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Original Article

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Lathe Check Characteristics of Fast Growing Sengon Veneers and Their Effect on LVL Glue-Bond and Bending Strength

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Abstract

Fast growing sengon (*Paraserianthes moluccana*) is largely rotary-cut to produce veneer for core plywood production. In order to provide better information on veneer production and utilization, in this study the effects of wood juvenility and veneer thickness on lathe checks of rotary-cut sengon veneers were evaluated. Before veneer manufacturing, sengon logs were boiled at 50 °C and 75 °C for 4 and 8 hours respectively. The boiled logs were peeled to produce veneer of 1 mm, 1.5 mm, 2 mm in thickness. Lathe checks of veneers were measured on the loosed side at every 5 mm veneer length under an optical video microscope and their frequency, depth, and length were characterized. Twenty sampling points of 5 mm veneer length were prepared from each segmented ring of 1 cm width from pith to bark. Isocyanate resin adhesive were used to produce laminated veneer lumber (LVL) of 20 mm thick, which consisted of 24-ply of 1 mm veneer thick, 14-ply of 1.5 mm veneer thick, and 11-ply of 2 mm veneer thick, for glue bond and bending strength test. Results showed that wood juvenility and veneer thickness determined the frequency, depth and length of lathe checks for the sengon rotary-cut veneers. In general, the frequency of lathe checks of the veneer increases with increasing veneer thickness, and also increases from pith to bark. Boiling of logs before rotary-cutting could decreases the frequency of lathe check of the veneer. The results indicated that boiling of logs at 50 °C for 8 h and at 75 °C at least 4 h before peeling the logs could minimize the frequency of lathe check in manufacturing rotary cut veneer thickness of 1 mm, 1.5 mm, and 2 mm from juvenile wood of fast growing sengon. The frequency of lathe check affect significantly the glue bond and bending strength, in which the glue bond, Modulus of Elasticity (MOE), and Modulus of Rupture (MOR) decrease as the frequency of lathe checks increases.

Keyword : Lathe check, Rotary-Cut Veneer, Fast Growing Sengon, Boiling, Glue-bond, Bending Strength, Laminated veneer lumber

1. Introduction

Sengon (*Paraserianthes moluccana*) is a fast growing wood species widely planted by community in Indonesia. The sengon tress in the age of 7 years can reach breast height diameter up to 38 cm. Though all part of the tress in the age of 7 years are juvenile (**Darmawan et al., 2013**), however they have been felled in that age because demand of the sengon woods for wood industry is high, and are important incomes for the communities (**Krisnawati et al., 2011**). Sengon is the most common species used for packaging and pulp in Indonesia. Recently the sengon wood has been rotary cut for laminated-wood products. Since the sengon wood is being used in the laminated wood industry, high bonding properties are expected. However, as the sengon logs are being peeled and much more juvenile woods are being utilized, severe lathe check veneer would undoubtedly be produced and manufactured. Therefore, it considerably needs to study lathe checks of veneer peeled from the sengon logs, and their effect on the glue bond and bending strength.

The bonding strength of the veneers depends upon a variety of factors. These factors are classified as veneers quality (moisture content, density, lathe checks, and surface roughness) and as adhesive quality (type of adhesive, mixture of adhesive, and its viscosity) and as bonding quality (glue spread, pressure time and temperature, relative humidity, and temperature of air) (**Dundar et al., 2008a**). Among these factors, lathe check is one of the important factors on the bonding strength. The bonding strength decreases, probably because of the presence of important lathe checks. Also, the veneers with lathe checks require much more glue spread because of the degradation of veneer surface topography (**Daoui et al., 2011**). Veneers with lathe checks can also cause excessive resin use and may result in resin-bleed through the inside of veneer.

In rotary-cut veneer manufacturing, when peeling starts, the wood tends to split along the grain. Lathe checks are formed at the veneer's loose side (**Fig. 1**) as tension force of the lathe's knife pulls the veneer away from the peeler block and flattens the veneer from its natural curvature (**DeVallance et al., 2007**). With respect to the cross section of the veneer, this advance splitting causes the formation of vertical cracks (known as lathe checks). The depth, length and frequency of lathe checks have been widely taken into account during veneer surface quality evaluation. The risk of this checking can be reduced by using a nosebar (**Kollmann et al. 1975**). However, recent spindle less rotary lathes, which are widely used to peel small log diameter of fast growing wood species, have not been completed with an adjustable nosebar. A boiling treatment of bolts would be considered to reduce the lathe check.

There are many factors which contribute to the formation and severity of veneer lathe checks. It is usually very difficult to determine the exact cause of checking for any given incident. However, experience and research have taught us some of the most common and severe influences of veneer lathe checking. Veneer lathe check can be affected by wood log's characteristic (specific gravity, wood pores, juvenile and mature wood). In addition, pretreatment and manufacturing conditions such as steaming or boiling, knife bevel and nose bar pressure, peeling temperature, peeling thickness and peeling speed, may also affect lathe checks.

The pretreatment and manufacturing factors affecting lathe check can be controlled to achieve better veneer surface. Log temperature at the time of peeling veneer significantly affects the quality of veneer. Low temperatures produce veneers with deeper and more spaced checks than high temperatures log (**Suh and Kim, 1988**; **Dupleix et al., 2012**).

Other studies indicated that higher peeling temperatures reduced the severity of lathe check depth (**Palka, 1974**). Most wood species are said to produce the best veneer quality when log temperatures are between 100 °F to 160 °F. **Dundar et al. (2008b)** found that when beech logs boiled in water at 60–70 °C for 20 h, 40 h, and 60 h, the veneers obtained from a 40 h boiling period could minimize the mean surface roughness values for all veneers obtained from inner (heartwood), center or outer (sapwood) portion of the logs. The magnitude of compression applied to veneer surface was considered as important factor that affects peeled veneer quality. Pressure can be applied ahead of the knife by use of nose bar pressure. In eucalyptus veneer, the lathe check was found to decrease when the veneer was peeled with nose bar pressure up to 5% (ratio of lead gap opening to thickness). Between 0.5 to 5% pressures, deformation is within the elastic zone of the eucalyptus (**Acevedo et al., 2012**). Another study indicated that settings the nose bar pressure up to a certain point by adjusting the lead and exit gap lathe (5% to 20%) reduced lathe check depth in redwood veneer (**Cumming and Collett, 1970**) and also showed a tendency to produce more frequent shallow lathe checks. In many instances, higher horizontal pressures are needed for thicker veneers and lower pressure for thinner veneers, and in general, the thinner the veneer, the better the resulting peeled veneer quality. Rotary cutting speed (meter of veneer produced per minute) is another variable that affects veneer lathe check. An increase in cutting speed results in weaker veneer with deeper lathe checks (**Lutz, 1974**). An increase in speed causes reductions in nose bar pressure and can result in more severe lathe check formation.

Differences in log's wood properties have shown significant relationships to lathe check formation when peeled into veneer. In particular, tree growth rate, specific gravity, juvenility (the pith-to-bark variation in wood traits such as density, fiber length, microfibril angle, longitudinal shrinkage, ring width, latewood proportion, and lignin-cellulose composition), and log conditioning have shown to affect veneer quality. A spindle-less rotary lathe allows manufacturers to peel smaller log’s diameter and to produce more veneer sheet up to the log's core. When fast-grown logs were peeled, deeper lathe checking resulted. In general, it has been found that peeled quality is reduced as peeling from the log's sapwood to core material, due to factors such as lower specific gravity, highest growth rate, cutting speed, and highest angle of attack at the core material (**Palka and Holmes, 1973**). It has been noted that the best veneer was produced when peeling logs with growth rings orientated at 0^{o} to the knife, while veneer quality decreased progressively as growth ring angle varied in either the plus or minus directions (**Cumming and Collett 1970**). Past research indicated that coarse grain, higher specific gravity veneer tends to check more significantly than does fine grain, lower specific gravity veneer. Lathe check depth was significantly less for fast growing trees (**Cumming et al. 1969**). Species of wood with fine pores check less than wood with large pores. This is because deep lathe checks and large pores create weak spots on the face veneer which provide less resistance to failure when the face veneer is under stress.

The effect of lathe checks on glue-bond quality, modulus of elasticity (MOE) and modulus of rupture (MOR) during laminated veneer lumber (LVL) production should be also important by considering that the increasing of lathe check on the veneer would lead to lower glue-bond quality and bending strength (MOE and MOR). Veneer with more frequent lathe checks may result in a higher incidence of delamination. To avoid delamination, the LVL may be typically produced by increasing the adhesive spread rate. Although increasing the adhesive spread rate is a common practice, however a question on how lathe checks affect the LVL glue-bond and bending strength would exist.

Investigation of lathe check characteristics of veneer from fast growing sengon and its LVL glue-bond and bending strength, gets less concern. Therefore it requires such study. The objectives of this study were 1) to evaluate the effects of wood juvenility, boiling temperature and veneer thickness on lathe checks of the rotary-cut sengon veneer (*Paraserianthes moluccana*); and 2) to determine the impact of veneer lathe checks on the LVL glue-bond and bending strength.

2. Material and method

2.1 Sample tree origin

Sample trees were obtained from a plantation forest planted by community at the West Java, Indonesia. The plantation site was located at Bogor region. Six sengon trees (*Paraserianthes moluccana*) were selected from the plantation site as representative specimens. The sample trees having straight stems and free external defects were chosen with the intent of minimizing tree-to-tree variation. The selected sample trees were 5 years old. The sample trees had a height of branch-free stem range from 6 to 8 m, and a diameter at breast height level (1.3 m above ground level) vary between 26 to 28 cm. After felling the trees, log sections (bolts) in length of 50 cm were taken from each tree from the bottom part up to the end of the free-branches tree stem. The sample logs were wrapped in plastic, kept cold, and maintained in the green condition before they were transported to the wood workshop for the rotary-cutting.

2.2 Logs preparation for rotary-cutting

Tree rings have been used for a long time in areas outside the tropics to characterize the presence of juvenile and mature wood. Considering distinct growth rings are absence in sengon tree, segmented ring was considered to be practically useful for characterizing their juvenility. A specified 1 cm width of segmented rings was made from pith to bark on the cross section of logs and numbered consecutively (No. 1-7) as shown in **Fig. 1.** Veneer characteristics (veneer thickness, and veneer lathe checks) were measured at each segmented ring, and used to characterize the quality of sengon veneers.

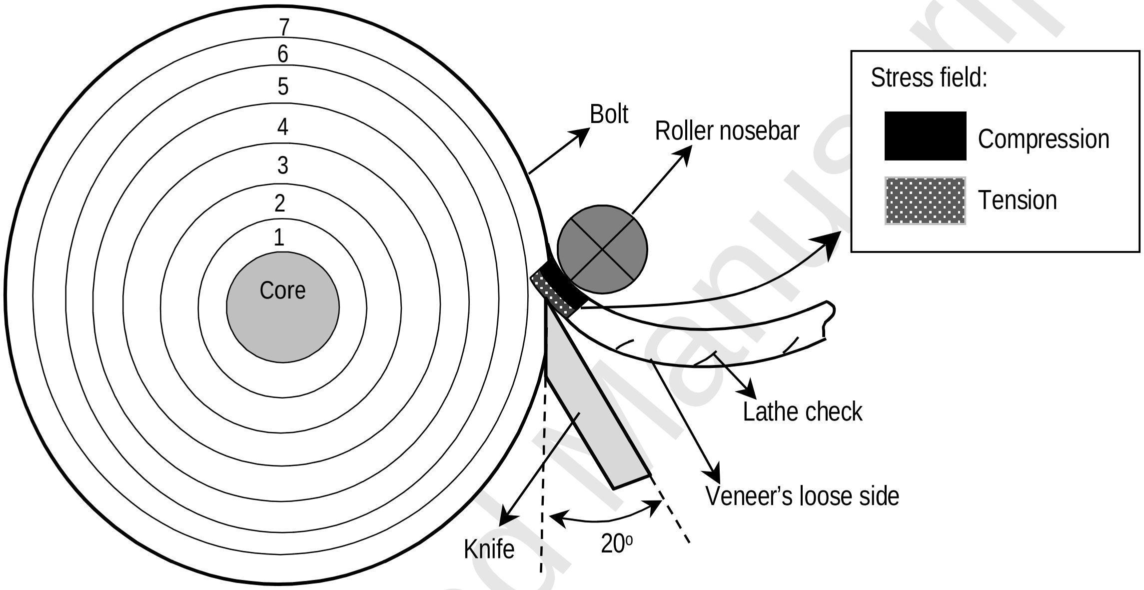

Fig. 1-Peeling diagram on the cross section of logs to produce veneers from segmented rings number 1 to 7, and stress (tension and compression) occurring during the peeling

Thirty bolts of minimum 26 cm in diameter were selected, thus the first six bolts were soaked in water at room temperature, and the other bolts were subjected to boiling process in hot water at 50 and 75 ^{o}C for 4 and 8 h, respectively. Subsequently, the bolts in each boiling treatment were peeled off to obtain veneers in the thickness of 1.0, 1.5, and 2.0 mm. For each boiling treatment, a sharp knife was used. The other factors such as knife angle, peeling angle, nose bar pressure, log temperature, peeling speed were kept constant in the study. The clearance angle was 0◦, and knife angle was 20◦. The veneers were peeled using a spindle less rotary lathe. The bolts were peeled up to core diameter of 10 cm in order to produce veneers from the 7 different segmented rings (**Fig. 1**). The veneers were collected and grouped for each segmented rings and numbered consecutively from near the pith (number 1) to near the bark (number 7). Veneer in each segmented rings was measured for characterizing the lathe checks (frequency, depth, and length), thickness variations, glue-bond, and bending strength.

2.3 Measurements

Veneer sheets produced from each segmented rings were collected and clipped to 30 cm x 50 cm veneer specimens. Ten specimens from each segmented rings were randomly selected and kept in plastic bags for test specimens. Two test specimens were used for the measurement of thickness variations. Six points of thickness measurement were marked on the side of each test specimens.

Lathe check frequency, depth, and length

The test specimens were kept in the green condition. Subsequently, an optical scanning system was used to evaluate lathe check characteristics of the veneers. In this study, an optical video microscope was used to capture images from the surface of veneer's loose side. Before capturing, veneer samples of 1.0, 1.5, and 2.0 mm in thickness were arched on their loose side over a pulley in diameter of 20, 35, and 50 mm respectively. An illustration for the veneer thickness of 1.5 mm arched on the 35 mm pulley is presented in **Fig. 2a**, which depict the presence of lathe checks. Concerning the nature of veneer which is very fragile, then the success of measurement is strongly influenced by the choice of pulley diameter. **Palubicki (2010)** investigated that when diameter of the pulley is too small, the measurement process would lead to cracking and increased the depth of fissure thus the measure was not reliable. Otherwise, if diameter of pulley is too large, veneer cracks would not be opened so it was difficult to be detected by the camera. **Palubicki**

(2010) recommended to use the pulley diameter between 10 to 70 mm for veneer thickness between 0.5 to 3.5 mm. The loose side of the arched veneers was set up on the table of optical video microscope under 30x magnification. Length of captured images on the loose side of the arched veneer was recorded to be 5 mm each. For each segmented rings, 20 images were captured and stored in a disk. The images then were analyzed using motic image software to count the lathe checks frequency, then measure their depth (D_c) and length (L_c) (**Fig. 2b**). The measurement technique was based on the opening of cracks occurring on the loose side of arched veneers. Frequency of lathe check was presented as the number of lathe check per 10 cm length of veneer.

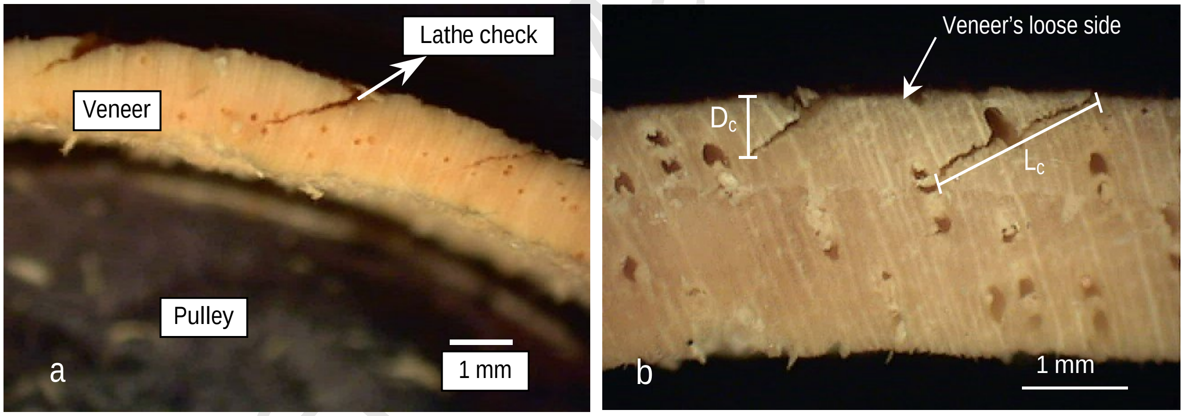

Fig. 2 – Arched veneer presenting the lathe checks (a), and diagram for the lathe checks measurement (b)

Glue-bond and bending strength test

The veneer specimens were conditioned at relative humidity (RH) of 85% and temperature of 25 ◦C to an air-dry moisture content of 12%. Water based polymer Isocyanate resin adhesive was used for producing 20 mm thick of LVL panels. The isocyanate resin had a viscosity of 5000 - 15000 cps at 23°C, pH 6.5 – 8.5, solid material 40 - 44% and a density of 1.23 g/cm^3. LVL panels with dimension of 20 mm x 30 mm x 500 mm were manufactured by 1 mm veneer thick (24-ply), 1.5 mm veneer thick (14-ply), and 2 mm veneer thick (11-ply) at each segmented rings. The spread volume of the isocyanate resin was 200 g/m^2 on single bonding surface of the veneers as recommended by the manufacture. The glue was uniformly spread on the surface of veneers by hand brushing. Assembled samples were pressed in a cold press at a pressure of 10 kg/cm^2 for 5 hours. The resulting LVL panels were allowed to a stable condition for 72 h before cutting into test specimens.

Tests for the glue bond and bending strength properties were conducted on test specimens prepared from the LVL panels. Prior to the testing, the specimens were conditioned for 2 weeks at 25 °C and 85% relative humidity (RH) to air dry moisture content (around 12%). The air-dry glue bond and bending strength were tested. Five specimens were tested for each treatment combination. The glue bond and bending tests were carried out on an INSTRON universal testing machine. The shear strength of the glue bond was tested and measured with the lathe checks being pulled closed, as tested by **Rohumaa et al. (2013)**. Perpendicular to the fiber and glue line (flatwise) modulus of rupture (MOR) and modulus of elasticity (MOE) tests were carried out according to JAS standard **(JAS SE 11, 2003)**. Specimen size for the bending tests was 300 mm long by 20 mm wide by 20 mm thick of LVL. Glue-bond tests were also carried out according to JAS SE 11. The dimension of test samples was 50 mm length by 20 mm width by 20 mm thick. A loading rate of 10 mm/min was used in all tests according to the JAS SE 11. Loading on the glue bond test was continued until separation between the surfaces of the specimens occurred.

3. Results and discussion

3.1 Characteristics of sengon tree

The breast height diameters for the sample sengon trees varied from 26 to 28 cm at the age of 5 years. The branches-free height of the sample sengon trees was between 6 to 8 m. Differences in diameter and in braches-free height among tress in this study reflect the sengon wood's sensitivity to environmental conditions. Sengon tree has been growing very fast and can flourish in tropical forests with an altitude of 0 to 1000 m above sea level. The breast height diameters indicate that the mean diameter growth for the sengon tree species would be about 5 to 6 cm/year. Investigation results for the sengon trees on the forest stand indicated that sengon tree stem has unique characteristics that are straight-trunked cylindrical and long braches-free height, which are very well used to manufacture veneers for plywood or LVL. In addition, density of sengon wood was reported to be 250 kg/m^3 close to the pith, and to be 450 kg/m^3 near the bark (**Darmawan et al., 2013**). This low density would bring a benefit in peeling the sengon trees for veneer production.

3.2 Characteristics of sengon veneer

Variation of veneer thickness

Uniformity of veneer thickness is a very important factor affecting the quality of glue bond strength in LVL or plywood. The result in **Fig. 3** shows that thickness variations of rotary-cut sengon veneers were slightly occurred. The thickness of sengon veneer peeled from some bolts, which was intended to be 1.0 mm, ranged from a minimum of 0.93 mm to a maximum of 1.08 mm, and the veneer thickness intended to be 2.0 mm ranged from a minimum of 1.95 mm to a maximum of 2.11 mm. Coefficient of variations of the veneer thickness from pith to bark calculated from the ranges was 5.3%, 5.8%, 5.9% for the intended veneer thickness of 1.0, 1.5, and 2.0 mm respectively. By considering the coefficient of variations less than 6%, the bolts of sengon were correctly peeled to maintain the thickness regularity.

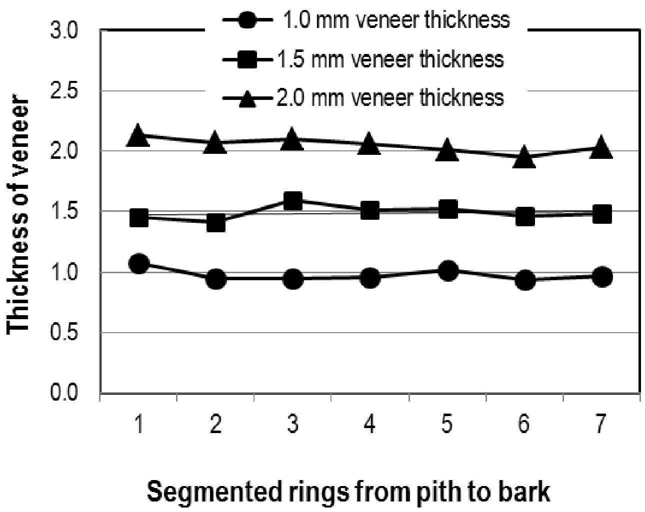

Fig. 3 - Variation of veneer thickness from pith to bark

Lathe check frequency, depth, and length

Fig. 4 shows average values of frequency of lathe check per 10 cm of veneer length taken from the loose side of the veneer. The average frequency of lathe check tended to decrease from pith to bark of the veneers. The veneers near to the pits showed larger frequency of lathe check. Higher lignin content of the wood near the pith could be responsible for high frequency of lathe check of the veneers taken from the inner parts of the sengon logs. **Bao et. al. (2001)** noted that juvenile wood is an important wood quality attribute because it can have lower density, larger fibril angle, and high (more than 10%) lignin content and slightly lower cellulose content than mature wood. Higher frequency of lathe check near the pith could be also caused by smaller radius of its natural curvature in the bolt, which imposed greater tension during the flattening. Further **Tanritanir et al. (2006)** investigated the effect of steaming time on surface roughness of beech veneer and they also found that the roughness of veneer sheets taken from heartwood (near pith) had higher values than those of sapwood (near bark).

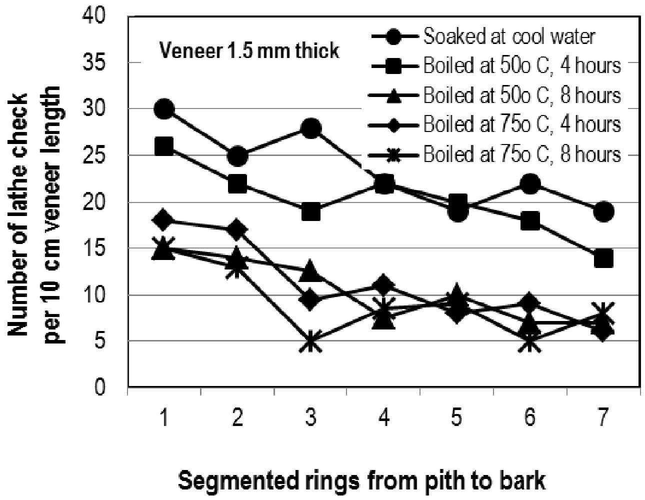

Fig. 4 - Variation of lathe check frequency from pith to bark for the 1.5 mm veneer thickness

The results in **Fig. 4** also reveal that veneers with lower frequency of lathe checks were produced by bolts boiled for 4h and 8h at temperature of 75 ^{o}C, and for 8h at temperature of 50 ^{o}C, when compare to unboiled bolts. However, the bolts boiled for 4h at 50 ^{o}C produced the same frequency of lathe checks as the unboiled bolts. This result gives an indication that boiling at a higher temperature resulted in better surface properties of the veneers. It could be announced that sengon bolts boiled for 8h at 50 ^{o}C or 4h at 75 ^{o}C could be proposed before manufacturing veneers from the sengon wood. The boiling of sengon bolts at the temperatures and periods is considered to soften the sengon bolts during the peeling process. A softening process does temporarily alter the microstructure of the wood, making it more plastic due to thermal expansion of crystal lattice of cellulose, and softening of lignin in the cell wall **(Jorgensen, 1968)**. The softening by heat has produced a degree of plasticity roughly 10 times than that of wood at normal temperature, and subsequently rendering the wood more pliable. The temperatures applied in this work caused the sengon wood polymers to soften, and therefore the flattening of the veneer from its natural curvature is more easily accommodated with less formation of lathe checks.

Fig. 5 shows the values of lathe check from pith to bark for different veneer thickness. Lathe check frequency of the veneers decreased from pith to bark. The lathe check frequency of veneers near the pith was twice larger than near the bark. The results in **Fig. 5** indicated that the lathe check frequency tended to increase as the veneer thickness increased. It can be considered that lathe checks on the loose side of veneer were generated due to tensile stress in bending at the rake face of the knife **(Fig. 1)**. Then, further unbending process for flattening the veneer from its natural curvature caused the increase of lathe checks. Surface tension generated by the unbending process would increase with veneer thickness, and so it would cause small fracture (lathe check) more frequently. With respect to the cross section of the veneer, the greater surface tension caused the formation of more severe lathe checks.

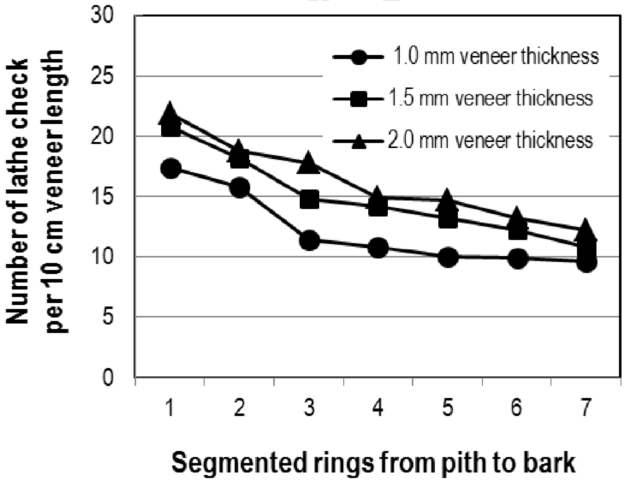

Fig. 5 - The effect of veneer thickness on the frequency of lathe checks

The second variable that is important in determining the veneer quality is deep lathe checks or shallow lathe checks. This study found that though the frequency of lathe checks decrease from pith to bark (**Fig. 5**), however the depths of lathe check in percent of veneer thickness are not significantly change from pith to bark (**Fig. 6b**), and did not differ prominently among the veneer thick. This result indicates that the thicker the veneer peeled, the deeper the lathe check will be (**Fig. 6a**). The average lathe check depths for the intended veneer thickness of 1.0 mm, 1.5 mm, and 2.0 mm were 0.28 mm, 0.41 mm, and 0.57 mm respectively (in the average depth of 28% of veneer thickness) .

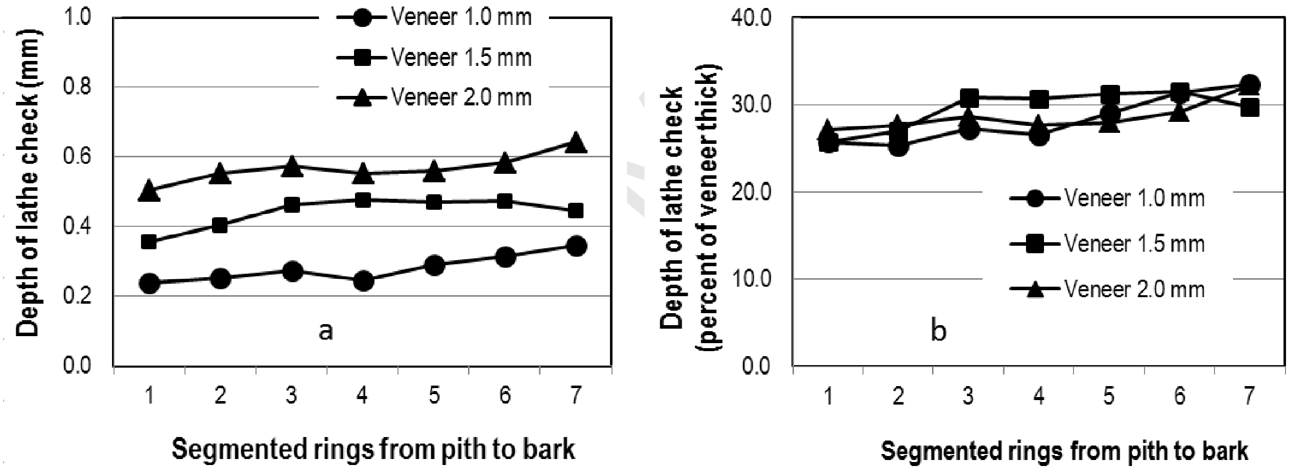

Fig. 6 - The progress of depth of lathe check from pith to bark

The other lathe check measured in determining veneer quality was length of lathe check. The lengths of lathe checks tended to slightly fluctuate from the pith to the bark. The length of lathe check follows the behavior of the depth of lathe check. The result in **Fig. 7** indicates that the thicker the veneer peeled, the longer the lathe check will be, however their depth and length ratio is almost the same. The average lathe check length for the intended veneer thickness of 1.0 mm, 1.5 mm, and 2.0 mm was 0.44 mm, 0.63 mm, and

0.88 mm respectively. The ratios between depth and length of the lathe check were 0.64, 0.65, and 0.65 for the veneer thickness of 1.0, 1.5, and 2.0 mm respectively.

In this study the lathe checks were propagated in the same radial direction at a roughly 45° angle to the annual ring for all veneer thickness, as shown **in Fig. 2**. It could be considered that the surface tension generated by the unbending process during flattening the veneer from its natural curvature would increase with veneer thickness and much more cutting splits occurred during the peeling, and so it would generate deeper and longer length of lathe check. During the rotary peeling of veneer for plywood or the laminated veneer lumber manufacture, lathe checks are formed in the veneer that are as deep as 20 – 30 % of the veneer thickness (**Rohumaa et al., 2013**). In this study the average lathe check depth was 28% of the veneer thickness, and the ratios between depth and length of the lathe check for all intended veneer thickness was 65%. Therefore, these results suggest that obtaining higher glue bond strength will need to reduce the lathe check frequency rather than the depth and the length of lathe checks.

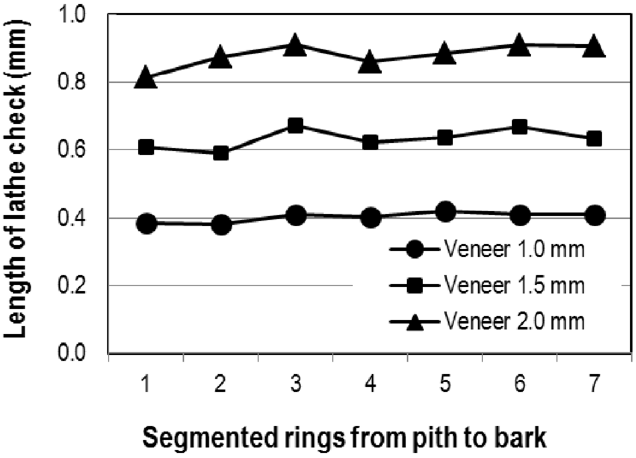

Fig. 7 - The progress of length of lathe check from pith to bark

3.3 Effect of lathe check on glue bond and bending strength

The glue bond strengths of veneer glue-line on the LVL increased from pith to bark (**Fig. 8**) for all veneer thickness. The results suggest that increasing proportion of veneer near the pith would decrease the glue-line's capacity to withstand concentrated shear stresses, thus resulting in higher amounts of glue-line failure and a reduction in percent wood failure. However, as the proportion of veneer near bark at the tight-side glue-line increased, percent glue-line failure decreased. This was attributed to an interaction between the juvenility (**Fig. 8a**) and the frequency of lathe check (**Fig. 8b**). The glue bond strength had a statistically significant, high, negative correlation to lathe check frequency, and its correlation coefficients according to the lines in **Fig. 8b** are summarized in **Table 1**. The results show that the regression coefficients for the glue bond strength linear equations depicted by the veneer thickness varied from -0.814 to -1.124. These variations indicate that the glue bond strength would decrease as the veneer thickness increase (**Table 1**).

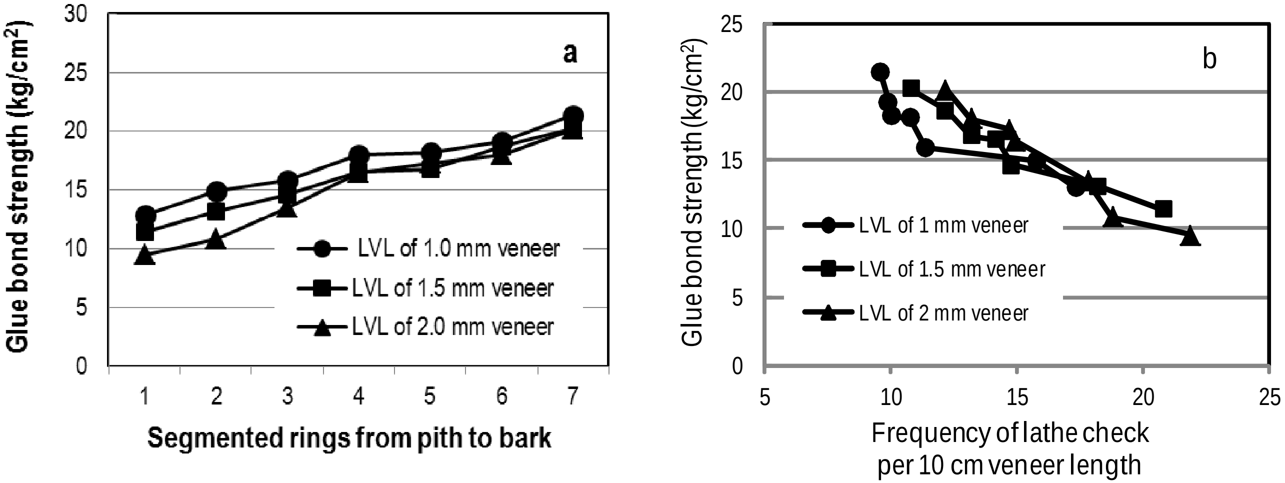

Fig. 8 – The effect of juvenility and lathe check on the glue bond strength for different veneer thickness

Lathe check frequency was the first variable analyzed to explain the glue bond strength. As lathe check frequency of veneers in between the glue line increased, the amount of "bridging" wood material between each lathe check decreases. This decrease would reduce contact between the layers resulting in a weak glue line and low glue bond strength of the LVL. This results are in agreement with **DeVallance et al. (2007)**, who reported that a high frequency of lathe checks results in lower strength. Increasing veneer thickness generally goes to a reduction of glue bond strength. We attribute this relation mainly due to lathe checking that increases with veneer thickness, and due to higher impregnation rate of veneers and lathe checks with glue. The LVL failures after glue bond test were observed and evaluated visually. The specimens failed mainly along a line delineated by the propagation of fracture of lathe checks within the veneer itself. This failure confirmed to the observation results of **Rohumaa et al. (2013)**, in which the failure when specimens pulled closed involved a predominantly mode II (shear) mechanism, which tends to drive wood failure toward the loose side of veneer.

Table 1 - Linear regression equations and correlation coefficients according to Fig. 8b (**y = glue bond strength, x = frequency of lathe check, r = correlation coefficient)**

Veneer thickness	Linear equation	r
1.0 mm	y = -0,814x + 27,10	0.90
1.5 mm	y = -0,857x + 28,68	0.97
2.0 mm	y = -1,124x + 33,33	0.98

The behaviors of modulus of elasticity (MOE) and modulus of rupture (MOR) from pith to bark for sengon solid wood was published (**Darmawan et al. 2013**). It was noted in the article that juvenile woods of sengon near pith have a significantly lower MOE and MOR than the juvenile wood near the bark. The lower MOE and MOR of juvenile wood near pith are due to larger microfibril angle, and lower density. Mean MOE and MOR values from pith to bark for sengon wood reported in the study were 43651 kg/cm^2 and 302 kg/cm^2, respectively. **Martawijaya et al. (2005)** also found out that the MOE and MOR of sengon were 44500 kg/cm^2 and 316 kg/cm^2, respectively. It was found in this study that MOE and MOR values of sengon LVLs are slightly lower compared to those of sengon solid woods. The average MOE for the sengon LVL made of 1 mm veneer thick (24-ply), 1.5 mm veneer thick (14-ply), and 2 mm veneer thick (11-ply) was 42953, 40172, and 38907 kg/cm^2, respectively, and their average MOR was 269, 233, 216 kg/cm^2, respectively.

This research approved that the MOR and MOE of sengon LVLs were lower than those of corresponding solid sengon wood. The decrease could be due to the presence of lathe checks on the sengon veneer. **Fig. 9** shows that the MOE and MOR's of all three different thicknesses (number of plies) of LVL decrease when the frequency of lathe check in the veneer is increased. Both the MOR and MOE seem to be influenced by the lathe check. Lathe check had little effect on the MOE of sengon LVL, but had more adverse effect on the MOR of sengon LVL. The results in **Fig. 9** indicated that the MOE of 11, 14 and 24 ply LVL was reduced in the average of 20.6 percent and the MOR of 11, 14 and 24 ply LVL was reduced in the average of 26.9 percent when lathe check in the veneers of LVL was increased in the amount of 5 lathe check. This suggests the lathe checks may cause a great deal of local stresses on tensile side of the bending specimen, and determine the bending failure of LVL when the lathe checks are situated under the maximum bending moment. The lack of proper connection among the fiber elements is the reason of the frequent rupture on the tensile side.

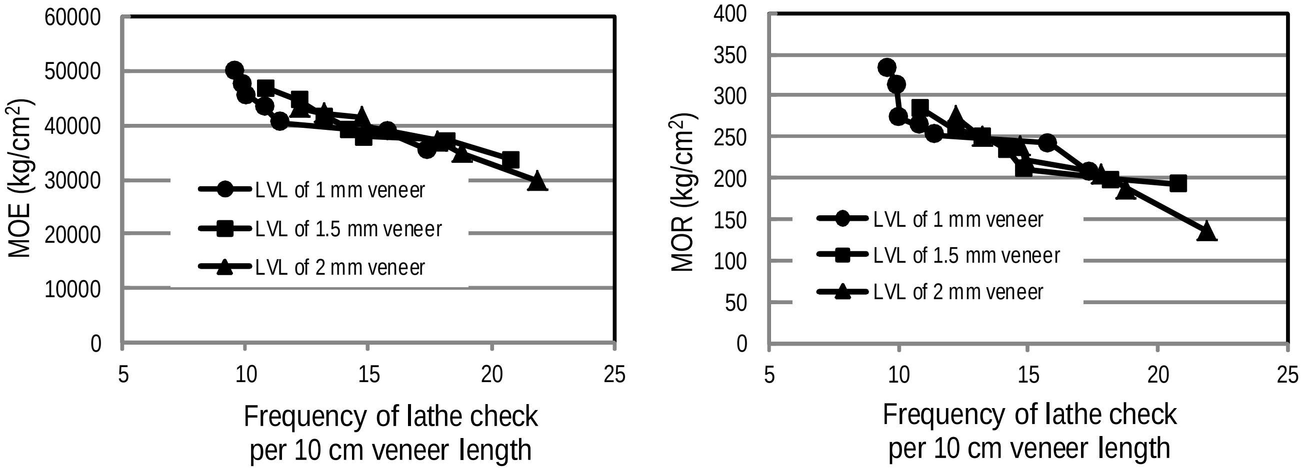

Fig. 9 – The effect of lathe check on the bending strength (MOE and MOR) for different veneer thickness

The results in **Fig. 10** show that both MOE and MOR increased with an increase in glue bond strength. Though MOE are almost the same among the veneer thickness, however MOR among veneer thickness is slightly different. As shown in **Fig. 10** the 22-ply LVL had higher MOR compared to those of 14 and 11-ply. This is mainly due to the higher glue bond strength produced in the glue-lines between the plies of the 22-ply which consisted of veneers of less lathe check frequency. The thinner the veneer the higher amounts of glue were needed in the manufacturing process resulting in better compaction of the wood during the pressing. This strongly suggest that by using thinner veneers (higher number of ply), the LVL will exhibit higher strength compare to those thicker veneers in production of LVL. This finding confirms with results published by **Kilic et al. (2006)**. It was reported in his article that the bending properties of LVL produced with thinner veneers were higher compared to those from thicker veneers.

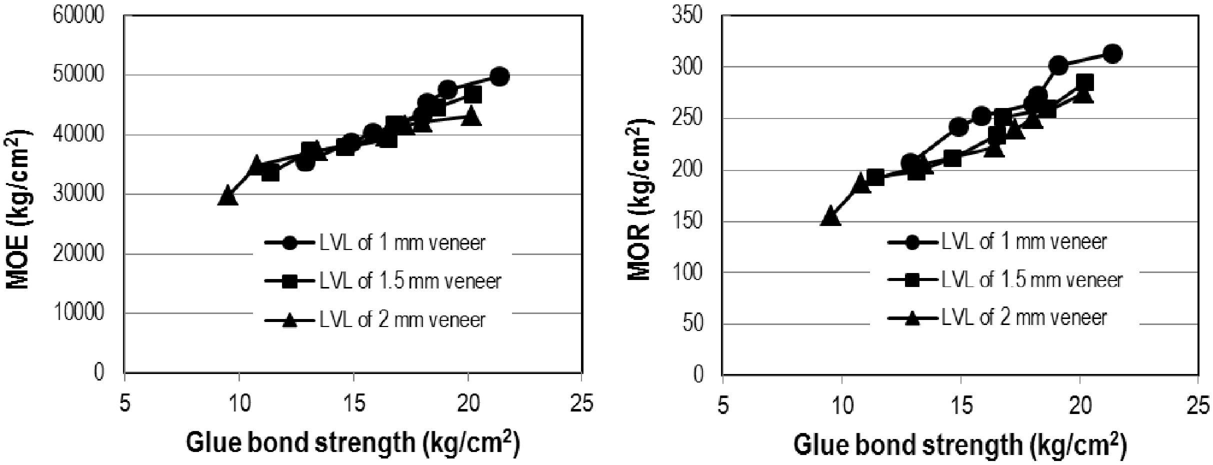

Fig. 10 - Relation between glue bond strength with MOE and MOR

4. Conlusion

In conclusion, we have found that the frequency of lathe check decreased from pith to bark. The increases in boiling temperature significantly decreased the lathe check frequency of the veneers peeled from the pith to the bark. When the logs boiled in water for 8 h at 50 ^{o}C, and 4 – 8 h at 75 ^{o}C, the veneers obtained from the pith to the bark of the logs showed significantly less lathe check than those boiled for 4 h at 50 ^{o}C. The thicker veneer peeled from the logs tend to produce larger frequency of lathe check compared to thinner veneer. The MOE and MOR of sengon LVL from the bending test decreased with increasing in the lathe check frequency of the veneers. Higher glue bond strengths were also obtained for sengon LVL manufactured from veneers having lower frequency of lathe checks. The thin veneer provides better glue bond strength, MOE and MOR compared to thicker veneers. Using thinner veneers in LVL manufacture improved the strengths of the resulting panel.

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