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European Journal of Advances in Engineering and Technology, 2017, 4(8): 617-622

Research Article ISSN: 2394 - 658X

Effects of Hydrogen Peroxide Treated Pineapple Leaf Powder on Mechanical Properties of High Density Polyethylene Composites

Eze IO[1], Igwe IO[1], Ogbobe O[1], Obasi HC[1], Ezeamaku UL[1], Nwanonenyi SC[1], Anyanwu EE[2] and Nwachukwu I[3]

[1]*Department of Polymer and Textile Engineering, Federal University of Technology, Owerri, Nigeria*
[2]*Department of Mechanical Engineering, Federal University of Technology, Owerri, Nigeria*
[3]*Department of Microbiology, Federal University of Technology, Owerri, Nigeria*
innocento4u@yahoo.com

ABSTRACT

The effects of hydrogen peroxide (H_2O_2) treated pineapple leaf powder (PALP) on the mechanical properties of high density polyethylene (HDPE) composites were studied. HDPE and PALP (untreated, and treated) composites were prepared by injection moulding technique. The filler (PALP) contents investigated were 2, 4, 6, 8, and 10 wt %. Results showed that the tensile strength, tensile modulus, flexural strength, abrasion resistance, and hardness of the composites increased with increases in filler content for all the filler contents investigated, while the elongation at break (EB) for PALP/HDPE composites was found to decrease with increases in filler content for all the filler contents investigated. It was observed from the results that H_2O_2 treated PALP/HDPE composites exhibited better mechanical properties than the untreated PALP/HDPE composites for all filler contents investigated. The present study has shown that surface treatment of PALP with H_2O_2 has proved to be an efficient alternative in bringing about an improved adhesion/compatibility between PALP and HDPE, thereby improving the mechanical properties of the composites.

Keywords: High density polyethylene, pineapple leaf powder, injection moulding techniques, surface treatment, mechanical properties

INTRODUCTION

Natural fibre-reinforced thermoplastic composites form a new class of materials which seem to have good potential in the future as a substitute for wood based material in many applications [1]. However, lack of good interfacial adhesion and poor resistance to moisture absorption makes the use of natural fibre-reinforced composites less attractive. Various fibre surface treatments like mercerization, isocyanate treatment, acrylation, latex coating, permanagante treatment, acetylation, silane treatment and peroxide treatment have been carried out which may result in improving composite properties [2-3]. Research on a cost effective modification of natural fibres is necessary since the main attraction for today's market of bio composites is the competitive cost of natural fibre. Interfaces play an important role in the physical and mechanical properties of composites. Natural fibres are amenable to modification as they contain hydroxyl groups from cellulose and lignin present in the fibres.

The hydroxyl groups may be involved in the hydrogen bonding within the cellulose molecules thereby reducing the reactivity towards the matrix. Chemical modifications may activate these groups or can introduce new moieties that can effectively interlock with the matrix [4-5]. Simple chemical treatments can be applied to the fibres with the aim of changing surface tension and polarity of fibre surfaces. Mir *et al* [6] investigated the mechanical properties of coir based polymer composites. The composites were prepared using coir fibre treated with varying pre-treatment conditions. The results showed increase in the mechanical and modulus of rupture properties of coir based polymer composites and these were as a result of chemical composition modification, and surface modification of the fibres. Li *et al* [7] studied flax fibre reinforced linear low density polyethylene (LLDPE) and HDPE bio composites processed by extrusion, and injection moulding processes. Five surface modification methods (alkali, silane, potassium permanganate, acrylic acid, and sodium chlorite treatments) were employed to improve the interfacial bonding between fibres and matrix. It was found that the biocomposite tensile strengths were increased after fibre surface modifications.

The aim of this paper is to investigate the effect of H_2O_2 treatment of pineapple leaf powder on the mechanical properties of pineapple leaf powder filled high density polyethylene. This was necessitated by the fact that sodium hydroxide treatment having performed when it was used to modify PALP surface in our previous research work, it was recommended that other types of surface treatments should be investigated to ascertain whether they will also perform. This, we believe, will give viable options to whoever wants to chemically modify natural fibres/fillers in polymer industry.

MATERIALS AND METHODS

Materials

High density polyethylene (HDPE) and pineapple leaf powder were used in this study. The high density polyethylene (HDPE) used in this study was obtained from Ceeplast Industries, Aba, Abia state, Nigeria. It has a density of 0.97 g/cm^3, and melt flow index of 9.0 g/10 min. at 170 ^{0}C. The pineapple leaves from where the powder was prepared were collected from a pineapple orchard near Umuagwo Polytechnic, Owerri, Imo State, Nigeria. Hydrogen Peroxide (H_2O_2) was the major chemical used. The processing equipment used includes Mesh sieve (0.3 mm), injection moulding machine (Negri Bossi, Italy), instron machine (Instron ltd., United Kingdom), electronic weighing balance (Contech, India), shredding machine, thermometer, oven, desiccator, grinding machine, personal protective equipments (PPEs).

Pineapple Leaf Powder Preparation

Pineapple leaves collected from Umuagwo, Imo State, Nigeria were cut into smaller sizes and sun-dried for fourteen days. The dried leaves were later oven-dried for 24 hrs at 80^{o}C prior to grinding. A manual grinder was used to grind the chopped dry pineapple leaves into powder. The pineapple leaf powder (PALP) obtained was sieved with a sieve grid of 0.3 mm (75 µm).

Hydrogen Peroxide Treatment

35g of PALP was placed in a 500 cm^3 beaker containing 320cm^3 hydrogen peroxide, and 1g of NaOH at 85^{o}C, and stirred for 1 hour. At the expiration of 1hr, the content of the beaker was filtered; the PALP was washed with distilled water, and dried in an oven at 50^{o}C to a constant weight. Later, the PALP was kept in a desiccator for subsequent use.

Preparation of High Density Polyethylene Composites

High Density Polyethylene composites of the pineapple leaf powder (PALP) were prepared by thoroughly mixing 200 g, 198 g, 196 g, 194 g, 192 g and 190 g of high density polyethylene with 0, 2, 4, 6, 8 and 10 wt % filler contents of the untreated PALP respectively. The process was repeated for the H_2O_2 treated PALP. The formulated blend compositions were each processed at the same temperature (165^{o}C) using an injection moulding machine.

Measurement of Mechanical Properties

Tensile properties of the composites were determined by using an Instron Testing Machine (Lloyds, capacity 1-20 kN) according to standard method (ASTM D638). The tensile properties of PALP/HDPE composites that were determined are: (i) tensile strength, (ii) elongation at break, and (iii) tensile modulus. Other properties of the composites that were determined are: (i) abrasion resistance (ASTM D1044), (ii) hardness (ASTM D2240), and flexural strength (ASTM D790).

RESULTS AND DISCUSSIONS

Mechanical Properties

Effect of H_2O_2 Treated PALP Content on Tensile Strength of Composites

The effect of filler surface treatment (H_2O_2) on the tensile strength of PALP/HDPE composites is shown in Fig.1. It can be observed that the H_2O_2 treated PALP/HDPE composites showed appreciable increases in tensile strength than the untreated PALP/HDPE composites for all the filler contents investigated. It has been reported that H_2O_2 treatment of fibres reduces the fibre diameter and increase the aspect ratio [8]. The report showed that H_2O_2 treatment helped in the removal of lignin and hemicellulose which affect the tensile characteristics of the fibres. When the hemicellulose is removed, the interfibrillar region is expected to be less dense and rigid, thereby making the fibrils more capable of rearranging themselves along the direction of tensile deformation [8]. This treatment also removes certain amounts of lignin, wax and oils covering the external surface of the fibre's cell wall, depolymerises the native cellulose structure and exposes the short length crystallites [7-9]. The tensile strength of the untreated PALP/HDPE composites was found to increase by 6.49% at 2 wt% filler content (least filler content), and 30.39% at 10 wt% filler content (maximum filler content). For the H_2O_2 treated PALP/HDPE composites, the tensile strength was increased by 21.66% at 2 wt% filler content, and 42.85% at 10 wt% filler content.

Effect of H_2O_2 Treated PALP Content on Tensile Modulus of Composites

It can be observed from Fig. 2 that the tensile modulus of PALP/HDPE composites increases with increase in filler content for both the untreated, and treated PALP/HDPE composites. Generally, incorporation of natural fillers into a polymer brings about increase in the tensile modulus of the polymer composite. The H_2O_2 treated PALP/HDPE composites was observed to be higher than that of the untreated PALP/HDPE composites for all the filler contents investigated. Valadez-Gonzalez *et al* [10] in their studies reported that H_2O_2 treatment of fibre has two effects on the fibre: (i) it increases fibre surface roughness resulting in better mechanical interlocking, and (ii) it increases the amount of cellulose exposed on the fibre surface, thus increasing the number of possible reaction sites in the fibre. It was also observed that H_2O_2 increases the stiffness of fibre as it modifies the fibre's surface. According to other authors [11], H_2O_2 treatment of natural fibres enhances both the tensile strength and tensile modulus of the fibres.

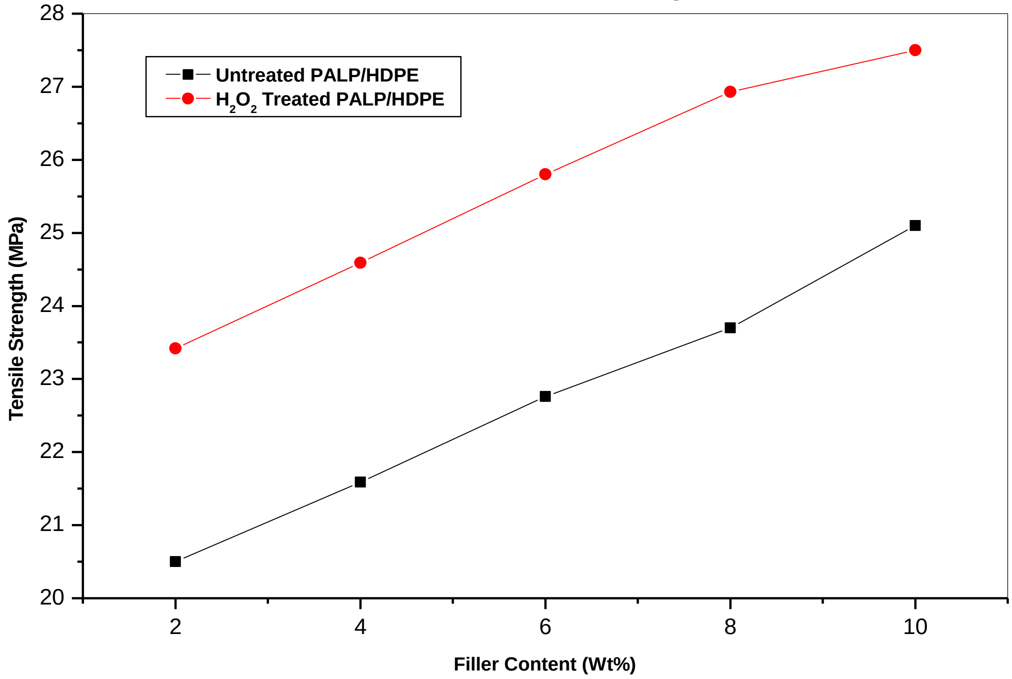

Fig. 1 Effect of H_2O_2 Treated PALP Content on Tensile Strength of Composites

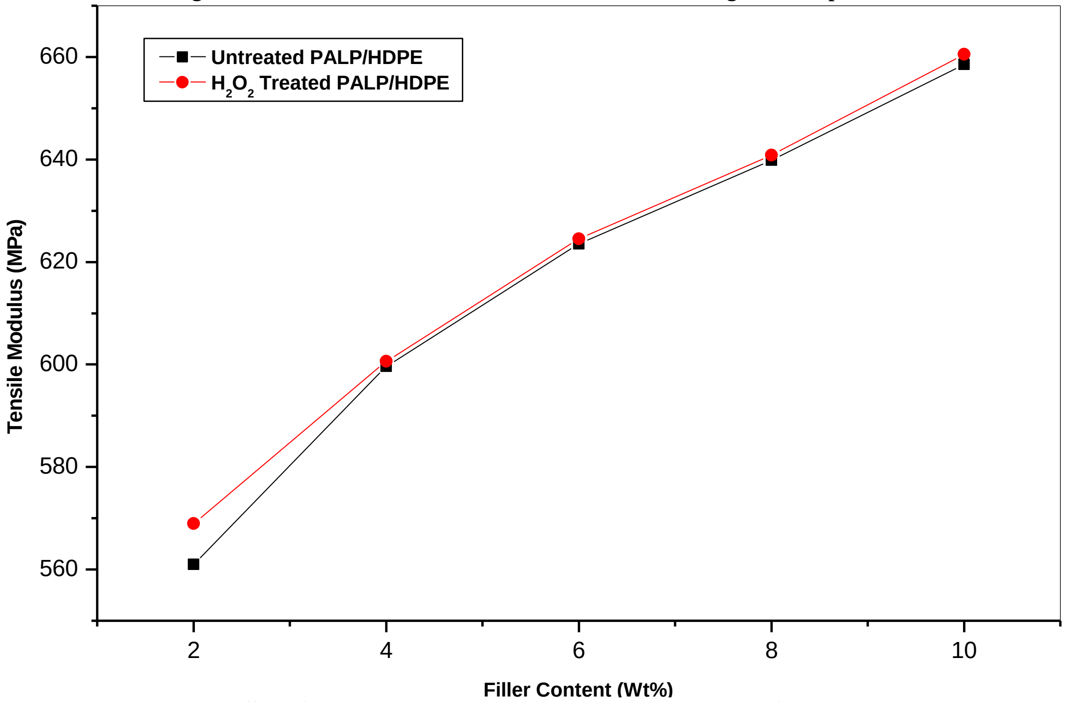

Fig. 2 Effect of H_2O_2 Treated PALP Content on Tensile Modulus of Composites

Effect of H_2O_2 Treated PALP Content on Elongation at Break of Composites

Jacob *et al* [12] in their studies reported that the addition of stiff fibre into a polymer matrix interrupted the polymer (HDPE) segments mobility and thus, making the polymer to become brittle. This makes the elongation at break of the composites to decrease with increases in filler content. From Fig. 3, the elongation at break of H_2O_2 treated PALP/HDPE composites was observed to be lower than that of the untreated composites for all the filler contents investigated. Generally, surface treatment makes fillers to become stiffer than the untreated fillers, thereby, further reducing their elongation at break [11-13]. The elongation at break of untreated PALP/HDPE composites was found to decrease by 2.40% at 2 wt% filler content, and 10.24% at 10 wt% filler content; while the elongation at break of H_2O_2 treated PALP/HDPE composites decreased by 14.91% at 2 wt% filler content, and 16.69% at 10 wt% filler content.

Effect of H_2O_2 Treated PALP Content on Abrasion Resistance of Composites

Fig. 4 shows that the abrasion resistance of PALP/HDPE composites increases with increase in filler content for both the untreated, and treated PALP/HDPE composites. The abrasion resistance of the H_2O_2 treated composites was observed to be higher than that of the untreated composites. This may be attributed to the fact that in addition to the H_2O_2 treatment making the filler (PALP) harder and stiffer than the untreated, the H_2O_2 may also hinder polymer chains mobility thereby making the polymer (HDPE) to become hard and stiff which will, in turn, further increase the abrasion resistance of the H_2O_2 PALP/HDPE composites [14].

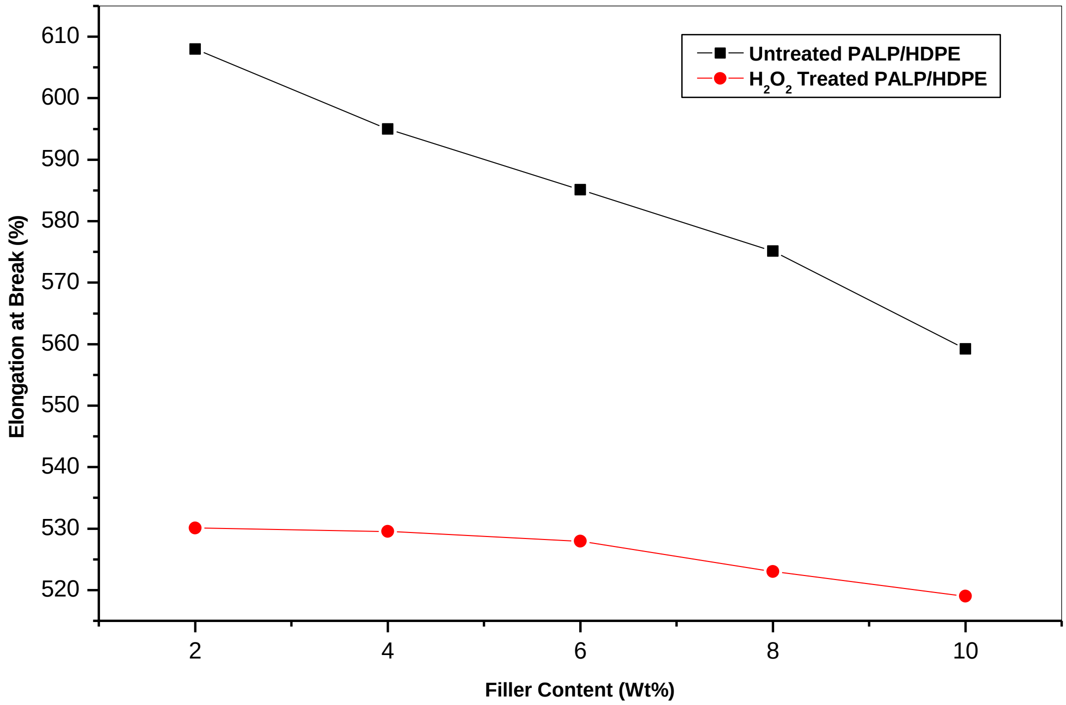

Fig. 3 Effect of H_2O_2 Treated PALP Content on Elongation at Break of Composites

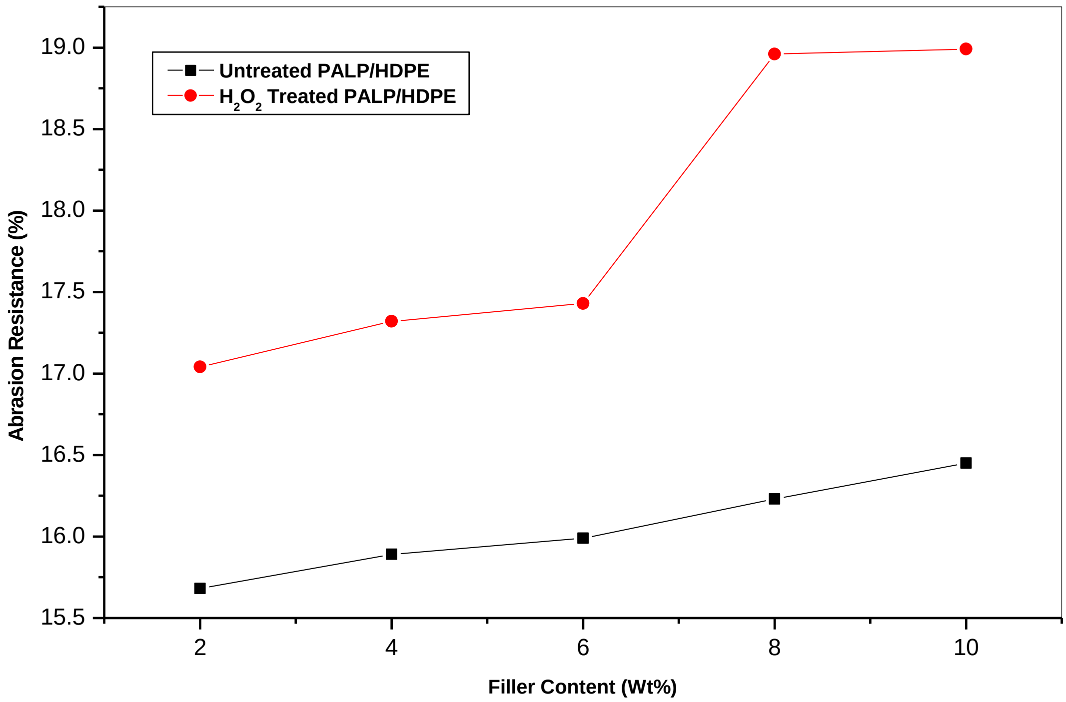

Fig. 4 Effect of H_2O_2 Treated PALP Content on Abrasion Resistance of Composites

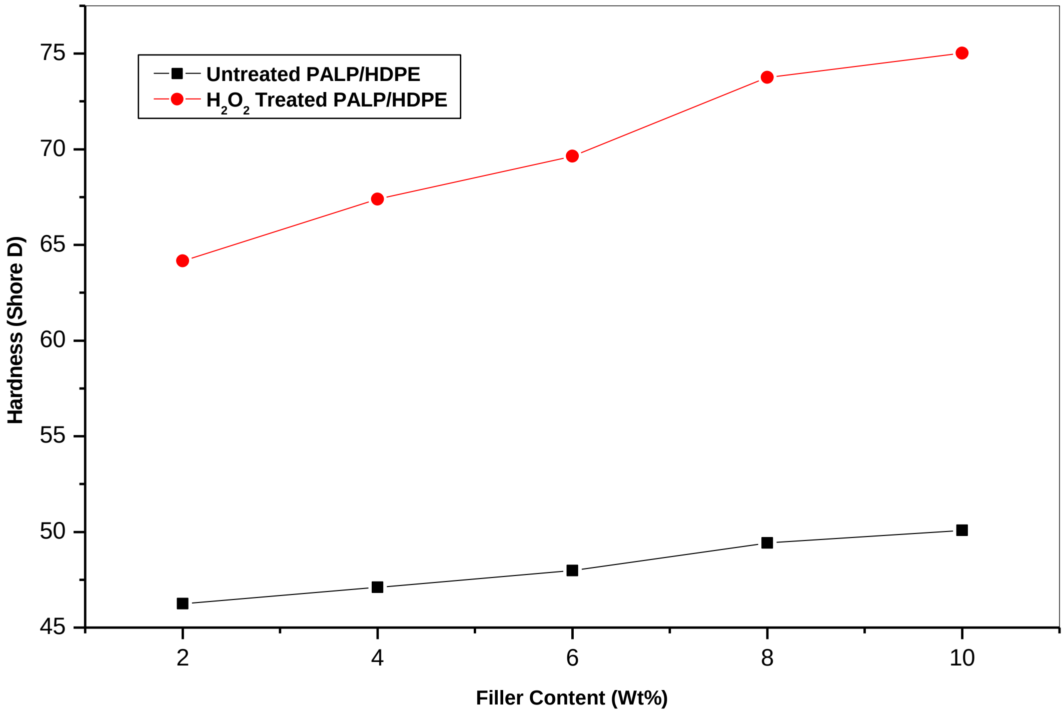

Fig. 5 Effect of H_2O_2 Treated PALP Content on the Hardness of Composites

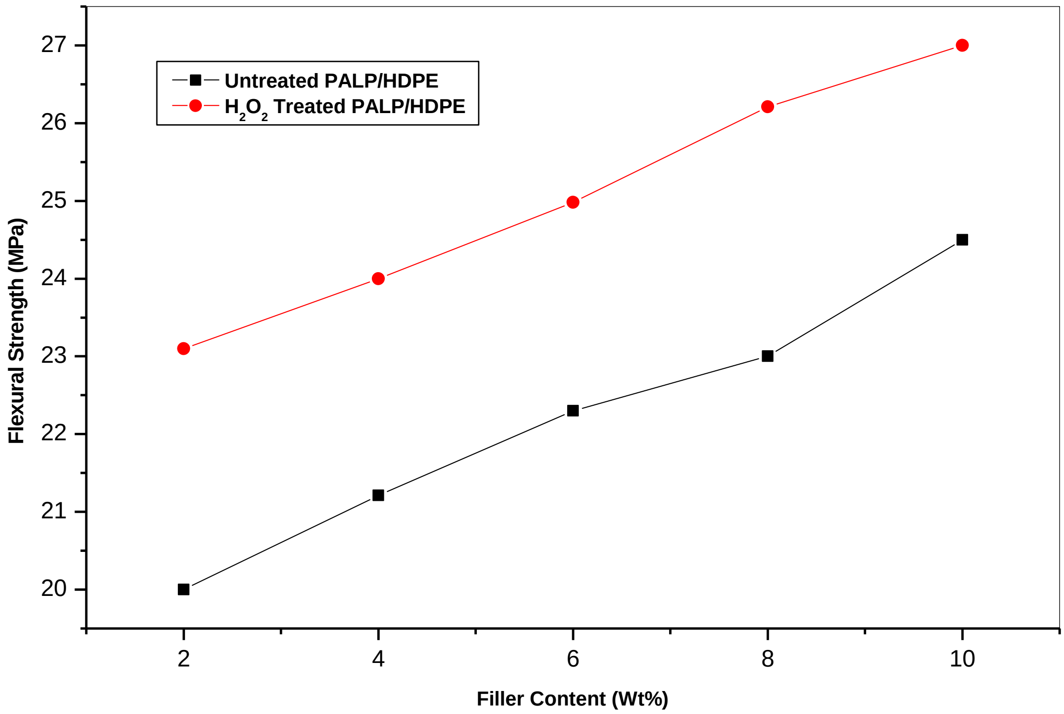

Fig. 6 Effect of H_2O_2 Treated PALP Content on Flexural Strength of Composites

Effect of H_2O_2 Treated PALP Content on the Hardness of Composites

It can be observed from Fig. 5 that the hardness (Shore D) of H_2O_2 treated PALP/HDPE composites was higher than that of untreated PALP/HDPE composites for all the filler contents investigated. It has been reported that the higher the tensile modulus of fibre, the higher will be the hardness of natural fibre/polymer composites [15-16]. This may also be attributed to the fact that in addition to the H_2O_2 treatment making the filler (PALP) harder and stiffer than the untreated ones, H_2O_2 may also hinder polymer chains mobility which makes the polymer (HDPE) to become hard and stiff, and this in turn, will further increase the hardness of the PALP/HDPE composites [14].

Effect of H_2O_2 Treated PALP Content on Flexural Strength of Composites

The effect of H_2O_2 treated PALP content on the flexural strength of PALP/HDPE composites can be seen from Fig. 6. The flexural strength was seen to increase with increases in filler content for both the untreated, and treated composites. It was also observed that the H_2O_2 treated PALP/HDPE composites had higher flexural strength than that of the untreated PALP/HDPE composites for all the filler contents investigated. The observed increases in flexural strength of the treated composites may be due to the removal of impurities from the fibre surface after treatment which leads to the better adhesion of the filler with the matrix [17-18].

CONCLUSION

The present study has shown that H_2O_2 treatment of pineapple leaf powder (PALP) has proved to be a viable and efficient method of surface treatment of fibre which helps to improve the interfacial bonding between the fibre and matrix, thereby enhancing the mechanical properties of composites. This can be justified from the results of the mechanical properties carried out in this study which showed that the H_2O_2 treated PALP/HDPE composites generally exhibited better tensile strength, tensile modulus, flexural strength, abrasion resistance, and hardness than the untreated PALP/HDPE composites for all the filler contents investigated; while the elongation at break values of the H_2O_2 treated PALP/HDPE composites was lower than that of untreated PALP/HDPE composites for all the filler contents investigated. It is recommended that other types of filler surface treatments should be investigated for the processing of HDPE composites so as to identify the method with the best promising result.

REFERENCES

[1] IZ Bujang, MK Awang, AE Ismail, Study on Dynamic Characteristics of Coconut Fibre Reinforced Composites, *Regional Conference on Engineering Mathematics, Mechanics, Manufacturing and Architecture*, **2007**, 185-202.
[2] RM Rowell, JS Han, JS Rowell, Characterization and Factors Affecting Fibre Properties, *Natural Polymers and Agrofibres Composites*, **2000**, 15-129.
[3] B Wang, S Panigrahi, L Tabil, W Crerar, Effects of Chemical Treatments on Mechanical and Physical Properties of Flax Fibre-Reinforced Rotationally Molded Composites, *ASAE Annual Meeting*, **2007**, 2, 127-892.
[4] K Joseph, LHC Mattoso, RD Toledo, S Thomas, LH de Carvalho, L Pothen, S Kala, B James, Natural Fibre Reinforced Thermoplastic Composites, Natural Polymers and Agrofibres Composites, *Composites Science and Technology*, **2000**, 23 (2), 1231-1352.
[5] F Corrales, F Vilaseca, M Llop, J Giron`es, JA M´endez, P Mutj`e, Chemical Modification of Jute Fibres, *Journal of Hazardous Materials*, **2007**, 144, 730-735.
[6] SS Mir, SMN Hasan, MJ Hossain, M Hasan, Chemical Modification Effect on the Mechanical Properties of Coir Fibre, *Engineering Journal of Science*, **2013**, 16, 73-83.
[7] X Li, LG Tabil, S Panigrahi, LG Tabil, A Study on Flax Fibre-Reinforced Polyethylene Biocomposites by Injection Moulding, *Applied Engineering in Agriculture*, **2009**, 25, 525-531.
[8] D Ray, BK Sarkar, AK Rana, NR Bose, The Mechanical Properties of Vinylester Resin Matrix Composites Reinforced with Alkali-Treated Jute Fibres, Composites: Part A, *Journal of Applied Science*, **2001**, 32, 119 –127.
[9] E Zini, M Scandola, Green Composites: An Overview, *Polymer Composites Journal*, **2011**, 32 (12), 1905-1915.
[10] A Valadez-Gonzalez, JM Cervantes, R Olayo, PJ Herrera-Franco, Mechanical Properties of Biocomposites, *Biocomposite Engineering*, **1999**, 30, 309-345.
[11] I Van de Weyenberg, J Ivens, A De Coster, B Kino, E Baetens, I Vepoes, Characterization of Filled Polyester Composites, *Composites Science Technology*, **2003**, 63, 1241-1272.
[12] M Jacob, S Thomas, KT Varughese, Mechanical Properties of Sisal Oil Palm Hybrid Fibre Reinforced Natural Rubber Composites, *Composite Science and Technology*, **2004**, 64, 955-965.
[13] R Malkapuram, V Kumar, SN Yuvraj, Recent Developments in Natural Fibre Reinforced Polypropylene Composites, *Journal of Reinforced Plastics and Composites*, **2008**, 28, 1169-1189.
[14] T Saira, A Munawar, N Munawar, UK Shafi, Natural Fibre-Reinforced Polymer Composites, *Processing Pakistan Academy of Science*, **2007**, 44 (2), 129-144.
[15] W Wang, M Sain, PA Cooper, Study of Moisture Absorption in Natural Fibre Plastic Composites, *Composites Science and Technology*, **2006**, 66 (4), 379-386.
[16] KB Sanjaya, *Study on Mechanical Behaviour of Polymer Based Composites with and without Wood Dust Filler*, A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Bachelor of Technology in Mechanical Engineering, Department of Mechanical Engineering National Institute of Technology Rourkela, India, **2010**, 123-189.
[17] M Pracella, D Chionna, AI Irene, Z Kulinski, E Piorkowska, Functionalization, Compatibilization and Properties of Polypropylene Composites with Hemp Fibres, *Composites Science and Technology*, **2006**, 66, 2218–2230.
[18] LA Pothan, S Thomas, G Groeninck, The Role of Fibre-Matrix Interaction on the Dynamic Mechanical Properties of Chemically Modified Banana Fibre/Polyester Composites, Composites Part A, *Applied Science and Manufacturing*, **2006**, 37 (9), 1260-1269.