

## Analysis on Wood Quality, Geometry Factor, and Their Effects on Lathe Check of Samama (*Anthocephalus macrophyllus*) Veneer<sup>1</sup>

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### ABSTRACT

Relatively little information is available regarding the correlation between wood and veneer quality, especially for Samama wood, an endemic wood species in eastern Indonesia. This study addresses the quality of 8 years old Samama wood and its effect on the veneer quality. Samama wood quality was determined by evaluating its specific gravity, moisture content, fiber dimensions, and microfibril angle from pith toward bark. Meanwhile, veneer quality was assessed by examining veneer thickness and lathe check characteristics. Geometry factor model was constructed to elaborate the quantities of lathe check from pith toward bark. Results show that fair variations of veneer thickness, ranging from 1.5 mm to 3.0 mm, could be obtained from Samama wood. The quantity, depth, and length of lathe check were noticeably decreasing toward bark. Further, in the same manufacturing process, geometry factor was determined as the dominant factor over other wood properties in affecting the frequency of lathe checks from pith towards bark. These facts should be put into consideration in producing veneer from Samama wood. Moreover, these results enlighten the potential of Samama wood as plywood and other excellent veneer-based products.

**Keywords :** geometry factor, lathe check, Samama wood, veneer

### 1. INTRODUCTION

Wood quality varies on its cross section. Early growth wood in vicinity of the pith is known as juvenile wood, which gradually matures toward bark. The characteristic of juvenile wood is more varied and tend to show lower quality than of mature wood which is more stable and stronger

(Barnett and Jeronimidis, 2009). Identifying the transition from juvenile to mature wood is a first step to elucidate the quality of wood and to improve its utilization. Previous study identified that 30.4-38.9% of Samama wood (*Anthocephalus macrophyllus*), which is endemic in eastern Indonesia (Celebes and Moluccas islands), showed maturity features at 8 years old (Cahyono

<sup>1</sup> Date Received July 26, 2016, Date Accepted September 13, 2016

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*et al.*, 2015). The wood is classified into strength class of III and IV (Cahyono *et al.*, 2012). Samama is superior than Jabon in wood maturity as the whole part of 7 years old Jabon wood (*Anthocephalus cadamba*) is still comprised of juvenile (Darmawan *et al.*, 2013). Additionally, Samama wood has straight and high branchless stem. Moreover, it is necessary to further investigate this wood to improve its utilization for plywood, laminated veneer lumber (LVL), or other veneer based products.

Wood is peeled into veneer prior fabrication into plywood products or laminated veneer lumber (LVL). Bonding strength of veneer is affected by moisture content, density, lathe check, and surface roughness (Dundar *et al.*, 2008). Among those factors, lathe check is considered as an important factor in relation with bonding strength of veneer. Bonding strength is reduced by the increase of lathe checks (Darmawan *et al.*, 2015). Moreover, veneer surface that contains lathe checks requires more adhesive due to topography degradation of the veneer surface (Daoui *et al.*, 2011). Veneers with lathe checks can also cause excessive resin use and may result in resin-bleed through the inside of the veneer (Darmawan *et al.*, 2015).

In general, there are two factors affecting lathe check: firstly, manufacture process (pretreatment on log and peeling parameters), and secondly, wood quality. Study by Duplex *et al.* (2013) found that during veneer production, low temperature log would result in veneers with deeper and more spaced checks than high temperatures log when checks are closer

and less deep. Nosebar pressure more than 5% would also reduce lathe checks (Acevedo *et al.*, 2012). The peeling rate could also affecting the lathe checks (Lutz, 1978). Furthermore, wood quality factors which affect veneer quality are specific gravity, wood pore, proportion of juvenile and mature wood, microfibril angle (MFA), longitudinal shrinkage, latewood proportion and lignin-cellulose composition (Darmawan *et al.*, 2015). Sapwood produces better quality of veneer than wood at pith's vicinity due to its lower specific gravity, higher growth rate, cutting speed, higher angle of attack at the core material (Palka and Holmes, 1973).

This study addresses the veneer quality caused by the difference in diameter of cross sectional wood from bark inward pith, which thus far was less discussed in many previous studies. Wood peeling will transform the wood from round shape into sheet form. The circumference of outer part is larger than that of inner part in which the inner part would then adjust to the size of outer part circumference by forming cracks on the surface of inner part. Those cracks are called lathe checks. This study addressed this factor as an approach to determine the changes of lathe check quantities from pith toward bark.

In the foreseeable future, industrial veneer supply in Indonesia will be dominated by fast growing and potential local wood species such as Samama. Therefore, information on the quality of Samama veneer would be necessary to support the utilization of this material for high quality veneer-based products. Wood and veneer

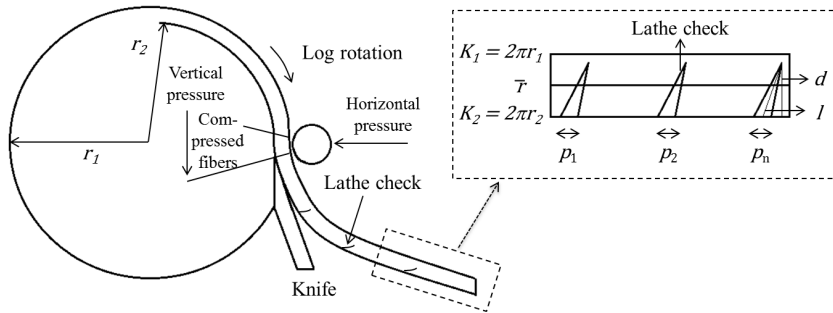


Fig. 1. Process of veneer peeling (left) and illustration of geometry factor (right).

quality were mostly discussed separately in many previous studies, and correlation of both parameters is rarely addressed. In this study, quality of Samama wood based on its specific gravity, moisture content, fiber dimensions, and MFA were analyzed and attributed to the quality of the produced-veneer. Mathematical equation based on the difference of veneer circumferences would be constructed to define the quality phenomenon of lathe check from pith vicinity toward bark. The results were expected to be put into consideration in veneer production of Samama wood. Moreover, this finding was also expected to provide reliable information on diameter's effect on veneer quality.

## 2. THEORETICAL BASIS

Fig. 1 illustrates veneer-peeling process. During the process, circumferences of outer part will be longer than that of the inner part. When veneer is assumed as a rigid material, the total difference of circumferences of outer part and inner part would become lathe checks. Even though veneer is not completely rigid (it has slight flexibility), the difference of veneer circumference would

still tend to produce lathe checks. Therefore, if the circumference of outer part is  $K_1 = 2\pi r_1$ , and that of inner part is  $K_2 = 2\pi r_2$ , thus the difference between  $K_2$  dan  $K_1$  is:

$$K_3 = 2\pi(r_1 - r_2) = 2\pi t \dots\dots\dots (1)$$

$K_3$  is the shortage of veneer circumference;  $r_1$  and  $r_2$  are outer and inner radius;  $t$  is veneer thickness.

If the shortage of veneer circumference is the total sum of width of lathe checks ( $p_1 + p_2 + \dots + p_n$ ) for certain veneer length ( $L$ ) is:

$$\sum p_i = n\bar{p} \frac{L}{10} \dots\dots\dots (2)$$

For veneer length  $L$  is one circumference,  $L = 2\pi\bar{r}$  and  $\sum p_i = 2\pi(r_1 - r_2) = 2\pi t$ , consequently:

$$2\pi t = n\bar{p} \frac{2\pi\bar{r}}{10} \text{ or } n = \frac{10t}{\bar{p}\bar{r}} \dots\dots\dots (3)$$

In which  $n$  = numbers or quantity of lathe checks for 10 veneer length,  $\bar{p}$  = mean of width of lathe checks (cm),  $t$  = veneer thickness (cm) and  $\bar{r} = \frac{1}{2}(r_1 + r_2)$  = radius of veneer's center part (cm), 10 = veneer sample

length (cm).

Based on Equation 3, there is an exact relationship between number of lathe check ( $n$ ) and geometry factor ( $\frac{t}{pr}$ ). The equation was built within assumption that the veneer is rigid. Since there is slightly flexibility properties of the veneer, a constant  $C$  must be given (Equation 4).

$$n = C \frac{10t}{pr} \dots\dots\dots (4)$$

Furthermore, Fig. 1 also illustrates that  $\frac{\bar{p}}{d} \cong b$  and  $\frac{\bar{p}}{l} \cong c$ , in which  $d$  = depth of lathe check (cm);  $l$  = length of lathe check (cm); while  $b$ ,  $c$  are constants. The ratio ( $t/\bar{r}\bar{p}$ ) in equation 3 is called geometry factor with ( $\text{cm}^{-1}$ ) as its unit. Since the geometry factor has  $\text{cm}^{-1}$  unit and 10 has cm unit,  $n$  has no unit. In this study,  $n$  was counted for each 10 cm veneer sample length.

If one piece of log is peeled, it must be conducted in one manufacture parameter because it is almost impossible to change the manufacture parameter when the log is being peeled. So the average of lathe check width ( $\bar{p}$ ) for veneer which peeled form a log can be considered constant. Moreover, as  $\bar{p}$ , 10, and  $C$  can be considered constant at each veneer-peeling, Equation 4 can be transformed into:

$$n = C \frac{t}{r} \dots\dots\dots (5)$$

Which constant ( $C$ ) represented the veneer flexibility, veneer sample length (10 cm), and mean of width of lathe checks ( $\bar{p}$ ). Since  $C$  is constant, the geometry factor in this study was

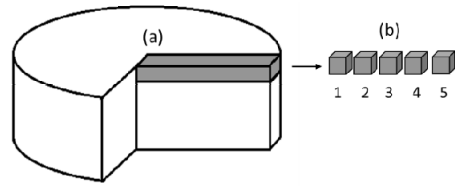


Fig. 2. A 10 cm-thick wood disc (a), block samples (b).

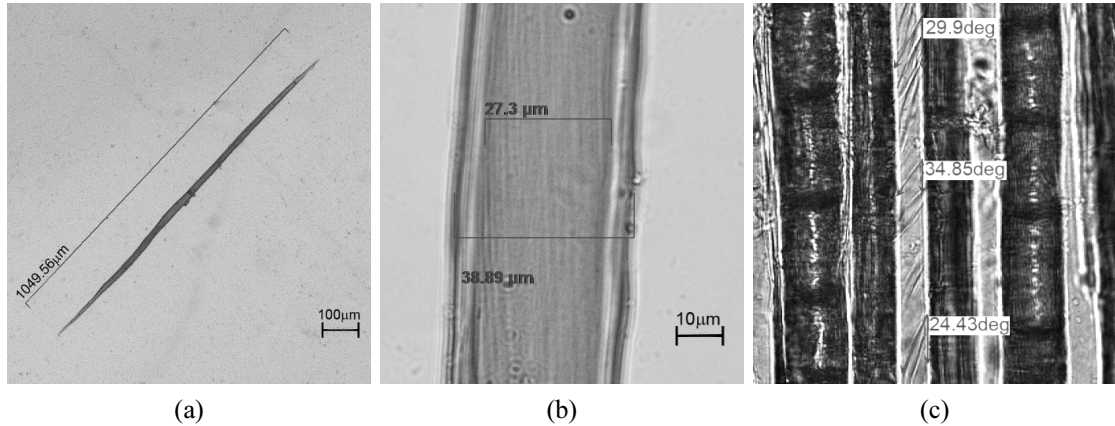
simplified as the ratio between veneer thickness ( $t$ ) and radius of veneer’s center part ( $\bar{r}$ ).

### 3. MATERIALS and METHODS

The primary material in this study was Samama wood (*Anthocephalus macrophyllus*) from Saleman village, District Maluku Tengah, Maluku Province. Three trees of 8 years old Samama with straight and defect-less stem were purposively sampled. The diameters at breast height (DBH) of the trees were 39, 40 and 40 cm. Subsequently after felled, a 10 cm thick of disc sample was made from log part at distance of 1.5 m from above ground to determine its wood quality. The remaining 50 cm length of log was prepared for veneer quality analysis. All pieces of sample were wrapped in plastic bags to keep their freshness. This study used chainsaw, circular saw, spindleless rotary cutter, ruler, camera, microscope and other equipment that would be detailed in Method section.

#### 3.1. Determination of wood quality

Test samples were taken from wood at its height of 1.5 m above the ground in the form of 10 cm-thick wood disc (Fig. 2a). Test sam-



**Fig. 3.** Measurement of fiber length (a), fiber wall thickness (b), and microfibril angle (c).

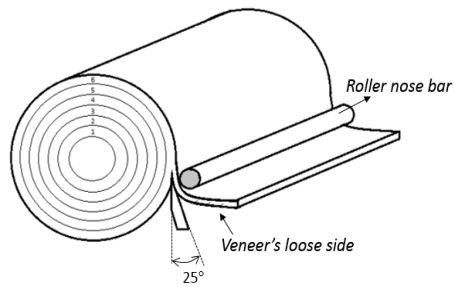
ples were subsequently segmented from pith toward bark into 2 cm × 2 cm × 2 cm blocks (Fig. 2b). The wood quality was determined using its specific gravity (SG), moisture content (MC), fiber length (FL), fiber wall thickness (FWT), MFA. SG and MC were determined in accordance with British Standard 373-1957 (BSI, 1957). FL and FWT (Fig. 3a, 3b) were measured using Schulze method (Darmawan *et al.*, 2013).

MFA was determined with Iodine method as follows: block sample was sliced using microtome into sheets ± 30 μm thin at tangential direction. Two solutions (A and B) were prepared for object observation. Solution A is Schulze solution which comprised of 100 ml 35% nitric acid + 6 g potassium chlorate. Solution B contained 100 ml distil water + 3 g iodine + 4 g potassium iodide. Microtome slices were immersed in solution A for 15 min. Subsequently after dehydration process, the slice was set on standard slide of 7.5 × 2.5 cm. The preparete on the standard slide was dripped

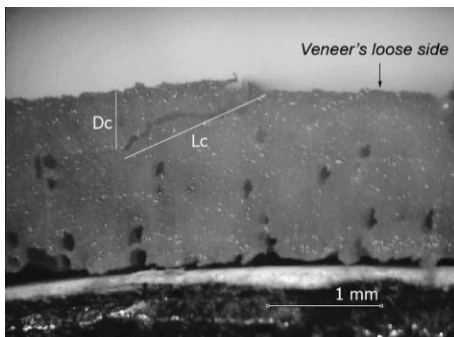
with solution B + 50% nitric acid to form iodine crystal. Prior to image capture, 25% glycerol was dripped onto the preparete and the residual droplets were wiped from the standard slides using filter paper. There were 5 slides for each segment. Each slides were observed using Axio Imager 2 polarization-type microscope in order to obtain 3 images of cell that show the microfibril clearly (Fig. 3c). Each image was further analyzed using AxioVision SE64 software to determine its MFA. The MFA measurements were replicated three times for each cell image as reported by Wahyudi *et al.* (2014).

### 3.2. Quality of Samama veneer

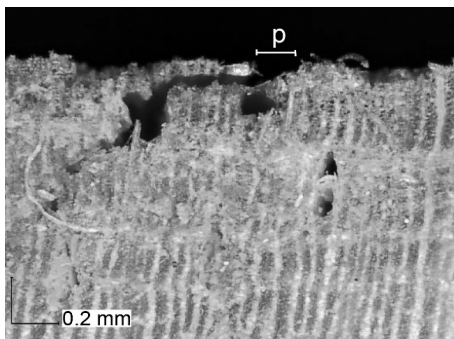
The determination of Samama veneer's quality was conducted by making 2 cm width of wood segments from pith toward bark on the cross section (Fig. 4a). This 2 cm width was followed the width of segmentation in testing method on wood quality. Calculation of segmentation on veneer length was conducted us-



(a)



(b)



(c)

**Fig. 4.** Segments illustration of veneer peeling (a) and lathe check (b, c).

ing the Tsoumis' method (Tsoumis, 1991). Measurement of veneer characteristics (thickness and lathe check) were carried out on each segment to determine the quality of Samama

veneer.

As many as 18 fresh Samama logs were prepared to be peeled without pretreatment in which 9 logs were peeled at thickness target of 1.5 mm and the remaining 9 logs were at thickness target of 3.0 mm. The peeling was conducted using spindle-less type Shuntong XT1300H machine. In this study, peeling parameters such as knife angle, clearance angle, nose bar pressure and peeling rate were assumed as constant. The clearance angle was  $0^\circ$  and knife angle ( $\beta$ ) was  $25^\circ$ , the nose bar pressure was 5%, and the peeling rate was  $1 \text{ m s}^{-1}$ . Thickness of the produced veneer was measured according to the modified-method of Darmawan *et al.* (2015). Lathe check, meanwhile, was evaluated using modified-method of Pabungicki *et al.* (2010), in which each veneer was bent in particular diameter with regard to veneer thickness. Afterwards, the length ( $L_c$ ), depth ( $D_c$ ), and numbers of lathe check ( $N_c$ ) at each 10 cm of veneer length ( $n$ ) were measured (Fig. 4b). The images of lathe check characteristics were captured using optical video microscope in  $30\times$  magnitude, whereas  $L_c$  and  $D_c$  were measured using Software Motic Image Ver. 2.0. The width of lathe check ( $p$ ) was measured using the same method but it was done without bent the veneer and with  $300\times$  magnification (Fig. 4c).

### 3.3. Geometry factor

Geometry factor was stated as the ratio of veneer thickness ( $t$ ) and distance from pith ( $\bar{r}$ ).

**Table 1.** Quality of Samama wood from pith vicinity toward bark

Distance from pith (cm)	Fiber length ( $\mu\text{m}$ )	Fiber wall thickness ( $\mu\text{m}$ )	Microfibril angle ( $^\circ$ )	Specific gravity	Moisture content (%)
3	1428.5 $\pm$ 121.5	5.62 $\pm$ 1.14	42.34 $\pm$ 6.30	0.37 $\pm$ 0.01	156.6 $\pm$ 10.4
5	1558.8 $\pm$ 108.6	5.89 $\pm$ 1.12	38.88 $\pm$ 8.14	0.39 $\pm$ 0.02	135.5 $\pm$ 14.7
7	1675.8 $\pm$ 89.5	6.06 $\pm$ 1.03	35.89 $\pm$ 6.52	0.39 $\pm$ 0.01	79.4 $\pm$ 5.4
9	1667.1 $\pm$ 92.1	6.12 $\pm$ 1.17	32.84 $\pm$ 4.57	0.43 $\pm$ 0.01	72.3 $\pm$ 5.7
11	1674.3 $\pm$ 96.7	6.22 $\pm$ 0.98	33.17 $\pm$ 6.62	0.42 $\pm$ 0.01	56.5 $\pm$ 8.3
13	1604.2 $\pm$ 72.7	6.03 $\pm$ 0.82	34.75 $\pm$ 6.34	0.43 $\pm$ 0.03	66.3 $\pm$ 4.6
15	1700.4 $\pm$ 87.6	6.08 $\pm$ 1.01	33.76 $\pm$ 5.73	0.42 $\pm$ 0.01	58.1 $\pm$ 4.2
17	1703.1 $\pm$ 99.7	6.28 $\pm$ 0.91	32.65 $\pm$ 6.27	0.43 $\pm$ 0.02	69.8 $\pm$ 7.3

Veneer thicknesses were 1.5 mm and 3.0 mm, and the distance from pith was 3-17 cm in accordance with the defined segment.

### 3.4. Data analysis

Wood quality (SG, MC, FL, fiber wall thickness (FWT), and MFA, veneer thickness, length and depth of lathe check were descriptively analyzed. To determine the effect of distance from pith and veneer thickness toward lathe check width ( $p$ ), completely randomized factorial analysis was used. Meanwhile, regression analysis was conducted in several stages: 1) determination of geometry factor's value based on distance from pith, 2) determination of the best subset regression analysis between  $n$  with geometry factor and wood quality. Best Subset Regression method in this study was determined using Statistica v10 software. The chosen model was the one with the highest  $R^2$ -adjusted value. The  $P$  value was used to define the significance of regression model in which  $P$  value  $<$  0.05 reflected a significant regression model.

## 4. RESULTS and DISCUSSION

### 4.1. Quality of Samama wood

Wood quality implies its degree of excellence (Barnett and Jeronimidis, 2009). Wood quality is defined in various criteria, each depends on its utilization. Exploring particular basic characteristics of wood is an approach to determine wood quality. Table 1 shows particular basic characteristics of Samama wood segments from pith toward bark. SG of wood segment in pith vicinity was  $0.37 \pm 0.01$  and that of close to bark was  $0.43 \pm 0.02$ . SG variation for each segment is important to be considered in further utilization such as drying, processing, and product assembling. Lutz (1978) stated that SG is among the important factors in veneer production. Low SG wood is usually recommended for core veneer in plywood and for crossband of decorative plywood. Lutz (1978) also noted that SG of wood for plywood is around 0.41-0.55; for core and crossband veneer in decorative panel is 0.32-0.45; for hardwood face veneer is 0.43-0.65. However, at some cas-

es, particular species with low SG could also be used as face veneer due to its decorative pattern.

Furthermore, wood moisture content (MC) is also an important trait that presumably defines the result of veneer peeling. Usually, log is peeled subsequently after felling while it is considered fresh. The apparent suitable MC for peeling process is about the upper limit of fiber saturation point, ranging 50-60% (Lutz, 1978). In this recent study, Samama wood segment with 5 cm distance from its pith had 100% MC, as the next segment showed MC of 50-80%. The range of the previously discussed MC and SG implies that Samama log can be peeled at green or fresh condition without pretreatment.

Mean of FL, FWT and MFA were  $1546.53 \pm 198.8 \mu\text{m}$ ,  $5.94 \pm 0.76 \mu\text{m}$  and  $37.10 \pm 8.49^\circ$ , respectively. According to the classification of International Association of Wood Anatomists (IAWA) (Wheeler *et al.*, 1989), FL of Samama wood is of medium category (FL = 900-1600  $\mu\text{m}$ ). Based on the same IAWA classification, FWT of Samama wood is categorized as thin. In comparison, 7 years old Jabon wood has FL 1224  $\mu\text{m}$  and MFA of pith vicinity  $62^\circ$  (Darmawan *et al.*, 2013). Study by Kim *et al.* (2013) presents FL  $1402 \pm 341 \mu\text{m}$  for Jabon. For more comparison, 5 years old Teak wood has FL 1071  $\mu\text{m}$  and MFA  $30.57^\circ$  (Wahyudi *et al.*, 2014).

The relationship between fiber dimensions with veneer quality is rarely discussed in many studies, thus the information is less available.

Study on fiber dimension mostly associates with the suitability of some woods for pulp material, e.g. study by Fajriani *et al.* (2013) noted that, based on its fiber dimension and derived values of fiber dimension, Jabon was categorized as class quality 1 for pulp material. Fiber wall thickness is associated with specific gravity and shrinkage. The thicker the fiber wall, the specific gravity and shrinkage tend to also be higher (Tsoumis, 1991). Specific gravity is also an important factor in peeling process of wood into veneer.

Correlation between MFA and fiber wall thickness has been discussed and acknowledged. Hiller (1964a) found curvilinear correlation between MFA and tracheid wall thickness of *Pinus elliotii* and *P. taeda*. It is found that tracheid wall thickness was the best single predictor of MFA ( $R^2 = 80\%$ ) among nine variables including age, distance from pith, ring width, percent latewood, tracheid length, tracheid width, wall thickness, length/width, and age  $\times$  tracheid length (Hiller, 1964b). All nine variables were significant predictors, accounting jointly for 88% of the variation in MFA. Moreover, Evans *et al.* (2000) found a significant correlation between MFA and density on *Eucalyptus nitens*. Therefore, parameters of wood quality discussed in this study were presumably could define the quality of Samama veneer.

#### 4.2. Quality of Samama veneer

The peeling for 1.5 mm and 3.0 mm of tar-



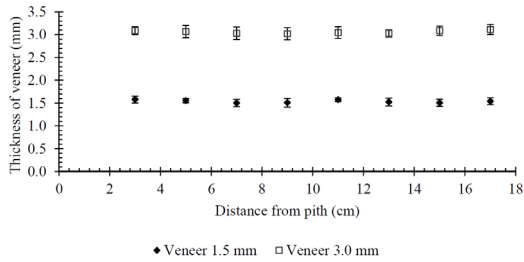


Fig. 5. Thickness variation of Samama veneer.

geted-thickness created the average  $1.54 \pm 0.08$  mm and  $3.07 \pm 0.11$  mm thickness of veneer, respectively (Fig. 5). SNI 7838-2012 requires maximum standard deviation of 0.1 mm for 1.5 mm veneer and 8% for  $> 1.5$  mm veneer (BSN, 2012). In comparison, Lutz (1978) determined 0.076 mm and 0.102 mm tolerances for 1.6 mm and 3.2 mm veneer, respectively. Therefore, the results of this study show that Samama wood could be transformed into veneer due to its fair thickness variation.

Veneer thickness is mostly affected by the peeling process. If the moving part of the peeling machine is loose, it will cause inconsistencies in veneer thickness. When the wood is deflected by the pressure bar beyond the knife edge, an inconsistency in veneer thickness can also happened (Hoadley, 1962). Knife angle is also an influential factor as low knife angle will give a thicker wavy veneer (Feihl and Godin, 1970). Moreover, high MC tends to produce a relatively thicker veneer. Douglas fir's sapwood is found to produce thicker veneer than its heartwood in the same peeling method (Bryant *et al.*, 1965). Thus, peeling equipment must be in perfect condition and operated with care to obtain the required veneer thickness.

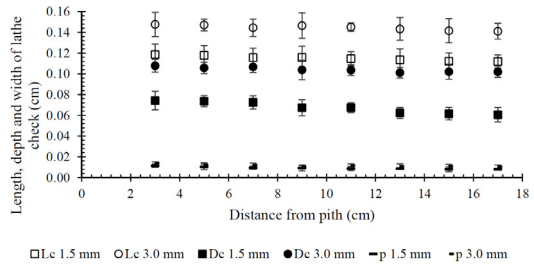


Fig. 6. Length (Lc), depth (Dc) and width ( $p$ ) of lathe check of Samama veneer.

In general, length (Lc) and depth (Dc) of lathe check tend to decrease toward bark (Fig. 6). The comparison between veneer thicknesses exposed that 3.0 mm-thick veneer had higher Lc than 1.5 mm veneer, which were  $0.145 \pm 0.003$  cm to  $0.115 \pm 0.007$  cm, respectively. This trend is also found on Dc in which 3.0 mm veneer had higher Dc than 1.5 mm veneer:  $0.101 \pm 0.008$  cm to  $0.067 \pm 0.006$  cm, respectively. This results are similar with the study conducted by Lutz (1978) that found the heartwood of yellow birch had deeper lathe check than sapwood. Apparently, polyphenol compound causes the heartwood to become less plastic than sapwood. Pałubicki *et al.* (2010) explained that the depth of lathe check increases by the increasing of veneer thickness, thus in consent with the results of this recent study in which depth of lathe check of 3 mm veneer reached 70% of veneer thickness.

Fig. 6 also shows the width of lathe check ( $p$ ) from pith toward bark, which are  $0.010 \pm 0.003$  cm and  $0.012 \pm 0.004$  cm for 1.5 mm and 3.0 mm veneer, respectively. The width of lathe check tends to increase from bark toward pith; however, such trend is not statistically

significant. This was proven using analysis of variance; there is no significant  $p$  difference from pith to bark ( $P$  value = 0.057). Conversely, veneer thickness is affecting  $p$  ( $P$  value = 0.003). The width of lathe check was less discussed in many previous studies, however, the presented data of width of lathe check in this study proves that width of lathe checks do not different from pith toward bark.

#### 4.3. Geometry factor and the numbers of lathe check per 10 cm veneer length ( $n$ )

Veneer peeling transforms wood from round shape into flatted-sheet form. This phenomenon can be elaborated using two approaches: the first one from potential energy point of view to transform bended material into straight one, and the second one by considering the differences of inner and outer circumferences. The circumferences' difference will incite reactions on wood surface to form checks, which are called lathe checks. Mathematic equation can be built to explain the numbers of lathe checks created by the circumferences' difference. The resulted value from the equation is called geometry factor ( $t/\bar{r}$ ). Geometry factor tends to be higher near the pith and decreases near bark (Fig. 7). The comparison between veneer thicknesses shows that geometry factor was higher on the thicker veneer. As seen on the equation 4, the geometry factor of the log tends to be equivalent with the number of veneer's lathe checks for certain veneer length. This fact indicates that pith vicinity tends to

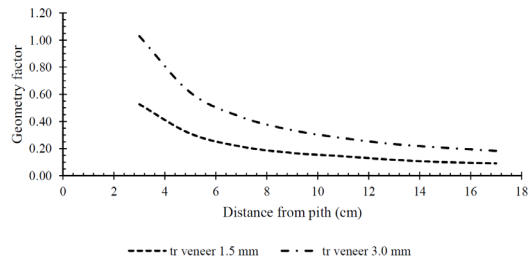
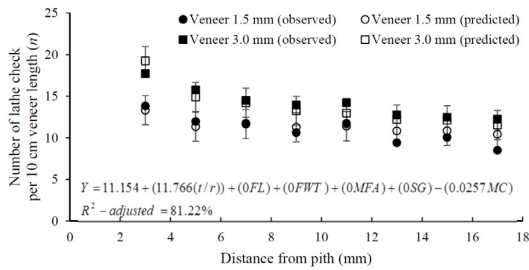


Fig. 7. Geometry factors from pith toward bark.

have more  $n$  and verified that thicker veneer is stiffer than the thinner one, thus it is potential to increase the  $n$ .

The number of lathe check for each 10 cm length section of veneer ( $n$ ) is presented in Fig. 8. In this study,  $n$  for 1.5 mm and 3.0 mm veneers are 11 and 14, respectively. In comparison,  $n$  of 1 mm and 2 mm of veneer from 5 years old Sengon (*Paraserianthes moluccana*) peeled with the same method were 12 and 16, respectively (Kabe *et al.*, 2012). Meanwhile, the same-age Jabon peeled with the same method showed an equal  $n$  with that of Sengon (Kabe *et al.*, 2014). Furthermore, it is noticed that the bonding strength of Sengon and Jabon veneer in LVL product increases by the decreasing of  $n$  (Darmawan *et al.*, 2015). These findings suggest that Samama wood is advantageous to be used as veneer-based products with regard to its lowest  $n$  as compared to that of Sengon and Jabon.

Fig. 8 also denotes the decreasing of  $n$  from pith toward bark. This occurrence was consistently observed in both 1.5 mm and 3.0 mm veneers. Geometry factor could elaborate this trend. The number of lathe check for veneer peeled in one log rotation was supposedly the



**Fig. 8.** Numbers of lathe checks for each 10 cm length of Samama veneer.

same value; however, due to the decreased diameter toward pith, the numbers will increase at pith direction as adjustment to the different diameter. Best subset regression analysis between  $n$  and geometry factors and wood quality (SG, MC, FL, FWT and MFA) shows the  $R^2$ -adjusted of 0.81 ( $p$  value =  $7.5 \times 10^{-6}$ ). The analysis also suggests that the dominant factor causing the differences of  $n$  from pith toward bark was geometry factor. On the other hand, the parameters of wood quality (SG, MC, FL, FWT, and MFA) were less dominant in causing lathe check ( $p$  value > 0.05). Therefore, due to the differences in diameter, it is apparently difficult to obtain veneer with the same quality from the part close to the bark and the part near the pith, even with the same manufacture process.

Equation presented in Fig. 8 ( $Y = 11.154 + (11.77 (t/\bar{r})) + (0FL) + (0FWT) + (0MFA) + (0SG) - (0.0257MC)$ ) explained that number of lathe check ( $n$ ) has linear relationship with geometry factor ( $t/\bar{r}$ ), since both are equivalent each other with 11.77 constant. This constant was arising since there were three points affecting number of lathe checks as described in

equation 3 and 4, which were veneer flexibility, mean of width of lathe checks, and veneer sample length which considered constant. This equation proved that the number of lathe check mainly affected by geometry factor ( $t/\bar{r}$ ) and moisture content (MC), while another log parameter (FL, FWT, MFA, and SG) could be ignored during veneer peeling process. This study recommended to simplify the parameter measurement in veneer peeling process by focusing on geometry factor and moisture content measurement since the other parameters were not significantly affected to number of lathe check ( $n$ ). Number of lathe check ( $n$ ) represented the veneer quality.

Modern veneer peeling has been accommodating various peeling factors to obtain best quality veneer. One of them is the type of peeling machine. Unlike the spindle peeling machine with its constant angular velocity ( $\omega$ ), this study has used rotary spindle-less machine with constant linear velocity ( $v$ ) while also increasing the angular velocity ( $\omega$ ) with the decrease of the peeled log's diameter. Although the  $v$  is constant, this research's data show that the varieties of  $n$  are increasing for the veneer from the parts near the pith. Geometry factor can explains those variety patterns. There is similar pattern between geometry factor (Fig. 7) and the number of peeling check (Fig. 8).

Previous studies mostly discussed the differences in veneer quality in general; rarely they specifically addressed the cause of that  $n$  variation. Variation in veneer quality is caused by the differences in wood quality factors, i.e.

quality differences between juvenile and mature wood. Juvenile possesses lower SG and higher MFA. Juvenile is also found to have shorter fiber length and thinner fiber wall compared with the mature wood (Zobel and Sprague, 1998). Moreover, juvenile contains higher lignin content (more than 10%) and lower cellulose than of mature wood (Bao *et al.*, 2001). These would increase the rigidity of juvenile part, which in turn would affect the veneer quality. The low quality of veneer due to its high portion of juvenile part was also discussed in Zhang *et al.* (2004). As previously discussed in the introduction of this paper, manufacturing process also significantly affects veneer quality. The results of Darmawan *et al.* (2015) indicate that smaller diameter in pith vicinity may causes higher pressure tension during peeling process, which explains the result of this recent study in which  $n$  tends to be larger toward pith. Thus, unlike previous studies that mostly focus on wood traits and manufacturing process, this study verifies the dominance of geometry factor over wood traits (SG, MC, FL, FWT, and MFA) in elaborating  $n$  variation from pith toward bark.

It is noteworthy that  $n$  is an important factor to be considered during veneer production because  $n$  defines the shear strength in plywood (DeVallance *et al.*, 2007) and LVL products (Darmawan *et al.*, 2015). The impact of length of lathe check (Lc) on product quality is rarely discussed in previous studies. While the depth of lathe check (Dc) do not affect LVL's elasticity, it causes defects on the product (Harding and Orange, 1998). In addition, the increase of

Dc by 40-80% would cause the decrease in shear strength by 40% in open-type testing on plywood of birch wood, but this is hardly found in closed-type testing (Rohumaa *et al.*, 2013).

## 5. CONCLUSION

Samama wood can be peeled into veneer with fair thickness variation of 1.5 mm and 3.0 mm. The number of lathe checks per 10 mm of veneer length ( $n$ ) tends to decrease toward bark and thicker veneers would have more  $n$  than thinner ones. Length and depth of lathe check show the same trend in resulting numbers of lathe checks while width of lathe check ( $p$ ) shows the same value from pith towards bark. The  $n$  variation from pith toward bark can adequately be explained using geometry factor. The dominant factor in defining numbers of lathe check at the same manufacturing process is found to be the geometry factor, while the factors of wood quality are less dominant; hence, it is difficult to obtain a consistent quality of veneer from pith toward bark. Moreover, these results indicate the prospective of Samama wood as material in plywood production and other veneer-based product, e.g. laminated veneer lumber (LVL). Furthermore, to enhance its usability, it is important to investigate the effect of Samama veneer quality on bonding process and product quality.

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