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Influence of Coupling Agent and Fibre Treatment to Mechanical Properties of Oil Palm Fibre Reinforced Polymer Matrix Composite

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ABSTRACT

This research investigates the effect of alkali treatment and the coupling agent to the mechanical properties of oil palm reinforced polymer composites. The polypropylene was used as the reinforcement matrix whereas the oil palm fibres were used as the reinforcement fibres. The oil palm fibres were prepared in two conditions namely alkali treated and untreated fibres. During the composite material preparation, the untreated fibres were prepared in two conditions; i.e. without coupling agent and with coupling agent. Here, the coupling agent used was the Polypropylene grafted Maleic Anhydride (PPgMA). The fibres were determined at 10% for all specimens. All specimens were mechanically tested for Charpy impact and tensile tests. The results show that the impact strength and the ultimate tensile strength were not influenced by the alkali treatment. However, alkali treatment significantly increases both strain percentages at the ultimate tensile and at the break points. It was also observed that by adding the coupling agent, the impact strength and the strain percentage at ultimate tensile and break points were improved significantly. However, the tensile strength of the specimens were not influenced by the coupling effect. This finding was essential in determining the influence of coupling agents in polymer matrix composite strength.

Keywords: *Oil Palm Fibre, Alkali treated composites, Coupling Agents*

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Introduction

Polypropylene (PP) was extensively used in functional applications such as carpet backing, upholstery fabrics and many interior trims for automobiles and other appliances. PP is the simplest chemical polymer which is classified as thermoplastic. PP is available as a crystalline homo-polymer with an excellent balance of chemical and heat resistance, low density and low unit cost [1]. Although very similar to the High Density Polyethylene (HDPE), PP has lower density (0.9 g/cm^3) and a higher softening point, withstand to boiling water and many steam sterilizing operation. PP are used as many as 30% for fibre products, 15% for housewares and toys, 15% for automotive parts and 5% for appliance parts [2]. The mechanical properties of PP are moderate. Though the polypropylenes are tough, flexible and water repellent, but it has low strength [3].

The largest users of injection molded PP are in transportation, particularly automotive and truck battery cases. PP co-polymers have secured about 90% of this market as a result of a drive by automotive manufacturers to reduce weight and cost. In addition to being light-weight, PP also provides outstanding resistance to creep and fatigue, high temperature rigidity, impact strength and resistance to corrosion [3].

Some of PP were used as composites which combine with fibre. Composite material is a composition of individual materials (metals, ceramics or polymer) which is designed to achieve a combination properties that is not displayed by any single material, and also to incorporate the best characteristics of each of the component materials [4]. A familiar example is fibre glass composite, in which glass fibre was embedded within a polymeric material. Fibre glass composite acquires strength from the glass, and flexibility from the polymer.

Recently, due to lower cost and their properties, natural fibers were exploited as potential replacement of current conventional fibers such as glass, aramid and carbon. The properties of natural fibers are fairly good in mechanical properties, posseses high specific strength, non abrasive, eco-friendly and biodegradability characteristics [5]. There are many types of natural fibres that have been investigated to be used as reinforcement or even just as a filler of composite materials [6, 7]. Karina et al. [8] explored the physical and mechanical properties of natural fibres filled polypropylene composites and its recycle. Shinoj et al. [9] have made a review about Oil Palm fibre and its composites, i.e. oil palm fibre-natural rubber composites, oil palm fibre-polypropylene composites, and oil palm fibre-polyurethane composites. It was found that oil palm fibre have been investigated by many researchers, but the information on properties of thermal, electric resistance, rheology, characteristic of high voltage breakdown, characteristic of weathering and degradation, thermal environment deflection and resistance to various chemicals are still limited. In addition to Shinoj et. al. [9] work, Zaleha et al.

[10] have made a review about mechanical and physical properties of natural fibres, whereas Azwa et al. [11] made a review about the degradability of polymeric composites based on natural fibres. These reviews have demonstrated the feasibility of natural fibres as a promising alternative materials for reinforcement in composite materials.

The addition of ultra violet (UV) stabilizer and fire retardant materials were suggested to enhance outdoor and fire performance of natural fibre/polymer composite but compromises its strength. Therefore, from the collected data and various experimental results, it was concluded that an optimum blend ratio of chemical additives must be employed to achieve a balance between strength and durability requirements for natural fibre composites [11]. The addition of fibres into the epoxy had improved the thermal stability of the samples as well as its charring capability, with glass fibre giving the best result. However, alkalization reduced the decomposition of the kenaf fibre/epoxy composite and produced lesser char than an untreated composite caused by the removal lignin [13]. In summary, the addition of fibres and additive materials into composites was identified to have change the mechanical properties of the composites.

Therefore, the aim of this study is to investigate the influence of fibre treatment and coupling agent to the mechanical properties of polymer matrix composite reinforced with oil palm fibres.

Materials and Methods

This research utilised the natural oil palm fibres, obtained from Kian Hoe Plantation Berhad, Malaysia. Whereas the matrix material used here was a commercially graded homo-polymer Polypropylene. The coupling agent PPgMA was supplied by Shenzhen Jindaquan Technology Co. Ltd. while the alkali solution of Natrium Hydroxide (NaOH) was selected for the alkalisation treatment.

Figure 1 highlighted the schematic flow of this research work. Initially, the oil palm fibres extracted from the oil palm plantation are full of dirts and require cleaning processes. Depending on the dirt condition, these fibres were washed with plain water for at least 3 to 5 times. After being cleaned by water, the oil palm fibres were dried for at least 2 or 3 days under sunlight until complete dry to avoid any problem happen during sample preparations.

The dried oil palm fibres were then divided into 3 sections for preparing 3 types of different samples, i.e. Untreated, Treated and coupling agent samples. Untreated fibre was defined as normal fibre having cleaned by plain water. As for coupling agent, it was the untreated fibre that was mixed with PPgMA during mixing process. Treated fibre was categorised as fibres that undergoes alkalisation treatment with NaOH solution. For the alkali treated one, before mixing in Brabender machine, the fibres were soaked in 3% NaOH and 97% water for 90 minutes. The fibres were then washed with plenty of water and dried in oven at 70^{o}C for 15 hours.

After having a thorough cleaning, rinsing and drying processes, the untreated fibres were directly cut into short fibres, estimated not more than 10mm in length. The alkali treated fibres also underwent the similar cleaning processes, however, the fibres were only cut into similar size of short fibre after the alkalisation treatment was done. These fibres were then mixed with polypropylene at temperature 190 ^{0}C, with composition of 10 wt. % fibre and 90 wt. % PP using Brabender machine. Exceptions for coupling agent samples, the compositions are 10 wt. % fibre, 3wt. % PPgMA and 87 wt. % PP.

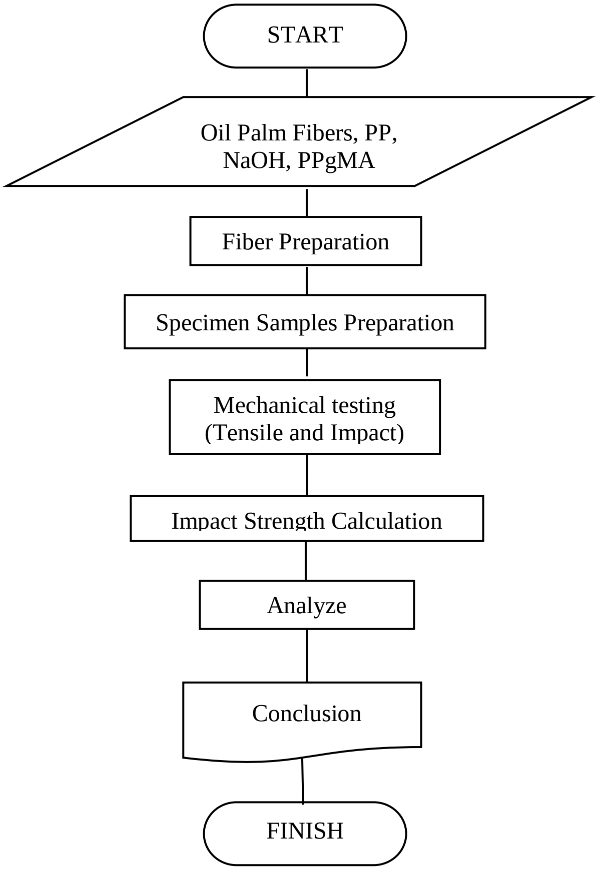


Figure 1: Schematic flow of research

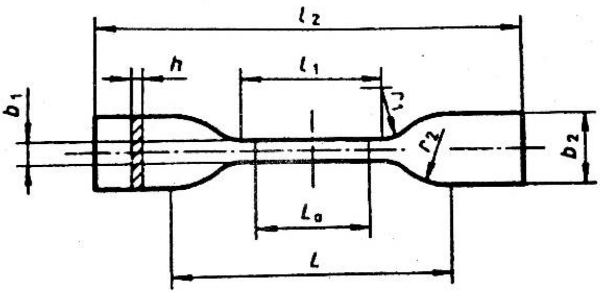
About PPgMA

PPgMA which is familiar with the name MAPP is very efficient in improving the interfacial adhesion between fibre and polypropylene matrix. The formation of the covalent linkages and hydrogen bond between the hydroxyl group and anhydride of the fibre are assisted by MAPP [14]. El-Sabagh [15] investigated the effect of MAPP to mechanical and thermal behaviour of natural fibre composites. The natural fibre used here are flax, hemp and sisal. It was found that the optimum MAPP to fibre ratio is different for each MAPP source and each natural fibre type.

In this work, PPgMA was used to improve bonding into untreated fibres mixed with polypropylene. However, only 3% of PPgMA was used in this work.

Charpy Impact and Tensile Test Specimens

After the mixing process using Brabender machine, the samples were crushed with crushing machine to produce pellets. These pellets were ready to be processed in injection molding machine, to produce the tensile test specimen based on ISO 527-2:1993 and Charpy impact specimen based on ISO 179-1:2001.



Type of specimen 5A (in millimetres):

l_2 (Overall Length), minimum	$\geq$ 75
b_2 (width at ends)	12.5 $\pm$ 1
l_1 (length of narrow parallel side portion)	25 $\pm$ 1
b_1 (width of narrow parallel side portion)	4 $\pm$ 0.1
r_1 (Small radius)	8 $\pm$ 0.5
r_2 (Large radius)	12.5 $\pm$ 1
L (Initial distance between grips	50 $\pm$ 2
Lo (Gauge length)	20 $\pm$ 0.5
h (Thickness)	$\geq$ 2

Figure 2: The tensile test specimen based on ISO 527-2: 1993.

The tensile test specimens were prepared according to ISO 527-2: 1993 specimen type 5A, as shown in Figure 2. The dimension of the specimen's based on this standard was also highlighted in Figure 2. Figure 3 demonstrated the configuration of specimen type 1 with B notch according to ISO 179-1:2001. These two specimens were applied for all composites samples, e.g. untreated, treated and coupling agents composites.

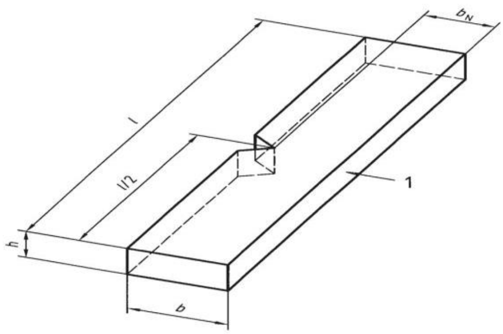


Figure 3: Charpy edgewise impact with single-notched specimen based on ISO 179-1: 2001

All the experimental works were conducted in the Polymer Laboratory, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia (UTHM). The tensile tests were done by using a universal testing machine (UTM). This experiment produced three properties of the specimens, i.e. the Ultimate tensile strength, Percentage of strain at Ultimate strength and Percentage of strain at break point. The Charpy impact test was done by using the Wolpert Charpy impact equipment with a maximum capacity of 4 Joules. The Charpy impact strength in kilojoules per square meter with notch A, B or C is calculated using Equation 1 as follows:

$$a_{cN} = \frac{E_c}{h \cdot b_N} \tag{1}$$

Where:

- a_{cN} is the Charpy impact strength, in kilojoules per square meter
- E_c is the corrected energy, in joules, absorbed by breaking the test specimen;
- h is the thickness, in millimetres, of the test specimen
- b_N is the remaining width, in millimetres, of the test specimen

Results and Discussions

Figure 4 demonstrated the impact energy and impact strength resulted from Charpy impact test, conducted for all specimens. The impact strength for every specimen were calculated using Equation 1. The value of impact energy was represented by the left axis whereas the value of impact strength was represented by the right axis. The figure shows that the impact energy of the treated fibres produced almost the same values with the untreated fibres. The average impact energy for untreated and alkali treated were 0.131 J and 0.132 J, respectively. It indicated that alkali treatment to the oil palm fibres, was not significantly affecting the impact energy of a composite material. However, the coupling agent specimen shows higher impact energy with significantly difference with samples without coupling agent. The average impact energy for coupling agents' composite was 0.162 J, an increment of 22.7%.

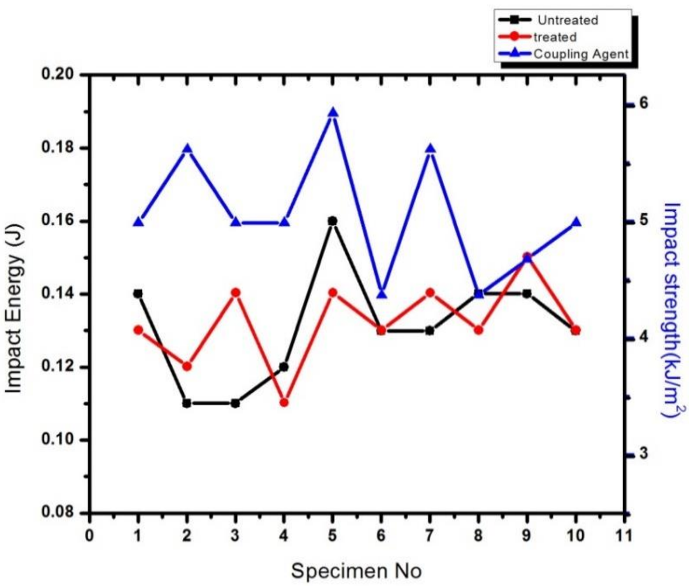


Figure 4: The impact energy and impact strength of the untreated, treated and the coupling agent specimens

Figure 4 also demonstrated the impact strength for the three samples. Since the graph of impact energy and strength are identical, the characteristics were also similar for all untreated, treated and coupling agent fibres. The average impact strength for untreated and alkali treated were 4.094 and 4.125 kJ/m^2, respectively. The impact strength of composites was influenced by the coupling agent (PPgMA). The average impact strength for coupling agents' specimen was 5.065 MPa, with an average increments percentage of 23.67%, compared to previous specimens. PPgMA was observed to improve the impact strength of the composites.

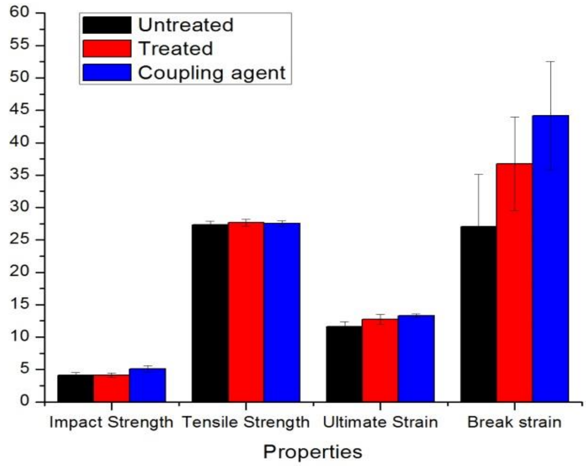


Figure 5: The summary of mechanical properties for all composites

Figure 5 show the recapitulation of the average data of mechanical properties of untreated fibre, alkali treated fibre and coupling agent added composite materials. Figure 5 demonstrates that the tensile strength for all specimens were consistent. There were insignificant changes in strength values of which the average tensile strength for untreated, alkali treated and coupling agents' were 27.32, 27.69 and 27.5 MPa, respectively. It can be assumed that the alkali treatment and coupling agent didn't affect the tensile strength of the composite materials. The increases of the average strain percentage at the ultimate tensile for alkali treated and coupling agents' were 1.35% and 0.84%, respectively with reference to untreated fibre composites.

Figure 5 also show that the alkali treated fibre composite has a higher strain percentage at the ultimate strength compared to the untreated fibre composites. But the highest strain percentage at the ultimate tensile is the coupling added specimens. The increase of the average strain percentage at the ultimate tensile are 9.7% and 14.6%, for treated and coupling agents' specimens, respectively.

The percentage of strain at break point for each composite was demonstrated also in Figure 5. It was observed that the alkali treated fibre composite has a slightly higher in strain percentage compared to untreated fibres composite. It was also observed that the highest break strain percentage is achieved for the coupling agents' added specimens. This is because PPgMA not only increases the interfacial adhesion between fibres and polypropylene matrix, but also assists the formation of the covalent linkages and hydrogen bond between the hydroxyl group and anhydride of the fibre [13]. The increase of the average break strain percentage are 35.7% and 63.3% for alkali treated and coupling agents' composite, respectively, with reference to untreated fibre composites.

It is observed from these data that not all of the mechanical properties of the composite materials is influenced by the fibre treatment or coupling agent. Different treatments gave different results as demonstrated in Figure 5. However, the findings demonstrated that by adding coupling agent PPgMA to the fibres, improvement were observed in impact strength, and strain percentage at both ultimate and break points. This was due to the characteristics of PPgMA itself that increases the interfacial adhesion and bonds within fibres. This finding was in agreement with previous works done by El-Sabagh [14]. Though alkali treated composite has little contribution towards strength, it was however improved in terms of the strain percentages at both ultimate and break points. It was noted that tensile strength was not improved for all alkali treated and coupling agents' composites. This highlighted that little contribution to the tensile strength.

Conclusion

The influences of coupling agent and alkali treatment to the oil palm fibre reinforced composites were evaluated. Several mechanical properties of composite have been identified. The findings show that by adding the PPgMA as coupling agent to the fibre has improved the impact strength, strain percentages at ultimate and break points of the composites. Whereas, alkali treatment have improved the strain percentages at ultimate and break points compared to untreated fibre composites. However, both coupling agent and alkali treatment have little significant or influence towards improving the tensile strength of the composites.

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