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Characterizing Surface Defects of Solid Wood of Dark Red Meranti (*Shorea* sp.), Melunak (*Pentace* sp.) and Rubberwood (*Hevea brasiliensis*) in Planing Process

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Abstract: The machining parameters affect surface quality and usually, wood planing process is heavily influenced by external parameters. External parameters concern mainly the machining process parameters such as: the feeding speed, the depth of cut, the cutting tool diameter and geometry, the cutting geometry, the cutting technique (up or down milling). This study was carried out to determine the planing properties of naturally grown Melunak (*Pentace* sp.), Dark Red Meranti (*Shorea* sp.) and Rubberwood (*Hevea brasiliensis*). Some machining defects such as fuzzy grain, torn grain and chip marks often occur in lumbers at the planing process and it decreases the machining yield. To understand and optimize the planing characteristics of this wood species, a series of experiments were carried out using a weinig Unimate 23E moulder (cutter-head rpm of 6000, cutter diameter 120 mm) to produce machined surface with differing depth of cut ranging from 0.8 to 2.4 mm, by altering the feed rate from 8 to 16 m min^{-1} according to ASTM D 1666-87. Based on the preliminary results of this study, the best results were obtained at 0.8 mm of depth of cut and feed rate of 8 m min^{-1} for Dark Red Meranti. While, the poorest results was on Melunak wood at 2.4 mm of depth of cut and 16 m min^{-1} of feed speed. 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.

Key words: Wood machining, planing, machining parameters, 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 values 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, but published information on its machining characteristics is relatively spare (Ratnasingam *et al*., 1997).

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 in Peru was studied by Bernui *et al*. (1992). Lihra and Ganev (1999) studied machining properties of 17 wood species grown in Canada, Europe and Asia. Malkocoglu and Ozdemir (2006) determined wood machining properties of some hardwoods and softwoods naturally grown in Eastern Black Sea Region of Turkey. Also, Ratnasingam and Scholz (2006, 2007) investigated machining and related machining properties of Rubberwood grown in Malaysia.

Of all effective factors of wood surface quality during machining, the amount of material removed from the surface seems to be easiest to overlook. And it is often the most difficult to diagnose when a problem arises. Removing a heavy amount of stock most often does not affect finish quality, assuming all of the related performance criteria are within limits, such as the number of knives present in relation to peripheral and feed speed. The cutting tool knife passing through the material is well supported beneath, ahead of and by the adjacent areas of that being cut away-by the material itself. Removing only a very shallow or small amount of material poses several problems that are difficult to

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diagnose, especially after the cut (Effner, 2001). A series of tests was made by Davis (1962) with four depths of cuts. The shallowest cut gave the best results, with progressively poorer work as deeper cuts were made. The difference between cuts was much greater than between any other two successive cuts.

In the more general case in which all other factors remain constant, an increase in feed speed increases the instantaneous radius of curvature of the knife path, increases the height of the individual knife marks and increase the distance between knife marks. The last two results mentioned cause surface quality to suffer, as feed speed increases (Koch, 1964). The planing qualities of wood are enhanced with decreasing feed speed or with increasing number of knife marks. The best planing performance of wood species are obtained with 20 knife marks and the worst with 8 cutting marks (Malkocoglu and Ozdemir, 2006).

The purpose of this study was to investigate machining properties of some tropical hardwoods planed in different feed speed and depth of cut condition.

MATERIALS AND METHODS

In order to ensure that the study covered the full variations of the wood in Malaysia, the samples were collected from several local suppliers from the south, east and west area of Peninsular Malaysia. Approximately 90 kiln dried boards of 20 mm in thickness and 153×1200 mm of size of No. 1 board 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 planing test were 19 mm by 102×910 mm, all the primary boards were obtained in bigger sizes than the final size (Fig. 1).

Fifty specimens for each treatment with dimensions of 910×102×19 mm were machined by a planer unit,Weinig Unimat 23E. Only the bottom spindle of the machine, with 4 knives mounted on a 120 mm cutting head diasmeter was used. 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.

The test specimens of 19 mm thick permitted making 14 cuts with 0.8 mm depth before the specimen became

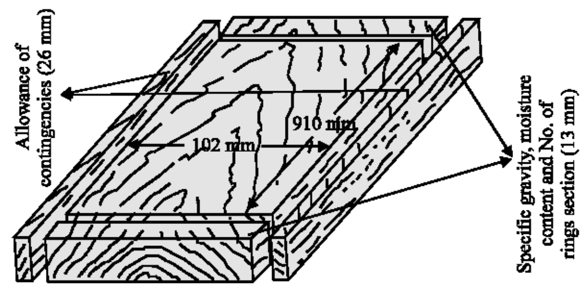

Fig. 1: Diagram for sawing Lumber samples into smaller samples for planing tests

Table 1: The test condition for the planing

Species	Feed rate ($m\ min^{-1}$)	Depth of cut (mm)	No. of treatments	Repetition	Total
Rubberwood	8, 12, 16	0.8, 1.6, 2.4	9	5 ×10	450
Dark red meranti	8, 12, 16	0.8, 1.6, 2.4	9	5 ×10	450
Melunak	8, 12, 16	0.8, 1.6, 2.4	9	5 ×10	450
Total No. of wood specimens (cuts)					1350

thin enough to introduce a new variable. This means that one board with 19 mm thickness can be planed 14 times with a depth of cut of 0.8 mm (This means that one board with 19 mm thickness can be planed 14 times with a depth of cut of 0.8 mm). Consequently, 4 boards were needed for one test (one species×0.8 mm depth of cut×one value of feed speed). In this manner, 8 boards were needed for the depth of cut of 1.2 mm (7 permissible cuts) and 17 boards for the depth of cut of 2.4 mm (3 permissible cuts) and therefore, a total of 30 boards were prepared for the three values of depth of cut, on one value of feed rate for one species (Table 1).

The knives used in the experiments were High Speed Steel (HSS) which were of industry standard. 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.

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, (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. Figure 2 shows the three intermediate grades of torn grain on Melunak, where No. 2 is good, No. 3 is fair and No. 4 is poor.

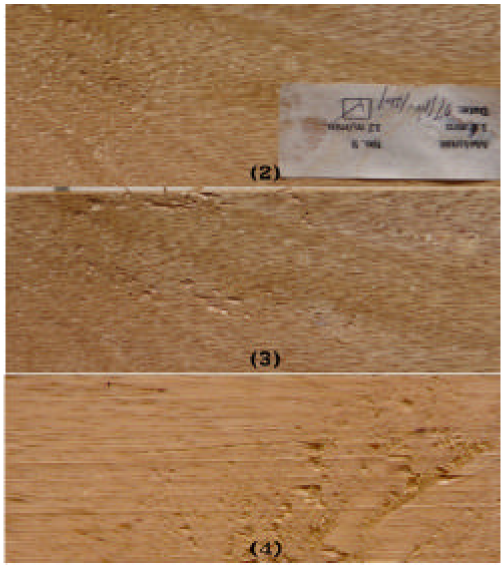

Fig. 2: Torn grain in Melunak, grades No. 2, 3 and 4

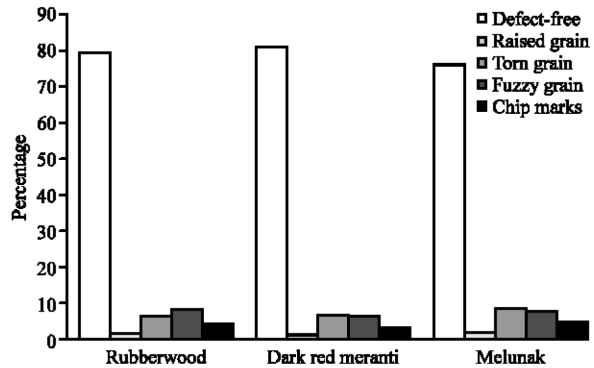

Fig. 3: Averages of different types of defects

RESULTS AND DISCUSSION

The results in Fig. 3 show, the most common type of defect was fuzzy grain (at average 7.8%), with a small contrast to torn grain, while the defect of the least occurrence was raised grain (at average 1.8%). The least amount of raised grain, on the other hand, occurred (at average 1.4%) on Rubberwood pieces and also, the most defective samples due to fuzzy grain (at average 8.5%) was on Rubberwood (Fig. 3). While, most Dark Red Meranti (7.1%) and Melunak pieces (8.9%) were defected with torn grain, with a small difference from fuzzy grain.

Main effect of the factors on surface defects: The statistical analysis of data showed among the three used factors in this research, depth of cut, was the only factor with significant effect on surface defects. On the other hand, the difference between the three levels of depth of cuts was significant at the 0.01 level. In the situation that the wood species and feed rate factors have been studied by a visual inspection of the plot, there was no clear-cut result. A general conclusion that can be drawn is that, when the depth of cut is not constant, the quality of work also is changed. The effect of this factor on surface quality is very clear and measurable. To be significant that the depth of cut proved to be the main factor effecting quality of work, when comparing this factor with other factors in this research (wood species and feed rate). Any increasing or decreasing amount of this factor should directly increase or decrease the amount of machining defects. While, the effects of feed rate and wood species on planing defects as an independent factor was not clear.

Although, the results for wood species and feed speed were not significant, but their effects can be discussed. In this research, the analysis of variance did not show a significant difference between three levels of these two factors. However, it does not mean that there was no quality difference on the wood surface by changing the levels of the factors. As a matter of fact, the positive or negative effects of each factor were nullified in an interaction between the existing factors. The F test in the analysis of variance did not reveal probable differences between the treatments. To reveal probable differences between the treatments, the Duncan Multiple Rang Test (DMRT) was used.

This test revealed the small differences between the different levels of the feed rate factor on surface quality. The slowest feed rate (8 m min^{-1}) gave the best results, with progressively poorer work as fastest feed speed was made. The difference between the feed rate at 8 m min^{-1} and those at 12 m min^{-1} was quite similar between any another successive feed rates. Similarly, the behavior of different wood species and depths of cuts on the results were ignored.

The result of the DMRT on species showed that there was no significant difference between the different wood species. But, this test showed the small differences between different species factor on surface quality. Dark Red Meranti gave the best results, with progressively poorer work on Melunak. The difference between Dark Red Meranti and the other wood species was similar to the difference between any other two species. In this context, the behavior of different feed rates and depths of cuts on results were also ignored.

Interaction effect of the factors on surface defects: The results showed the interactions between the three factors in this research had no significant effect on the quality of surface finish. In other words, no clear relationship between feed rate, depth of cut and wood species in a combination was seen in this study. Generally, all affecting factors were independent variables, where the effect of each factor on the resultant of planing surface quality was free of the effect of the other factors. However, it does not mean that there was no quality difference on the resultant wood surfaces through the combinations of the levels of the factors. As a matter of fact, the positive or negative effects of each factor were nullified through the interaction between the influencing factors.

With comparison the results, the poorest quality of work was observed in the combination of the highest depth of cut of 2.4 mm and the fastest feed rate of 16 m min^{-1} on the Melunak samples. While, at this depth of cut, the surface samples which were machined at the 8 and 12 m min^{-1} had better surface qualities. Generally with increasing depth of cut and the simultaneous increase in feed rate, the number of defects on the wood samples was more than when only one factor was increased.

CONCLUSION

An in-depth analysis of 1350 surfaces, machined under the three parameters of processing, as defined by the ASTM D 1666-87 standard was under taken in this study. It was found that among these three factors, depth of cut had most significant effect on torn and fuzzy grain. Further, the machined surface quality of wood species was positively influenced as the feed speed decreased. Fuzzy grain was the only defect among all the defects evaluated in this study that was affected by the type of wood.

This research also revealed that the combination of feed rate, depth of cut and wood species used had no significant effect on the machined surface quality. Although, the meagre effect of any treatment (combination) in comparison to others shown in this study were reflective of industrial practice, but in general there was no strong relationship between these the three factors used.

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