UNIVERSITI PUTRA MALAYSIA

CHARACTERISATION AND OPTIMISATION OF MECHANICAL, PHYSICAL AND THERMAL PROPERTIES OF SHORT ABACA (MUSA TEXTILE NEE) FIBRE REINFORCED HIGH IMPACT POLYSTYRENE COMPOSITES

AGUNG EFRIYO HADI

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By

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CHARACTERISATION AND OPTIMISATION OF MECHANICAL, PHYSICAL AND THERMAL PROPERTIES OF SHORT ABACA (*MUSA TEXTILE NEE*) FIBRE REINFORCED HIGH IMPACT POLYSTYRENE COMPOSITES

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June 2011

Chair : Professor Mohd Sapuan Salit, PhD, PEng.

Faculty : Engineering

Mechanical properties of polymer composites are influenced by many factors such as the types of fibres, the types of polymer matrix, the additives used and the adhesion between fibres and polymer matrix. To improve the interfacial adhesion between high impact polystyrene (HIPS) matrix and abaca fibres, the study of optimum use of coupling agent maleic anhydride (MAH) and impact modifier, styrene-butadiene-styrene, (SBS) is presented in this research. Abaca fibre reinforced high impact polystyrene (HIPS) composites are produced with different fibre loadings (30, 40 and 50 wt%), different compositions of coupling agent, MAH (1,2 and 3 wt%) and

different compositions of impact modifier (4,5 and 6 wt%). A response surface methodology using Box-Behnken design (BBD) is used in the design of experiments and analysis of results. Statistical analysis of mechanical properties gives very satisfactory model accuracy, because the coefficient of determinant is 0.9817 for impact strength, 0.9789 for tensile strength, 0.9672 for tensile modulus, 0.9700 for flexural strength, and 0.9747 for flexural modulus. In this study, loading abaca fibre 36.76 wt%, maleic anhydride 3 wt% and impact modifier 4 wt% are parameters that are optimum for individual impact strength. On the other hand, optimum individual tensile strength and tensile modulus were achieved when the loading of abaca fibre is close to 40.76 wt%, maleic anhydride 3 wt% and impact modifier 6 wt%, but the optimum individual flexural strength and flexural modulus were found when loading of abaca fibre is close to 40.03 wt%, maleic anhydride 3 wt% and impact modifier 4 wt%. Based on the analysis of variance (ANOVA) and BBD analysis, the Brinell hardness number (BHN) was not influenced by the significant increase of abaca fibre and coupling agent (maleic anhydride (MAH)) and also by the interaction between impact modifier and coupling agent (maleic anhydride (MAH)). The interaction between abaca fibre and impact modifier, represented by the negative coefficient X13 (β_{13} = -0.1413 and p-value < 0.05) indicated unfavourable effect and partitioning influence in the abaca fibre reinforced HIPS composites. The interaction between abaca fibres and impact modifier is less likely for Brinell hardness number (BHN) of the composites. The physical properties by natural fibre had a great importance especially in the structure of natural fibre which reinforced matrix. Based on response surface methodology, Box-Behnken design, the individual optimum conditions of

melt flow index was found with loading of abaca fibre 36.71 wt%, maleic anhydride 3 wt% and impact modifier 4.02 wt%. The optimum condition for water absorption of abaca fibre reinforced HIPS composites followed the decreasing trend of value of melt flow index. Differential scanning calorimetry (DSC) was used to study the thermal behaviour of abaca fibre reinforced high impact polystyrene (HIPS) composites. In this research, glass transitions temperature (Tg) of neat HIPS occurred below the Tg of optimum condition of composites as the temperature of an amorphous state. The endothermic peak of composites was in the range of 430 ^{0}C – 435 ^{0}C including neat HIPS and it was observed that enthalpy of abaca fibre reinforced HIPS composites was yielded below the enthalpy of neat HIPS of 748.79 J/g. In this research, thermogravimetric analysis (TGA) within optimum condition of abaca fibre reinforced HIPS composites was compared to the neat HIPS. The measurements were carried out in temperatures ranging from 25 ^{0}C – 600 ^{0}C at heating rate of 20 ^{0}C min-1 and nitrogen gas flow of 50 mL min-1. The results from TGA analysis have shown that the combination of the coupling agent maleic anhydride, impact modifier and abaca fibre has improved the thermal stability of composites.

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

PENCIRIAN DAN PENGOPTIMUMAN SIFAT - SIFAT MEKANIKAL, FIZIKAL DAN TERMAL BAGI KOMPOSIT POLISTIRENA IMPAK TINGGI DIPERKUAT GENTIAN PENDEK ABAKA (*MUSA TEXTILE NEE*)

Oleh

AGUNG EFRIYO HADI

Juni 2011

Pengerusi : Profesor Mohd Sapuan Salit, PhD, PEng.

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Sifat mekanikal bagi komposit polimer dipengaruhi oleh pelbagai faktor seperti jenis gentian, jenis matriks polimer, bahan tambah yang digunakan dan rekatan antara gentian dan matriks polimer. Bagi memperbaiki rekatan antara muka antara matriks polistirena impak tinggi (HIPS) dan gentian abaka, satu kajian bagi penggunaan optimum agen gandingan maleik anhidrida (MAH) dan pengubah suai impak, stirina-butadina-stirina, (SBS) dipersembahkan dalam penyelidikan ini. Komposit polistirena impak tinggi (HIPS) dihasilkan dengan pembebanan gentian yang berbeza (30, 40

dan 50 wt%), komposisi agen gandingan yang berbeza, MAH (1,2 dan 3 wt%) dan komposisi pengubah suai impak yang berbeza (4,5 dan 6 wt%). Metodologi permukaan tindak balas menggunakan reka bentuk Box-Behnken (BBD) digunakan dalam reka bentuk eksperimen dan analisis keputusan. Analisis statistik bagi sifat mekanikal memberikan ketepatan model yang sangat memuaskan, kerana pekali penentu adalah 0.9817 bagi kekuatan hentaman, 0.9789 bagi kekuatan tegangan, 0.9672 bagi modulus tegangan, 0.9700 bagi kekuatan lenturan, dan 0.9747 bagi modulus lenturan. Dalam kajian ini, pembebanan gentian abaka 36.76 wt%, maleik anhidrida 3 wt% dan pengubah suai impak 4 wt% adalah parameter yang optimum bagi kekuatan hentaman individu. Sebaliknya, kekuatan dan modulus individu yang optimum dicapai bila pembebanan gentian abaka kira-kira 40.76 wt%, maleik anhidrida 3 wt% dan pengubah suai impak 6 wt%, tetapi kekuatan dan modulus tegangan individu yang optimum didapati bila pembebanan gentian abaka menghampiri 40.03 wt%, maleik anhidrida 3 wt% dan pengubah suai impak 4 wt%. Berasaskan analisis varian (ANOVA) dan analisis BBD, nombor kekerasan Brinell (BHN) tidak dipengaruhi dengan signifikan oleh pertambahan gentian abaka dan agen gandingan (maleik anhidrida (MAH)) dan juga saling tindak antara pengubah suai impak dan agen gandingan (maleik anhidrida (MAH)). Saling tindak antara gentian abaka dan pengubah suai impak, yang diwakili oleh pekali negatif X_{13} (β_{13} = -0.1413 dan nilai-p < 0.05) menunjukkan kesan yang tidak diingini dan pengaruh pemetakan dalam komposit HIPS diperkuat gentian abaka. Saling tindak antara gentian abaka dan pengubah suai impak agak sukar untuk berlaku bagi nombor kekerasan Brinell (BHN) bagi komposit. Sifat fizikal bagi gentian asli mempunyai

kepentingan yang besar terutamanya dalam struktur gentian yang memperkuat matriks. Berasaskan metodologi permukaan tindak balas, reka bentuk Box-Behnken, keadaan optimum individu bagi indeks aliran cairan telah didapati dengan pembebenan gentian abaka 36.71 wt%, maleik anhidrida 3 wt% dan pengubah suai impak 4.02 wt%. Keadaan optimum bagi penyerapan air bagi komposit HIPS diperkuat gentian abaka mengikuti arah aliran yang berkurangan bagi nilai indeks aliran cairan. Kalorimetri pengimbasan kebezaan (DSC) telah digunakan bagi mengkaji kelakuan termal komposit polistirena impak tinggi diperkuat gentian abaka. Dalam penyelidikan ini, suhu peralihan kaca (*Tg*) bagi HIPS tulen berlaku di bawah *Tg* bagi keadaan optimum bagi komposit sebagai suhu pada keadaan amorfus. Puncak endotermik bagi komposit adalah dalam julat 430 ^{0}C - 435 ^{0}C termasuk HIPS tulen dan adalah diperhatikan bahawa entalpi bagi komposit HIPS diperkuat gentian abaka dihasilkan dibawah entalpi bagi HIPS tulen iaitu 748.79 J/g. Dalam penyelidikan ini, analysis termogravimetrik (TGA) dalam kedaaan optimum bagi komposit HIPS diperkuat gentian abaka telah dibandingkan dengan HIPS tulen. Pengukuran telah dijalankan dalam suhu berjulat 25 ^{0}C – 600 ^{0}C pada kadar pemanasan 20 ^{0}C min^{-1} dan aliran gas nitrogen 50 mL min^{-1}. Keputusan daripada analisis TGA telah menunjukkan bahawa gabungan agen gandingan maleik anhidrida, pengubah suai impak dan gentian abaka telah menambah baik kestabilan termal bagi komposit.

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I certify that an Examination Committee has met on 28 June 2011 to conduct the final examination of Agung Efriyo Hadi on his Doctor of Philosophy thesis entitled "Charaterisation and optimisation of mechanical, physical and thermal properties of short abaca (*Musa Textile Nee*) fibre reinforced high impact polystyrene composites" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the Doctor of Philosophy.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not previously, and is not concurrently, submitted for any other degree at Universiti Putra Malayasia or any other institutions.

AGUNG EFRIYO HADI

Date: 28 June 2011

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