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Induced Tensile Properties With EB- Cross Linking of Hybridized Kenaf/Palf Reinforced HDPE Composite

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ABSTRACT

Electron beam irradiation, without any addition of cross-linking agents, was investigated at varying doses of EB-Irradiation to develop an environmentally friendly hybridized kenaf (bast)/ pineapple leaf fibre (PALF) bio-composites. Improvement in tensile property of the hybrid was achieved with the result showing a direct proportionality relationship between tensile properties and increasing radiation dose. Statistical analysis software (SAS) was employed to validate the result. HDPE has been shown to have self-cross-linked, enabling interesting tensile properties with irradiation. Statistical analysis validated the results obtained and also showed that adequate mixing of fibres and matrix had taken place at 95% confidence level. Hybridization and subsequent irradiation increased the tensile strength and modulus of HDPE up to 31 and 185%, respectively, at about 100kGy. Meanwhile, SEM was used to view the interaction between the fibres and matrix.

Keywords: Hybrid, cross linking, EB-irradiation, tensile properties, statistical analysis

INTRODUCTION

For many years, research has been carried out on the use of natural fibres for both automobile and structural applications. This has helped to reduce the use of synthetic materials for the sake of our environment. Nowadays, natural fibres are used to reinforce polymers that serve as matrix. Several factors have aided the

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use of these natural fibres, including low cost, light weight, environmental friendliness, ease of formulation, availability in most countries, specific strength, relative non-abrasiveness to processing equipments (George *et al*., 2001; Lee *et al*., 2005; Li *et al*., 2008; Aji *et al*., 2009), just to mention a few. Meanwhile, some marketable reasons in replacing synthetic fibres with natural ones include low cost (~1/3 of glass fibres), lower density (~1/2 of glass), as well as acceptable specific strength properties and enhance energy recovery, CO_2 sequesterization and its natural tendency to degrade (Kim *et al*., 2007).

Electron beam irradiation (EBI) technique is gaining increased attention as a surface modifier and properties enhancer of various polymers, natural and synthetic fibre composites. This is because the process is devoid of wet conditions, while its clean and cold process gives rise to energy saving and high-speed enhancement of properties.

It has been reported by Han *et al*. (2006) that the presence of inner pore structure of natural fibril can be maintained by the use of EBI treatment unlike its destruction when fibres undergo alkali treatment. These pore structures can serve as insulators and collision absorbers when such composites are used in automobile and structural part. Similarly, to achieve superior strength in natural fibre composite, there is a basic need to improve fibre/matrix adhesion, and the use of adequate coupling agents and EB-Irradiation is one of the ways to achieve this (Czvikovszky, 1996). However, hybridization has been shown to be one of the ways to achieve this objective (Aji *et al*., 2011).

This work presents the response of Hybridized Kenaf/PALF reinforced HDPE Composite's tensile properties to EB-Irradiation without the addition of cross linking agents to develop an environmentally friendly bio-composite.

MATERIALS AND METHOD

Materials

Pineapple leaf (*Ananas comosus*) was bought from Perniagaan Benang Serat Nanas M&Z, with the source from Johor pineapple plantation, Malaysia. It was manually decorticated from the PALF variety of "*Josephine"*. Kenaf (*Hibiscus cannabinus*) of variety V36, which was purchased from KEFI Malaysia Sdn. Bhd., was utilized in this research. These fibres were reinforced with high density polyethylene, which was also purchased from KEFI Malaysia. The tensile strength and modulus of HDPE used as tested by us using ASTM D-638 was 29.44 MPa and 287.70 MPa, with a melting point of 180 – 240^{o}C, in addition to a melt mass flow rate of 0.10/10min (190^{o}C/2.16 kg) and a density of 0.95 g/cm^3.

Preparation of the Composite

The fibres of Kenaf and PALF (at a ratio of 1:1) and the fibre length of 0.25 mm were utilized for this particular experiment. The fibres were carefully and thoroughly mixed together in a Brabender Plasticod at a fibre loading of 50%, in 190^{o}C, at 40 rpm processing speed and for 25 minutes operating (Aji *et al*., 2011). The mixed composite obtained from the internal mixer was cut into pellets and compressed in a compression-moulding machine set at 170^{o}C, with 7 min preheat, 5 min full press, 10 seconds of venting process, and 5 min cooling of the compressed hybrid composite sheet. Thereafter, a Dog-bone tensile specimen of 10 mm X 1.5 mm X 1 mm was cut out using a pneumatic tensile sample cutter. The test specimens were conditioned in an oven for 21 hrs at 105^{o}C prior to the tensile test.

Electron Beam Irradiation

The tensile specimens produced as described earlier were irradiated using an electron beam (EB) accelerator EPS Model-3000 at a dose range of 10–100 kGy in the sequence of 10, 20, 30, 40, 60, 80 and 100 kGy at 10 kGy per pass. All the samples were irradiated at room temperature, with accelerator energy of 2 MeV, beam current of 2 mA, and conveyor speed of 1.88 m/m.

Tensile Testing

The tensile measurement of the hybrid composite specimen was conducted using a 5 kN Bluehill INSTRON universal testing machine according to ASTM D638 as the test condition. 2 mm/min crosshead speed was used to run the machine.

RESULT AND DISCUSSIONS

The effect of radiation on the hybrid composite produced without the addition of cross-linkers is shown in Fig.1. It is clear that the tensile strength and modulus of the composite increased with the increase in the radiation dose. Although the strength of the composite dropped as compared to pure HDPE, it increased after exposure to radiation at 10 kGy and above. The increases of the tensile strength and the modulus of the hybrid composite upon irradiation are due to the fact that HDPE is a radiation cross-linkable polymer (Wilson & Burton, 1974; Singh & Silverman, 1992a; Singh, 2001). The EB irradiation of agro-fibres has been shown to induce formation of radicals that may undergo subsequence radical-radical reactions that lead to chemical bonding or may undergo radical induced chain scission that leads to degradation upon exposure to high energy radiation (Singh & Silverman, 1992b). In the current system, the radical formation of HDPE and agro-fibres led to the cross-linking between the two materials and contributed to the enhancement of the properties at lower dose of about 10 kGy. However, at higher doses, the competition between cross-linking and degradation, in particular for agro-fibres, is prominent and hence there is no significant increase in the properties of the hybrid composites between 20 kGy and 100 kGy.

SAS was used to analyze the tensile properties obtained so that statistical validation of the results can be obtained. This can help to see if adequate mixing of the hybrid has been achieved because it is the pre-requisite to achieving optimum mechanical properties. The GLM procedure and Duncan multiple range test results are shown in Table 1 for both strength and modulus. It is clear that an adequate mixing of fibres and matrix had taken place although at a probability of 5%, the replication of the specimen produced and tested is significant at lower doses. Increasing the radiation dose on the hybrid has also shown to significantly assist in improving the tensile property of the hybrid, especially in terms of the hybrid's modulus. The results have also shown that for tensile modulus, even at a probability of 1%, increasing the amount of irradiation dose is very significant in improving hybrid's modulus. Duncan's grouping

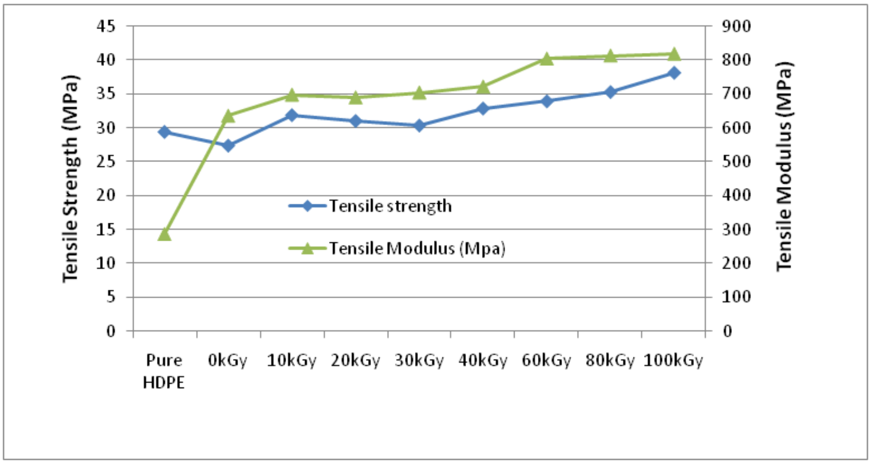

Fig.1: Variation in the tensile properties of hybridized composite

has also shown that lower dosed hybrid is closely interacting with each other. This meant that the dose applied to the hybrid was not significantly different between 10 and 40 kGy until about 60 kGy onward, where significant formation of the radicals that underwent subsequence radical-radical reactions led to increase chemical bonding, leading to greater improvement in properties, especially that of the hybrid's modulus. Hybridization and subsequent irradiation increased the tensile strength and modulus of HDPE to 31 and 185%, respectively, at about 100 kGy.

Fig.2 and Fig.3 show that this close interaction took place within the composite at lower and higher doses. This must have been the reason why there was a direct proportionality relationship between the amount of dose and the tensile properties obtained in the hybrid composite produced. It is clear that there is a tendency for higher tensile properties with the increase in dose that can be received by this kind of hybrid.

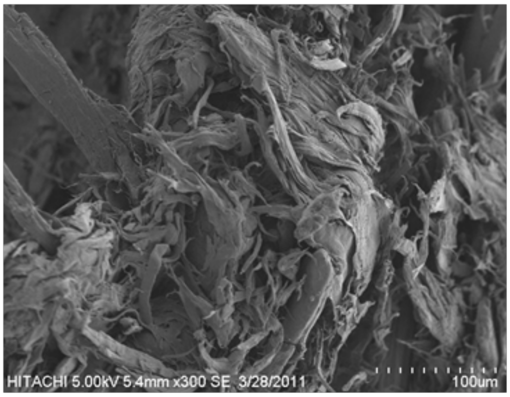

Fig.2: Tensile specimen at 10kGy without cross linking

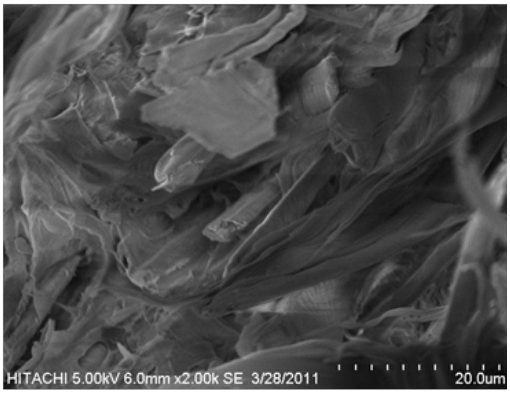

Fig.3: Tensile specimen at 100kGy without cross linking

TABLE 1: The SAS analysis for Tensile strength and Modulus: Means with the same letter are not significantly different (alpha = 0.5)

Dependent Variable: TStrength (Alpha = 0.5)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	497.709442	41.475787	2.05	0.0605
Error	26	524.918198	20.189161		
Corrected Total	38	1022.627640			

R-Square	Coeff Var	Root MSE	TStrength Mean
.486697	14.03633	4.493235	32.01146

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	4	115.6834183	28.9208546	1.43	0.2514
Trt	8	382.0260238	47.7532530	2.37	0.0463

Duncan Grouping	Mean	N	Trt
A	38.099	3	100kGy
B A	36.124	4	80kGy
B A C	33.916	5	60kGy
B A C	32.870	4	40kGy
B A C	31.899	4	10kGy
B A C	31.041	5	20kGy
B C	30.369	4	30kGy
B C	29.445	5	Neat HDPE
C	27.419	5	Un-irradiated Hybrid

TModulus

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	1060713.996	88392.833	9.30	<.0001
Error	26	247137.190	9505.277		
Corrected Total	38	1307851.186			

R-Square	Coeff Var	Root MSE	Tstrength Mean
0.811036	14.43587	97.49501	675.3662

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Rep	4	62140.6451	15535.1613	1.63	0.1956
Trt	8	998573.3508	124821.6689	13.13	<.0001

Duncan Grouping	Mean	N	Trt
A	819.90	3	100kGy
A	814.92	4	80kGy
A	805.82	5	60kGy
B A	723.01	4	40kGy
B A	705.56	4	30kGy
B A	699.12	4	10kGy
B A	691.14	5	20kGy
B	637.16	5	un-irradiated hybrid
C	287.70	5	Neat HDPE

CONCLUSION

In the current study, electron beam irradiation, without the addition of any cross linking agents, was investigated at varying doses of EB-Irradiation to develop environmentally friendly bio-composites. Improvement in the tensile properties of the hybrid was achieved, with the result showing a direct proportionality relationship between tensile properties and increased radiation dose. In particular, HDPE has been shown to be self-cross-linked, enabling interesting tensile properties with irradiation. Meanwhile, the statistical analysis conducted validated the results obtained and showed that an adequate mixing of fibres and matrix had taken place at very significant level in tensile modulus of the hybrid.

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