Standard Blank for Wood Lamination on *Khaya Ivorensis*

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Abstract

This paper focuses on the standard blank for wood lamination on *Khaya ivorensis*. Standard blank is a cutting standard for a blank which are provides improving and increasing the value of sawn timber. Parameters for standard blank were machining practices and lamination process. Adhesives used for the study is Polyvinyl Acetate (PVAc). The purpose of standard blank based on machining practices (system) and lamination process (process). Explain that, the different machine used in producing sawn timber provides different result for surface roughness that affects the gluing properties during lamination process. The physical and mechanical properties were tested as Modulus of Rupture (MOR), Modulus of Elasticity (MOE), Compression shear and Delamination test were evaluated based on reference standard of in house method testing; BS 373:2008 (MOR and MOE), BS 373:1957- reconfirm 2008 (Compression shear) and JAS 1751 2008 (Delamination test). For the system, there are two type of system; sanding system (S1) and without sanding system (S2). Overall results show that the without sanding system is recommend in the production. Other than that, there are three type of lamination process that need to be compare for this study which are plane and plane (P1), rip and rip (P2) and plane and rip (P3). From the three type of lamination process, the most suitable surface used for lamination process by using different machining practices is plane and plane.

Keyword: Standard blank, wood lamination, Khaya wood.

1. INTRODUCTION

Wood is unique renewable resources that are high in demand consider of its properties. Either hardwood or softwood is still remaining used for construction, etc. There are many type wood species founded such as Mahogany, Kempas, Teak, Rubberwood, etc. *Khaya* is one of the types of the genus of Meliaceae and Swietenia related the species of Mahogany (Flynn, 2007). East, Central and West Africa are the originated distribution of five *Khaya* species which is *Khaya grandifoliola, Khaya senegalensis, Khaya anthotheca, Khaya nyasica* and *khaya ivorensis* (Patterson, 1988). *Khaya ivorensis* is high in demand for furniture industry because of its unique and aesthetical value. Furthermore, the value of the furniture depends on the decorative grain from the wood (Opuni-Frimpong, Kamosky, Storer, and Cobbinah, 2008).

Nowadays, the world has generates the substitute of wood materials in the form of engineered wood materials. Engineered wood can be defined as the reconstituted of wood. A human had invented by involve the other material such as less dimension of wood from the rough cut, particle and binding material such as resin (Milner, 2009). Wood lamination or laminated wood is an engineered wood product. Wood lamination is the composed of the layers of wood, either solid wood or veneers which are glued together by using certain adhesives [7].

In construction, adhesives are the important component to bind the other substrate to another substrate. Adhesives are the binder for two surfaces of the substrate. Adhesives can be classified into two types, natural and synthetic (Hoadley, 1980). Thermoplastic adhesives are the category of resin that is can be shape and reshaped by heating and become solidified when cooled (Biron and Marichal, 2013). Normally, the type of thermoplastic adhesives is able to use when supplied. The solidification of this type of resin happen when temperature of surrounding turns down or cooling. There is the type of adhesives from thermoplastic category; Polyvinyl Acetate (PVAC), Polyvinyl Alcohol (PVA), hot melts, contact adhesive, etc. Polyvinyl Acetate (PVAC) adhesives are aqueous emulsions or known as white glue (Charles and Wake, 1976). PVAC adhesives are commonly used for numerous applications, either for wood working and other application. The bond strength of PVAC adhesives advance in loss of water into the wood (Wing-Hing, 1991). PVAC adhesives are inexpensive, low toxicity, low flammability, etc. Moreover, it has excellent dry adhesion (bond) strength, good gap-filling properties, fast setting, and colourless glue lines after sanding and ease of application (Salvini, Saija, Lugli, Cipriani, and Giannelli, 2011).

Standard blank is a standard for machining practices for the surface quality of wood or blank (Adams, Jeannete

and Stieri, 1975). Other than that, the machining affects the surface quality of wood. Standard blank provides improving and increasing the value of furniture as final product is connected to the surfaces smoothness of the wooden materials (Richter, Feist and Kanebe, 1995). Wood surface quality can divide by three categories of roughness such as first class, second class and bad texture. The decreases in surfaces roughness decrease the problems in gluing and upper surface of finishing (Stumbo, 1960). Machining process such as planning, sanding, ripping, etc. are provides different value of the wood surface (Aslan, Coşkun and Kılıç, 2008).

2. METHODOLOGY

2.1 Preparation of sample

Khaya ivorensis is the type of fast growing species. It is also the type of forest plantation species in Peninsular Malaysia which is also known as African mahogany. The density of the wood is in around of 530 kg/m^3 to 700 kg/m^3.

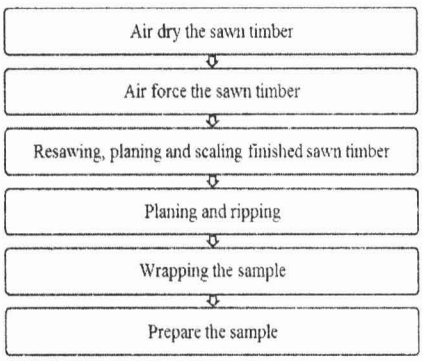

Figure 1: Flowchart of the process

Figure 1 shows the flowchart of the process. In the study, *Khaya* wood used around 10 years old from plantation at Forest Research Institute Malaysia (FRIM). The diameter ranging from 35 to 40 cm through thinning system. Thinning system is the process in removing the unwanted trees to allow the new trees to grow without any competition from the others. The *Khaya* wood already provided in form of sawn timber that has been air dry for a week after saw milling process.

2.2 Air force the sawn timber

Forced air dry or also known as Fan Shed Drying (FSD) is a drying process where the air has been force through the wood stack that placed in the shed. The shed has a fan that pull outside air go through inside of the shed. Furthermore, the shed prevent the wood exposed to wet or high humidity from environment The temperature of forced air dryer is (± 60 °C) and usually runs for 24 hour but it has flexible time duration that depend on thickness and wood species. Moisture content of air-force dry wood is at 12% to 15%.

2.3 Cutting method

In producing sawn timber there are numerous type of cutting method. In this study, sawn timber provided is plain sawn timber. Currently, the plain sawn cutting method is the most popular method because of certain factor such as simplest method, economic way to produce sawn timber and reduce wood waste. Unfortunately, the exposed tangential grain by cutting process makes the blank has been faced drying defect such as cup, twist, bow and crook. Other than that, this method also makes the sawn timber tend to absorb moisture more compare to quarter sawn cutting method.

2.4 Machining practices

Planing, ripping and sanding are the type of wood machining process in producing quality sawn wood used for constructions, panelling, etc. These machine practices can provide good sawn wood and give minimal effort for the finishing or lamination process.

2.5 Lamination process

For lamination phase, there are three process need to be made as lamination. The three process is refer to the machine practices and system (sanding and without sanding). The processes have been label as plane and plane (process 1), rip and rip (process 2) and plane and rip (process 3). Besides, the system was label as system 1 (sanding) and system 2 (without sanding). There is showing the experimental design for lamination process:

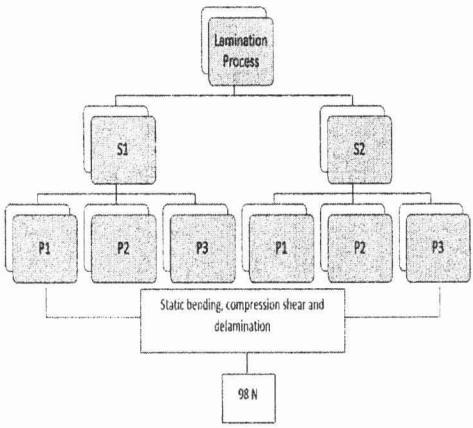

Figure 2: Experimental design for lamination process

Clamping process is important in the lamination process. A constant pressure is needed for the lamination to be set and the glue to spread evenly. There are many types of clamps that come in different length. For this study, A bar

clamp had been used with 1m of length. The blank was clamped for 3 days.

2.7 Method of testing

In producing engineered products such as lamination, commonly the products need to be test the strength based on Codes of Practice (COP) that published by British Standard Institution (BSI). BSI has been published variety of COP, but the practices need to be considering the suitability and availability for the each country. For this study, the COP used for the testing procedure is British Standard (BS) and Japanese Agricultural Standard (JAS). All test method applied by using universal test machine, according to the procedure of British Standard (BS 373) and Japanese Agricultural Standard (JAS 1751). Static bending strength (MOR and MOE) and compression shear strength are referring to BS 373 standard. Meanwhile, the delamination test is referring to JAS 1751 standard.

2.7.1 Static bending test

The mechanical properties of the lamination are measured by using static bending. The COP of the testing is BS 373:2008, which is the span for this testing is 360 mm with speed 10 mm/min. Besides, it is measured the Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) of the sample. This testing identified the mode of failure of the products that is for structural application which is requiring strength and rigidity.

2.7.2 Compression shear test

The COP of compression shear test is BS 373:1957 re-conform based on BS 373:2008. The span and speed of cross head is similar to the static bending test because of it is used the same universal machine test. Compression shear test is determined behaviour of material under crushing loads. The sample is compresses and deformation at various loads is recorded. Besides, it is also determined the failure of the wood behaviour on the applied load.

2.7.3 Delamination test

The delamination test for this study based on JAS 1751:2008, with size 40mm×40mm×75mm. Delamination test or known as internal bonding test is to determine the water resistance of the engineered products or wood sample. Moreover, the test also measured the performance of glue application on the products. There are two type of delamination testing method which is Hot Water Soak (HWS) and Cold Water Soak (CWS). In this study, the delamination method used is HWS.

3. RESULTS AND DISCUSSIONS

3.1 Differences between density, MOR and MOE and compression shear of the lamination process with sanding system and without sanding on finding

Table 1: Arrangement of density, MOR and MOE and compression shear of three type lamination with sanding system.

Lamination process	Density	MOR	MOE	Comp shear
P1				
Average	561.35	58.37	5354.85	4.596
Std. Deviation	43.57	7.83	574.13	0.805
P2				
Average	627.52	58.49	6233.12	2.961
Std. Deviation	7.64	7.64	533.65	0.36
P3				
Average	605.69	45.47	5785.95	2.834
Std. Deviation	43.92	10.49	1059.47	0.580

From Table 1, it is apparent that there were differences between the density, MOR and MOE and compression shear for three type of lamination process for sanding system (S1). For the average of density, the results showed that the lamination 2 have the highest density which is reached at 627.52 kg/m^3. However, the lamination 1 shows lowest density at 561.35 kg/m^3.

Meanwhile, for the raw data of MOR and MOE, the lamination 2 and 3 have the highest value which is at 58.37 MPa for MOR and 6233.12 MPa for MOE. Besides, sequences of the lowest value of MOR and MOE are for lamination 3 that have reached at 45.47 MPa for MOR and 5785.95 MPa for MOE. The raw data of compression shear shows that the lamination 1 is appear as the highest value which is at 4.596 MPa. However, the lowest value for compression shear raw data is lamination 2 which is at 2.961 MPa.

Table 2: Arrangement of density, MOR and MOE and compression shear of three type lamination without sanding system.

Lamination process	Density	MOR	MOE	Compshear
P1				
Average	511.98	67.25	5725	7.34
Std. Deviation	8.1	8.24	680.36	0.54
P2				
Average	491.81	47.24	4590.02	4.51
Std. Deviation	12.15	9.14	503.38	0.34
P3				
Average	540.5	59.32	5696.67	5.54
Std. Deviation	34.72	6.05	380.97	0.07

From Table 2, it is shows that there were differences between the density, MOR and MOE and compression shear for three type of lamination process for without sanding system (S2). For the average of density, the results shows that the lamination 3 have the highest density which is reached at 540.5 kg/m^3. Meanwhile, the lamination 2 shows lowest density at 491.81 kg/m^3.

Lamination 1 shows that the MOR and MOE are higher than other two type of laminations which are at 67.25 MPa for MOR and 5725 MPa for MOR. Other, the lamination 2 shows lowest value which for MOR is 47.24 MPa and 4590.02 MPa. On the other hand, for the raw data the lamination 1 is highest value of compression shear which is at 7.34 MPa and the lowest value is lamination 2 which is at 4.51 MPa.

Table 3: ANOVA table for system and lamination

SOV	Df	MOR	MOE	Compression shear
System	1	1.298^{ns}	3.571^{ns}	154.227**
Lamination	2	4.099*	0.638^{ns}	47.33**
S and L	1	5.32*	6.426*	4.832*

Note: ns for not significant ($p>0.05$), * or 1 star for significant ($p<0.05$), ** or two or double star for highly significant ($p<0.01$)

Table 3 shows that the SOV of MOR for the system is 1.298^{ns} which is considered as not significant. Besides, the MOE for the system is 3.571^{ns} also shows sign of not significant. Whereas, the compression shows that the value is 154.227** for the system. The double star for the value consider as it is highly significant.

SOV of MOR for the lamination is 4.099** is consider as significant refer to the star shows. Moreover, the MOE for the lamination shows 0.638 ^{ns} is not significant value of SOV. Other than that, for the compression shear result of lamination shows that the value is 47.33** with double star means that it is highly significant. The SOV of the system and the lamination shows the MOR is 5.32* with one star which is consider as significant value. The MOE for the system and lamination is 6.426* also with one star which shows it is significant. The compression shear for the system and lamination is 4.832* shows one star which is significant value.

3.2 Effect of system for lamination process on MOR, MOE and compression shear

Table 3: Result of MOR for the system of the lamination process

System	Mean	Std.	N
S1	54.115	12.32687	18
S2	57.9389	11.75522	18
Total	112.0539	24.08209	36

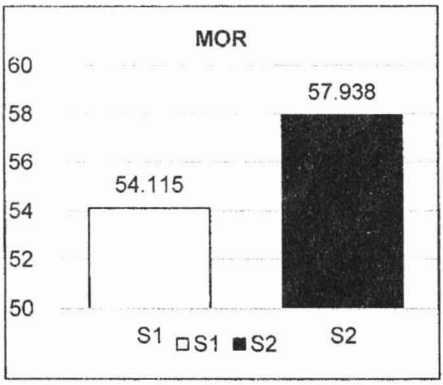

Figure 4: Comparison between the results of MOR for the two systems

Table 4: Result of MOE of the system for the lamination process

System	Mean	Std.	N
S1	5791.3083	865.5453	18
S2	5337.23	774.4439	18
Total	11128.5383	1639.9892	36

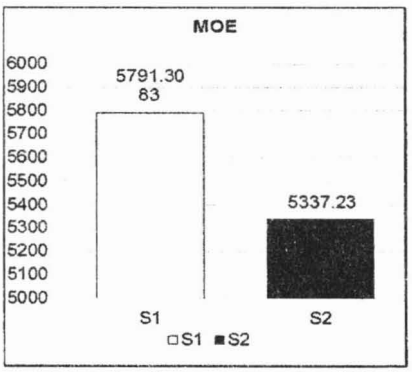

Figure 5: Comparison between the results of MOE for the two systems

MOR, MOE and compression shear are the method that proving that effect on mechanical properties of system for lamination process. Figure 34, figure 35 and figure 36 shows the comparison of the result for Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) between the two systems which are sanding system (S1) and without sanding system (S2).

Figure 4 shows the result of MOR for without sanding system (S2) at 57.938 MPa which is consider as higher than the sanding system (S1) at 54.115 MPa. When, figure 35 shows the result of MOE for the sanding system (S1) at 5791.3083 MPa which is higher than the without sanding system (S2) at 5337.23 MPa. Between the both systems with the static bending test show the comparison of MOR and MOE results which are conclude as vice versa.

That means, the result for the both systems for the lamination process is can be used to refer in producing a

blank. But, it is might be conclude as high cost in production if the industry used S1 whereas S2 also does not affect the lamination process. So, the S2 is recommend to use in lamination process which are can reduce the cost and time of the production. Other than that, the used of abrasive paper with 100 grit also does not give differences in lamination process.

Table 5: Result of compression shear for the lamination process

System	Mean	Std.	N
S1	3.4432	0.98504	18
S2	5.7326	1.20271	18
Total	9.1758	2.18775	36

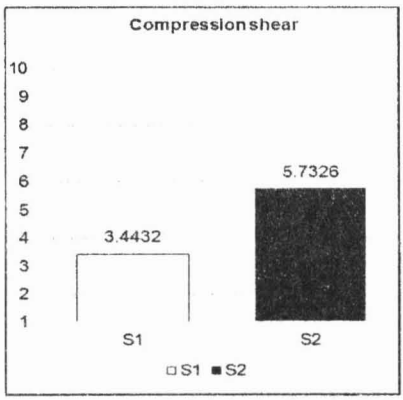

Figure 6: Comparison between of compression shear result for the two system

Compression shear important to measure the ability of the wood resist failure by sliding over the shear block to the cross surface of the samples. Figure 36 shows that the result for compression shears between the two systems. It is shows that the S2 at 5.7326 MPa which is higher than S1 at 3.4432 MPa. The results of compression shear between the both systems are slightly different. The result concludes that, the S2 can resist to the shear failure because of adhesion factor. It is can be conclude that, the S2 have good cohesion because of the adhesion factor. S2 have high mean for the result because of it is have less smooth surface compare to S1 and can be conclude as has better adhesion process compare to the S1. According to Pizzi 1994 [11], refer to the adhesion theory of mechanical interlocking, the adhesive anchored to the less smooth surface of substrate by interlocking the pore, cavities or fiber from the rough surface of the substrate.

3.3 Effect of lamination process for the samples

Table 6: Result of MOR on lamination process for the sanding (S1) and without sanding system (S2)

System	Lamination process	Mean	Std.	N
S1	P1	58.375	8.58095	6
	P2	58.4983	13.2	6
	P3	45.4717	11.49337	6
S2	P1	67.2567	9.02895	6
	P2	47.24	10.02088	6
	P3	59.32	6.6375	6

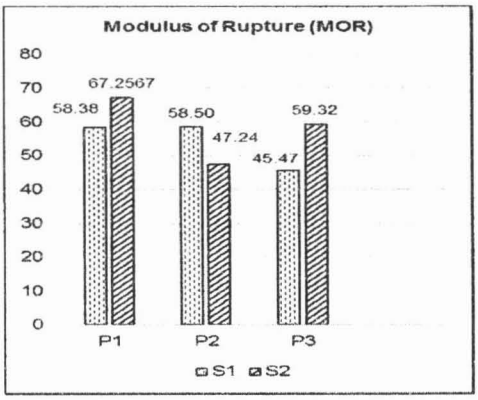

Figure 7: Result of MOR for lamination process with sanding system and without sanding system

Figure 7 shows a result of MOR that shows the three lamination process; plane and plane (P1), rip and rip (P2) and plane and rip (P3) with sanding system (S1) and without sanding system (S2). The result shows MOR values for lamination process, P1 for S2 is 67.2567 MPa higher than P1 for S1 which is at 58.375 MPa. Besides, MOR values P2 for S1 is 58.4983 higher than P2 for S2 which is at 47.24 MPa. Other, MOR values P3 for S2 is 59.32 MPa higher than P3 for S1 which is at 45.4717 MPa.

Refer to SOV, lamination process at table 3 shows the significant value for MOR because of the planing and ripping process have differences between the surface roughness and give effect to lamination process. Besides, according to Wagner 1974 [17], the preparing wood for gluing is important and the surfaces of sample may reduce the slip during gluing process which enhance the strength of the lamination. The result shows that, the P1 from S2 consider as the highest value for MOR in lamination process. Means that, it can be conclude as for lamination production the P1 from S2 is the best machining practices that can be applied for better result in the production.

Table 7: Result of MOE on lamination process with sanding and without sanding system

System	Lamination process	Mean	Std.	N
S1	P1	5354.846	628.9336	6
	P2	6233.123	584.586	6
	P3	5791.308	1160.598	6
S2	P1	5724.995	745.3064	6
	P2	4590.018	551.4342	6
	P3	5696.676	417.3396	6

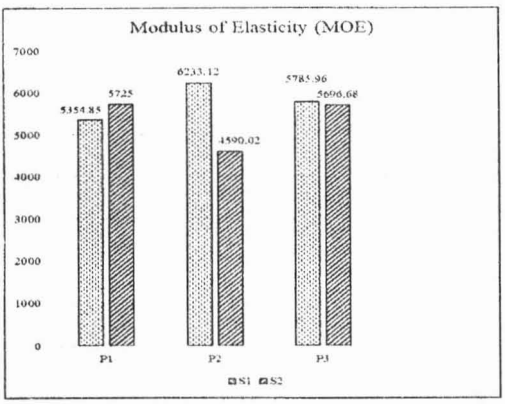

Figure 8: Result of MOE for lamination process with sanding and without sanding system

Figure 8 is a result of MOE that shows the three lamination process; plane and plane (P1), rip and rip (P2) and plane and rip (P3) with sanding system (S1) and without sanding system (S2). The result shows MOE, P1 for S2 is 5724.995 MPa the higher than P1 for S1 which is at 5354.8467 MPa. Then, MOE values P2 for S1 is 6233.1233 MPa higher than P2 for S2 which is at 4590.0183 MPa. Other, MOR values P3 for S1 is 5785.955 MPa higher than P3 for S2 which is at 5696.6767 MPa

The overall result of MOE for lamination process is P2 from S1 consider as the highest value of MOE. But, the differences between the other lamination process are not slightly different and consider as not significant when analyze the data by using ANOVA. It can be discuss as the density of *Khaya* wood effect the value of modulus of elasticity. According to Forsyth and Miyata 1987 [4], the high density tree is flexible in term of tolerate with the wind and other factor which are disturb the branches and tree crown. It can be conclude as the high density of wood provides high flexibility to the wood during applied force.

Table 8: Result of compression shear on lamination process for sanding and without sanding system

System	Lamination process	Mean	Std.	N
S1	P1	4.4817	0.8815	6
	P2	3.0163	0.3944	6
	P3	2.8317	0.6362	6
S2	P1	7.1842	0.5912	6
	P2	4.4953	0.3764	6
	P3	5.5183	0.0796	6

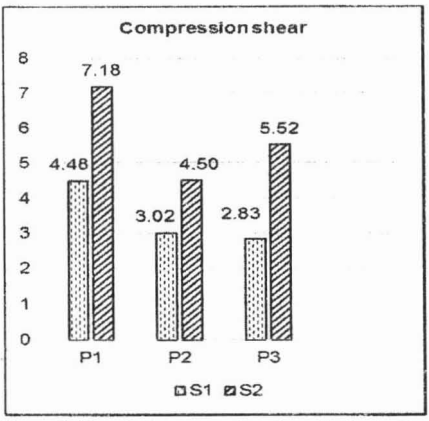

Figure 9: Result of compression shear for lamination process with sanding system

Figure 9 is a result of compression shear that shows the three lamination process; plane and plane (P1), rip and rip (P2) and plane and rip (P3) with sanding system (S1) and without sanding system (S2). The result shows compression shear value for P1 for S2 is 7.1842 MPa is the higher than P1 from S1 which is at 4.4817 MPa. Besides, the compression shear values of P2 for S2 are higher than P2 for S2 which is at 3.0163 MPa. Other, compression shear values of P3 for S2 is 5.5183 MPa higher than P3 for S1 which is at 2.8317 MPa.

Refer to the table 3 shows that SOV for lamination process for compression shear is highly significant. Means that, the comparison between the three lamination processes are slightly different. The different value of compression shear result is due to the pressure applied during clamping process. The bar clamps have been used and applied by manually. This proves that the certain part of the lamination process is lack of pressure. Besides, certain wood in lamination process has warping and need more pressure during clamping process. If the clamping process is by using hydraulic pressure clamp, it will increase the value of compression shear. It is because the constant pressure applied on the entire wood lamination.

3.4 Effect of the delamination of the system and lamination process

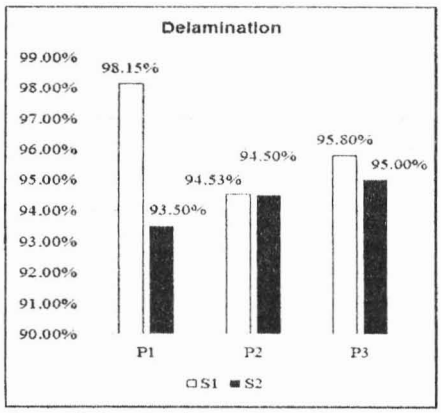

Figure 10: Result of delamination (%) for lamination process (P1) with sanding and without sanding system

Figure 10 shows the result of Hot Water Soak (HWS) delamination shows the three lamination process; plane and plane (P1), rip and rip (P2) and plane and rip (P3) with sanding system (S1) and without sanding system (S2). For delamination test or known as internal bonding test if the percentage exceed 89% and above. Average for the P1 for S1 is 98.15% which the highest percentage of delamination, while the P1 for S2 is 93.5% which is the lowest value of the percentage. The all products or samples consider as it is pass for this test. It is shows that the amount of adhesive in this test is enough for the lamination process.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

This study investigates the suitability of machining practice such as plane and rip on *Khaya* wood for lamination. From the finding, the machining practices that have been study conclude that the system used in the lamination process is vice versa. That means the sanding system (S1) and without sanding system (S2) are available used for lamination process. Other than that, there are three type of lamination process that need to be compare for this study which are plane and plane (P1), rip and rip (P2) and plane and rip (P3). From the three type of lamination process, the most suitable surface used for lamination process by using different machining practices is plane and plane. Plane and plane (P1) consider as the best standard blank for the lamination process on the finding. According to Wagner 1974 (Wagner, 1974), the planing process by using thickness planer produce a smooth surface without too much loose of wood fibre if it is compare to the ripping process which is by using circular table saw.

Besides, the wood behaviour of *Khaya* wood need to be consider before applied any type of machine in processing wood blank. The present of fuzzy grain of the *Khaya* would affect the machining process and the surface quality of the blank. There are the differences between ripping and planing process which is ripping is a cut in grain direction, while the planing process is flatten or roughing down the blank surface. According to Vazquez 2003 (Vazquez-Cooz, 2003), the fuzzy grain gives friction to the blank in the machining process. Therefore, by using plane and plane (P1) is the most suitable standard for producing a blank for *Khaya* wood.

4.2 Recommendation

Recommendation for this study, the system used in the process need to be change for the future study. It is because the level of grit abrasive used is 100 (2/0) which is for medium type of grain. To differentiate the system the number of grit and type of abrasive need to be consider. The system from sanding and without sanding may be can change with sanding system but with different abrasive paper type or same abrasive paper type with different grit number as the variable. It is recommended to change the system because of the result show is not slightly give the best answer for the finding either one is better system used for wood lamination.

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