2-4 GPA and a tensile strength of 20-70 Mpa when reinforced with short glass fibres yields composites of modulus 10GPa and tensile strength of 110MPa. The ratio of the modulus of filled polymer to that of unfilled polymer at the same strain is known as the enhancement factor. For a given system, the enhancement factor depends on the amount and type of filler that is used, shape of particles, length to diameter ratio and orientation of the fibers (Katchy, 2000).

Generally, fine particles when well dispersed improved the impact behaviour. Inadequate dispersion of filler particles can be a possible cause of crack initiation and feature in service.
The enhancement factor decreases with increasing strain (Katchy, 2000) so that in assessing filler, modulus measurements should preferably made at strains to which the material is likely to be subjected.

The physical and mechanical properties of polymer/filler composites are known to be dependent upon the dispersion and size of fillers in polymer matrices (Tjong et al, 2008). The study shows that a uniform dispersion of fillers in polymer matrices usually leads to enhanced properties, but poor dispersion may result in a drastic deterioration of properties. Materials design or selection method is considered as an effective route to control the dispersion of fillers in polymer matrices. This method is based on proper selection of appropriate polymeric materials of the composites such that reinforcing fillers are dispersed uniformly in desired phases. A typical example is the dispersion of filler particles in the carbon black reinforced polyethylene/polystyrene composites (Tjong et al, 2008). In this system, carbon black particles are found to disperse either within Polystyrene or Polyethylene phase or at their inter phase region. According to the study, such dispersions of carbon black particles greatly affect the electrical properties of the mechanical properties of the composites (Tjong et at, 2008). This issue can be solved by using semi-crystalline homopolymers, such as polyethylene, as the matrix of the composites (Tjong et al, 2008). Semi crystalline polymers generally have crystalline and amorphous phases and their morphology can be tailored by controlling the crystallization conditions. (Tjong et al, 2008).

This present study investigated the mechanical properties of the fiberglass waste from cross-arm production as a filler to reinforce Polypropylene.

2. Materials and Method

2.1 Sample Preparation

The fiberglass reinforced plastic wastes were cut in small pieces (10mm x 10mm) using a hand saw. They were then ground with a saw mill to get them in fibrous form. They were later sized with latex rubber to reduce the itching nature of the fiber and to enable it to be ground into powder form with a manual grinder. The powdered form was then size-classified as150microns, 200microns; 250microns and 300microns. The FRP waste fillers and the fiber-forming polypropylene were weighed with an electronic weighing machine according to the filler-polymer ratio 100/0%, 97.5/2.5%, 95/5% and 90/10%.

The FRP filler/polymer compositions at the various loadings were fed into the injection moulding machine at Ceeplast Industries Nig. Limited, located in Aba, Abia State, Nigeria for proper mixing and homogenization. 2 % (4g) maleic grafted Polypropyle (MA-g-PP) was added constantly as a compactibilizer. Glycerol was added as a plasticizer to reduce the modulus of the composites by lowering its glass transition temperature, T_g. The molten mixture was produced in sheets form and then put in water to allow or cooling. The sheets were then cut according to standards for the various tests.

2.2 Modeling

The modelling was performed with Matlab software. It requires a little knowledge of programming language. The dependent and independent variables were defined and the ‘polyfit’ command used to produce the modeling equations. The equations that did not produce line of best fit were subjected further to least square polynomial fit by designing the process blocks.

3. Results and Discussion

3.1 Tensile Strength

The results obtained showed that the tensile strength increased with increasing fiberglass content since the strength of the fiberglass (reinforcing element) is greater than that of pure polypropylene matrix. This could be as a result of high tensile strength possessed by the fiberglass itself and the reinforced epoxy resin waste. The tensile strength of 10 wt% was around 40% higher than that of pure polypropylene (see Fig. 3.1). [Hornsby, 1994] [Wang et al., 1996] and [Wang et al., 2001] in their discoveries found out that more than 60 wt% loading of metal hydroxide was required to obtain adequate flame-retardant property and such high loading leads to a great decrease in the mechanical properties of filled polymer materials. However, in the fiberglass reinforced polymer waste filled polypropylene investigated, it was discovered that increase in the filler loading up to 10 wt% had a great improvement in the tensile strength of the composites. Also, from the modeled data, the tensile strength increased beyond 10 wt% without affecting the flame retardance result. This could be attributed to the high strength and stiffness of the filler and the materials used in the reinforcement of the fiberglass reinforced polymer wastes.

All the fiberglass reinforced polymer waste filled polypropylene had improved tensile properties than the individual tensile properties of epoxy composites and pure polypropylene.

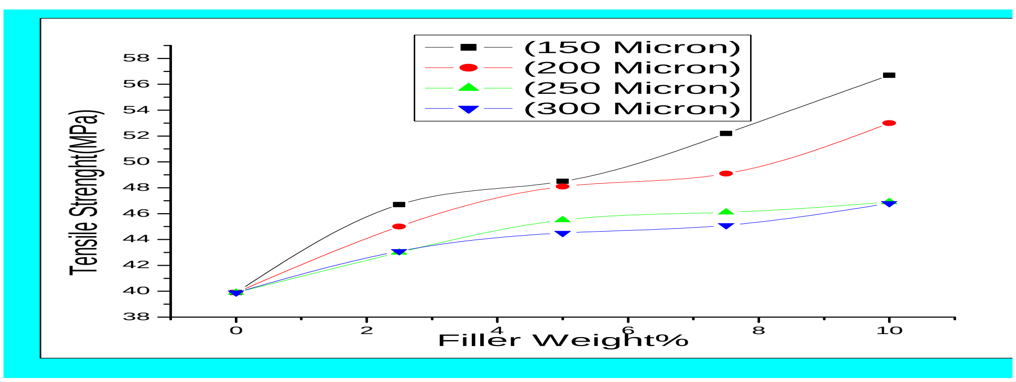

Fig. 3.1 Graph of Tensile Strength against Filler Content

3.1.1 Modeling of Tensile Strength

The model curve equation is given as: $TS_m = 0.0192x^3 – 0.3371x^2 +2.551x + 39.91$ [3.1]

The 300 microns gave the best fit with coefficient of regression, R of 0.9989. The maximum tensile strength of the 300 Micron at 20 wt% was 91.7MPa.

The 150 and 200 microns had upward deviations to the model curve from 0 -10 wt% while the 250 and 300 microns exhibited downward deviations. When the filler loadings were predicted up to 20 wt%, the tensile strength of the various composites had smooth and gradual increase in strength. However, the 250 Micron had a slight fall in strength.

3.2 Elongation at Break Test Results

The results revealed that the addition of fiberglass fillers decreased the elongation at break of the composites (see Fig. 3.2). This could be attributed to the stiffness and brittleness of the fiberglass and the epoxy resin waste. Hence, the composites developed lower elasticity than the virgin polypropylene. Besides, the breakage of the material initiates from the interface between polymer matrix and additives. When the fibreglass increased, the breakage increased. The results showed that the %elongation of the 10wt% was 65% decreased from that of the virgin polypropylene. The incorporation of maleic-anhydride grafted polypropylene (MA-PP) led to a slight increase in the elongation at break.

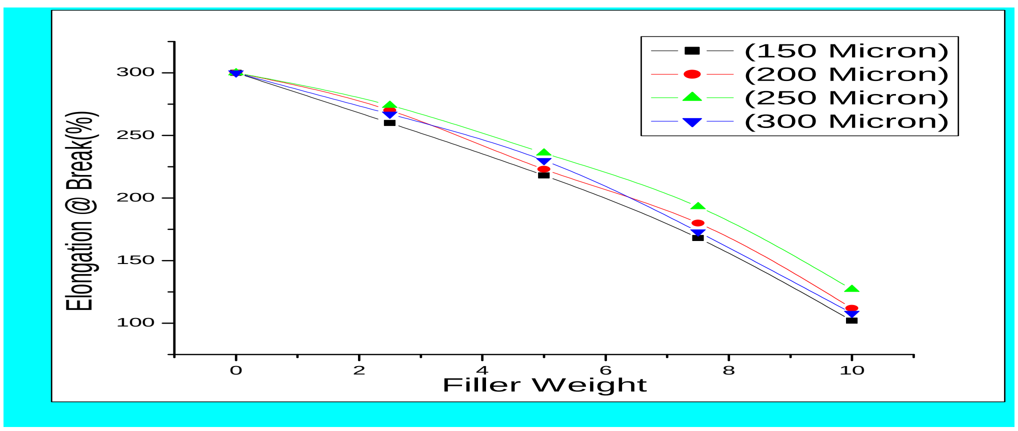

Fig. 3.2 Graph of Elongation at Break Vs Filler content

3.2.1 Modeling of Elongation at Break

The model curve equation is given as:

$$E_m = -0.02133x^3 - 0.64x^2 - 10.67x + 299.6 \qquad [3.2]$$

The 250 micron gave the best fit with coefficient of regression, R of 0.9995. The 150 and 250 microns had noticeable downward and upward deviations repectively, while the 200 and 300 microns had close relations with the model with the 200 micron having slight downward deviation between 3 -6 wt% and upward deviations at 2.5 wt% and 7.5 wt%.

3.3 Hardness Test Results

From the results, the hardness was increased with increasing filler loadings (see Fig.3.3). This could be attributed to the stiffness and rigidity of the fiberglass. Also, the toughness of the polyester resin could be the reason for this increase.

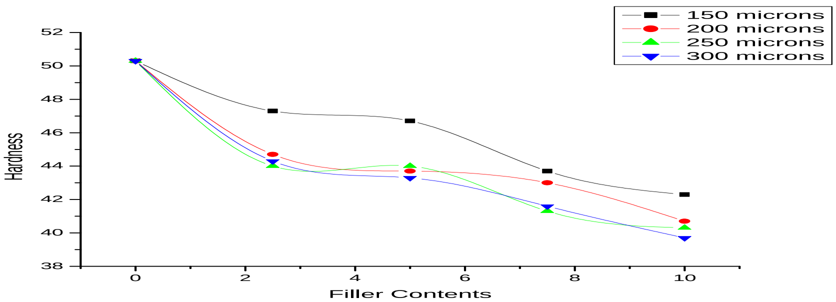

Fig. 3.3 Graph of Hardness against Filler Contents

3.3.1 Matlab Modeling of Hardness

The model curve equation: $HD_m = -0.0235x^3 + 0.4160x^2 -2.7733x + 50.2$ [3.3]

The 200 micron gave the best fit with coefficient of regression, R of 0.9984. The 150 micron had a remarkable upward deviation while the 250 and 300 microns had downward deviations. The 200 micron had a slight upward deviation between 0 -1.5 wt%, a downward deviation between 1.5 - 6.5 wt% and another upward deviation between 6.5 - 10 wt%.

3.4 Indentation Test Results

The indentation was increased gradually with respect to filler loadings. The 300 microns had highest indentation than the other samples. The curve is shown in Figure 3.4.

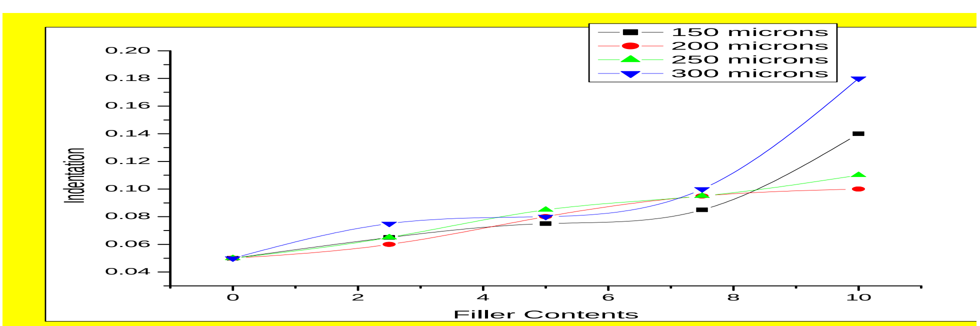

Fig. 3.4 Graph of Indentation against Filler Contents

3.4.1 Matlab Modeling of Indentation

The model curve equation:

$$ID_m = 0.0001x^3 – 0.0018x^2 +0.0097x + 0.0499 \quad [3.4]$$

The 300 micron gave the best fit with coefficient of regression, R of 0.9998. All the composites exhibited a rise and fall deviation from the model curve.

4. Conclusion

The polymer composites were prepared from fiberglass reinforced polymer wastes obtained from cross-arm manufacturing and injection moulded after treating with latex rubber and oven dried to reduce the itching nature of the fiberglass.

From the experimental results, it is observed that the tensile strength and indentation increased with corresponding increase in filler loadings while elongation at break and hardness decreased. Using modelling, it was observed that the 150microns particle size had the best performance on the mechanical properties of the composites. These were attributed to the enhanced properties of fiberglass used for the reinforcement.

References

1. Chen X, Gue Q and Mi Y. Bamboo Fibre-Reinforced Polypropylene Composites: A Study of the Mechanical Properties. ***J Appl Polyrn Sci***. 1998, 69:1891-1899
2. Coutinho FMB and Costa THS. Performance of Polypropylene-Wood Fibre Composites. ***Polymer Testing***. 1999, 18, 581-587
3. Chuanmei J and Xilei C. Flammability and Thermal Degradation of Intumescent Flame-Retardant Polypropylene Composites. ***Wiley InterScience***. 2009
4. Katchy EM. Effects of Additives on Mechanical Properties of polymers. ***Principles of polymer Science***. 2002
5. Marcovish NE, Maria M, Reboredo Mirta I. Aranguren. Mechanical Properties of Wood flour/ Kenal Fibre Polypropylene Hybrid composites. ***Journal of Applied Polymer Science***. 1998, 70: 2121-2131
6. Mouritz AP, Mathys Z and Gibson AG. Heat Release Rate of Polymer Composites in Fire. ***Composites Part A: Applied Science and Manufacturing***. 2006, 37:1040-1054
7. Tjong SC, Liang GD and Baso SP. Effects of crystallization on dispersion of carbon Nanotubes and Electrical properties of polymer Nanocomposites. ***J PolymEng Sci***. 2008

8. Stark NM et al. Flame Retardant and Mechanical Properties of Natural Fibre/Polypropylene Composites containing Magnesium Hydroxide. ***Polymer Degradation Stabilization*.** 2004, 83: 363-367
9. Weil ED. In Fire and Polymers. ACS Symposium Series 425, ***ACS***, Washington DC, 1990, 97-108