

**THE EFFECTS OF FILLER LOADING AND
COUPLING AGENTS ON PROPERTIES OF
RECYCLED HIGH DENSITY POLYETHYLENE/
WOOD FIBER COMPOSITES**

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UNIVERSITI MALAYSIA PERLIS

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WOOD FIBER COMPOSITES**

by

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A thesis submitted in fulfillment of the requirements for the degree of
Master of Science in Materials Engineering

School of Materials

UNIVERSITI MALAYSIA PERLIS

Year

2015

ACKNOWLEDGEMENT

Alhamdulillah, thank god for His graciousness and mercifulness has gave me the strength and ability to complete this thesis successfully.

The author would like to express his foremost gratitude and sincere appreciation to his senior supervisor Associate Professor Dr. Supri A. Ghani, and Associate supervisor Dr. Firuz Zainuddin. Their invaluable support, guidance and encouragement throughout the research period are the impetus behind the successful completion of this work on time.

The author is equally thankful to the committee members Dr. Khairul Rafezi Ahmad, Dean of School of Materials Engineering for their comments and suggestions. The author also thanks the School of Bio Process Engineering and Department of Nano Materials, University Malaysia Perlis, for the technical supports for helping with testing and characterizes the wood plastic composites. I would like to thanks all the academic staff, technical staff and colleagues at School of Materials Engineering for their immeasurable assistance during my research work.

The author is also immensely grateful to the Government of Malaysia for providing Mybrain15 postgraduate scholarship to pursue the Master of Science degree at the University Malaysia Perlis. A heartfelt gratitude is extended to the UniMAP friends in Perlis for their encouraging support and inspiration during my stay here. Finally, the author would like to give my respect to my parents, brother, sister, and young sister for their support and encouragement in all his endeavors. The author is also grateful to University Malaysia Perlis for giving me the opportunity to be one of their MSc program students. Thank you very much.

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| 3.1 | Molarity | 49 |
| 3.2 | Water absorption (%) | 55 |
| 3.3 | Absorbance | 55 |
| 3.4 | Crystal orientation ratio | 56 |
| 3.5 | Bragg's law | 56 |

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LIST OF ABBREVIATIONS

| | |
|-------|--|
| AHA | Alpha-hydroxy acid |
| AKD | Alkyl ketene dimer |
| ASTM | American Society for Testing and Materials |
| BF | Banana fiber |
| BP | Bamboo powder |
| DSC | Differential Scanning Calorimetry |
| EPDM | Ethylene propylene diene monomer |
| EPM | Ethylene propylene rubber |
| ESP | Eggshell powder |
| EVA | Ethylene vinyl acetate |
| FDT | Final Decomposition Temperature |
| FTIR | Fourier transforms infrared spectroscopy |
| HDPE | High density polyethylene |
| HMDIC | Hexamethylene diisocyanate |
| HW | High length |
| ICI | Imperial Chemical Industries |
| KBr | Potassium Bromide |

| | |
|----------|--|
| KF | Kenaf fiber |
| KP | Kenaf powder |
| LDPE | Low density polyethylene |
| LLDPE | Linear low density polyethylene |
| MAH | Maleic anhydride |
| MAPE | Maleic anhydride-grafted-polyethylene |
| MAPP | Maleated polypropylene |
| MDPE | Medium density polyethylene |
| MMA | Methyl methacrylate |
| MW | Molecular length |
| NaOH | Sodium hydroxide |
| NBR | Acrylonitrile butadiene-rubber |
| NDE | Non-destructive evaluation |
| NFPC | Natural fiber reinforced polymer composite |
| NR | Natural rubber |
| OH | Hydroxyl groups |
| PAH | Phthalic anhydride |
| PE | Polyethylene |
| PE-g-MAH | Polyethylene-grafted-maleic anhydride |

| | |
|------------|---|
| PEO-g-MAH | Maleic anhydride grafted Poly(ethylene octane) |
| PLA | Poly (lactic acid) |
| PP | Polypropylene |
| PP-g-MAH | Polypropylene-grafted-maleic anhydride |
| PS | Polystyrene |
| PVC | Poly (vinyl chloride) |
| rHDPE | Recycled high density polyethylene |
| RHP | Rice husk powder |
| rLDPE | Recycled low density polyethylene |
| rNBR | Recycled acrylonitrile butadiene-rubber |
| rPP | Recycled polypropylene |
| SA | Salicylic acid |
| SCB | Sugarcane bagasse |
| SEM | Scanning electron microscopy |
| SEBS-g-MAH | Maleic anhydride grafted styrene-(ethylene-co-butylene)-styrene |
| SW | Short length |
| TGA | Thermogravimetric analysis |
| UHMWPE | Ultra-high molecular weight polyethylene |
| UV | Ultra-violet |

| | |
|-----------------|--|
| VPP | Virgin isotactic polypropylene |
| WPC | Wood polymer composite |
| vHDPE | Virgin high density polyethylene |
| VLDPE | Very low density polyethylene |
| WHF | Water hyacinth fiber |
| WHF | Wheat hush fiber |
| WF | Wood fiber |
| WF _m | Wood fiber treatment with salicylic acid |
| WPC | Wood plastic composite |
| XRD | X-ray diffraction analysis |

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LIST OF SYMBOLS

| | |
|--------------------|------------------------------|
| cm^3 | Cubic centimeter |
| cm^{-1} | Reciprocal centimeter |
| CPS | Count per second |
| g/cm^3 | Gram per cubic centimeter |
| kV | Kilovolt |
| mA | Milliampere |
| MPa | Mega Pascals |
| ml/min | Milliliter per minute |
| O_c | Organic content |
| phr | Part per hundred resins |
| rpm | Rotation per minute |
| T_g | Glass transition temperature |
| T_m | Melting temperature |
| % | Percentage |
| %T | Transmittance |
| $^{\circ}\text{C}$ | Degree Celsius |
| 2θ | Two theta |

Kesan-Kesan Pembebanan Pengisi dan Agen-Agen Gandingan Terhadap Sifat-Sifat Komposit Polietilena Ketumpatan Tinggi Kitar Semula/Serat Kayu.

ABSTRAK

Polietilena ketumpatan tinggi kitar semula (rHDPE)/serat kayu (WF) komposit telah disediakan menggunakan Brabender Plasticorder pada suhu 160°C dengan kelajuan rotor pada 50 rpm. Kesan pembebanan serat kayu dan agen gandingan ke atas sifat tegangan, penyerapan air, ciri-ciri morfologi, pencirian spektroskopi infra merah (FTIR), sifat degradasi terma (TGA) dan pencirian (XRD) terhadap komposit rHDPE/WF telah dikaji. Keputusan menunjukkan bahawa penambahan serat kayu telah mengurangkan kekuatan tegangan, pemanjangan pada takat putus dan jarak antara zarah, manakala modulus keanjalan, peratus keseimbangan penyerapan air, kestabilan terma dan nisbah orientasi kristal komposit meningkat. Agen-agen gandingan seperti asid salisilik, maleik anhidrida dan phthalik anhidrida telah digunakan, di mana kesan positif pada sifat tegangan, penyerapan air, kestabilan terma dan peratusan penghabluran komposit rHDPE/WF telah dihasilkan. Kehadiran agen-agen gandingan meningkatkan kekuatan tegangan, modulus keanjalan, kestabilan terma dan nisbah orientasi kristal, akan tetapi menurunkan pemanjangan pada takat putus, penyerapan air dan jarak di antara zarah (d). Keputusan pelbagai agen gandingan pada rHDPE/WF30 komposit telah diperiksa. Kajian mendapati komposit rHDPE/WF_m/MAH menunjukkan kekuatan tegangan, modulus keanjalan, kestabilan terma dan nisbah orientasi hablur yang lebih tinggi diikuti dengan komposit rHDPE/WF_m/PAH > rHDPE / WF_m (serat kayu yang dirawat dengan asid salisilik) komposit > rHDPE / WF komposit mengikut turutan. Tambahan pula, lebih rendah pemanjangan pada takat putus, rendah peratusan keseimbangan penyerapan air dan jarak diantara zarah menjadi lebih kecil (d). Mikroskop penskanan elektron (SEM) permukaan patah tegangan bagi komposit dengan agen-agen gandingan menggunakan asid salisilik, maleik anhidrida, dan phthalik anhidrida menunjukkan bahawa interaksi antara permukaan dan lekatan di antara WF dengan permukaan rHDPE adalah lebih baik daripada komposit rHDPE/WF.

The Effects of Filler Loading and Coupling Agents on Properties of Recycled High Density Polyethylene/Wood Fiber Composites

ABSTRACT

The recycled high density polyethylene (rHDPE)/wood fiber (WF) composites had been prepared using Brabender Plasticorder at temperature 160°C with rotor speed of 50 rpm. The effect of wood fiber loading and coupling agents on tensile properties, water absorption, morphology, spectroscopy infrared (FTIR) analysis, thermogravimetric analysis (TGA) and x-ray diffraction (XRD) of rHDPE/WF composites were investigated. The results show that the addition of wood fiber reduced the tensile strength, elongation at break and interparticle spacing (d), whereas the modulus of elasticity, equilibrium water absorption percentage, thermal stability, and the crystal orientation ratio of composites increased. The coupling agents such as salicylic acid, maleic anhydride, and phthalic anhydride were used, which resulted in positive effect on tensile properties, water absorption, thermal stability and percentages of crystallinity of rHDPE/WF composites. Whereas the presence of coupling agents had increased the tensile strength, modulus of elasticity, thermal stability and crystal orientation ratio but decreased the elongation at break, water absorption and interparticle spacing (d). The results of various coupling agents on properties of rHDPE/WF30 composites have been examined. The study was showed that rHDPE/WF_m/MAH composites showed higher tensile strength, modulus of elasticity, thermal stability and crystal orientation ratio followed by rHDPE/WF_m/PAH composites > rHDPE/WF_m (wood fiber treated salicylic acid) composites > rHDPE/WF composites in orders. Furthermore, lower the elongation at break, lower percentage equilibrium water absorption and lower interparticle spacing (d). The scanning electron microscopy (SEM) micrographs of tensile fracture surfaces for the composites with coupling agents of salicylic acid, maleic anhydride, and phthalic anhydride indicated that the interfacial interaction and adhesion between WF and rHDPE phases were better than rHDPE/WF composites.

CHAPTER 1

INTRODUCTION

1.1. Research Background

High amount of waste generated, non-biodegradability and fast depletion of natural resources was the reason of plastic becomes major problem nowadays. Wood also implies the problem with lesser degree than plastic where trees and forests are becoming more depleted and its waste are either burned or disposed resulting in extra consumption, depletion and pollution of nature (Bovea et al., 2010; Astrup et al., 2009).

Wood plastic composite (WPC) is a product which can be produced from plastic and wood. WPC is a composite that consisted of mixture of wood waste and polymeric materials and WPC composite also has rapid growing usage nowadays (Soury et al., 2009). This WPC composite can help reduce solid waste content and conserves the natural resources thus allow of saving costs, energy and reduce depletion virgin materials. In addition, sustainability of materials over incoming years can be assured for future generation's use (Talbot, 2013).

It is well known that recycling contributes to a reduction in resources consumption and pollution. For example, the technology developed by Waste and Resources Action Programme (WRAP) for the recycling HDPE milk bottles from kerbside and brings scheme collections in the United Kingdom reported by Kosior, (2006). The results from

the rheological tests, processing tests and the mechanical tests show that the recycled HDPE is technically very similar to the virgin resin used to make milk bottles.

The recycled HDPE content was lowered 30 % of transparency compared to virgin HDPE. The other differences that were noted are the presence of gels and black specks and the odor after processing, however, these were not at a level that detracted from us as a commercially acceptable bottle. According to Adhikary et al., (2008a) reported that the composites made from post-consumer recycled HDPE are shown better mechanical properties than composites from virgin HDPE in similar to or in some cases.

Earlier studies show that the recycled HDPE properties were not largely different than the virgin HDPE and the cost also less expensive from those of virgin HDPE. Therefore, recycled HDPE can be used for many applications while offering the vision of subsidizing waste disposals and decreasing the costs of product (Adhikary et al., 2008a; Lu & Oza, 2013) studied the mechanical properties of hemp fiber with virgin and recycled high density polyethylene matrix. From the findings, they indicated that hemp fiber composites with recycled HDPE matrix performed better than composites with virgin HDPE in mechanical and thermo-mechanical properties.

Rheological analysis shows the normal flow of recycled LDPE can be promoted by virgin LDPE and thus mobility of chain segments in flow are improved. As a result, blend with recycled LDPE and virgin LDPE has better rheological and processing properties compared to recycled LDPE (Zhao et al., 2013). One of the most important advantages of recycled high density polyethylene is its consistent density and melt flow index in majority of the recycling plants (Mishra & Yagci, 2008).