UNIVERSITI PUTRA MALAYSIA

CHARACTERIZATION OF MACHINING DEFECTS IN WOOD PLANING OPERATION

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By

SAEID REZA FARROKHPAYAM

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

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

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April 2010

Chairman: **Jegatheswaran Ratnasingam, PhD**

Faculty: **Forestry**

The objective of this study was to evaluate the effect of some machining factors on the machinability of selected Malaysian hardwoods and to quantify the major types of machining defects in the planing operation. The study aims to reveal the relationship between the types of surface defects generated after planing with the variable factors. It also studies the sanding process as an indicator to reveal loss thickness (yield) after the planing process on defective planks.

For this research, three wood species, Rubberwood (*Hevea brasiliensis***),** Melunak (*Pentace spp)* and Dark Red Meranti *(Shorea spp)* were chosen based on their machining characteristics, commercial position in the local and global market, and their usage as a solid material in the furniture industry. 50 clear samples of each wood species, for each treatment, in a uniform moisture content (10%), of the final size of 19 by 102 × 910 mm, were machined by a planer unit, Weinig Unimat 23E using only the bottom spindle of the machine. The cutterhead had 4 knives with a

diameter 120 mm, rotating at 6000 revolutions per minute (RPM). The depth of cut (0.8, 1.6 and 2.4 mm) and feed rate (8, 12 and 16 m/min) were the experimental variables, while all other factors were kept constant. The surface quality of the individual sample was examined both visually, and sense of tactile to classify the samples into five grades based on the amount and severity of defects present, as given in the standard (ASTM, D 1666 – 87).

In every instance, 60 percent or more of the samples were defect-free, and the slightly defective pieces outnumber the more seriously defective ones, by a wide margin. An in-depth analysis of the samples surfaces, machined under the three parameters of processing, found that among these three factors, depth of cut had the most significant effect on torn and fuzzy grain. This research also revealed that the combination of feed rate, depth of cut and wood species used had no significant effect on the surface quality of samples.

This research showed that the planing operation as a part of wood products manufacturing can influence the quantity or volume of product parts manufactured from a given amount of lumber and labor by affecting the processing yield. The proper machining factors in relation to the wood species used decreases the surface defects. These defects results in increasing labor cost, machining cost and loss of wood material. Therefore, the optimal condition for planing operation of the three Malaysian woods to produce the best yield was realized at the minimum of depth of cut, and maximum cutting marks number per millimetre.

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

SIFAT KECACATAN-KECACATAN PEMESINAN DI DALAM OPERASI PENGETAMAN KAYU

Oleh

SAEID REZA FARROKHPAYAM

April 2010

Pengerusi: **Jegatheswaran Ratnasingam, PhD**

Fakulti: **Perhutanan**

Objektif penyelidikan ini adalah untuk mengkaji kesan beberapa faktor pemesinan spesies kayu keras Malaysia terpilih dan mengesan jenis-jenis kecacatan major akibat pemesinan pada proses pengetaman. Penyelidikan ini juga mengkaji perkaitan di antara jenis kecacatan permukaan selepas proses pengetaman dengan beberapa jenis factor, serta mengkaji proses pelicinan sebagai indikator untuk mengemukakan kehilangan hasil selepas proses pengetaman pada permukaan sampel-sampel yang cacat.

Kayu Getah (*Hevea brasiliensis*), Melunak (*Pentace spp)* dan Meranti Merah Tua *(Shorea spp)* adalah spesies kayu yang telah digunakan di dalam penyelidikan ini. Pemilihan spesies kayu-kayu ini adalah berdasarkaws kepada sifat-sifat pemesinan, kedudukan komersil di pasaran tempatan dan luar negara dan penggunaanya sebagai bahan mentah utama di dalam industri perabot. Sebanyak 50 sampel bagi setiap spesies kayu ini telah diuji. Sampel-sampel ini yang mempunyai kadar kandungan air (10%), dan bersaiz 19mm X 102mm X 910m, telah dimesin dengan

menggunakan unit mesin pengetam, Weinig Unimat 23E, dengan hanya menggunakan spindal bawah yang mempunyai 4 mata pisau, berdiameter 120 mm, pada kelajuan 6000 revolusi per minit (rpm). Kedalaman pemotongan adalah 0.8, 1.6 dan 2.4 mm dan kelajaam pemotongan adalah 8, 12 dan 16 m/min, dimana kedua-duanya faktor ini merupakan factor berubah, manakala faktor-faktor yanag lain adalah dikekalkan seragam. Kualiti permukaan setiap sampel telah diperiksa dengan mata kasar dan secara fizikal, untuk diklasifikasikan kepada lima gred bergantung kepada jumlah dan jenis kecacatan yang terhasil, seperti yang tertera dalam standard ASTM, D 1666 – 87.

Secara umum, 60 peratus atau lebih daripada sampel-sampel didapati bebas dari kecacatan, dan hanya sebilangan sampel-sampel yang mempunyai kecacatan yang sederhana, manakala sampel-sampel yang mempunyai kecacatan yang sangat tinggi adalah sangat jarang.

Analisis yang mendalam pada permukaan sampel-sampel yang telah dimesin dengan menggunakan tiga proses parameter tersebut menunjukkan bahawa hanya faktor kedalaman pemotongan mempunyai kesan yang tinggi pada ira koyak dan ira serabut , berbanding dengan faktor-faktor yang lain.

Selain itu, penyelidikan ini turut mendedahkan bahawa kombinasi di antara kadar pemotongan, kedalaman pemotongan dan spesies kayu yang digunakan tidak mempunyai kesan ketara terhadap kualiti permukaan sampel-sampel. Penyelidikan ini menunjukkan bahawa operasi pengetaman adalah sebahagian daripada proses pembuatan produk kayu yang mempengaruhi kuantiti atau jumlah produk yang

dihasilkan, selain daripada jumlah kayu dan tenaga kerja melalui hasil yang diperolehi. Faktor pemesinan yang bersesuaian dengan spesies kayu yang digunakan akan mengurangkan kecacatan pada kualiti permukaan. Kecacatan ini akan menyebabkan peningkatan tenaga kerja, peningkatan kos pemesinan dan kerugian kayu. Keadaan optimum operasi pengetaman bagi tiga jenis kayu Malaysia ini, untuk mendapatkan hasil yang terbaik boleh dicapai pada kedalaman pemotongan yang minimum dan jumlah pemotongan per mm yang maksimum.

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I certify that a Thesis Examination Committee has met on 14 April 2010 to conduct the final examination of Saeid Reza Farrokhpayam on his thesis entitled "Characterization of Machining Defects in the Wood Planing Operation" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1988. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

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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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DECLARATION

I declare that that thesis is based on my original work expect for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

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SAEID REZA FARROKHPAYAM

Date: 1 May 2010

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LIST OF ABBREVIATIONS

2D	Two Dimensions
3D	Three Dimensions
ANOVA	Analysis of Variance
ASME	The American Society of Mechanical Engineers
ASTM	The American Society for Testing and Materials
CBP	Cement Bonded Particleboard
cm	Centimeter
CRD	Complete Randomized Design
DIN	The German Institute for Standardization
DMRT	Duncan Multiple Range Test
DRM	Dark Red Meranti
FSP	Fiber Saturation Point
HSS	High Speed Steel
ISO	The International Organization for Standardization
JIS	Japanese Industrial Standards
kg	Kilogram
KS	Kolmogorov-Smirnove
kW	Kilowatt
LDS	Laser Displacement Sensor
m	Meter
Mbf	One thousand board feet
MDF	Medium Density Fiber

min	Minute
mm	Millimeter
MOE	Modulus of Elasticity
MOR	Modulus of Rupture
MPa	Mega Pascal
MTC	Malaysian Timber Council
RPM	Revolutions Per Minute
N	Newton
s	Second
USD	The United States dollar
α	Rake Angle
β	Sharpness Angle
γ	Clearance Angle
µm	Micrometer

CHAPTER I

INTRODUCTION

Wood is one of the most versatile materials known to humans. Wood is used to produce a diverse range of products and services that the society relies upon for many activities. From building houses to manufacturing furniture to printing books, wood has become a key resource. In this context, the forestry and wood industry is still one of the major engines of the Malaysian economy. Wood industry exports in Malaysia during 2007 rose nearly 60% to USD6 billion, compared with the figures from 10 years ago. Furniture exports stood at USD1.9 billion, and the furniture were exported to more than 160 countries, with the largest market, the US, receiving about USD2 billion worth of exports (Pillay, 2008).

Wood machining processes have gained great importance in recent years due to the short supply of wood, and the increasing environmental awareness among users and manufacturers. Wood machining techniques that are in use emphasizes on the maximum utilization of wood, especially to produce finished products, which helps in reducing wastage. As the world becomes more attuned to the competing requirements of resource sustainability, industrial economics and the environment is better off with better utilization of wood resources. One of the keys to a more effective use of wood is the development of a vigorous secondary manufacturing, sometimes called value added industry, which results in finished products. The success of secondary manufacturing of wood products is dependent on effective machining processes.

Usually, the outcomes of wood machining processes are heavily influenced by workpiece surface quality considerations. Tool sharpness requirements as well as machine feed and speed parameters often influence the workpiece surface quality. Research on surface quality measurement technology is being aimed at identifying and quantifying defects associated with the machining processes. The degree of roughness of a surface often affects the way the material itself is used. In general, surface irregularities can cause misalignment and part malfunctions, excessive loading over small areas, friction and lubrication problems, general finish and reflectivity problems, as well as other catastrophic failures.

Although surface quality for wood products has been a key issue since woodworking first began, the level of precision required does not approach the level that is found in metal working. This has been due, in part, to wood's inherent dimensional instabilities. The other main reason is that many common uses for wood did not require exceptional surface finishes, as compared to many metal applications. The evaluation of surface irregularities in wood is, however, important to assure proper fit of machined parts for gluing, acceptable surface finish for furniture, and as a methodology to evaluate the accuracy of the manufacturing process.

The last reason has become even more important in recent years due to the increased cost of raw materials, the increased production costs, and the higher production speeds available. Any deviations in expected product quality can quickly cause significant economic losses. There has also been a trend toward tighter tolerances for many forest products industries. An example of this would be the lamination of wood, or wood-based products with plastic films or ultra thin veneers. Even the

slightest irregularity on the surface will show up through the top laminate (Lemaster, 2004).

In wood products manufacturing, the quality of the wood surface requires much more attention, since wood has several unique characteristics such as complex natural composites, visco-elastics, hygroscopic, anisotropic, fibrous, porous and inherent natural defects. These characteristics, combined with the machine variables, complicate the production of machined wood surface with an acceptable quality.

Planing and moulding is a complex and subtle machining process that has much in common with milling and grinding of metals. These metal machining processes, have however been widely studied. In contrast to the vast amount of research and publication for metal machining, the planing of wood has received little attention (Jackson et al., 2001).

Determination of surface quality of wood is a complex process influenced by the heterogeneous structure of the wood, kinematics of the cutting process, and machining conditions. Machining properties of woods are directly related to machining defects such as fuzzy grain, chip mark, raised grain, chipped grain, etc. (Davis, 1962; Hernandez et al., 2001; Malkocoglu et al., 2006). Wood materials exhibit a wide range of defects due to biological as well as machining-related causes. In some cases there is no clear distinction between biological causes of poor surface quality as opposed to machining related causes. An example of this is the phenomenon of raised grain; wherein the growth rings of the wood structure are elevated from the normal wood plane, creating a series of raised areas (lines) on the