



UNIVERSITI PUTRA MALAYSIA

***THERMO-MECHANICAL PROPERTIES OF SUGARCANE
BAGASSE-FILLED POLYVINYL CHLORIDE COMPOSITES***

RIZA WIRAWAN

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**THERMO-MECHANICAL PROPERTIES OF SUGARCANE BAGASSE-FILLED
POLYVINYL CHLORIDE COMPOSITES**

By

RIZA WIRAWAN

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

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Chairman: Professor Mohd Sapuan Salit, PhD, PEng

Faculty: Engineering

This research is an attempt to convert bagasse, an abundant waste of agricultural product, into a natural fibre/polymer composite, which is of higher economical value. Composites of sugarcane bagasse in polyvinyl chloride (PVC) matrix were produced by a compression moulding method followed by material testing to determine the mechanical and thermal properties of the composite. Tensile test, impact test, flexural test, and dynamic mechanical and thermal analysis (DMTA) were performed to both PVC and sugarcane bagasse/PVC composites in variation of fibre contents and fibre sources, which are the inner (pith) and the outer (rind) parts of sugarcane. It was observed that the tensile strength and modulus of rind/PVC composites are higher than the unfilled PVC at fibre contents of 30% and 40% , however the impact energy and thermal stability of all composites are lower than that of unfilled PVC.

Further investigation was then performed to the rind/PVC composites at the fibre content of 40%. Various chemical treatments, included fibre treatment with benzoic acid, fibre treatment with sodium hydroxide, and the incorporation of poly-[methylene(polyphenyl) isocyanate] (PMPPIC) as coupling agent were carried out. Among the three chemical treatments, the incorporation of PMPPIC gave the highest tensile strength and modulus. Both tensile strength and modulus, however, are lower compared to those of untreated sugarcane bagasse-filled composite when unwashed bagasse, which contained sugar, was used, indicating that sugar give contribution to the tensile strength and modulus of the composites.

Finally, the compression moulding of the untreated composite was followed by various heat treatment processes, involving slow cooling (annealing), fast cooling (quenching), and re-heating to a temperature below T_g . The effects of the thermal history were examined by the measurement of tensile strength and strain at break as well as by differential scanning calorimetry (DSC). It was observed that the heat treatments affected the strain at break of unfilled PVC significantly with less significant effect on the tensile strengths. In contrast, various tensile strengths of sugarcane bagasse PVC composites were observed after various heat treatments with less significant effect to the strain at break. In addition, recycling of the composites erase the effect of thermal history. In conclusion, sugarcane bagasse, especially the rind part has a great potential to be used as filler in a PVC matrix composite. It increases the strength and stiffness of PVC without further expensive chemical treatment. However, it should be noted that the impact strength and thermal stability of the composites are lower than those of unfilled PVC.

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

**SIFAT-SIFAT TERMA-MEKANIK KOMPOSIT POLIVINIL KLORIDA
BERISI HAMPAS TEBU**

Oleh

RIZA WIRAWAN

Februari 2011

Pengerusi: Professor Mohd Sapuan Salit PhD, PEng

Fakulti: Kejuruteraan

Penyelidikan ini merupakan usaha untuk meningkatkan nilai ekonomi dari hampas tebu, yang merupakan sisa produk pertanian yang berlimpah, dengan menjadikannya komposit polimer. Komposit dari hampas tebu dengan matriks poli(vinil klorida) (PVC) dihasilkan dengan kaedah pengacuan mampatan, dilanjutkan dengan pengujian sifat mekanik dan terma. Ujian tegangan, hentaman dan kelenturan, dan analisis mekanik dinamik dan terma (DMTA) dilakukan untuk menentukan sifat mekanik dan terma PVC dan komposit hampas tebu / PVC dalam variasi kandungan dan sumber gentian, yaitu bahagian dalam (teras) dan bahagian luar (kulit) tebu. Hasil penyelidikan menunjukkan bahawa kekuatan dan modulus tegangan komposit kulit tebu/ PVC dengan kandungan gentian 30 dan 40% lebih tinggi dari kekuatan dan modulus PVC, namun kekuatan hentaman dan kestabilan terma bagi semua komposit lebih rendah daripada PVC tanpa pengisi.

Penyelidikan lebih lanjut dilakukan pada komposit kulit tebu/ PVC pada kandungan gentian 40%. Rawatan kimia termasuk pemrosesan gentian dengan asid benzoat, rawatan

gentian dengan sodium hidroksida, dan penambahan poli-[metilen(polifenil)isosianat] (PMPPIC) sebagai agen pengganding. Rawatan kimia didapati berkesan meningkatkan kekuatan dan modulus tegangan komposit apabila hampas tebu yang dibasuh digunakan. Di antara tiga rawatan kimia, penggunaan PMPPIC memberikan kekuatan dan modulus tegangan tertinggi. Walau bagaimanapun, kedua-dua kekuatan tegangan dan modulusnya, adalah lebih rendah berbanding dengan komposit dari hampas tebu yang mengandungi gula. Ia menunjukkan bahawa gula memberikan sumbangan terhadap kekuatan tegangan dan modulus komposit.

Yang terakhir, pemampatan komposit diikuti oleh pelbagai proses perlakuan panas yang melibatkan pendinginan lambat, pendinginan segera, dan pemanasan ulang pada suhu di bawah T_g . Kesan dari sejarah terma diperiksa dengan pengukuran kekuatan tegangan dan terikan pada takat putus, juga dengan analisis kalorimetri pengimbas pembezaan (DSC). Didapati bahawa perlakuan panas mempengaruhi terikan pada takat putus PVC secara signifikan dengan kesan kurang signifikan pada kekuatan tegangan. Sebaliknya, kesan signifikan terhadap nilai kekuatan tegangan komposit PVC hampas tebu diamati selepas perlakuan panas yang berbeza dengan kesan yang kurang signifikan terhadap terikan pada takat putus. Selain itu, kitar semula komposit boleh memadam pengaruh sejarah terma. Sebagai kesimpulan, hampas tebu, terutama bahagian luar, mempunyai potensi besar untuk digunakan sebagai bahan pengisi dalam komposit bermatriks PVC. Ia meningkatkan kekuatan dan ketegaran PVC tanpa rawatan kimia yang mahal. Walau bagaimanapun, kekuatan hentaman dan kestabilan terma komposit lebih rendah daripada PVC tanpa pengisi.

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APPROVAL

I certify that a Thesis Examination Committee has met on 24 February 2011 to conduct the final examination of Riza Wirawan on his thesis entitled “Thermo-Mechanical Properties of Sugarcane Bagasse-Filled Polyvinyl Chloride Composites” in accordance with Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Examination Committee are as follows:

Shamsuddin Sulaiman, PhD

Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Aidy Ali, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Rizal Zahari, PhD

Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Faiz Mohammad, PhD

Professor
Faculty of Engineering and Technology
Aligarh Muslim University
(External Examiner)

NORITAH OMAR, PhD

Associate Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 19 April 2011

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:

Mohd Sapuan Salit, PhD, PEng

Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Robiah Yunus, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Khalina Abdan, PhD

Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

HASANAH MOHD GHAZALI, PhD

Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 12 May 2011

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 other institution.



RIZA WIRAWAN

Date: 24 February 2011

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