UNIVERSITI PUTRA MALAYSIA

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By

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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman : Professor Mohd. Sapuan bin Salit, PhD, PEng

Faculty : Engineering

Despite being mechanically and environmentally sound, pineapple leaf fibers (PALF) are the least studied natural fibers especially as reinforcement in polymer composites and currently of little use in Malaysia. As the industrial importance and plantation area increase, efforts to develop applications utilizing PALF and simultaneously reduce environmental pollution must be carried out. This thesis aimed to contribute by studying a few fundamental aspects of PALF and PALF-reinforced composites. As species strongly dictates natural fiber properties, PALF from the three most popular Malaysian cultivars were characterized physically, mechanically and thermally. Effects of a simple abrasive combing and pretreatments on PALF properties were evaluated. PALF were used to reinforce vinyl ester resin (VER) using liquid composite molding (LCM) and the composite properties compared with those of hand-laid neat VER, glass fiber and PALF-VER composites. A factorial study was carried out on the effects and interactions of catalyst amount and selected process parameters on the properties of LCM VER sheets. Influence of fiber diameter, fiber property-retention after long storage, simple pretreatments, fiber location on the leaves and fiber separation techniques on mechanical properties

of PALF-VER composites were also investigated. PALF tensile strength fits well with two-parameter Weibull distribution. Though uncritical for PALF-thermoset composites, the 20^{o}C difference in thermal stability of PALF of different varieties is significant for PALF-thermoplastic composites. Josapine cultivar is the most appropriate PALF species in terms of potential fiber quantity, fineness, high tensile strength and modulus, thermal stability and ease of extraction. Vascular bundles and fiber strands were similar chemically and structurally thus differed by diameter only. The former were effectively stronger due to the presence of bonding tissues. Bundles from different locations in the leaves and those stored for a six-month period in hot humid conditions may be used without significantly affecting composite mechanical properties. At low weight fraction and consolidating pressure, PALF regardless of diameters and locations performed equally well in enhancing flexural properties in static loading. Composite toughness was higher when fine strands were used. Washing PALF with water improved PALF-VER adhesion while prolonged soaking produced no extra benefits. PALF and PALF-VER adhesion were not improved with the use of dilute aqueous sodium hypochlorite solution. Abrasive combing viably separated and produced fine and clean PALF of reasonable properties. Abrasive-combed PALF equaled technical fibers in reinforcing VER while their lower ductility reduced composite toughness. Untreated PALF bundles may be used to reinforce VER to produce real composites using LCM with water resistance significantly enhanced by molding pressure. Judicious process parameter selection is required to produce quality VER sheets and by extension PALF-VER composites. Molding VER-unsaturated polyester blend resulted in a significantly different material and a potential matrix for PALF composites.

Abstrak tesis yang di kemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SIFAT FIZIKAL, MEKANIKAL DAN TERMAL GENTIAN DAUN NENAS DAN KOMPOSIT VINIL ESTER YANG DIPERKUAT DENGAN GDN

Oleh
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Walaupun GDN amat baik dari segi mekanikal dan untuk alam sekitar, ianya amat sedikit dikaji terutamanya sebagai peneguh dalam komposit polimer serta kurang digunakan di Malaysia. Dengan peningkatan kepentingan industri serta kawasan penanaman nanas, usaha membangunkan aplikasi menggunakan GDN sekaligus mengurangkan pencemaran alam mesti dilaksanakan. Tesis ini menyumbang ke arah ini melalui pengkajian beberapa aspek asas GDN dan komposit polimer-GDN. Kerana kultivar faktor terpenting menentukan sifat gentian, GDN dari tiga kultivar nanas paling popular di Malaysia diuji sifat-sifat fizikal, mekanikal dan termal mereka. Kesan penggunaan sikat lelas dan rawatan awalan mudah ke atas sifat GDN juga dikaji. GDN digunakan bagi mengukuh damar vinil ester (VER) menggunakan pembikinan komposit cecair dengan mampatan (LCM) dan sifat komposit terhasil dibandingkan dengan sifat damar serta komposit menggunakan GDN dan gentian kaca diperbuat secara manual. Kajian faktorial dijalankan ke atas kesan dan interaksi di antara kandungan pemangkin dan parameter proses pada sifat kepingan VER dihasilkan melalui LCM. Sifat mekanikal komposit VER-GDN dikaji untuk mengenalpasti kesan garispusat GDN, tempoh simpanan, rawatan awalan, lokasi GDN pada daun serta teknik pemisahan gentian. Daya regangan GDN berpadanan

dengan distribusi Weibull dua parameter. Meskipun tidak kritikal untuk komposit GDN-termoset, perbezaan 20^{o}C dalam kestabilan termal GDN dari pelbagai kultivar sangat signifikan untuk komposit GDN-termoplastik. Spesies Josapine adalah GDN paling sesuai dari aspek kuantiti gentian, kehalusan, sifat regangan, kestabilan termal dan kemudahan ekstraksi. GDN kasar dan halus didapati sama dari segi struktur dan kimia serta dibezakan oleh garispusat sahaja. Kekuatan GDN kasar lebih efektif dengan kehadiran ikatan tisu-tisu. GDN dari lokasi berbeza pada daun serta yang disimpan selama enam (6) bulan pada suhu dan kelembapan tinggi boleh digunakan tanpa mempengaruhi sifat mekanikal komposit secara signifikan. Pada jumlah kecil dan tanpa mampatan, GDN tanpa mengira lokasi dan garispusat sama baiknya dalam meningkatkan lenturan komposit bagi bebanan statik. Ketangguhan komposit lebih tinggi jika diperkuat dengan GDN halus. Pencucian GDN dengan air meningkatkan adhesi GDN-VER tapi tiada manfaat tambahan pada rendaman berpanjangan. GDN dan adhesi GDN-VER tidak diperbaiki dengan penggunaan larutan cair natrium hipoklorit. Sikat lelas berpotensi menghasilkan gentian halus dan bersih dengan sifat-sifat yang baik. GDN yang disikat-lelas setara GDN halus dalam menguatkan VER dalam aplikasi statik manakala sifat senang putus mereka mengurangkan ketangguhan komposit. GDN kasar tidak dirawat boleh digunakan untuk menghasilkan komposit VER secara LCM di mana sifat ketahanan air komposit meningkat secara signifikan hasil penggunaan mampatan. Pilihan bijak parameter proses perlu bagi mendapatkan kepingan VER dan komposit VER-GDN berkualiti. Tuangan campuran VER-poliester menghasilkan satu bahan dengan sifat-sifat yang berlainan berpotensi digunakan sebagai matrik untuk komposit GDN.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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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 been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or any other institutions.

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