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Effects of Alkali Treatments on the Tensile Properties of Pineapple Leaf Fibre Reinforced High Impact Polystyrene Composites

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ABSTRACT

A study on the effects of alkali treatment and compatibilising agent on the tensile properties of pineapple leaf fibre (PALF) reinforced high impact polystyrene (HIPS) composite is presented in this paper. The tensile properties of natural fibre reinforced polymer composites are mainly influenced by the interfacial adhesion between the matrix and the fibres. In this study, several chemical modifications were employed to improve the interfacial matrix-fibre bonding and this resulted in the enhancement of tensile properties of the composites. In this study, the surface modification of pineapple fibre with alkali treatments and compatibilizer were used to improve the adhesion between hydrophilic pineapple fibre and hydrophobic polymer matrix. There are two concentrations of NaOH treatments and compatibilizer used in this study, namely, 2 and 4 wt. %. The results show that the alkali treated fibre and the addition of compatibilising agent in PALF/HIPS composites have improved the tensile strength and tensile modulus of the composites.

Keywords: Pineapple leaf fibre, high impact polystyrene, compatibilising agent, alkali treatment

INTRODUCTION

The properties of the composites depend on the matrix, fibres and their interfacial bonding. The adhesion between the reinforcing fibres and the matrix in the composite materials plays an important role in the materials (Alawar *et al.,* 2009). The inherent differences between the highly polar natural fibres and the non-

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polar polymer matrix can result in difficulties in the dispersion of fibres, along with poor fibre-matrix interactions (Gassan & Gutowski, 2000). This is one of the significant drawbacks in utilizing natural fibre to reinforce polymer composites.

This problem can be overcome by treating these natural fibres with suitable chemicals to decrease the hydrophilic hydroxyl groups on the surface of fibres. Chemicals such as alkaline (Gomes *et al*., 2007), silane (Abdelmouleh *et al*., 2007) and compatibilising agent (Bledzki & Gassan, 1999) can react with hydrophilic hydroxyl groups of the fibre and thus improve the hydrophobic characteristics and facilitate a better bonding with the matrix. Many studies have been carried out using the chemical treatments of natural fibres to improve the mechanical properties of composites. It was found that tensile and flexural strengths of the bagasse fibre composites pre-treated with 1% NaOH increased by 14 and 16%, respectively, as compared to the untreated fibre composites (Cao *et al*., 2006). The addition of compatibilising agents, such as maleic anhydride grafted polypropylene (MAPP), has been shown to be one of the most suitable coupling agents available for use in natural fibre reinforced polypropylene composites (Lu *et al*., 2000). It consists of long polymer chains with a MA functional group grafted onto one end. In more specific, MAPP acts as a bridge between the non-polar polypropylene matrix and the polar fibres by chemically bonding with the cellulose fibres through the MA groups, and bonding to the matrix by means of the polymer chain entanglement. This study aimed to investigate the effects of alkaline and compatibilising agent treatment on the tensile properties of PALF/HIPS composites.

MATERIALS AND METHODS

Materials

The pineapple leaf fibres (*Ananas comosus*) were obtained from Pemalang, Central Java, Indonesia. The size of the pineapple leaf fibres was used in this research was 10-40 mesh. The high impact polystyrene (HIPS) used as the polymer matrix was Idemitsu PS HT 50, which was supplied by the Petrochemical (M) Sdn. Bhd., Pasir Gudang, Johor, Malaysia. The poly(styrene-*co*-maleic anhydride) (PScoMa) was used as a compatibilising agent. Sodium hydroxide (NaOH) was used in the surface modification of the pineapple leaf fibres.

Alkali (NaOH) Treatment

The short pineapple leaf fibres were soaked in two different concentrations (namely, 2% and 4%) of the NaOH solutions in a water bath for 1 hour at room temperature. The ratio of the

Table 1: Denotation of the sample composites

Sample	Material
Untreated	50% fibre + 50% HIPS
PScoMA2	50% fibre + 48% HIPS + 2% PScoMA
PScoMA4	50% fibre + 46% HIPS + 4% PScoMA
Alkali2	Treated fibre with 2% NaOH (50% fibre + 50% HIPS)
Alkali4	Treated fibre with 4% NaOH (50% fibre + 50% HIPS)

fibres to the solution was 1:20 (w/v). These specific concentrations were selected according to the previous work reported by George *et al.* (1998) and Jacob and Thomas (2004). After the treatment, the fibres were washed, rinsed several times with distilled water, and then dried in an oven at 80°C for 24 hours.

Compatibilising Agent

There were two different weight concentrations (2% and 4%) of the compatibilising agent. The weight of the short PALF, which was 50% of the total formulation, was kept constant while the ratio of HIPS and compatibilising agent were varied (Table 1).

Composite Manufacturing

The pineapple fibres were incorporated into the HIPS matrix using a Brabender Plasticorder intensive mixer, model PL2000-6 at 165°C. The mixing process was performed in the following order: First, the HIPS and compatibilising agent were mixed for 2 minutes and the screw speed was set at 50 rpm. Afterward, PALF was added into the mixing chamber for 10 minutes. The total time for the mixing process was 12 minutes. The resulting material was then compressed in the mould using a Carver laboratory press at 165°C for 5 minutes, after undergoing the process of pre-heating for 5 minutes at the same temperature. This was followed by a cooling process of 5 minutes and the final result of the composites was formed into sheets.

Tensile Testing

In this study, the tensile test was carried out following the ASTM D638-03: Standard Method for Tensile Properties of Plastics. The specimens were tested using the Universal Instron model 4301 testing machine fitted with a 1kN load cell and operated at cross-head speed of 1mm/min. Seven specimens were tested to failure and the results obtained from the five specimens were used to calculate the average tensile value.

RESULTS AND DISCUSSION

Tensile Testing

The influence of the alkali treatment of PALF and the addition of compatibilising agent on the tensile strength of PALF/HIPS composites are shown in Fig.1. The tensile strength of untreated PALF/HIPS composites is only 23 MPa. Incorporating untreated PALF fibres in the polymer HIPS matrix results in a creation of weak interfacial region due to incompatible non polar hydrophobic HIPS and polar hydrophilic PALF fibres. This weak interfacial region may result in the reduction of efficient stress transfer from the matrix to the reinforcement fibre, and thus reducing the tensile strength of the PALF/HIPS composites. Natural fibres also exhibit a poor resistant to moisture, which leads to high water absorption, and this subsequently results in poor tensile properties of the natural fibre reinforced composites.

The addition of compatibilising agent of 2 wt. % of PScoMA has increased the tensile strength of composites by about 34 MPa. This particular treatment has brought improvement around 48% as compared to the untreated ones. Meanwhile, the tensile strength of the composites increases up to 36 MPa with the increase in the PScoMA content, i.e. from 2 wt. % to 4 wt. %. Improvement in the tensile strength is attributed to the increased adhesion between the PALF fibres and HIPS that facilitates better stress transfer through bonding to PALF fibres. Arbelaiz *et al.* (2005) used MAPP, Epolene E43 and G3003 to treat flax fibre reinforced polypropylene composites. Their results showed that 5 and 10 wt. % compatibilizers for E43 and G3003 were the optimum doses as the tensile strength increased by about 42% and 58%, respectively.

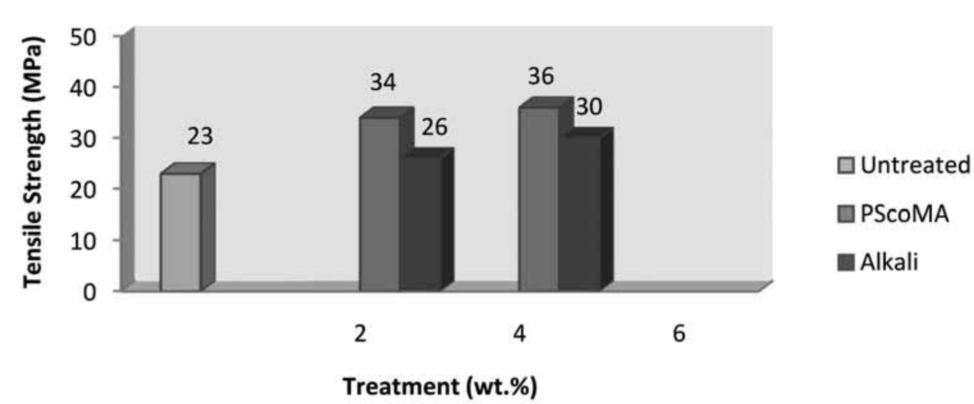

Fig.1: The effect of treatments on the tensile strength of PALF/HIPS composites

The effects of the alkali treatments (2 and 4%) on PALF fibre in the tensile strength were examined using the treated fibre (50 wt. %) composites. The NaOH treatment of the PALF fibres improved the tensile strength of the PALF/HIPS composites. Similarly, the tensile strength of the PALF/HIPS composites improved with 2 and 4% NaOH treatments by 12 and 24%, respectively, as compared to the untreated fibre composites. Rout *et al*. (2001) observed that the enhancement in the tensile strength with alkali treated fibre composites was attributed to the improved wetting of alkali treated fibre with the matrix. In particular, the alkali treatment improves the natural fibre-matrix adhesion due to the removal of natural and artificial impurities (Bisanda, 2000). The removal of impurities and waxy substances from the fibre surface and the creation of a rougher topography after alkalization resulted in a better bonding between the fibre and the matrix polymer in a composite by providing additional sites for mechanical interlocking (Mwaikambo & Ansell, 2003).

Tensile modulus is a measure of rigidity of the material (Bachtiar *et al*., 2008). Fig.2 shows that the tensile modulus of the untreated fibre composites is about 824 MPa. The addition of the compatibilising agent from 2 wt. % to 4 wt. % of PScoMA has increased the tensile modulus of composites from 1125 MPa up to 1222 MPa. The treatment of 4 wt. % PScoMA has increased the tensile modulus by 48% as compared to that of the untreated composites. This improvement could be related to a better dispersion of the fibres in polymer matrix (Sanadi *et al.,* 1997). The chemical composition of the compatibilising agent allows them to react with the fibre surface to form a bridge of chemical bonds between the fibre and matrix.

Most researchers found that these treatments are effective and have shown a better interfacial bonding. Meanwhile, the tensile modulus of the composites was observed as 1197 MPa and 1284 MPa in the 2 and 4% alkali treated samples, respectively. Thus, it can be concluded that the composites containing 4% of the NaOH treated fibres have slightly higher tensile modulus as compared to the untreated fibre composites and the composites containing 4% PScoMA treated fibre.

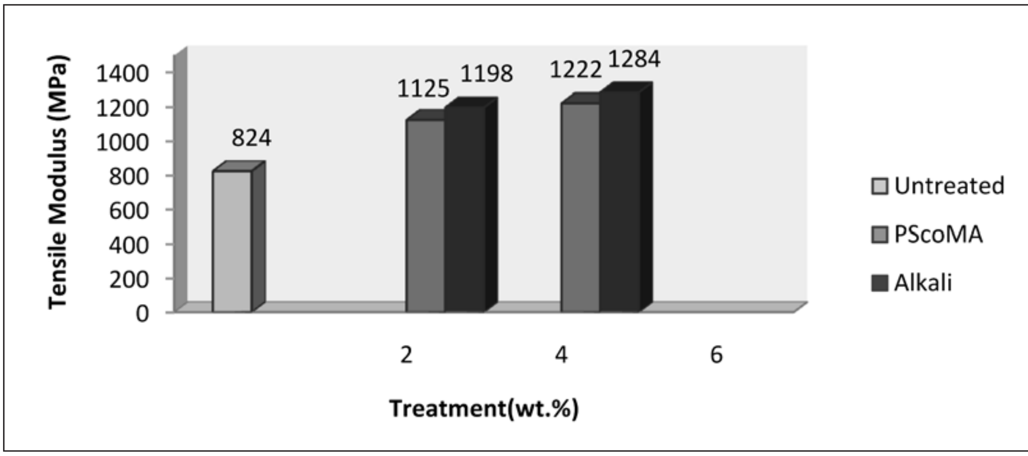

Fig.2: The effect of treatments on the tensile modulus of PALF/HIPS composites

CONCLUSSIONS

The effects of the treatments on the pineapple leaf fibre reinforced high impact polystyrene composites were studied in the current work. The results obtained revealed that the use of alkali treatment and poly(styrene-co-maleic anhydride) compatibilising agent resulted in improved tensile properties of the PALF/HIPS composites. In particular, the composites containing compatibilising agent of 4% PScoMA appeared to be significantly stronger than the untreated fibre composites and also the composites containing NaOH treated fibre.

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