J. Basic. Appl. Sci. Res., 1(11)2329-2335, 2011

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

The Effect of Machine Parameters on the Surface Quality in Planing of Rubberwood

[1]Saeid Reza Farrokhpayam[*]; [2]Jegatheswaran Ratnasingam; [3]Morteza Nazerian; [4]Edi Suhaimi Bakar; [5]Tang Sai Hong

[1, 3]Natural Resources Faculty, Wood Science & Industries Department, Zabol University, Zabol, Iran.
[2,4]Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
[5]Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

ABSTRACT

Some machining defects such as fuzzy grain, torn grain and chip marks often occur in Rubberwood lumbers in the planning process, and it decreases the machining yield. To understand and optimize machine-planning characteristics of this wood species, a series of experiments were carried out using a Weinig Unimate 23E moulder (cutter-head rpm of 6000, cutter Ø 120 mm) to produce machined Rubberwood surface with differing depth of cut ranging from 0.8 mm to 2.4 mm, by altering the feed rate from 8 m/min to 16 m/min according to ASTM D 1666-87. The rake angle was constant at 20°. Test specimens prepared from the lumber cut tangentially from logs, were machined at 10% moisture content using HSS tools, and surface quality obtained is visually graded on a scale of 1-5 (defect free or excellent to very poor). Best surfaces resulted in the lowest machining factors among the samples, i.e with 0.8 mm depth of cut and 8 m/min feed rate. Fuzzy grain was the most frequent occurred defects, and torn grain was the deepest occurred defect. The surface quality was found not to be affected very much by the feed rate, while depth of cut significantly affected on machining defects. This research also revealed that the combination of feed rate and depth of cut on Rubberwood had no significant effect on the machined surface quality of samples.
KEYWORDS: Rubberwood; wood machining; planning; depth of cut; feed rate; surface defects.

INTRODUCTION

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) Rubberwood is the most important raw material for the furniture industry throughout South East Asia, published information on its machining characteristics is relatively spare (Ratnasingam et al., 1997)

The planning operation affects the yield as well as the overall throughput rate of the wood processing mill. The machining-planning process of Rubberwood is plagued with low yield, often as low as 65%, due to the high incidence of machining defects (Ratnasingam, 2004; Hong et al., 1994) However, researches have shown that the productivity of the planning operation is closely related to the type of wood material being cut, process variables and machine factors. It has been reported that the rate of stock removal is the most important factor that affects the resultant surface quality, while the amount of work done influences the process economics, particularly as it governs tool wear and energy consumption. Previous research on this subject has shown that the stock removal rate is a function of the depth of cut and feed rate, while the amount of work done is correlated to the density of the material being cut and the stock removal rate (Stewart, 1974; Munnanis et al., 1986)

The machining properties of different wood species have been reported in previous works. The machining and related properties of 32 hardwoods in the United States had reported by Davis (1962). Gilmore and Barefoot (1974) studied surface quality on six tropical hardwoods from Southern America. Nine wood species grown in tropical forest was studied in Peru by Bernui et al (1992). Lihra and Ganev (1999) studied machining properties of 17 wood species grown in Canada, Europe and Asia. Malkocoglu et al. (2006) determined wood machining properties of some hardwoods and softwoods naturally grown in Eastern Black Sea Region of Turky. Also, Ratnasingam et al. (2006, 2007) investigated machining and related machining properties of Rubberwood grown in Malaysia.

The objective of this study is to extend the access of Rubberwood in Malaysia to favor the use of lumber in more value-added products, and a better understanding of its wood machining properties.

***Corresponding Author:** Dr. Saeid Reza Farrokhpayam, Wood Science & Industries Department, Natural Resources Faculty, Zabol University, Zabol, Iran. Email: farrokhpayam@gmail.com

MATERIALS AND METHODS

In order to ensure that the study covered the full variations of the wood in Malaysia, samples of the Rubber wood from the area south of Peninsular Malaysia (SJI Industries), east of Peninsular Malaysia (LY Furniture) and west of Peninsular Malaysia (Lim Ah Soon) were collected from several local suppliers. Approximately 30 boards of kiln dried of 20mm in thickness and 153×1200 mm of size of No. 1 board (No. 1, a board that practically is free from any natural and drying defects.) from each supplier were obtained. The lumbers used were of commercial flat grain, clear, well-manufactured, and accurately identified as to the wood species. Samples were large enough to yield the minimum acceptable size, of the prescribed moisture content, and surfaced smoothly on two sides. Because, the final size of samples for planning test were 19mm by 102 × 910 mm, all the primary boards were obtained in bigger sizes than the final size (Fig. 1).

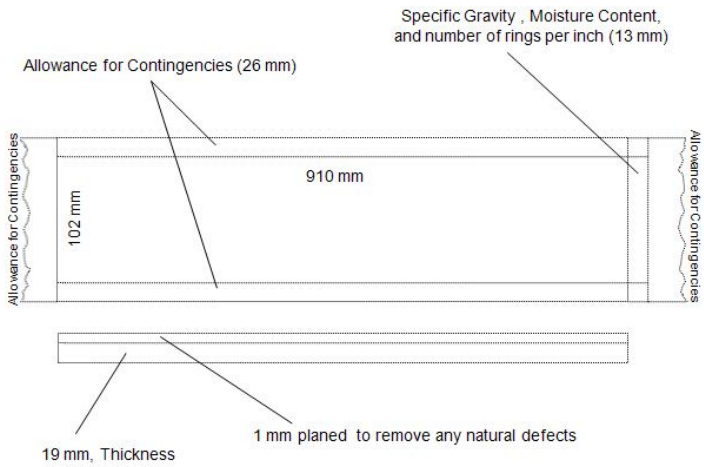

Figure 1: Diagram for sawing Lumber samples into smaller samples for planing tests

Lumber samples were usually dried to a uniform moisture content of 12 percent, before testing. A humidity-controlled conditioning room was used for the conditioning the test materials to the desirable moisture content. In this research all samples were conditioned to a final moisture content of 10 percent.

Table 1: The machining condition for the planing test

Processes	Cutting arrangement (and continuously)	Feed rate *(m/min)*	Depth of cut *(mm)*	Cutter marks number per 2 mm	Rake angle *(°)*	RPM	Feed direction For each treatment (One species × one feed rate × one depth of cut)
1	Random	8	0.8	6	20	6000	Half with grain and half against the grain
2	Random	8	1.6	6	20	6000	Half with grain and half against the grain
3	Random	8	2.4	6	20	6000	Half with grain and half against the grain
4	Random	12	0.8	4	20	6000	Half with grain and half against the grain
5	Random	12	1.6	4	20	6000	Half with grain and half against the grain
6	Random	12	2.4	4	20	6000	Half with grain and half against the grain
7	Random	16	0.8	3	20	6000	Half with grain and half against the grain
8	Random	16	1.6	3	20	6000	Half with grain and half against the grain
9	Random	16	2.4	3	20	6000	Half with grain and half against the grain

(): Number of occurrence of defects per 50 samples

Fifty specimens for each treatment with dimensions of 910 mm × 102 mm × 25 mm were machined by a planer unit, Weinig Unimat 23E using only the bottom spindle of the machine, with 4 knives mounted on a 120 mm cutting head diameter. Knives were jointed and back-beveled on the rake face, to ensure a constant rake angle. All the specimens were run butt to butt, to eliminate the occurrence of possible defects, such as burn marks due to overheating of the knife edges.

All samples for a given wood species were machined consecutively. Because there were several treatments that were being tested, and they should be well mixed to minimize the effect of the gradual dulling of the knives. The order of the treatments was kept random, and the depth of cut and feed rate were variable, while other factors were kept uniform as shown in Table 1. One half of the samples were machined against the grain and one half with the grain. Several cuts were made from each sample under different conditions. The knives used in the experiments were High Speed Steel (HSS) which were of industry standard. Corrugated M2-HSS grade blades were used in the bottom cutter head. Every precaution was taken to keep the sharpness of the knives uniformly good in all tests, by changing to a new set of knives, when necessary.

A total of 50 specimens (cuts) for the wood species were carried out, for each configuration of the machining test. The surface qualities of individual samples were examined both visually and with a sense of tactile (touching) to classify the defects into five grades, namely: (1) Excellent or defect free, (2) Good, (3) Fair, (4) Poor and (5) Very poor, based on the amount and severity of the defects present on the sample, as given in the standard (ASTM, D 1666 – 87). The specimens were also visually graded based on the presence of defects, such as fuzzy grain, raised grain, torn grain, chip marks. Each test specimen was carefully examined for planning defects after each run and the planning defects were recorded according to the degree on the prepared forms.

Results of the planning process of samples from the 9 treatments combinations are summarized in Table 2. The data presentation have been arranged systematically based on quantity and quality of defects which were resulted by the two variable factors, depth of cut and feed rate. This table also contains the percent of values for the defect-free samples among all planed samples in each treatment, and the percent of values for samples with defects among the all samples.

RESULTS AND DISCUSSION

In this study, the Analysis of Variance (ANOVA), Duncan Multiple Range Test (DMRT), Kruskal Wallis Test, Spearman correlation coefficient, were used to analyze the data. The surface quality assessments in this study are based on percentages of defect-free machined pieces. Table 2 illustrates the defect-free percentages of all samples in different conditions. A majority of the test samples were defect-free, and most of the defective samples were only slightly defective. Different samples were affected in different degrees by the feed rate and depth of cut factors, but in general the best results were obtained at 0.8 mm depth of cut and 8 m/min feed rate, while the poorest results at 2.4 mm depth of cut and 16 m/min. Generally, increasing depth of cut and feed rate caused a decrease in surface quality and defect-free pieces (Table 2). In all samples, the differences of surface quality has a downward trend with increasing depth of cut and feed rate, but the gradient of these differences were not same among the samples in the study. With increasing depth of cut and feed rate in different treatment components, the average amounts of all the four types of defects also increased, while the machined surface quality decreased. Figure 2 shows the upward trend in the number of defective pieces (inclusive of the four defects) for the different the treatment components on Rubberwood.

Table 2: Occurrence of planing defects types in treatment components

	Defect-free and Defected pieces *percent*								
Kind of defects	**0.8** *mm* **× 8** *m/min*	**0.8** *mm* **× 12** *m/min*	**0.8** *mm* **× 16** *m/min*	**1.6** *mm* **× 8** *m/min*	**1.6** *mm* **× 12** *m/min*	**1.6** *mm* **× 16** *m/min*	**2.4** *mm* **× 8** *m/min*	**2.4** *mm* **× 12** *m/min*	**2.4** *mm* **× 16** *m/min*
Defect-free	92(46)	88(44)	84(42)	82(41)	78(39)	76(38)	74(37)	70(35)	68(34)
Raised grain	0(0)	0.9(1)	0.6(1)	1.5(2)	1.3(2)	2.3(3)	1.6(2)	2.3(3)	0.9(1)
Torn Grain	2.3(2)	3.4(4)	4.7(8)	5(7)	6.7(10)	8.2(11)	8.1(10)	10(13)	10.1(11)
Fuzzy grain	4.6(4)	5.1(6)	7.1(12)	6.5(9)	7.3(11)	9(12)	10.6(13)	11.5(15)	14.6(16)
Chip marks	1.1(1)	2.6(3)	3.6(5)	5(7)	6.7(10)	4.5(6)	5.7(7)	6.2(8)	6.4(7)

In planning of Rubber wood, the occurrence of raised grain was at a very slight degree (Figure 3). For the planning of temperate wood species, the raised grain occurrence is more regular and abundant than that of tropical species. This is due to the reason that the arrangement and condition of growth rings in tropical species is different in contrast to the wood in the temperate zone. This phenomenon (raised grain) seems to be a characteristic of certain kinds or types of wood, rather than of the machining method of surfacing them. In some species, such as Cottonwood and Elm for example, raised grain occurs commonly, whereas it is troublesome in only certain types of lumber such as in Mahogany, Oak, and certain other species of hardwood, it is troublesome in only certain types of lumber. Generally, lumber surfaced with a sharp rotary planer does not show much of this type of defect (Koehler, 1932). Degrees No. 3, 4 and 5 (fair, poor and very poor) of this type of defects was not seen on Rubberwood in this research.

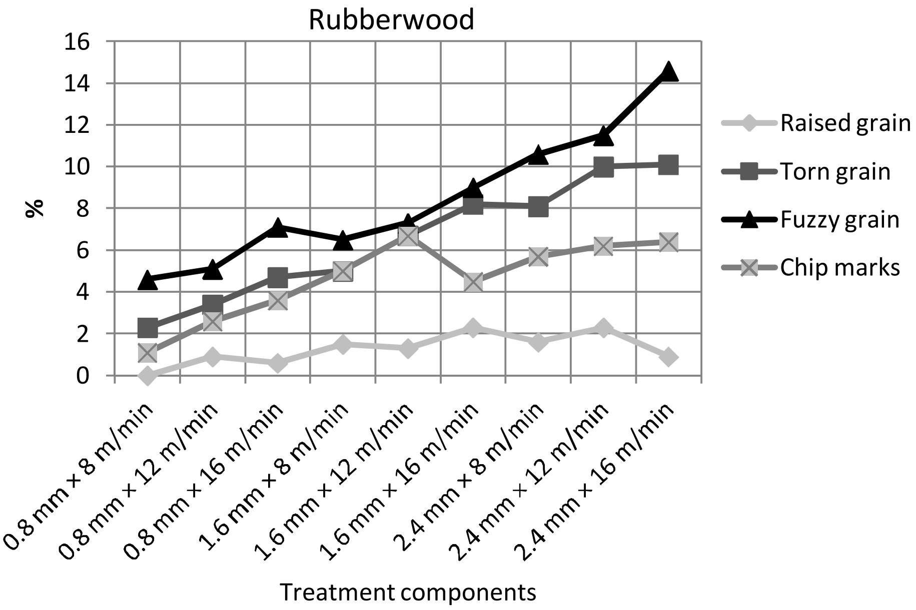

Figure 2: Percentage of defects of different defect types in different treatment components

Most of the torn grain defect was seen in samples which had been machined against the direction of the grain. The only reason for these differences between the samples, was possibly due to the grain direction in pieces and possibly, irregular and swirls grain which are more prevalent in some pieces, which caused more defects in them. The number and size of knots directly affected the torn grain occurrence. However, degrees No. 4 and 5 of this type of defects was not seen on Rubberwood in this research (Figure 3).

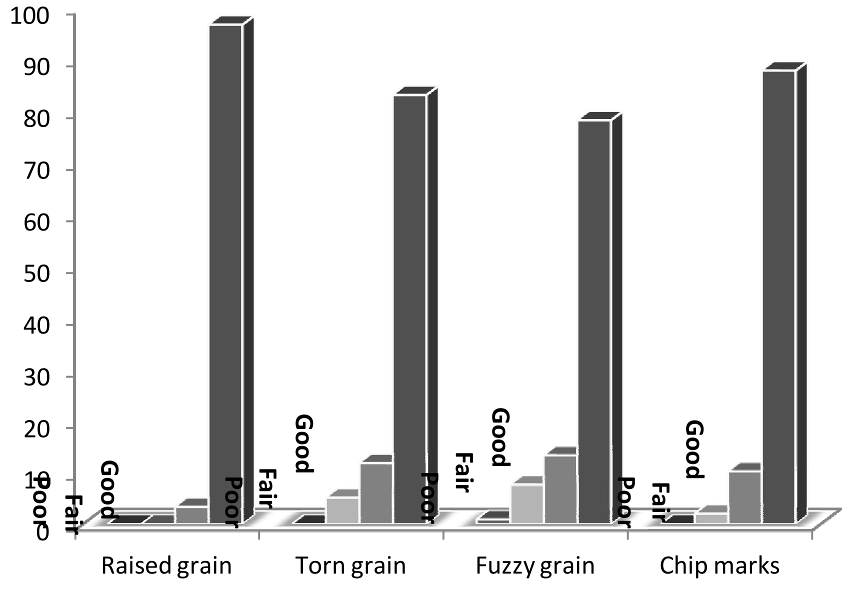

Figure 3: Frequency of type of defects based on their degrees

Figure 3 also shows the frequency (percentage) of various degrees of fuzzy grain defect in Rubberwood. Fuzzy grain had the highest frequency among the types of defects in this study. Different samples were affected in different degrees by the wood factors, such as abnormal type of wood known as tension wood. Based on previous experiences, some species of wood fuzz up more than others, and, in general, the hardwoods are more refractory in this respect than the softwoods.

Tension wood occurs most prominently on the upper sides of leaning broadleaved trees. The tension wood fibers frequently cause unusual behavior of surfaces of lumber. The presence of tension wood fibers, together with the high moisture content of green lumber, frequently is associated with cell collapse. Some planed or shaped surfaces also had zones of torn grain in the parts that included tension wood (Koehler, 1955).

The occurrence of tension wood is a common phenomenon in Rubberwood. Several studies on Rubberwood, indicate that the presence of tension wood in Rubberwood may be serious (Lim 1985 and Rao and Hermavathi, 1989). Tension wood is commonly found in branches and leaning trunks (Lim, 1998). It appears that the presence of tension wood in Rubberwood proved to be the main factor (species factor) affecting quality of work and fuzzy grain occurrence. It affected both the frequency and severity of fuzzy grain.

Chip marks are caused from chips that are lying on the end of the knife tip being embedded in the finished surface of the stock by the rotating cutterhead, resulting in a dent (Mitchell, 2005). Another type of chip marks (chip prints) are the zones of crushed wood below the surface and are generally produced by wood chips being compressed between the workpiece surface and a harder knife, feed roll and/or pressure bar of the planing machine (Stewart, 2007). Degrees No. 4 and 5 of this type of defects was not seen on Rubberwood in this research (Figure 3).

Effect of Feed Rate on the Defects

The results of the Kruskal-Wallis test for the feed rate effect on the types of defects shows that there were no significant differences between the three feed rates, for all types of defects. But, in comparison to the other types of defects, fuzzy grain with p value 0.074 showed a greater effect on fuzzy grain. This difference was related to fuzzy grain being inherent and the number of cuts per centimeters. With increasing number of cuts (decreasing feed rate at constant rpm) wood fibers will cut cleanly at the surface. Less feed rate may create (the range used in this research) a chance to cut standing fibers. Therefore, it can see that higher feed rate produce more fuzzed up surface. Generally, the feed rate factor, as a stand alone factor was not an effective factor to produce surface defects on the specimens in this research.

Effect of Depth of Cut on the Defects

The results of Kruskal-Wallis test for the depth of cut effect on the types of defects shows that, there were significant differences between the three levels of depth of cut for the types of defects. The significant level for torn grain, fuzzy grain and chip mark at 0.01 was higher than the raised grain at 0.05. In contrast to other factors, this test also showed that the depth of cut has a major influence on surface quality of work. The result showed the effects on torn grain and fuzzy grain was more than the effect on chip mark and raised grain. This difference with chip mark was probably related to interaction the between depth of cut and other existing variables (i.e. wood species and feed rate). Previously it was mentioned, the gradual tool wearing effect was minimized by randomly machining the samples, but this unavoidable factor will affect in an interactive way on the surfaces of the samples.

Interaction Effect of Depth of Cut and Feed Rate on Types of Defects

The interaction between the different levels depth of cuts and feed rates showed clear differences on surface quality. Reading the results across the three rows in Table 3, which related to the three levels of depth of cuts, the poorest quality of work can be seen at the highest depth of cut of 2.4 millimeters, and the fastest feed rate of 16 meters per minute. While, at the same depth of cut, the surfaces of samples which were machined at feed rates of 8 and 12 meters per minute had much better quality.

Table 3: Means for combination of depth of cuts and feed rates

	Depth of cut		
Feed rate	**0.8 mm**	**1.8 mm**	**2.4 mm**
8 m/min - - - - - - - - - - - - - - -	19.773 ^{A}	19.4 ^{AB}	19.167 ^{BC}
12 m/min - - - - - - - - - - - - - -	19.713 ^{A}	19.253 ^{BC}	19.067 ^{BC}
16 m/min - - - - - - - - - - - - - -	19.473 ^{AB}	19.24 ^{BC}	

Generally, with increasing depth of cut, and the simultaneous increase in feed rate, the number of defects was more than when, just one factor was increased. In Table 3, the means with similar suffixes or common letters did not show significant differences on the surface quality of samples.

Conclusion

Preliminary investigations show that there is little scientific information available to assist the industry with their Rubberwood planning process and machine set up. It is envisaged that the research would lead to a systematic characterization of the wood planning method to be used, and a guide to optimise their planning operations' performance, through the best configuration of feed rate, depth of cut and species parameters.

In this research, the effect of the two important machining factors, depth of cut and feed rate on Rubberwood (*Hevea brasiliensis)* lumbers, in terms of its surface quality characteristics was investigated. Based on the results of this study (the basis of defect-free percentage in all the wood species), a majority of the test samples were defect-free, and the defective samples were only in small percentage. In general, the best results were obtained at 0.8 millimetres of depth of cut and feed rate of 8 meters per minute ,While the poorest results was at 2.4 millimetres of depth of cut and 16 meters per minute of feed rate.

It was found that among these two factors, depth of cut had most significant effect on torn and fuzzy grain. Further, the machined surface quality of wood was positively influenced as the feed rate decreased. Fuzzy grain was the only defect among all the defects evaluated in this study that was affected by the type of wood.

REFERENCES

1. Bernui, C.R., A.A. Sato, and M.A. Lopez. 1992. Workability of the wood of nine species of Bombacaceae, Tevista-Forestal-del-Peru 19 (1) 69– 81

Doi: not available

2. Davis, EM. 1962. Machining and related characteristics of US hardwoods. Technical bulletin no. 1267, US Department of Agriculture-Forest Service, Washington, DC

Doi: not available

3. Gilmore, R.C., and A.C. Barefoot. 1974. Evaluation of some tropical woods imported into the United States from South America. Forest Product J. 24 (2) 24–28

Doi: not available

4. Hong, L.T. and H.C. Sim. 1994. Rubberwood: processing and utilization. Forest Research Institute, Malaysia

Doi: not available

5. Koehler, A. 1955. Raised grain—its causes and prevention. Forest Products Laboratory. Madison S. Wisconsin. Report No. 2044

Doi: not available

6. Lihra, T. and S. Ganev. 1999. Machining Properties of Eastern Species and Composite Panels. Forintek Canada Corp. Western Region, 2665 East Mall, Canadian Forest Service, Project No.: 2306, p. 62

Doi: not available

7. Lim, S.C. 1985. Observations on the anatomical structure of some Malaysian Woods by SEM. Report on the Training Course in Wood Technology at the State University of Ghent, Belgium. FRI Report No. 42, Forest Research Institute Malaysia, Kepong :11-28.

Doi: not available

8. Lim, S.C. 1998. Tension wood in Rubberwood. Timber Technology Centre (TTC), FRIM, Kepong, 52109 Kuala Lumpur. No. 5, 1998

Doi: not available

9. Malkocoglu, A. and T. Ozdemir. 2006. The machining properties of some hardwoods and softwoods naturally grown in Eastern Black Sea Region of Turkey. Journal of Materials Processing Technology 173(3):315–20

Doi:10.1016/j.jmatprotec.2005.09.031

10. Mitchell, P.H., J. Wiedenbeck and B. Ammerman. 2005. Rough mill improvement guide for managers and supervisors. United States Department of Agriculture. Forest Service. General Technical Report NE-329.

Doi: not available

11. Munnanis, L., B.J.H. River, and H.A. Stewart 1986. Surface and subsurface characteristics related to abrasive-planing conditions. Wood and Fiber Science, 18(1):107-117

    Doi: not available

12. Pillay, A.K. 2008. Malaysian Timber Industry Board seminar on incentives for wood-based industries. Kuala Lumpur

    Doi: not available

13. Rao, V.R., and T.R. Hermavathi. 1989. Reaction wood, a natural defect in rubberwood. Paper presented at the First National Seminar on Rubberwood (Abstract), Rubber Research Institute of India, Kottayam, India.

    Doi: not available

14. Ratnasingam, J. 2004. Economics of the Rubberwood processing industry; A South Weast Asian perspective. Asian Timb 23(2): 16-18

    Doi: not available

15. Ratnasingam, J. H.F. Reid, and M.C. Perkins, 1997. Furniture industry: Regaining the competitive edge. J Inst Wood Sci 14(3): 115-120

    Doi: not available

16. Ratnasingam, J. and F. Scholz. 2006. Optimal surface roughness for high-quality on Rubberwood (*Hevea brasiliensis*). Holz Roh Werkst. 64: 343–345

    Doi: 10.1007/s00107-005-0068-6

17. Ratnasingam, J. and F. Scholz. 2007. Characterizing surface defects in machine-planing of Rubberwood (*Hevea brasiliensis*). Holz Roh Werkst. 65: 325–327

    Doi: 10.1007/s00107-006-0163-3

18. Stewart, H.A. 1974. A comparison of factors affecting power for abrasive and knife. planing of hardwoods. Forest Products Journal: 24(3): 31-34

    Doi: not available

19. Stewart, H.A. 2007. Burning, glazing from machining. FDM; Apr 2007; 79, 4; ABI/INFORM Global. Pg. 70

    Doi: not available