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Effect of Potassium Permanganate on Tensile Properties of Sugar Palm Fibre Reinforced Thermoplastic Polyurethane

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Abstract

Background: The high-performance engineering products derived from natural resources are in great demand worldwide, based on renewability and environmental problems. **Method:** The outcome of Potassium Permanganate ($KMnO_4$) treatment on the tensile behaviours of treated Sugar Palm Fibre (SPF) with 6% NaOH reinforced thermoplastic polyurethane composites was investigated. The sugar palm fibres were treated by 6% NaOH solution, followed by $KMnO_4$ surface treatment of the alkali treated sugar palm fibres. Three different concentrations of $KMnO_4$ (i.e. 0.033, 0.066, and 0.125 %) were applied in the treatment. The extruder and hot press machines were used to mix the sugar palm fibres and polyurethane resin, to get the desired polyurethane composites. Tensile behaviours including (tensile strength and modulus, and the elongation at break) were investigated by following the ASTM D-638 standard. **Findings:** The highest tensile strength recorded was 8.986 MPa with $KMnO_4$ concentration of 0.125 %, with 6 % alkali pre-treatment. Therefore, the $KMnO_4$ concentration ~0.125 % exhibited best results for tensile test. **Improvements:** This study aids an improvement in the alkaline activation method for the TPU/SPF composite fabrication.

Keywords: KMnO4 Treatment, NaOH Treatment, Sugar Palm Fibre, Tensile Properties, Thermoplastic Polyurethane

Introduction

Currently, a dispute to reduce environmental pollution has amplified the human conscientization, in relation with the exact removal of waste materials. Specifically, there is a determination to employ natural waste materials as renewable means for number of applications. Therefore, in current years there has been an evolution in the progress of materials meeting international implications including economic viability, usage, cost and environmental impression. Several experimental findings have been presented with emphasis on the application of natural fibres as strengthening filler in the composites with polymer patterns[1] of thermoplastic or thermoset, in nature.

The investigation of natural fibres composites, considers the following parameters; the attribute of natural fibre engaged, the surface activation of the fibre, and the composites treating in the last possessions of the material. These are very imperative factors, the material could be employed in extensive range of applications, which includes packaging industry, aerospace, sports, construction, and particularly in the automotive industry[2]. The fibre intended to improve the adhesion, after chemical treatment, do not only change the surface but also support in improving the strength for better adhesion of the fibre withthe polymer matrix. This may reduce the water absorption of composites with improvement in their mechanical properties.

In[3] presented mechanical properties the jute fibres composites while studying the influence of stearic acid, potassium permanganate $KMnO_4$, toluene diisocyanate, and polypropylene when improved with maleic anhy-

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dride actions. It was mentioned that by adding jute (55.89 wt%), in the matrix resulted in a significant improvement in the mechanical behaviours (tensile, flexural and impact tests). Out of these, $KMnO_4$ treatment was observed to be, the most operative to enhance the tensile by (53.06 MPa to 68.26 MPa) and modulus by (2557 MPa to 3278 MPa) strength behaviours, when compared with composites treated with other treatments, respectively.

In[4] studied a compatibility between the hydrophilic cellulose fibre and hydrophobic polypropylene PP by sodium hydroxide treatment of cellulose fibres, isocyanates, maleic anhydride modified polypropylene MAPP benzyl chloride and permanganatestated that tensile properties improved by different treatments considerably, but with different changing gradations. The $KMnO_4$ concentration were between 0.055- 0.2 %, it was proved from the results that after 0.055 % $KMnO_4$ the tensile strength dropped. In[5] established 60 DT Light Posts, by applying five diverse chemical surface activations with two respective composites, respectively to get a support. The surface treatments containing engraving with Potassium permanganate; 10% hydrogen peroxide; 21% sodium ethoxide, then with potassium permanganate and 10 vol. % HCl; were executed on the post's surface. The backlog was achieved by means of (A) Core Paste XP (Dent Mat) and (B) Unifil Flow (GC), respectively. Potassium permanganate results exhibited a noteworthy influence on micro-tensile interfacial bond with both the tested materials. Later the post-superficial actions improved the bond durability predominantly of the Core Paste XP.

In[6] found a good interfacial adhesion of natural fibre as reinforcement for polymeric composites with epoxy matrix, by alkali $KMnO_4$ treatments on the mechanical properties.

Thermoplastic polyurethane (TPU) displayed good mechanical properties and it has elastic nature like the natural rubber. TPU is polar in nature, which reduces the fibre–polymer incompatibility. Moreover, it is environmental friendly (for recycle)[7].

The sugar palm fibre (SPF) presents higher resistance and durability to the sea water and the bad weather[8]. The availability of SPF in the nature make its cost very low. However, SPF, like all natural fibre, faces some difficulties that prevent its widespread use, such as hydrophilicity. In[9] used different concentrations of NaOH solution to treat the SPF reinforced TPU matrix. The 6 % NaOH solution showed improved tensile modulus and strain. However, the highest tensile strength calculated in SPF treated fibre, at 6% of NaOH solution was recorded to be ~5.49 MPa[9].

The present study is focused on the effect of different potassium permanganate concentrations (0.033-0.066 %), on the tensile properties of the fibre treated with 6% of NaOH; matrix adhesion of TPU and SPF composites (to enhance the NaOH treatment method). All the specimens were treated by NaOH and surface activated by $KMnO_4$, lately, to optimize the best used concentration of $KMnO_4$ for a higher tensile strength. ASTM standard D638[10] standard, of the composites was employed to measure the tensile properties.

2. Materials and Methods

The materials employed in this study are Estane® 58311 is an 85A Polyether- Type Thermoplastic Polyurethane (TPU), was used as supplied by manufacturers (Bayer Co. Malaysia). Sugar palm fibre SPF was collected locally in raw form, in the city of Raub, Pahang, Malaysia. Sodium hydroxide pellets NaOH used of Grade AR, Potassium Permanganate $KMnO_4$ Elixir brand High/Lab/AR Grade Fine Crystals and Acetone Dimethyl Ketone; 2-Propanone C_3H_6O, respectively were attained from Bayer Co. Malaysia.

2.1 Preparation of Fibre

The fibres were splashed thoroughly with tap water to get rid of dust and additional particulates, withered for two weeks in the atmospheric pressure at room temperature. Afterward grinded (machine Retsch ZM 200) and sieved by means of an auto shaker type FRITSCH, in order to achieve the fibre size of 250μm, as studied in previous research work[11].

2.2 Treatment of Fibre

The hydrophilic nature of the SPF makes the adhesion between the fibre and the hydrophobic TPU poor, which results in a weak composites structure[11]. For a good adhesion purpose, the clean, dried, and grinded fibres were washed many times with distilled water, after being soaked into 6 %sodium hydroxide solution, for a time period of 90 minutes[11,12]. Afterwards, the fibre was left to complete dry for almost two weeks at atmospheric pressure and lab temperature[11]. Finally, the treated fibres were soaked in three different $KMnO_4$(0.033, 0.066, to 0.125 %) concentrations, prepared in acetone.

2.3 Composite Preparation

TPU/SPF composite specimens, were fused by employing a Thermo SCIENTIFIC EUROLAB 16 extruder machine, with optimum rotating speed (40 rpm) at a temperature set of and 180-190-200 °C[11], respectively. Temperature and speed were set on the basis of previously reported studies, for the mechanical properties study of TPU/SPF composites. In the study, fibre loading of 30%, has been kept fixed, throughout the study with a 250µm fibre size. The treated fibre (with 6% NaOH) was treated with three different concentrations of $KMnO_4$ from 0.033, 0.066, and 0.125 %. A 30% fibre weight mixed into 70% TPU,extruded in extruder machineunder optimum conditions oftemperature of 180-190-200°C and atof 40 rpm[11]. The extruded composite bits were later constrained by using square mould, and afterward by using the hot press LOTUS SCIENTIFIC 25-ton compression moulding with the press pressure maintained at 10 MPa and temperature of 190°C, for a time of 10 min[13]. For the moulding, the samples were pre-heated, up to 190°C. Finally, the prepared sheet was cooled down to a temperature of 50°C.

2.4 Tensile Testing

Tensile behaviours were calculated by employing an Instron 3369Q3720 machine, following the ASTM D638[10].The specimens were arranged in to by dumbbell shapes by a manual saw cutter. Five specimens were studied, at a crosshead speed of 5 mm/min, respectively.

2.5 Scanning Electron Microscope

The scanning electron microscopy (SEM) (Carl Zeiss model EVO, Germany) was employed to study the morphology of the composites (specimens), after the tensile test.

3. Results and Discussion

Figure 1 displays the tensile strength of samples with altered concentrations of potassium permanganate solutions. It is evident that the tensile strength amplified steadily with the increase in the $KMnO_4$ concentrations. The strength calculated was 6 MPa with a $KMnO_4$ concentration of 0.033 %, which was later improved to around 9 MPa at higher (0.125 %) $KMnO_4$ concentration, respectively. The $KMnO_4$ surface activation has improved the surface properties of natural fibre in a polymer matrix[14,15]. That correlates with many researchers using different chemical treatment for the natural fibre polymer activation[16]. Tensile property enhancement, is a clear evidence of good impact of $KMnO_4$ treatment, on the tensile strength on the fibre which was treated with NaOH at 6% concentration.

Figure 2 displays the tensile modulus behavioursofthe matrices with different $KMnO_4$ activations, respectively. It is clear that the modulus amplified rapidly with the growing $KMnO_4$ concentrations. There was a dramatic rise in the modulus values for all the $KMnO_4$ activated samples, in comparison with treated composites when activated by 6 % NaOH, individually. The modulus was 300 MPa for 0.033 %, and improved largely to 900 MPa for 0.125 % $KMnO_4$. This results were in agreement with many authors that use $KMnO_4$ previously to make the surface more rough and active, and to remove lignin and wax[16,17].

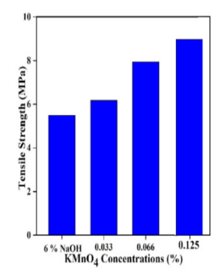

Figure 1. Effect of Potassium Permanganate Treatment on the Tensile Strength of TPU/SPF Composites.

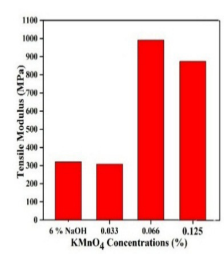

Figure 2. Effect of Potassium Permanganate Treatment on the Tensile Modulus of TPU/SPF Composites.

Figure 3 shows depicts the tensile strain values with diverse $KMnO_4$ concentrations, respectively. It is clear that the strain decreased down with the increase in $KMnO_4$ concentration. The strain calculated at 0.033 % concentration was 6 %, which reduced to almost 1% for $KMnO_4$ concentration of 0.125 %, respectively[16,18]. $KMnO_4$ is used chemically for cleaning the surface of plant fibre, where a natural fibre action as strong aqueous solution with concentrated base to yield greater inflammation with subsequent alterations in the fine assembly, dimensions and morphology, effecting the mechanical behaviours as well.

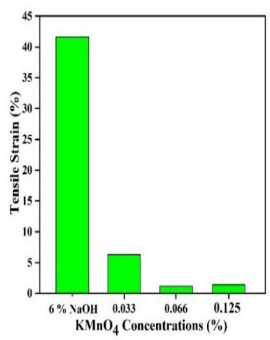

Figure 3. Effect of Potassium Permanganate Treatment on the Tensile strain of TPU/SPF Composites.

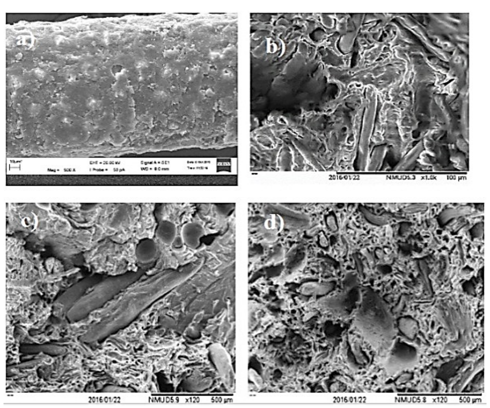

Figure 4. The Surface Illustration of (a) Untreated, (b) Treated by 0.033, (c) 0.066, and (d) 0.125 wt.% with $KMnO_4$by SEM Analysis of SPF Reinforced TPU.

The surface assembly ofthe untreated SPF fibres, is presented in Figure 4a. It is visible that the raw fibres surfaceswere dense and smooth with different impurities, revealed with white dots in the Figure. The holes are produced due to fibres, pulled out from the matrix, while the surface look like as clean, intact and free from any following polymer. After employing the $KMnO_4$ activation on the surface shown in Figure 4b, the fibres get fragmented nearby the surface and do not permitholes on the ruptured surface. When higher $KMnO_4$ solution concentration (0.066 and 0.125 wt. %) was used, an irregular and tarnished surface was observed, which is an indication for the elimination of impurities shown in Figure 4c and 4d, respectively. These analyses are in reputable agreement with the preceding studies reported by[4].

4. Conclusion

The study of consequence of alkali activation on the tensile behaviors of sugar palm fibre strengthened thermoplastic polyurethane composites, has been found improved by $KMnO^4$ method. From the above outcomes, it is concluded that the chemical treatments by Sodium hydroxide solutions and $KMnO^4$ respectively, have improved all the tensile properties of ultimate composite systems except the tensile strain. The top concentration of chemical solutions $KMnO^4$ is 0.066% by weight that gives the best tensile modulus. However, the 0.125 % of KMnO4 recorded the highest tensile strength. Nevertheless, the behavior of tensile strain for all diverse KMnO4 treatment is still poor than treated value of (6% NaOH). Consequently, the $KMnO_4$ method successfully improved the tensile properties of the new TPU/SPF composites.

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