UNIVERSITI PUTRA MALAYSIA

PROPERTIES AND DECAY RESISTANCE OF *MAHANG* (*Macaranga* sp.) TREATED WITH PHENOLIC RESIN AND ACRYLIC MONOMER USING VACUUM-PRESSURE PROCESS

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By

ANG AIK FEI

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

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chair: Zaidon Ashaari, PhD

Faculty: Forestry

Mahang (*Macaranga* sp.) was treated with phenolic resin and methyl methacrylate (MMA) monomer. Impreg is a type resin treated wood while Compreg refers to resin treated compressed wood. Mahang wood was impregnated with 15, 20 and 25% (Impreg) and 15% (Compreg) phenolic resin using vacuum-pressure process. The vacuum-pressure process could maximize the penetration of resin and monomer into wood. The resin in Impreg mahang was partially cured at 65ºC for 24 h prior to fully cure at 150ºC for 30 min in an oven while Compreg mahang was fabricated by compressed the treated wood with 0.3, 0.4 and 0.5 compression ratios (CR). The resin in treated wood was partially cured at 65ºC for 56 h prior to fully cure at 150ºC for 30 min under hot press. For MMA-treated wood, polymerization was carried out in a combination with a crosslinker trimethylolpropane trimethacrylate (TMPTMA). Polymerization was carried out by catalyst heat treatment at 65 ºC for 2 h. The resin weight percent gain (WPG) for Impreg mahang was in the range of 33-51% whereas for Compreg mahang was 27-31%. For MMA-treated wood, a fairly consistent acrylic retention ranged from 187.5-229.6%

was found in the wood when treated with or without crosslinker. The resin WPG of Impreg mahang was increased significantly when the levels of phenolic resin increased from 15-25%. The resin WPG for Compreg mahang was not differed significantly among 0.3, 0.4 and 0.5 CRs. It was found that the concentrations of crosslinker gave significant effect on the polymerization of MMA. The polymerization is at maximum with 1% crosslinker and beyond this concentration the polymerisation decreased. The density of Impreg, Compreg and MMA-treated mahang was improved significantly from 31-53%, 89-139% and 188-216%, respectively compared to untreated wood. The Impreg and MMA-treated mahang showed improvement in the dimensional stability compared to untreated wood but there is no improvement was recorded for Compreg mahang. The phenolic resin concentrations did not gave significant effect in the ASE of Impreg and Compreg mahang while the crosslinker concentrations gave significant effect in the ASE of MMA-treated mahang. Mositure excluding efficiency (MEE) of Impreg, Compreg and MMA-treated mahang was also improved significantly from 6.27-9.63%, 15.48-27.85% and 40.93-55.68%, respectively compared to untreated wood. The phenolic resin and crosslinker concentrations did not gave significant effect in the MEE. The improvement in reduction in water absorption (R) of Impreg, Compreg and MMA-treated mahang against untreated wood was ranged from 49.02-65.04%, 67.54-71.63% and 91.18-93.22%, respectively. The phenolic resin and crosslinker concentrations did not gave significant effect in the (R) except for Impreg mahang. Mechanical strength of Impreg mahang in terms of compressive stress and hardness were improved 75 to 266% and 32 to 62%, respectively compared to untreated wood. The compressive stress and hardness of MMA-treated mahang were 577 to 1387% and 219 to 386% greater than untreated wood. However, the stiffness (modulus of elasticity) did not change. All the

mechanical properties for Compreg mahang were improved significantly compared to untreated wood. In terms of specific strength (strength to density ratio), the treated material has less stiffness and less strength in lateral direction compared to untreated wood. However, the specific compressive strength perpendicular to the grain and hardness of the treated material were superior compared with the untreated. The decay resistance of Impreg, Compreg and MMA-treated mahang against white rot fungus, *Pycnoporus sanguineus* was improved significantly compared to untreated wood.

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

SIFAT DAN KETAHANAN PEREPUTAN KAYU *MAHANG* (*Macaranga* sp.) YANG DIRAWAT DENGAN RESIN FENOL DAN MONOMER AKRILIK MENGGUNAKAN KAEDAH VAKUM-TEKANAN PROSES

Oleh

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Mahang (*Macaranga* sp.) dirawat dengan resin fenol dan monomer metil metakrilat. Impreg merupakan kayu yang dirawat dengan resin tanpa mampatan manakala Compreg merupakan kayu yang dirawat dengan resin dan mampatan. Kayu mahang diresapi dengan 15, 20 dan 25% (Impreg) dan 15% (Compreg) kepekatan resin fenol meggunakan tekanan vakum proses. Tekanan vakum process boleh memaximakan retensi bahan kimia dalam kayu. Resin dalam Impreg mahang dibeku sebahagian pada suhu 65 º C selama 24 jam sebelum dibekukan sepenuhnya pada suhu 150 º C selama 30 minit dalam oven sementara Compreg mahang adalah dibuat daripada kayu yang dimampat dengan 0.3, 0,4 dan 0,5 nisbah mampatan. Resin dalam kayu yang dirawat dibeku sebahagian pada suhu 65 ºC selama 56 jam sebelum dibekukan sepenuhnya pada suhu 150 º C selama 30 minit di bawah tekan panas. Untuk kayu yang dirawat dengan metil metakrilat (MMA), pempolimeran dilakukan dalam kombinasi dengan agen salib penyambung trimethylolpropane trimethacrylate (TMPTMA). Pempolimeran dilakuka dengan kewujudan mangkin di bawah pemanasan pada suhu 65 ºC selama 2 jam.

Peratusan berat resin yang diperolehi untuk Impreg mahang berada di antara julat 33-51% dan Compreg mahang adalah 27-31%. Untuk kayu mahang yang dirawat dengan MMA, retensi akrilik yang konsisten dalam julat 187.5-229.6% didapati pada kayu yang dirawat samada kayu itu sudah dicampur dengan agen salib penyambung atau tanpa agen salib penyambung. WPG resin Impreg mahang meningkat secara signifikan bila tahap resin fenolik meningkat dari 15-25%. The WPG resin untuk Compreg mahang tidak berbeza secara signifikan antara 0.3, 0,4 dan 0,5 CR. Dijumpai bahawa kepekatan agen salib penyambung memberikan kesan yang signifikan terhadap pempolimeran MMA. Pempolimeran adalah maksimum pada 1% agen salib penyambung dan melebihi ini pempolimeran menurun. Kepadatan Impreg, Compreg mahang dan kayu yang dirawat dengan MMA masing-masing meningkat secara signifikan 31-53%, 89-139% dan 188-216% berbanding dengan kayu yang tidak dirawat. Impreg mahang dan kayu yang dirawat dengan MMA menunjukkan peningkatan kestabilan dimensi dibandingkan dengan kayu yang tidak dirawat tetapi tidak ada perbaikan dicatat untuk Compreg mahang. Kepekatan resin fenolik tidak memberikan kesan yang signifikan terhadap ASE Impreg dan Compreg mahang sedangkan kepekatan agen salib penyambung memberikan kesan yang signifikan terhadap ASE kayu yang dirawat dengan MMA. Kecekapan mengecualikan lembapan (MEE) untuk Impreg, Compreg mahang dan kayu yang dirawat dengan MMA juga masing-masing meningkat secara signifikan dari 6,27-9,63%, 15,48-27,85% dan 40,93-55,68% berbanding dengan kayu yang tidak dirawat. Kepekatan resin fenolik dan agen salib penyambung tidak memberikan kesan yang signifikan terhadap MEE. Perbaikan dalam pengurangan dalam penyerapan air (R) untuk Impreg, Compreg mahang dan kayu yang dirawat dengan MMA berbanding dengan kayu yang tidak dirawat adalah masing-masing di antara julat 49,02-65,04%, 67,54-

71,63% dan 91,18-93,22%. Kepekatan resin fenolik dan agen salib penyambung tidak memberikan kesan yang signifikan terhadap (R) kecuali untuk Impreg mahang. Kekuatan mekanik Impreg mahang dari segi stres penekanan dan kekerasan masing-masing meningkat 75-266% dan 32 62% berbanding dengan kayu yang tidak dirawat. Stres penekanan dan kekerasan kayu yang dirawat dengan MMA adalah masing-masing 577-1387% dan 219-386% lebih besar daripada kayu yang tidak dirawat. Bagaimanapun, kekenyalan (modulus kekenyalan) tidak berubah. Semua sifat mekanik untuk Compreg mahang telah meningkat secara signifikan berbanding dengan kayu yang tidak dirawat. Dari segi kekuatan khusus (kekuatan untuk ketumpatan nisbah), bahan yang dirawat kurang kaku dan kurang kekuatan dalam arah lateral berbanding dengan kayu yang tidak dirawat. Namun, khusus kekuatan penekanan tegak lurus kepada garisan kayu dan kekerasan daripada bahan yang dirawat lebih unggul dibandingkan dengan yang tidak dirawat. Hambatan pereputan Impreg, Compreg mahang dan kayu yang dirawat dengan MMA terhadap cendawan pelapuk putih, *Pycnoporus sanguineus* ditingkatkan secara signifikan berbanding dengan kayu yang tidak dirawat.

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APPROVAL SHEET 1

I certify that an Examination Committee has met on 8th April 2010 to conduct the final examination of ANG AIK FEI on his **master science** thesis entitled "**Properties and Decay Resistance of Mahang (*Macaranga* sp.) Treated with Phenolic Resin and Acrylic Monomer using Vacuum-Pressure Process"** in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the students be awarded the Master Science.

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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 concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

ANG AIK FEI

Date: 3 June 2010

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ANOVA	Analysis of variance
ASE	Antiswelling Efficiency
ASTM	America Standard Testing Material
BPO	Benzoyl Peroxide
BTCA	1,2,3,4-butanetetracarboxylic Acid
CA	Carboxylic Acid
CCA	Chromated Copper Arsenate
DMDHEU	Dimethyloldihydroxyethyleneurea
D.P.X.	Dibutylphthalate Polystyrene Xylene
EMC	Equilibrium Moisture Content
FAO	Food and Agriculture Organization of the United Nations
LKS	Lesser Known Species
PCA	Polycarboxylic Acid
PEG	Polyethylene Glycol
MMA	Methyl Methacrylate
MC	Moisture Content
MEE	Moisture Excluding Efficiency
MF	Melamine Formaldehyde
MOE	Modulus of Elasticity
MOR	Modulus of Rupture
OSB	Oriental Strand Board
PF	Phenol Formaldehyde

PMMA	Polymethyl Methacrylate
R	Reduction in Water Absorption
RH	Relative Humidity
MUF	Melamine-Urea Formaldehyde
SB	Static Bending
SEM	Scanning Electron Micrograph
SHP	Sodium Hypophosphite
TMPTMA	Trimethylolpropane Trimethacrylate
UF	Urea Formaldehyde
VTC	Viscoelastic Thermal Compression
WL	Weight Loss
WPG	Weight Percent Gain