**UNIVERSITI PUTRA MALAYSIA**

***PERFORMANCE OF LAMINATED COMPREG OIL PALM WOOD (Elaies guineensis Jacq.) ASSOCIATED WITH THE DIFFUSION AND COMPRESSION ON POLYMER LOADING***

**MUHAMMAD AIZAT BIN ABD GHANI**

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By

MUHAMMAD AIZAT BIN ABD GHANI

Thesis submitted to the School of Graduate Studies,
Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of
Master of Science

November 2014

# DEDICATIONS

This thesis is dedicated with deepest love and affection to:

**MY BELOVED PARENTS**

Abd Ghani Abdullah and Harpipah Hamid

**MY SIBLINGS**

Mohd Aliff Abd Ghani, Ameer Fahd Abd Ghani,

Nina Ameera Abd Ghani,

Farah Razimi

**MY NIECE AND NEPHEW**

Farah Zulaikha Mohd Aliff and Muhammad Jibril Mohd Aliff

**MY DEAREST FRIENDS**

Hamizan Ibrahim, Syazana Fatinah, Atiqah Abdullah,

And

"*Geng Writing*"

Their love, prayer, concerns and strength have inspired me to be the best I can be.

May ALLAH bless all of you

Abstracts of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment for the degree of Master Science

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**November 2014**

**Chairman : Professor Zaidon Ashaari, Phd**

**Faculty : Forestry**

Treatment of oil palm wood (*Elaeis guineensis*) with phenol formaldehyde (PF) resin and subsequently compressing at high hot pressure of oil palm wood is one of the potential ways to enhance its dimensional stability and strength properties. Factors such as molecular weight of PF resin, concentration of PF resin, penetration of PF resin as well as thickness of the material and compression ratio (ratio of the final thickness to the initial thickness of wood) need to be considered for efficient treatment. Study was undertaken to determine the effect of diffusion and compression on polymer loading and performance of laminated *compreg* oil palm wood (OPW) which had been treated with low and medium molecular weight phenol formaldehyde (LmwPF and MmwPF). OPW strips with 80-100% MC were soaked in LmwPF and MmwPF solutions separately for 24 h. Then, the treated strips were wrapped in plastics and left for diffusion for 2, 4, or 6 days, followed by pre-curing them in an oven at $65^0$C for 6 hours. The pre-cured strips were assembled parallel to each other to form three-layer laminated *compreg* OPW, followed by compressing them under hot press at 150°C for 20 min to compression ratios of 55%, 70% and 80%. Laminated untreated OPW bonded with commercial PF resin served as a control. The polymer loading, dimensional stability, mechanical properties and formaldehyde emission of the *compreg* laminated wood for each treatment condition were determined.

The results showed that, the polymer loading, as indicated by weight percent gain (WPG) of the laminated *compreg* OPW was significantly affected by the diffusion and compression processes. LmwPG-*compreg* OPW had higher WPG compared to MmwPG-*compreg* OPW. Compared to the laminated untreated OPW, the *compreg* products had superior properties where the LmwPF *compreg* OPW showed better performance than MmwPF *compreg* OPW. It was also found that density, anti-swelling efficiency (ASE), mechanical properties and formaldehyde emission of laminated *compreg* OPW were positively correlated with polymer loading, whilst water absorption and thickness swelling were negatively correlated with polymer loading for both laminated *compreg* OPW. Formaldehyde emission of the LmwPF laminated *compreg* OPW was relatively higher while formaldeyhde emission for MmwPF laminated *compreg* OPW was found within the threshold limit between 0.16 mg/l to 2.0 mg/l.

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**PRESTASI KAYU KELAPA SAWIT COMPREG BERLAPIS *(Elaies Guineensis* Jacq.) KESAN DARIPADA PROSES RESAPAN DAN MAMPATAN TERHADAP MUATAN POLIMER**

Oleh
**MUHAMMAD AIZAT BIN ABD GHANI**

**November 2014**

**Pengerusi: Professor Zaidon Ashaari, Phd**

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Rawatan kelapa sawit (*Elaeis guineensis*) kayu dengan fenol formaldehid (PF) dan seterusnya memampatkan pada tekanan tinggi adalah salah satu cara yang berpotensi untuk meningkatkan dimensi kestabilan dan kekuatan sifat-sifatnya. Faktor-faktor seperti berat molekul resin PF, kepekatan resin PF, penembusan resin PF dan ketebalan kayu dan nisbah mampatan (nisbah tebal takhir terhadap tebalan awal kayu) yang perlu dipertimbangkan untuk rawatan cekap. Kajian telah dijalankan untuk menentukan kesan resapan dan mampatan pada kemasukan polimer dan prestasi *compreg* berlamina kayu kelapa sawit (OPW) yang telah dirawat dengan molekul formaldehid berat fenol rendah dan sederhana (LmwPF dan MmwPF). Kepingan-kepingan kayu OPW dengan 80-100% MC telah direndam di dalam larutan LmwPF dan MmwPF secara berasingan selama 24 jam. Kemudian, kepingan kepingan kayu yang telah direndam dibungkus dalam plastik dan dibiarkan larutan LmwPF dan MmwPF meresap untuk tempoh 2, 4, atau 6 hari, diikuti dengan pra-pematangan dalam oven pada suhu 65$^{o}$C selama 6 jam. Kepingan- kepingan OPW yang pra-matang disusun secara selari antara satu sama lain untuk membentuk tiga lapisan kayu berlamina *compreg* OPW, diikuti dengan memampatkannya di bawah tekanan tinggi bersuhu 150$^{0}$C selama 20 min untuk nisbah mampatan sebanyak 55%, 70% dan 80%. Manakala, kayu berlamina OPW yang dilekatkan menggunakan PF komersial digunankan sebagai kawalan. Pemuatan polimer, kestabilan dimensi, sifat mekanikal dan pelepasan formaldehid daripada kayu *compreg* berlamina bagi setiap keadaan rawatan ditentukan.

Hasil kajian menunjukkan bahawa, muatan polimer, seperti yang ditunjukkan oleh peratus berat pertambahan (WPG) daripada kayu *compreg* OPW yang berlamina telah dipengaruhi dengan ketara oleh proses resapan dan mampatan. Peratus berat pertambahan (WPG) bagi kayu *compreg* berlamina yang dirawat dengan menggunakan LmwPF menunjukkan peratus yang lebih tinggi serta menunjukkan sifat-sifat yang lebih bagus berbanding kayu *compreg* berlamina yang dirawat dengan menggunakan MmwPF.

Didapati juga bahawa ketumpatan, kecekapan anti-bengkak (ASE), sifat mekanikal dan pelepasan formaldehid OPW *compreg* berlamina adalah berkadar positif dengan muatan polimer, manakala penyerapan air dan pembengkakan ketebalan menujukkan hubungan negatif terhadap muatan polimer. OPW *compreg* berlamina yang dirawat

dengan LmwPF menunjukkan kadar pelepasan formadehid lebih tinggi berbanding OPW yang dirawat dengan menggunakan MmwPF. Dan didapati, kadar pelepasan formaldehid daripada OPW *compreg* berlamina yang dirawat menggunakan MmwPF berada di dalam kadar lepasan global iaitu diantara 0.16 mg/l to 2.0 mg/l.

# ACKNOWLEDGEMENTS

**"ALHAMDULLILAH"**

**THANK YOU ALLAH**

I would never have been able to finish my dissertation without the guidance of my committee members, help from friends and support from my family.

I would like to express my deepest gratitude to my advisor, Prof. Dr. Zaidon Ashaari, for his excellent guidance, caring, patience and providing me with an excellent atmosphere for doing research. Patiently corrected my writing and financially supported my research and not to forget to my co-supervisor Dr. Edi Suhaimi. I would like also to thank Nabil Fikri, Zulfadzli, Thenmoli and Fadhlia were always willing to help and give his best suggestion. It would have been a lonely lab without them.

Many thank to "*Geng writing*" and other workers in the laboratory of Komposit Kayu and Ekologi Lab. My research would not have been possible without their helps.

I would also like to thank my parents, Ayah Ghani and Ibu Che'pah, my elder brother and his wife, Abg Aliff and Kak Farah same goes to my little brother and little sister, Ameer and Adik Nina. They were always supporting me and encouraging me with their best wishes. Not to forget, Syazana Fatinah, Hamizan, Atiqah and Faizal thank you so much for everything and always are there to support and for your time. Also thank to Muhamad A'sham for your help.

Finally, I would like to thank to Kementerian Pengajian Tinggi and UPM for offering me to do my study. Also to those whose contribute to assist me during my time of study.

THANK YOU

I certify that a Thesis Examination Committee has met on 26 November 2014 to conduct the final examination of Muhammad Aizat bin Abd Ghani, on his thesis entitled "Performance of laminated *compreg* oil palm wood (*Elaies guineensis* Jacq.) associated with the diffusion and compression on polymer loading" in accordance with the Universities and University Colleges 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 Master of Science.

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| | |
|---|---|
| ASE | Anti-swelling efficiency |
| CR | Compression ratio |
| DT | Diffusion time |
| EFB | Empty Fruit Bunches |
| EMC | Equilibrium Moisture Content |
| FSP | Fiber saturation point |
| LMWPF | Low molecular weight phenol formaldehyde |
| LVL | Laminated Veneer Lumber |
| MC | Moisture Content |
| MF | Melamine formaldehyde |
| MMWPF | Medium molecular weight phenol formaldehyde |
| MOE | Modulus of Elasticity |
| MOR | Modulus of Rupture |
| MPOB | Malaysian Palm Oil Boards |
| MPOC | Malaysian Oil Palm Council |
| MS | Malaysian Standard |
| OPF | Oil Palm Frond |
| OPT | Oil Palm Trunk |
| OPW | Oil Palm Wood |
| PF | Phenol formaldehyde |
| POPF | Pruning Oil Palm Frond |
| PPM | Part per million |
| RF | Resorcinol formaldehyde |
| RH | Relative humidity |
| SPSS | Statistical Package for Social Science |
| TS | Thickness swelling |
| UF | Urea formaldehyde |
| WA | Water absorption |
| WPG | Weight percent gain |
| mm | millimeter |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of study

Oil palm (*Elaeis guineensis*) is one of the most abundant agriculture crops planted and can be obtained at any plantation around in Malaysia. Malaysian Palm Oil Board (MPOB) reported that the total area of oil palm plantation was 5.1 million ha in 2012, and it is expected to increase annually (MPOB, 2012). Oil palm trunk (OPT) is cheap and abundantly available lignocellulosic materials and this biomass can be a potential raw material to substitute wood for high value added product if its properties can be enhanced. The use of oil palm biomass will not only reduce the production cost but in returns will increase the economic revenue of the nation (Sulaiman *et al.,* 2011).

Oil palm plantations have produced a large quantity of agriculture residues, for instance rice husk, coir fibre and oil palm fibre (Zulkifli *et al.*, 2008). These agriculture wastes especially oil palm fibres can be source of material in the production of wood composites. However, OPW has some drawbacks that need to be encountered before they can be fabricated into wood composites. Numerous researches have been conducted on oil palm residues for the production of laminated veneer boards (Razak *et al.*, 2008), medium density fibreboard and pulp and paper making from EFB (Astimar *et al*, 2002; Ridzuan *et al.*, 2002). Recently OPW has widely studied for the production of veneer and plywood manufacturing (Nordin *et al.*, 2004). In this case the OP veneers were treated with phenolic resin before they were fabricated into plywood.

Oil palm wood (OPW) from the trunk of oil palm tree has a great potential for raw materials in wood-based industry. However, due to the inferior properties, the oil palm trunk is not widely utilised commercially. Bakar *et al*., (2005) stated that OPW (i.e., the wood from the outer part of oil palm trunk) has at least four imperfections: low strength, low dimensional stability, low durability and poor machining characteristics. Amarullah *et al.,* (2010) found that treating OPW using phenolic resin significantly improve the performance of OPW, making them more usable in assessing the shortfall of wood supplies (Bakar *et al.,* 2007).

Hill (2006) reported that the quality of low density of timber can be enhanced through several chemical treatments such as bulking treatment, internal coating cross-linking and wood modifications. Recently, a series of work has been conducted at University Putra Malaysia to enhance the properties of low density tropical hardwood, Sesenduk (*Endospermum diadenum*), Jelutong (*Dyera costulata)* and Mahang *(Macarangga* sp.) by bulking treatment with low molecular weight phenol formaldehyde (LmwPF) resin. Impregnation with LmwPF (molecular weight 600) followed by curing under heat was found had increased the mechanical strength, dimensional stability and durability of these timbers against decay and termite (Izreen *et al*., 2011, Ang *et al.*, 2014). Impregnation with 30% LmwPF followed by compressing at high temperature has also been proven in enhancing the bending strength, dimensional stability and durability against fungal attack (Rabi'atol et al., 2012; Zaidon *et al*., 2014). This product, known as *compreg* (Rowell, 2005), normally has modulus of rupture (MOR), modulus of elasticity (MOE) and hardness greater than the untreated woods due to the increase in density.

Impregnation treatment normally involves either vacuum or a combination of vacuum and pressure process. The combination of vacuum and pressure (pressure process) are the conventional method for treating wood to force chemicals into the cell lumen (Zabel and Morrel, 1992). However these treatments are expensive and needs skilled labour for the operation process. One of the cost-effective methods to introduce chemical into the wood is through diffusion process.

Diffusion treatment is a process which the movement of molecules through a porous medium. In diffusion treatment, green or fresh wood and waterborne chemical are required to obtain deep and well distribution of chemical in the substrate. it involves soaking wood in solution but theoretically can extend to the use of pastels and wraps to deliver chemical into the wood (Hunt and Garrat, 1967). Tamblyn (1985) and Mac Lean (1952) found diffusion process can be successfully applied in impregnating boron compound into resistant timber. This treatment has also been used to treat green rattan (*Calamus* spp.) with water soluble boron compound (Zaidon and Petty, 1996).

**1.2 Problem statement and justification**

Oil palm trunk (OPT), oil palm frond (OPF), and pruning of oil palm frond (POPF) are the examples of agricultural wastes obtained from oil palm plantation sites (Subiyanto *et al.,* 2002). Specifically in the year 2009, all 421 Malaysian palm oil mills generated 19.47 million tonnes of EFB, 5.85 million tonnes of palm kernel shell, 11.99 million tonnes of mesocarp fibre and 10.95 million tonnes OPT to cut (Hoong, 2011). Since OPT contributes the most oil palm biomass up to 15.39 million tonnes and compared to other biomass residues, this material has a great potential for commercial development (Subiyanto *et al.*, 2002; Erwinsyah, 2008; Hartono, 2012) such as converting them as alternative material for wood based industries (Mohamad *et al*., 2005; Basiron, 2007). However, a proper treatment is needed to enhance the properties of OPW before it can be further utilised into high value added products.

For an efficient bulking treatment, several factors such as molecular weight of PF resin, concentration of PF resin, as well as thickness of the material and compression ratio (ratio of the final thickness to the initial thickness of wood) need to be considered (Zaidon *et al.*, 2014). PF resin with molecular weight (Mw) of 290-480 is able to penetrate and bulked the cell wall (Rowell, 2005), while higher molecular weight PF resin remains in the cell lumen without resulting in any significant stability (Furono *et al.,* 2004). Another important factor is resin penetration. A deep penetration of PF resin can be achieved by treating thin pieces of wood with LmwPF resin, followed by laminating and compressing them in a hot press to form three-layer *compreg* laminates. It was reported that 12-mm thick three-layer *compreg* laminates of sesenduk, jelutong and mahang had density gain of two to three folds than that of the control samples (Zaidon *et al.,* 2010). Other properties such as shear stress at the bonding line were slightly lower or comparable to, while hardness, strength and stiffness were significantly higher than those of the untreated wood. The anti-swelling efficiency (ASE) of the samples ranged between 60-70% (Rabi'atol *et al.,* 2012). It is anticipated that the treatment of green OPW with LmwPF and MmwPF, using a combination of soaking and diffusion processes followed by compressing under hot press would yield higher polymer loading and complete penetration in the treated material and as a results will enhance the performance of the product.

## 1.3 Objectives

The objectives of this study were;

1. To determine the treatability of oil palm wood (OPW) treated with low and medium molecular weight phenol formaldehyde (LmwPF and MmwPF) using diffusion treatment and different compression ratios.

2. To evaluate the effect of the phenolic resin treatment and compression ratio on dimensional stability, mechanical properties and formaldehyde emission of the laminated *compreg* OPW.

3. To determine the correlation between the polymer loading and the properties of the laminated *compreg* OPW.

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