UNIVERSITI PUTRA MALAYSIA

EFFECT OF AIR VELOCITY ON THE QUALITY OF KILN-DRIED RUBBERWOOD (*Hevea brasiliensis*)

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EFFECT OF AIR VELOCITY ON THE QUALITY OF KILN-DRIED RUBBERWOOD (*Hevea brasiliensis*)

By

SINGARAM

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

December 2007

Dedicated to
my wife, Puvaneswary,
daughter, Anusha
and son, Thineswar

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

EFFECT OF AIR VELOCITY ON THE QUALITY OF KILN-DRIED RUBBERWOOD (*Hevea brasiliensis*)

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Chairman : Associate Professor Zaidon Ashaari, PhD
Faculty : Forestry

The objective of this study is to address the effect of air velocity manipulation on drying quality of the rubberwood (*Hevea brasiliensis*) timber. The study involved three researches. First the industrial assessment of the commercially kiln dried rubberwood, secondly the experimental research to look into the drying behaviour of rubberwood with regard to the air velocity and finally the third research to investigate further the drying behaviour observed in the second research.

The industrial study shows that only a quarter of the timber pieces examined are free from any drying defects. Warping was the major defects observed, where spring was highest, followed by bowing and twist defects. Other defects such as end checks and surface checks were also noticed. Although this assessment was not part of the scientific study, the data and the information collected become useful for the next laboratory work.

The experimental drying tests performed on the rubberwood produces nonlinear exponential relationship between moisture content (Y) and the drying time (X). Timber subject to 1.52 m/s low air velocity produces $Y = 112.87\ e^{-0.0141X}$ (R^2 = 0.9395) relationship, while the 3.56 m/s high velocity schedule produces $Y = 102.49e^{-.0.0412X}$ (R^2 = 0.9542) relationship and the variable velocity of 3.56 & 1.52 m/s shows $Y = 97.10e^{-0.0145X}$ (R^2 = 0.9506). The drying time calculated using these relationships shows that manipulation of air velocity could not improve the drying time of the 3 cm thick timber. The drying time was found to be same irrespective whether it was dried using the 1.52 m/s low air velocity or at higher velocity of 3.56 m/s or varied from 3.56 m/s to 1.52 m/s. Application of higher air velocity during the initial drying period was beneficial. However, the moisture extraction rates become relatively slower at the latter stage and this off-set the time saved during the early period. It was also found that the slower drying rate during the latter drying stage particularly at higher velocity, is mainly due to the moisture being held deep in the wood. The analysis of the moisture content difference between the core and the shell shows that the high velocity drying schedule result in the steepest gradient compared to the other schedules. The observation of the ultra-structure of rubberwood samples by using the Scanning Electron Microscope indicates that the anatomical features particularly the pit aspiration could not account for slowing down the drying rate at the latter stage.

Based on the above observations, it is believed that if the temperature is increased higher than what is required by the standard schedule especially at the latter stage

of drying, the rate of moisture diffusion from the core can be expedited.

In these drying trials, it was observed that rubberwood can be dried without much drying defects by using the standard drying schedule. The quality of the timber that had being subjected to higher air velocity was also not adversely affected. However, the moisture gradient and the drying residual stress increase significantly when higher velocity was used.

Analysis of the final moisture content shows “good” relative dispersion among the samples dried at low air velocity schedule compare to the samples from the high velocity and variable velocity schedule.

In term of energy saving, the result shows that, when the air velocity is reduced from 3.56 m/s to 1.52 m/s, the corresponding electricity saving is 26 percent. When high velocity schedule is replaced by variable velocity schedule, electrical saving of 16 percent was recorded.

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

KESAN KELAJUAN ANGIN KEATAS KUALITI KAYU GETAH (*Hevea brasiliensis*) YANG DIKERING TANOR

Oleh

SINGARAM

December 2007

Pengerusi : Profesor Madya Zaidon Ashaari, PhD
Fakulti : Perhutanan

Objektif kajian ini adalah bagi mengkaji kesan halaju udara ke atas kualiti pengeringan kayu getah (*Hevea brasiliensis*). Kajian ini terdiri dari tiga penyelidikan. Pertama adalah penilaian industri terhadap kayu getah yang dikering tanor secara dagangan, kedua adalah penyelidikan makmal untuk mengkaji sifat pengeringan kayu getah yang berhubung-kait dengan kelajuan angin dan kajian ketiga adalah untuk menyiasat lebih lanjut gelagat pengeringan yang diperhatikan semasa kajian kedua.

Kajian industri menunjukan bahawa hanya suku dari keseluruhan kepingan kayu yang diperiksa bebas dari sebarang kecacatan. Cacat utama adalah menggeleding , dimana lentik adalah yang terbanyak, diikuti oleh lentung sabut dan pintalan. Lain-lain cacat seperti pecah hujung and retak permukaan juga dikesan.

Walaupun, penilaian ini bukanlah satu kajian saintifik, namun data dan maklumat yang diperolehi adalah berguna dalam penyelidikan makmal yang seterusnya.

Ujian pengeringan yang dilakukan pada kayu getah menghasilkan persamaan exponential bukan-linear antara kandungan lembapan (Y) dan tempoh pengeringan (X). Kayu yang didedahkan pada halaju udara rendah 1.52 m/s persamaan yang didapati adalah $Y = 112.87\ e^{-0.0141X}$ ($R^2 = 0.9395$), manakala bagi jadual halaju udara tinggi 3.56 m/s, persamaannya adalah $Y = 102.49e^{-0.0412X}$ ($R^2 = 0.9542$) dan bagi jadual halaju yang berubah 3.56 & 1.52 m/s, ianya adalah $Y = 97.10e^{-0.0145X}$ ($R^2 = 0.9506$). Masa pengeringan yang dikira menggunakan persamaan-persamaan diatas menunjukan bahawa manupulasi halaju udara tidak memberi kesan terhadap tempoh pengeringan kayu bersaiz 3 cm tebal. Tempoh pengeringan didapati sama walaupun ianya dikeringkan dengan menggunakan halaju udara biasa 1.52 m/s ataupun dengan halaju udara tinggi 3.56 m/s atau halaju berubah dari 3.56 m/s ke 1.52 m/s. Penggunaan halaju yang tinggi pada permulaan pengeringan ada kelebihannya. Namun, kadar penyejatan kelembapan adalah rendah secara bandingannya pada peringkat akhir pengeringan dan ini diimbangi dengan masa yang terjimat pada awal pengeringan. Kadar pengeringan yang rendah pada peringkat kemudian terutamanya apablia halaju udara digunakan adalah disebabkan air pada bahagian teras kayu masih lagi belum dikeluarkan. Analisa kelembapan pada teras dan kelompang menunjukkan jadual pengeringan yang menggunakan halaju yang tinggi menyebabkan kecerunan yang tinggi berbanding dengan jadual lain. Penelitian ultra-struktur kayu getah dengan

Mikroskop Elektron Pengimbas menunjukan bahawa cirri-ciri anatomi terutamanya aspirasi pit adalah tidak terlibat dalam menurunkan kadar pengeringan pada peringkat kemudian.

Berdasarkan pemerhatian diatas, adalah difikirkan bahawa sekiranya suhu dinaikan dari tahap yang ditentukan oleh jadual pengeringan standard terutamanya pada peringkat ahkir, kadar resapan lembapan dari teras boleh di tingkatkan.

Dalam ujian pengeringan ini, didapati bahawa kayu getah boleh dikeringkan tanpa cacat-cacat pengeringan dengan menggunakan jadual pengeringan standard. Kualiti kayu yang diuji dengan halaju tinggi juga tidak menerima kesan buruk. Tetapi, cerun kelembapan serta ketegasan sisa lepas-pengeringan meningkat secara signifikan apabila halaju udara yang tinggi digunakan.

Analisis lembapan akhir menunjukkan penyerakan relative yang baik dikalangan sample-sample yang dikeringkan dengan menggunakan halaju udara yang rendah; berbanding dengan sample-sample dari jadual yang mengunakan halaju udara yang tinggi dan juga jadual halaju udara yang berubah.

Dari segi penjimatan tenaga, kajian ini menunjukan bahawa sekiranya halaju udara dikurangkan dari 3.56 m/s kepada 1.52 m/s, penjimatan elektrik adalah 26 peratus. Apabila halaju udara tinggi digantikan dengan halaju udara yang berubah, penjimatan elektrik adalah 16 peratus.

ACKNOWLEDGMENTS

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Lastly, I would like to express my appreciation to my wife, for the supports, courage and sacrifices given for my attempt to obtain the doctorate title. I believe that my academic achievement would provide the motivating factor for my children – Anusha and Thineswar, to pursue their own interest with dedication.

I certify that an Examination Committee has met on 14 December 2007 to conduct the final examination of A. Singaram a/l Ayeru on his Doctor of Philosophy thesis entitled "Effect of Air Velocity on the Quality of Kiln-Dried Rubberwood (*Hevea brasiliensis*)" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Doctor of Philosophy.

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Date: 28 April 2008

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:

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Date: 8 May 2008

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

SINGARAM

Date: 17 March 2008

TABLE OF CONTENTS