UNIVERSITI PUTRA MALAYSIA

PROPERTIES OF OIL PALM (ELAEIS GUINEENSIS JACQ.) EMPTY FRUIT BUNCH FIBRES-POLYPROPYLENE COMPOSITES

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By

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Faculty: Forestry

The technical viability of using oil palm empty fruit bunch (EFB) fibres as fillers and/or reinforcements to polypropylene was investigated. The effects of moisture content (MC), fibre size, fibre loading, concentration of maleated polypropylene (MAPP), modes of electron beam (EB) irradiation, types and concentration of reactive additives (RAs) on the physical, chemical, morphological, mechanical, dimensional stability and thermal properties of EFB-PP composites were investigated.

EFB-PP composites were prepared from thermomechanically pulped EFB fibres and PP by melt-mixing them using a Brabender Plastic Corder PL-2000-6 at 180°C and compressing them in a hot-and-cold press machine. Properties of the composites were tested using ASTM standards. Results were subjected to Analysis of Variance (ANOVA) and Student-Newman-Keuls (S-N-K) multiple comparison of means.

The influence of the initial MC and sizes of EFB fibres on the properties of the EFB-PP composites were not so significant, although, the mixing torque of

blends were affected where higher MC and longer fibres gave higher mixing torque. The effects of different fibre loadings and concentrations of MAPP, however, were noteworthy. The mixing torque increased with increasing fibre loading up to 50% fibres then decreasing at higher loadings. The melt flow rate (MFR) 0f the composites reduced extensively with the addition of fibres and no flow was observed above 50% fibres. The density and MC of the composite boards also increased with increasing fibre content. The tensile and flexural strengths of the composites decreased with increasing fibre loading along with elongation at break and hardness while tensile and flexural modulus increased significantly. Their impact strengths increased for notched specimens while it decreased for the unnotched specimens. Water absorption and thickness swelling increased tremendously with the addition of more EFB fibres in the composites. Addition of MAPP caused a reduction in the mixing torque of the composite blends and an increase in the MFR of the composite melts. Two-percent MAPP, the optimum level of coupling agent addition, caused an increase in the density and MC of the boards, reduced fibre breakage during compounding, and improved most of the properties.

EB radiation and addition of RAs caused reduction in the mixing torque of composite blends, increase in gel content and produced better interaction between the PP matrix and EFB fibres. Irradiation caused an increase in MFR while addition of RAs caused reduction in MFR of the composite melts. Among the four techniques of irradiation tested, irradiating PP alone resulted in optimum mechanical properties. Among the RAs tested, trimethylol propane triacrylate (TMPTA) performed the best compared to hexadiol diacrylate (HDDA) and 2-ethylhexyl acrylate (EHA), and conventional additive,

MAPP. One percent of the RA was sufficient to enhance all the properties of the EFB-PP composites evaluated in the study.

Moreover, incorporation of EFB fibres affected the thermal properties of EFB-PP composites. Thermogravimetric analysis (TGA) revealed that the addition of EFB fibres lowered the thermal degradation temperature of the EFB-PP composites with increasing fibre loading. Dynamic mechanical analysis (DMA) showed that the EFB-PP composites with higher fibre loading have higher storage modulus (E') and loss modulus (E"). It was also determined that the E" obtained from the DMA technique was comparable to the flexural modulus determined by the 3-point bending test. Tan δ curves of the composites indicated that EFB fibres had insignificant effect on the damping properties of the composites. Addition of MAPP enhanced the tan δ values indicating the improvement in the interphase. The tan δ for the irradiated EFB-PP composites with the different RAs decreased with increasing degree of cross linking. The α-peak shifted to higher temperature with increasing functionality of RAs.

The incorporation of untreated EFB fibres to PP generally lowered the properties of the resultant composite, except for modulus, due to the incompatibility of the highly polar EFB fibres and the apolar PP. However, treatments such as addition of MAPP, EB radiation treatment and addition of RAs improved the interfacial strength and thus enhanced properties of the composites as displayed by the mechanical and thermal properties evaluated.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi untuk ijazah Doktor Falsafah

SIFAT KOMPOSIT GENTIAN DARI TANGKAI KOSONG KELAPA SAWIT (*ELAEIS GUINEENSIS* JACQ.)-POLIPROPILENA

Oleh

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Kesesuaian teknikal dalam penggunaan gentian dari tandan kosong buah kelapa sawit (EFB) sebagai pengisi dan/atau penambah keteguhan kepada polipropilena (PP) telah dikaji. Secara khususnya, kesan kandungan lembapan (MC), saiz gentian, pemuatan gentian, konsentrasi polipropilena malea (MAPP), mod sinaran alur elektron (EB), jenis dan konsentrasi bahan tambahan reaktif (RAs) ke atas sifat fisikal, kimia, morfologi, mekanikal, kestabilan dimensi dan termal bagi komposit EFB-PP juga telah diteliti.

Komposit EFB-PP dihasilkan daripada gentian EFB dan PP melalui proses termomekanikal dengan melarut-campuran mereka menggunakan Brabender Plastic Corder PL-2000-6 pada suhu 180°C dan mampatkan dalam mesin penekan panas-sejuk. Kandungan komposit diuji menggunakan standard ASTM dan BS. Keputusan adalah bergantung kepada perbandingan mean melalui kaedah "Analysis of Variance" dan " Student-Newman-Keuls".

Pengaruh kandungan lembapan awal dan saiz gentian EFB pada sifat komposit EFB-PP didapati tidak ketara, walaupun terdapat kesan pada tork di

mana kandungan lembapan tinggi dan gentian yang panjang menghasilkan tork yang lebih tinggi. Bagaimanapun, kepelbagaian pemuatan gentian dan kandungan MAPP memberikan kesan yang ketara. Tork bertambah dengan penambahan pemuatan gentian sehingga 50% gentian, kemudian menurun apabila pemuatan gentian meningkat. Kadar aluran percampuran (MFR) ketara berkurangan dengan penambahan gentian, dan tiada pengaliran diperhatikan pada pemuatan gentian yang melebihi 50%. Ketumpatan dan kandungan lembapan papan komposit juga bertambah dengan penambahan kandungan gentian. Kekuatan tegangan dan lenturan menurun dengan penambahan pemuatan gentian disertai dengan pemanjangan pada titik kegagalan dan kekerasan. Modulus tegangan dan lenturan bertambah di aras yang tinggi. Kesan kekuatan meningkat pada sampel berlekuk manakala menurun bagi sampel yang tidak berlekuk. Kadar serapan air dan ketebalan pembengkakan meningkat secara langsung apabila gentian EFB ditambah. Penambahan MAPP mengakibatkan pengurangan dalam tork untuk campuran komposit tetapi mengakibatkan peningkatan bagi kadar peleburan komposit MFR. Dengan dua peratus MAPP, ia mengakibatkan kenaikan ketumpatan dan kandungan lembapan pada papan komposit, menurunkan patahan gentian semasa pencampuran, serta memperbaiki kebanyakan sifat yang dikaji; namun begitu penambahan yang berterusan tidak memberikan kesan yang berbeza.

Radiasi EB dan penambahan RAs menyebabkan pengurangan tork bagi campuran komposit, peningkatan kandungan jel dan menghasilkan interaksi yang lebih baik antara matrik PP dan gentian EFB. Sinaran mengakibatkan

peningkatan dalam MFR, manakala penambahan RAs mengakibatkan pengurangan nilai bagi kadar peleburan komposit MFR. Di antara empat teknik sinaran yang dikaji, sinaran terhadap PP menghasilkan sifat mekanikal yang terbaik. Di antara RAs yang dikaji, trimetilol propan triacrilat (TMPTA) menunjukkan prestasi terbaik dibandingkan dengan hexan diol diacrilat (HDDA) dan 2-etilhexil acrilat (EHA) serta bahan tambahan biasa MAPP. Ini disebabkan oleh kadar tindakbalas yang lebih tinggi yang dirangsangkan oleh TMPTA jika di bardingkan dengar RAs yang lain. Kadar ini telah lebih menperkukuhkan pengikatan melintang yang terjadi.

Tambahan lagi, pangabungan gentian EFB juga mempengaruhi ujikaji sifat termal komposit EFB-PP. Penambahan gentian EFB mengurangkan suhu kemerosotan termal komposit EFB-PP secara langsung dengan peningkatan muatan gentian. Analisa mekanical dinamik (DMA) menunjukkan komposit EFB-PP yang mengandungi pemuatan gentian EFB yang lebih tinggi mempunyai penyimpanan dan kehilangan modulus yang lebih tinggi. Kajian juga menunjukkan, modulus penyimpanan yang diukur dengan menggunakan teknik DMA juga didapati setaraf dengan modulus lenturan yang diukur dengan ujian lentur 3 titik. Lengkungan tan δ komposit menunjukkan gentian EFB tidak memberi kesan ketara kepada sifat "damping" komposit. Penambahan MAPP meninggikan nilai tan δ mengambarkan pembaikan dalam "antara fasa". Tan δ bagi komposit EFB-PP yang telah disinarkan yang mempunyai kandungan RAs yang berbeza berkurangan dengan peningkatan tahap pengikatan melintang. Kemuncak α berpindah ke suhu yang lebih tinggi berikutan peningkatan tahap fungsi RAs.

Penambahan gentian EFB yang tidak dirawat ke PP biasanya mengurangkan sifat komposit yang dihasilkan. Ini adalah keran gentian EFB yang berpolar tinggi adalah tidak secocok dengan PP yang tidak berpolar. Rawatan seperti penambahan MAPP, EB dan penambahan RAs boleh memperbaiki kekuatan antarafasa dan mempertingkatkan sifat-sifat mekanikal dan termal komposit yang dihasilkan.

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