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Evaluation of Mechanical Performance of Homopolymer Polypropylene/Kenaf Fibre/ /Binder using Full Factorial Method

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Abstract – *The mechanical performance of kenaf fibre/homopolymer polypropylene/binder composites was studied. Tensile test was used to investigate the tensile strength, tensile modulus and percentage of elongation. Kenaf fibre-homopolymer polypropylene (KFHPP) composites were compounded in an internal batch mixer with the ratio of 10:90, 30:70 and 50:50 in weight fraction. Furthermore, maleated polypropylene (MAPP) as a binder with 1, 3 and 5 % expressed as percentage of weight ratio was mixed in KFHPP composites. A hot pressing machine was used for producing samples of dog bone. From this study, it is found that the tensile strength and tensile modulus increase with increasing kenaf fibre loading and higher percentage of MAPP. In addition, the elongation at break for KFHPP composites shows lower result for increasing kenaf fibre loading. However, when the percentage of MAPP added to KFHPP composites increases, the elongation at break increased slightly. Thus, the result shows that the binder can enhance the interaction between kenaf fibre and homopolymer polypropylene composites, with resulted in better tensile strength and tensile modulus but less function at elongation at break.*

Keywords: Polypropylene, Kenaf Fibre, MAPP, Full Factorial, Mechanical Performance

1.0 INTRODUCTION

Kalpakjian *et al* [1] expressed that composite materials have found increasingly wider applications in aircraft, space vehicle, satellites, offshore structures, piping, electronics, automobiles, boats and sporting goods. Therefore, many experiments have been done using various types of reinforcement in compounding of polymer composites such as reinforcement made from PTFE fibre in molten linear homopolymer polypropylene [2], fine fibre [3], kenaf fibre [4] and natural fibre [5]. Almost all reinforcement materials used in polymer composites are able to enhance the mechanical properties [6,7], rheological properties [8,9], and physical properties [10,11]. However, for natural fibre such as cellulosic fibre, which is kenaf core compounded with thermoplastic polymers, the main problem encountered is the poor interfacial adhesion between the hydrophobic polymer and hydrophilic filler. Binder materials have been used in polymer composites to enhance the contact between fibre as a reinforcement with polymer as matrix. Various types of binder have been used such as silane, alkoxysilane, maleic-anhydride grafted polypropylene (MAPP), and others. MAPP is widely used as it functions by enhancing the interactions between reinforcement and matrix.

Furthermore, the function of MAPP on homopolymer polypropylene composites is also to strengthen the binding between reinforcement and matrix [12]. Therefore, the purpose of this project is to determine the effect of MAPP as a binder on the mechanical properties of homopolymer polypropylene mixed with kenaf fibre at different ratios. The design of experiment using full factorial experimental design was utilized, and the responses of mechanical properties were analysed through statistical method using Design Expert software.

2.0 EXPERIMENTAL STUDY

Kenaf fibre was used as a filler and Propelinas G112 homopolymer polypropylene was used as the matrix purchased from Polypropylene (M) Sdn. Bhd. with a density and melt index specified as 0.9 g/cm^3 and 11 g/10 min at 230^{o}C, respectively. Polypropylene-graft-maleic anhydride, which is commercially known as maleated polypropylene (MAPP), was selected as the binder for kenaf fibre in homopolymer polypropylene composites. The kenaf fibre filler was cut into smaller length using scissor before it was blend in a blender. The filler was then sieved using a vibratory sieve-shaker machine to obtain the filler size of 120 µm to 0.634 µm. The compounding of the composite materials was carried out using an internal batch mixer. The propeller speed was set at 25 rpm with the temperature of 180˚C. The MAPP was loaded during the compounding process of kenaf fibre and homopolymer polypropylene. The concentrations of MAPP used are 1%, 3% and 5% (w/w). The compounds were unloaded after 15 min of compounding process. The compounds were transferred to a compression mould with the dimensions of 200 mm x 200 mm x 3 mm. Then, the compounds were preheated for 10 min at 200˚C, followed by heating at the same temperature for 10 min with the pressure of 40 kgf and then cold press for 10 min with the same pressure. Three ratios of the kenaf fibre-PP mixtures used were 10:90, 30:70 and 50:50 (w/w). The kenaf fibre/PP compositions and binder percentage used in this study are listed in Table 1. With the help of Design Expert software to analyse the result, full factorial experimental design was selected and the data were analyzed to study the main effects of responses. Two factors (i.e. kenaf fibre/PP ratio and percentage loading of binder) and three levels were used in this experiment. 9 runs were performed with 3 replications based on the equation of full factorial design.

Table 1: Formulations of KFHPP composites and MAPP

Factors		Levels	
KFHPP	10/90	30/70	50/50
MAPP	1	3	5

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3.0 RESULTS AND DISCUSSION

The result of experimental material characteristics on tensile strength, modulus strength and elongation at break is shown in Figure 1.

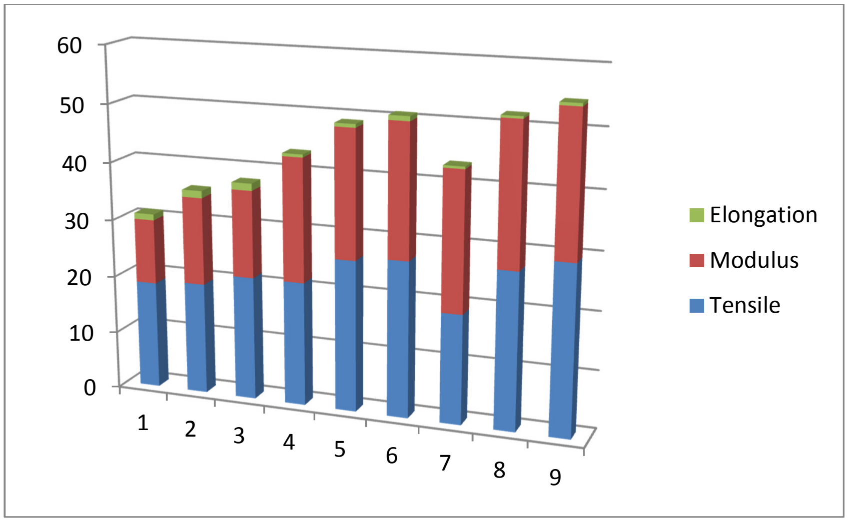

Figure 1: Mechanical properties for tensile strength, modulus strength and elongation at break.

3.1 Tensile strength

Figure 1 shows that the tensile strength of KFHPP composites treated with MAPP increased as the MAPP loading increased. The result shows that composites treated with binder at 3% for samples 4, 5, and 6, and 5% for samples 7, 8, and 9 display better tensile strength than those at 1% for samples 1, 2, and 3. Figure 2 shows the interactions of kenaf fibre and MAPP in molten homopolymer polypropylene for tensile strength. It is clear that the increase of kenaf fibre in KFHPP composites enhances tensile strength. The increase of strength of KFHPP composites becomes prominent as the loading of MAPP increases from 3% to high ratio of 5% in KFHPP compositions. Furthermore, high loading of MAPP 5% is significant at the beginning and then reduces as it reached at high loading. This is because the incorporation of binder enhances the tensile strength of the composites, which may be due to a good compatibility at interfacial regions between filler and matrix. M.J. Saad said that a good filler-matrix interaction could be derived from the formation of an ester bond between the anhydride groups of epolene 43 and the hydroxyl groups at the surfaces of kenaf filler [13].

3.2 Tensile modulus

The tensile modulus of the KFHPP composites increased as the MAPP binder loading increased, which can be seen clearly in Figure 1. According to results of tensile modulus in Figure 1, it indicates that the MAPP binder is able to enhance the stiffness of the composites. The binder ratio at 5% displays higher modulus than at 1% and 3%, especially at KFHPP composites having ratio 30/70 and 50/50 compositions. This may be due to the presence of more anhydride group from Epolene-43 binder that are connected with hydroxyl groups from kenaf fibre. Apart from that, the tensile modulus increased as the filler loading increased,

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which can be seen in Figure 1. Figure 3 shows that the interactions of kenaf fibre and MAPP increased the tensile modulus significantly when the loading of kenaf fibre increased to 30/70 in weight ratio for 1, 3 and 5 % of MAPP. The gap between the interaction of tensile modulus is almost near to each other.

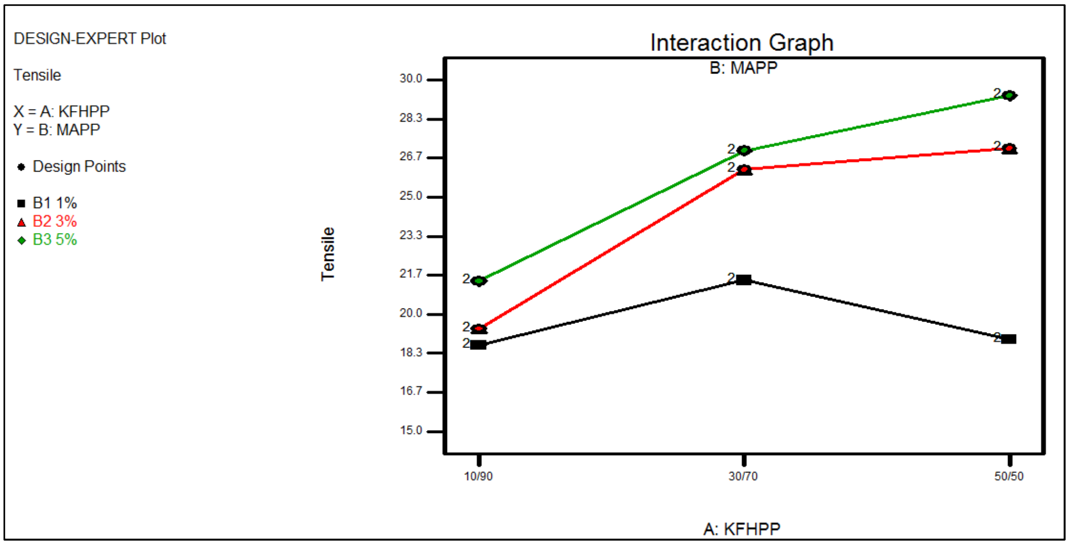

Figure 2: Interaction of kenaf fibre and MAPP for tensile strength.

However, the increase of MAPP binder in the KFHPP composites reduced the tensile modulus slightly compared to low loading of MAPP binder. This is a common phenomenon, which has been reported by other researcher in the case of kenaf-PP composites with Epolene-43. Since kenaf filler has more inherent stiffness than the matrix, the increase in filler loading increased the stiffness of the composites [14].

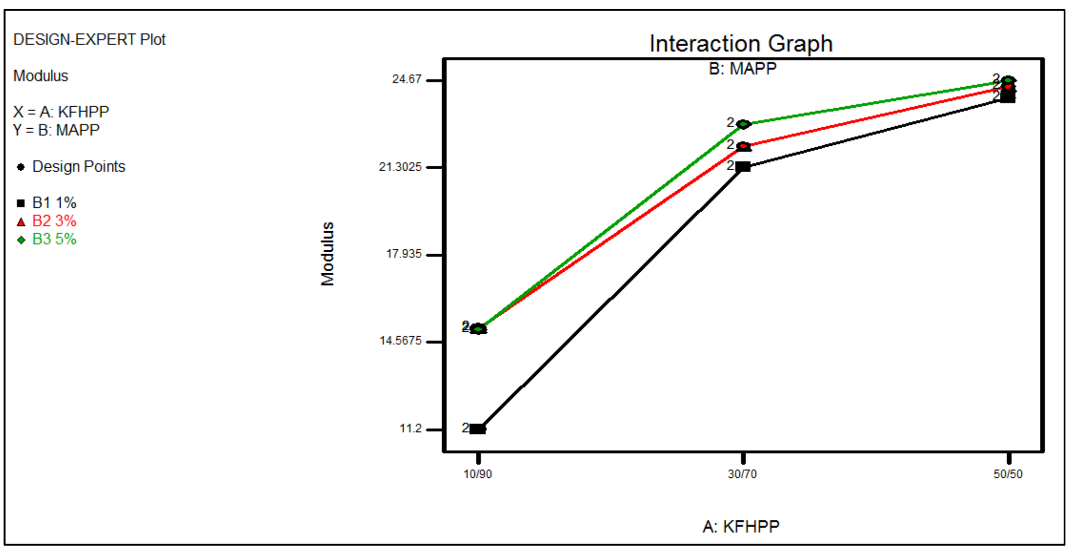

Figure 3: Interaction of kenaf fibre and MAPP for tensile modulus.

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3.3 Elongation at break

The percentage of elongation at break decreased for samples containing more filler as shown in Figure 1. This may be due to the hydrogen bonding bundled in the filler, thus weaken the sample. Kenaf and PP compositions having the ratio of 10:90 with binder show higher elongation at break rather than other formulations of KFHPP composites. Figure 4 shows the interactions of kenaf fibre and MAPP reduced from low loading of kenaf fibre to high loading of kenaf fibre. It shows that high percentage of MAPP at 5% still assists the elongation at break better compared to low loading of MAPP at 1%. The trend line observed by other researchers can also be seen in this study, where more filler loading decreased the elongation at break value [15].

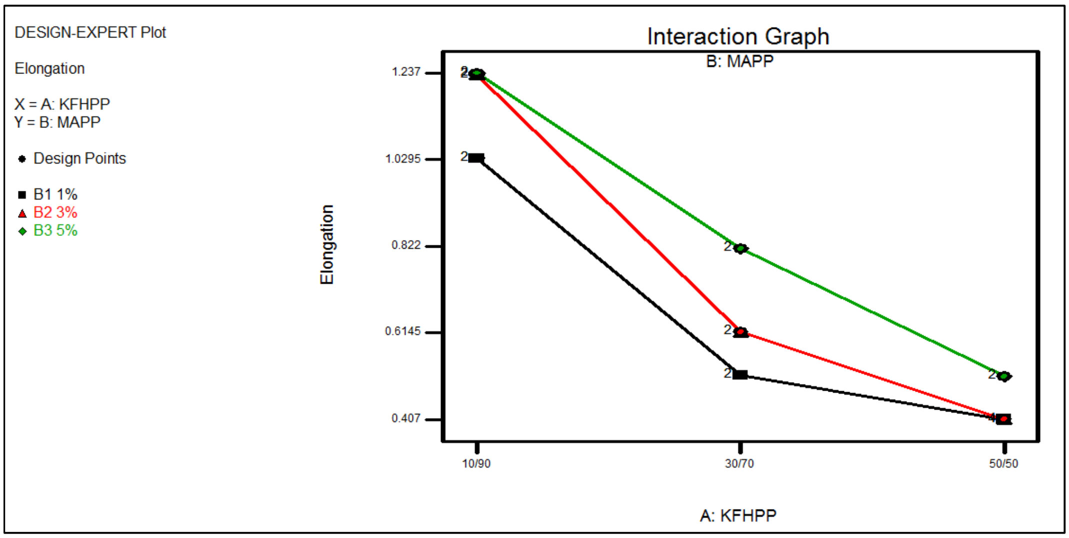

Figure 4: Elongation at break result (a) main effects and (b) surface plot.

4.0 CONCLUSION

This study shows that the tensile and modulus strength of kenaf-PP composites are enhanced by adding binder. The higher the binder loading in KFHPP composites, the better are the mechanical properties for both tensile and modulus strength, but lower for elongation at break. In conclusion, adding a small percentage of MAPP in kenaf fibre/homopolymer polypropylene composites enhances the mechanical properties to a certain value that gives more applications of polypropylene in global market.

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