EFFECTS OF SELECTED TREATMENTS ON PROPERTIES OF PINEAPPLE LEAF FIBRE REINFORCED HIGH IMPACT POLYSTYRENE COMPOSITES

JANUAR PARLAUNGAN SIREGAR

FK 2011 39
EFFECTS OF SELECTED TREATMENTS ON PROPERTIES OF PINEAPPLE LEAF FIBRE REINFORCED HIGH IMPACT POLYSTYRENE COMPOSITES

By

JANUAR PARLAUNGAN SIREGAR

DOCTOR OF PHILOSOPHY
UNIVERSITI PUTRA MALAYSIA

2011
EFFECTS OF SELECTED TREATMENTS ON PROPERTIES OF PINEAPPLE LEAF FIBRE REINFORCED HIGH IMPACT POLYSTYRENE COMPOSITES

By

JANUAR PARLAUNGAN SIREGAR

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

February 2011
Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

**EFFCETS OF SELECTED TREATMENTS ON PROPERTIES OF PINEAPPLE LEAF FIBRE REINFORCED HIGH IMPACT POLYSTYRENE COMPOSITES**

By

**JANUAR PARLAUNGAN SIREGAR**

February 2011

Chairman : Professor Mohd Sapuan Salit, PhD, PEng

Faculty : Engineering

The objective of this study was to investigate the physical, mechanical, and thermal properties of pineapple leaf fibre (PALF) reinforced high impact polystyrene (HIPS) composites. PALF is one of the natural fibres that is rich in cellulose and has high tensile strength properties. The fibres were obtained from the leaves of the pineapple plant. The PALF fibres were ground and sieved into different sizes of fibres; 10-40, 40-60 and 60-80 meshes. Six different fibre loadings of 0%, 10%, 20%, 30%, 40% and 50% by weight of pineapple fibre were used to reinforcement in high impact polystyrene. Mixing PALF fibre and HIPS was carried out using a melt mixer and then the resulting material was compressed in the mould using a Carver laboratory press at temperature 165°C. The results showed that the addition of untreated PALF fibre to reinforce HIPS has decreased the tensile strength, flexural strength, impact strength of composites but increased the tensile moduli, flexural moduli and hardness of the composites. The decrease of the strength of
HIPS/PALF composites was due to the poor compatibility of hydrophilic PALF and hydrophobic HIPS matrix resulting in poor dispersion of fibre in the matrix and weak interfacial bonding between the fibres and HIPS matrix. Consequently this study also investigated the effect of alkali treatment and compatibilising agent to improve the mechanical and thermal properties of the composites. The PALF fibres were soaked in two different concentrations of NaOH solution which were fixed at 2% and 4% of sodium hydroxide (NaOH) solution. Two types of compatibilising agent were used in this research, namely polystyrene-\textit{block}-poly(ethylene-\textit{ran}-butylene)-\textit{block}-poly(styrene-\textit{graft}-maleic anhydride) and poly(styrene-\textit{co}-maleic anhydride). The addition of fibre treatment and compatibilising agent has improved the mechanical and thermal properties of PALF/HIPS composites. The study of the effect electron beam irradiation and the addition of croslinking agent also increased the mechanical properties of the composites.
Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN RAWATAN BAGI KOMPOSIT POLISTIRENA HENTAMAN TINGGI DIPERKUAT GENTIAN DAUN NANAS

Oleh

JANUAR PARLAUNGAN SIREGAR

February 2011

Pengerusi : Profesor Mohd Sapuan Salit, PhD, PEng
Fakulti : Kejuruteraan

Objektif penyelidikan ini adalah untuk mengkaji sifat fizikal, mekanikal dan termal bagi komposit polistirena hentaman tinggi diperkuat gentian daun nanas. Gentian daun nanas adalah salah satu gentian asli yang kaya dengan selulosa dan mempunyai sifat kekuatan tegangan yang tinggi. Gentian daun nanas diperolehi daripada daun pokok nanas. Gentian daun nanas telah dihancurkan dan diayak kepada saiz gentian yang berbeza: 10-40, 40-60 dan 60-80 jejaring. Enam pembebanan gentian daun nanas yang berbeza 0%, 10%, 20%, 30%, 40% and 50% mengikut berat telah digunakan bagi memperkuat komposit polistirena hentaman tinggi. Pencampuran gentian nanas dan polistirena hentaman tinggi telah dijalankan menggunakan sebuah pencampur leburan (sebuah pencampur intensif Brabender Plasticorder, model PL2000-6) dan bahan yang dihasilkan telah ditekan di dalam acuan menggunakan penekan makmal Carver pada suhu 165 °C. Penambahan gentian nanas tidak dirawat bagi memperkuat polistirena hentaman tinggi telah menurunkan sifat mekanikal komposit tetapi telah meningkatkan modulus tegangan,
ACKNOWLEDGEMENT

First and foremost I would like to thank to my supervisor, Professor Ir. Dr. Mohd Sapuan Salit for all his encouragement, guidance, help, and support, without which this work would not have been possible. I am also thankful to my co-supervisors, Associate Professor Dr. Mohd Zaki Abdul Rahman and Dr. Mohd Khairul Zaman for many help suggestions during my study. I would like to thank the Ministry of Higher Education Malaysia for funding the research through Fundamental Research Grant Scheme (FRGS) grant number 5523413. I would like to thank Mr. Zahid from Malaysia Nuclear Agency for his support and guidance during the data collection. I would like to thank my parents and my family for their love support, understanding and patience. Special thanks to my research colleagues who provided constructive advice for the completion of this thesis. This include: Dandi Bachtiar, Riza Wirawan, Agung Efriyo Hadi and Mohamad Ridzwan Ishak.
I certify that a Thesis Examination Committee has met on the 11th of February 2011 to conduct the final examination of Januar Parlaungan Siregar on his thesis entitled “Effects of Selected Treatments on The Properties of Pineapple Leaf Fibre Reinforced High Impact Polystyrene Composites” in accordance with the 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 Thesis Examination Committee are follows:

**Shamsuddin bin Sulaiman, PhD**
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

**Robiah binti Yunus, PhD**
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

**Zulkiflle bin Leman, PhD**
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

**Faiz Mohammad, PhD**
Professor
Aligarh Muslim University
India
(External Examiner)

---

**NORITAH OMAR, PhD**
Associate Professor and Deputy Dean
School of Graduates Studies
Universiti Putra Malaysia

Date: 24 May 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 Bin Salit, PhD, PEng  
Professor  
Faculty of Engineering  
Universiti Putra Malaysia  
(Chairman)

Mohd Zaki Ab. Rahman, PhD  
Associate Professor  
Faculty of Science  
Universiti Putra Malaysia  
(Member)

Mohd Khairul Zaman, PhD  
Radiation Processing Technology Division  
Malaysia Nuclear Agency  
(Member)

HASANAH MOHD GHAZALI, PhD  
Professor and Dean  
School of Graduates Studies  
Universiti Putra Malaysia  

Date:
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 Malaysia or any other institutions.

________________________
JANUAR PARLAUNGAN SIREGAR

Date: 11 February 2011
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>iv</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>vi</td>
</tr>
<tr>
<td>APPROVAL</td>
<td>vii</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>ix</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xiii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xiv</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xv</td>
</tr>
</tbody>
</table>

## CHAPTER

1. **INTRODUCTION**
   - 1.1 Background
   - 1.2 Significance of study
   - 1.3 Problem statement
   - 1.4 The objectives of study
   - 1.5 Scope and limitation of the study
   - 1.6 The outline of the thesis

2. **LITERATURE REVIEW**
   - 2.1 Natural fibres
   - 2.2 Properties of natural fibres
     - 2.2.1 Physical properties of natural fibres
     - 2.2.2 Chemical properties of natural fibres
     - 2.2.3 Mechanical properties of natural fibre
     - 2.2.4 Advantages and disadvantages of natural fibres
   - 2.3 Pineapple leaf fibre
   - 2.4 Plastics
     - 2.4.1 Polystyrene (PS) and High impact polystyrene (HIPS)
     - 2.4.2 Polystyrene (PS) and High impact polystyrene (HIPS) on natural fibre composites
   - 2.5 Natural fibre reinforced polymer composites
   - 2.6 Modifications of natural fibre
     - 2.6.1 Alkali treatment
     - 2.6.2 Coupling agents
   - 2.7 Fabrication of natural fibre composites
   - 2.8 Mechanical properties of PALF reinforced polymer composites
   - 2.9 Thermal properties of PALF reinforced polymer composites
   - 2.10 Electron beam irradiation
   - 2.10 Conclusion

3. **MATERIALS AND METHODS**
   - 3.1 Materials
     - 3.1.1 Pineapple leaf fibre
     - 3.1.2 High impact polystyrene (HIPS)
   - 3.2 Methods
     - 3.2.1 Compatibilising agent and sodium hydroxide
3.2.2 Alkali treatment 43
3.2.3 Fibre content 44
3.2.4 Compounding 45
3.2.5 Granulating 46
3.2.6 Compression moulding 47
3.2.7 Electron beam irradiation 47
3.2.8 Preparation of test specimens 50
3.3 Mechanical testing 52
  3.3.1 Tensile test 52
  3.3.2 Flexural test 54
  3.3.3 Notched and unnotched impact test 55
  3.3.4 Hardness test 57
3.4 Physical testing 58
  3.4.1 Water Absorption and thickness swelling 58
  3.4.2 Melt Flow Rate (MFR) 59
  3.4.3 Specific gravity determination 60
3.5 Thermal test 61
  3.5.1 Thermogravimetric Analyzer (TGA) 61
  3.5.2. Differential Scanning Calorimetric 62
4. THE PHYSICAL PROPERTIES OF SHORT PINEAPPLE LEAF FIBRE (PALF) REINFORCED HIGH IMPACT POLYSTYRENE COMPOSITES 64
  Article 1 65
  Copyright permission 70
5. MECHANICAL PROPERTIES OF SHORT PINEAPPLE LEAF FIBRE (PALF) REINFORCED HIGH IMPACT POLYSTYRENE (HIPS) COMPOSITES 71
  Article 2 72
  Copyright permission 95
6. THE EFFECT OF COMPATIBILISING AGENT AND SURFACE MODIFICATION ON THE PHYSICAL PROPERTIES OF SHORT PINEAPPLE LEAF FIBRE (PALF) REINFORCED HIGH IMPACT POLYSTYRENE COMPOSITES 96
  Article 3 97
  Copyright permission 103
7. THE EFFECT ALKALI TREATMENT ON THE MECHANICAL PROPERTIES OF PINEAPPLE LEAF FIBRE (PALF) REINFORCED HIGH IMPACT POLYSTYRENE COMPOSITES 104
  Article 4 105
  Copyright permission 111
8. THE IMPROVEMENT OF MECHANICAL PROPERTIES OF PINEAPPLE LEAF FIBRE (PALF) REINFORCED HIGH IMPACT POLYSTYRENE (HIPS) COMPOSITES
   Article 5
   Copyright permission

9. THE EFFECT OF ELECTRON BEAM IRRADIATION ON THE MECHANICAL PROPERTIES OF PINEAPPLE LEAF FIBRE (PALF) REINFORCED HIGH IMPACT POLYSTYRENE (HIPS) COMPOSITES
   Article 6
   Copyright permission/Acceptance letter

10. THERMOGRAVIMETRIC ANALYSIS (TGA) AND DIFFERENTIAL SCANNING CALORIMETRIC (DSC) ANALYSIS OF PINEAPPLE LEAF FIBRE (PALF) REINFORCED HIGH IMPACT POLYSTYRENE (HIPS) COMPOSITES
    Article 7
    Copyright permission/Acceptance letter

11. SUMMARY GENERAL CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH
    11.1 Summary and general conclusions
    11.2 Recommendations for Future Work

REFERENCES
APPENDICES
BIODATA OF STUDENT