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Peeling of Poplar: Cultivars and Forest Stations Effect on Veneer Quality

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Abstract
In order to assess the quality of some new cultivars of poplar introduced in France, ten cultivars (five well known by professional and five promising new ones) coming from 4 different types of forest stations have been sampled. Two logs have been harvested per station and per cultivar. Peeling tests have been then performed on eighty trees: forty peeled in 1.4 mm thick, forty in 3 mm thick. Veneer quality has been evaluated measuring curl-up, surface quality (roughness, woolly surfaces), thickness variation and lathe checking. These tests show that it is absolutely not necessary to adapt peeling parameters to the different cultivars and according their forest stations.

1. Introduction
France is the third producer of poplar in the world. Average annual poplar harvesting reached 2.4 million m^3 [1]. According to Paillassa (2014) [2], plywood and veneer still account for the largest share of poplar products with 59.9 % of total production [3]. But, because of very serious sanitary problems occurring since many years (poplar rust, a fungi infection mainly observed on Beaupré, Ghoy…; woolly aphid on I214, I45/51, Dorskamp), it is really time to identify alternative clones able to resist to these biological attacks, at the same time producing wood of high quality for traditional and new markets.
Chen et al. discussed the relevant factors in the bonding technology and pressing processes as well as the mechanical properties, research direction and application prospects of structural laminated veneer lumber made from planted forest wood [4]. In a recent work, Zhang et al. propose a novel wood engineered scrimber with outstanding dimensional stability as well as excellent mechanical properties. A novel technique was exploited for preparation of thick finely fluffed poplar veneers (FFPVs). The physical properties of the veneers before and after fluffing process were compared, and the mechanical properties and dimensional stability of the resultant scrimber were also investigated [5]. Advanced research studied also the effects of hot air and microwave drying on kinetic rate and mechanical property of oil palm veneer [6].
Three French institutes (FCBA, IDF, Arts & Metiers ParisTech) have sampled logs composed for one half with very well-known cultivars and for the other half with promising new cultivars coming on the market with consequent volumes, in order to make comparisons and built a technological frame of reference about wood physical and mechanical properties. Each cultivar has been sampled in four different types of forest stations in order to study the possible influence of this factor on veneer and board's quality. Arts & Metiers ParisTech was in charge of peeling aspects, including veneer and plywood quality assessment, and of proposing new products for timber construction. In this paper, we will present the results relating to veneer quality.

2. Material and Methods
2.1. Sampling
The global sampling includes 10 cultivars: five currently present in industry (Beaupré, Blanc du Poitou, Dorskamp, I 214, Robusta) and five "newcomers" on the French market (I45/51, Flevo, Fritzi Pauley, Ghoy and Raspalje). The four different types of forest stations were defined as rich, deep, humid and clayey but, because

of the great number of cultivars, we have been obliged to find these stations into 13 different sites all across the country. For each site, two trees of a same cultivar have been harvested and from each tree, we have taken one bolt 600 mm long at a height of 2.70 m into the log. The peeling tests have then, been carried on 80 trees (2 x 4 x 10), 15-20 years old, and the diameter being fixed in a range of 350-450 mm.

2.2. Peeling

Poplar usually does not need any hydrothermal treatment before peeling. However, because of the constraint induce by the sampling all over France, all the tests have been performed along a period of one year. To avoid any wood temperature effects, due to the weather or seasons, on the cutting forces and veneer's quality, we always have kept the bolts for 48 h into a boiler set at 20°C before peeling.

The 80 bolts 600 mm long have been peeled on the industrial peeling lathe of LaBoMaP, instrumented to measure cutting and compression forces (Figure 1). For each cultivar/station couple, one bolt has been peeled in 1.4 mm, a quite usual veneer thickness in light packaging industry, and the other bolt in 3.0 mm, a standard thickness in plywood industry. All the peeling tests have been done at 1m/s until a residual diameter of 100 mm. The other settings of the peeling lathe were :

- clearance angle of 1°
- angular pressure bar set with an horizontal gap of 90% / veneer thickness
- angular pressure bar set with a vertical gap of 30% /veneer thickness.

The forces measured (Figure 2) are the orthogonal components of the resultant force exerted on the wood respectively by the knife (X_c, Y_c) and by the pressure bar (X_bY_b) [4].

Figure 1: The peeling lathe of LaBoMaP.

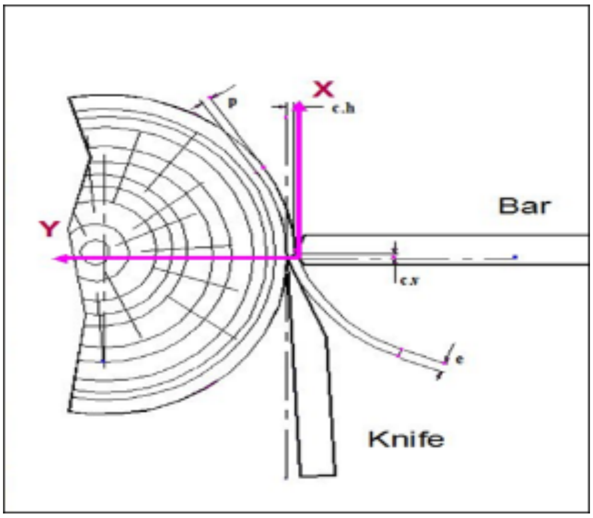

Figure 2: Orthogonal frame used for the decomposition of cutting force exerted by the knife and compression force exerted by the pressure bar.

2.3. Veneer quality measurement

The green veneers quality assessment has been made immediately after peeling considering five parameters:

- The curl-up: This defect can be very pronounced at the end of the peeling process (small peeling radius) for some wood species, inducing an important loose of material due to an auto-rolling up phenomenon. To quantify this defect, we have put the last 10 meters of the veneers ribbon of each bolt on the workshop floor, marked the warped zones and measured their amplitude and frequency (Figure 3).

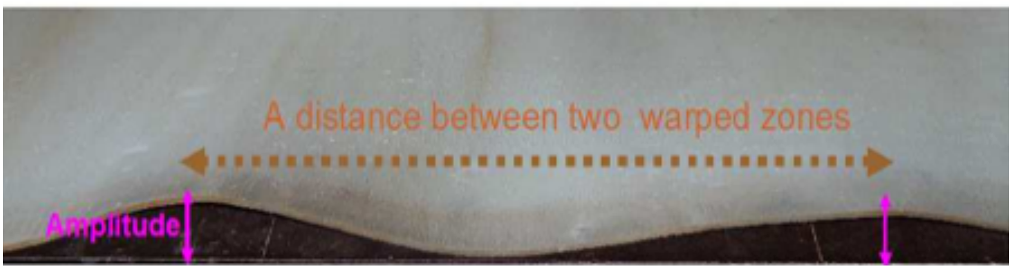

Figure 3: The curlup measurements.

- Woolliness: This surface defect is generally link to the presence of tension wood and increase on wood presenting low density [8]. It could be also accentuated using unsuitable peeling parameters (wood temperature too high, higher cutting speed, using a too high compression rate, etc…) [9,10]. This defect should absolutely be avoided for crate production because it makes the veneers no more printable. It could be also a big concern for plywood industry when using roller glue spreaders because the free fibbers would soot up the rollers, inducing glue joints of very bad quality. To quantify this defect, veneers ribbons have been clipped into 500 mm width sheets. Each one has been numbered according to its original tree and its radial position. These veneers have been sorted out in two categories of woolliness (Figure 4 and 5): with (no matter entirelyor partly) or without woolly grain. It allowed us to have a first approximate percentage of woolly veneers for each bolt.

Figure 4: Veneer presenting fuzziness

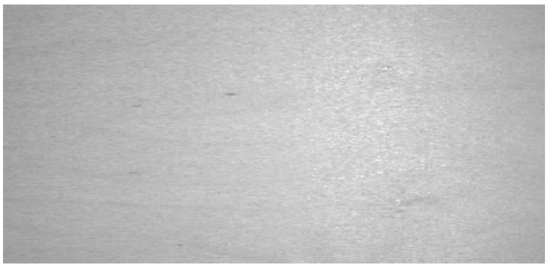

Figure 5: Veneer without any fuzziness

- Veneer thickness uniformity: This parameter is very important in order to obtain glue lines of great quality: lower the thickness variations are and better is the pressure distribution in glue lines during pressing. We have measured the thickness of each veneer in eight different points using a digital micrometer weighed down with a mass in order to flatten the veneer (Figs 6 and 7). We have then computed the mean thickness and coefficient of variation values for each veneer. For each bolt, we have sampled 28 veneers equi-distributed all along peeling radius in order to possibly detect juvenile/mature effects.

Figure 6 : The micrometer used for the measurement of the veneer thickness

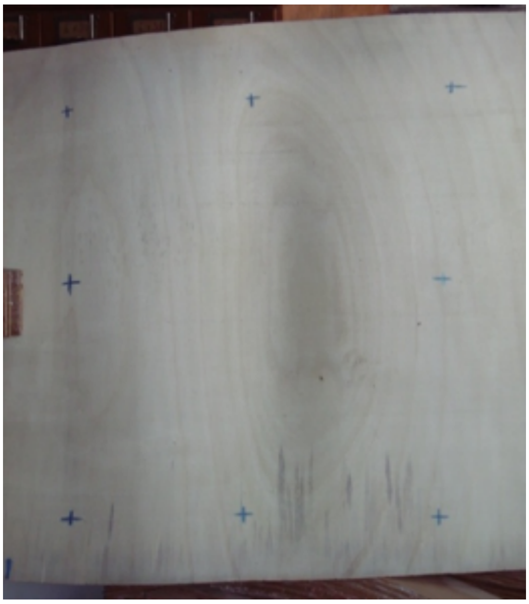

Figure 7: Veneer thickness: the position of the 8 points of measurement in the veneersheet.

- Veneer surface roughness: This factor has a very important influence on glue consumption and glue-line efficiency. Roughness has been measured using an analogical leakmeter (Figure 8), a pneumatic device based on the measurement of the air leakage between two metallic rings in contact with the surface to characterize. The flow increase with the surface roughness and a value of pressure is read on a column of water. This value moves into a range of 120 mm (the worth surface) to 390 mm of water (the smoother surface). For each face of each squared veneer previously sampled for thickness valuation, the measurements have been repeated 5 times (4 measurements near the corners and 1 measurement in the middle of the sheet). We have then computed the mean value and standard deviation per veneer and per bolt.

Figure 8: The leakmeter device used for roughness evaluation.

- Lathe checking occurrence: To estimate this defect, we have computed the differences between the roughness values obtained on veneer loose-side and tight-side, this difference being supposed to be correlated to the lathe checking occurrence.

The assessment of the results has been made using the software STATISTICA for Windows. We have mainly made analysis of variance.After these characterisations on green veneers, all the samples have been dried, glued and pressed in order to produce LVL and plywood boards to betested for their mechanical properties. The results on these mechanical tests are not discussed in this paper.

3. Results and discussion

3.1 Peeling forces

An overview of the orthogonal components of resultant forces respectively exerted on the tool (Fc) and on the pressure bar (Fd) shows that :

- For 1.4 mm thick veneer production, the peeling settings used here appear to be optimal whatever the cultivars. According to Marchal et al. (2009) [8]. A slightly negative Yc component means that there is a light diving tendency of tool, which constitutes the best situation for a steady-state peeling and the production of a veneer with a homogeneous thickness.
- With a clearance angle maintained at 0°, the tool diving tendency increases with veneer thickness, forces on the rake being proportional to the chip thickness [11].
- The tangential component Xc mean values are low compared to those obtained when peeling other wood species. Obviously, poplar wood doesn't require any important power to be peeled, because of its low density.
- Considering standard deviation values, it appears that these forces vary slightly for a given cultivar or station, which is quite normal in the case of homogeneous wood.

We have made an analysis of variance (ANOVA) for each of the two peeling thicknesses. These ANOVA don't reveal :

- any significant cultivar effect on cutting forces, in spite of some fluctuations that can be due to differences of mean density between some cultivars (Figure 9);
- Any significant station effect on the resultant forces Fc and Fb, whatever the nominal thickness may be (Figure 10).

To summarize, it clearly appears that it is absolutely not necessary to adapt peeling parameters to the different cultivars: at this level, poplar appear to be a unique wood specie.

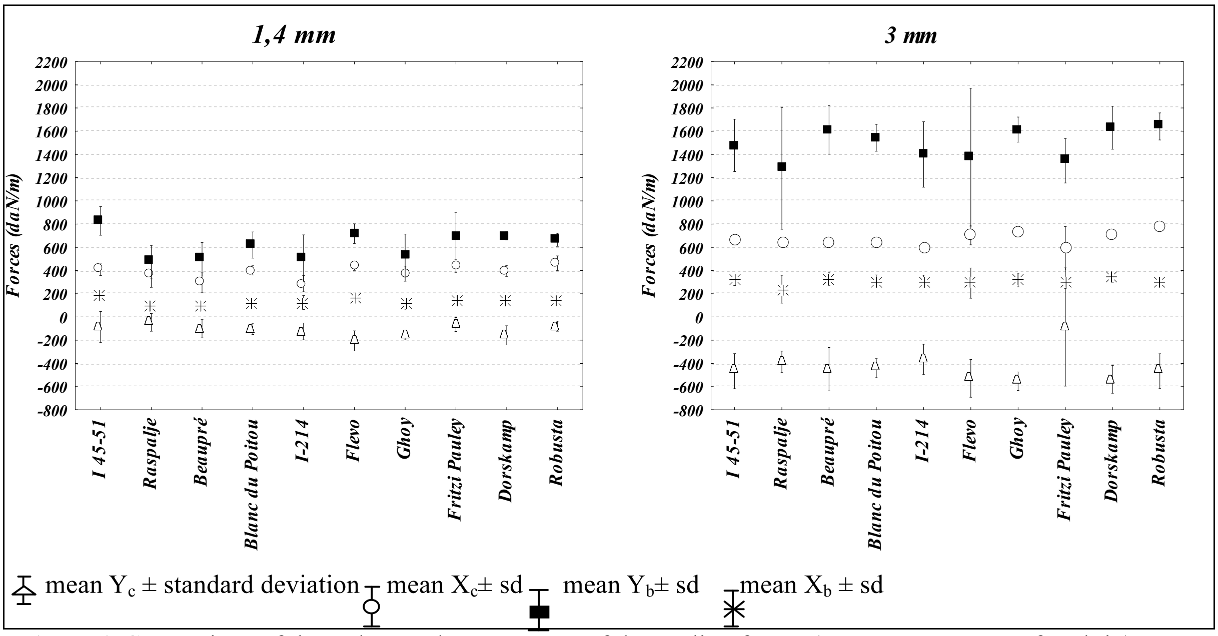

Figure 9: Comparison of the orthogonal components of the peeling forces (Newton per meter of tool tip)

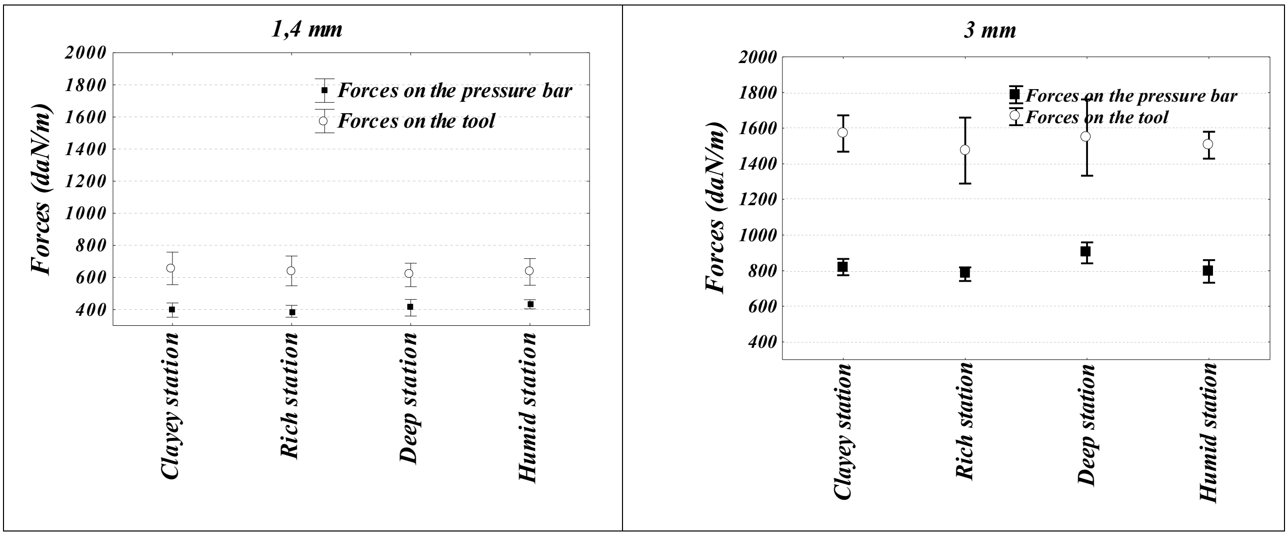

Figure 10: Variation of resultant peeling forces exerted on the tool and on the pressure bar according to the station.

3.1 Curl-up

The ANOVA doesn't reveal any significant station, cultivar or veneer thickness effect neither on curl-up amplitude nor on its frequency. Figures 11 to 14 illustrate this result. Most of the cultivars display a mean amplitude between 4 mm and 5.5 mm with the exception of Ghoy and I214 showing respectively a mean amplitude of 6 and 3.5 mm. The mean distance between two deformations is always between 20 and 30 mm. All these values show that curl-up phenomena will never be a big concern for veneer poplar producers using one of these cultivars.

3.2 Woolly surfaces

The ANOVA (Table 1) doesn't show any significant interaction or simple effect (cultivar, station, thickness) on woolly surfaces occurrence.But this result should be analysed very carefully because the method used to evaluate woolly surfaces proportion presents bad effects. A veneer sample having a low proportion of woolly surface being classified identically than a fully affected one. So the defects are overestimated and the results are strongly levelled.

Therefore, differences between cultivars or stations can be hidden. That is why we develop now a method using scanners and images analysis for a more accurate evaluation of this defect.

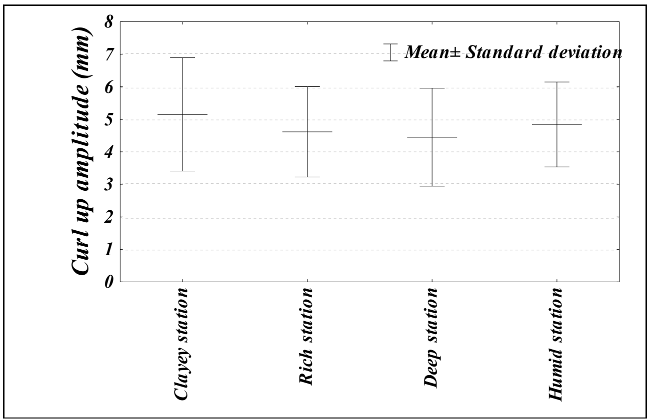

Figure 11: Mean amplitude of the curl up in the four stations.

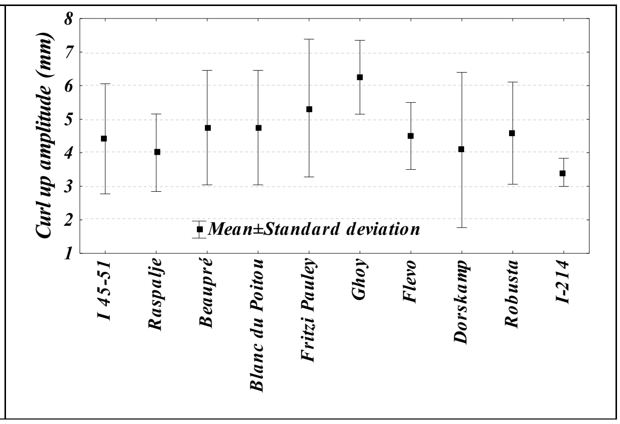

Figure12: Variation of the curl up according to the cultivars.

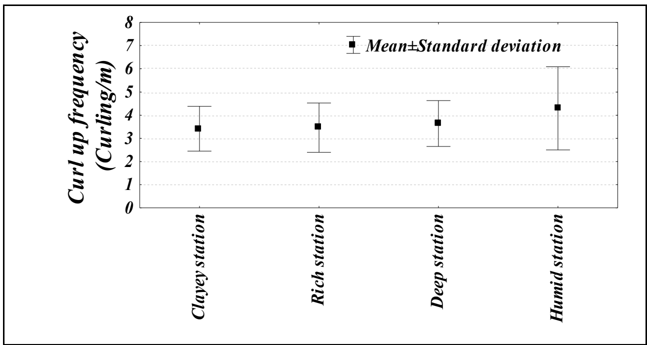

Figure13: Variation of the curl-up frequency according to the stations.

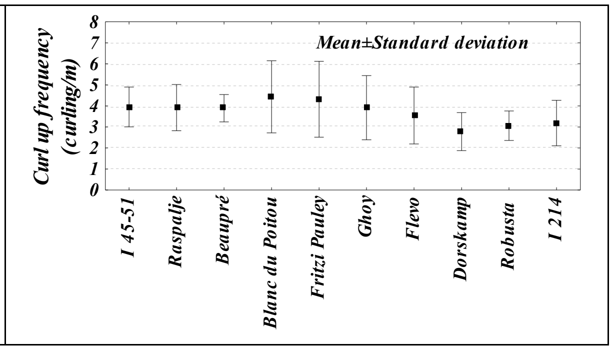

Figure14: Variation of the curl-up frequency according to the cultivars.

Table1: Results of ANOVA for the "woolly veneer percentage" criterion.

	SS	***DF***	***MS***	***F***	***P***
Station	*4146,4*	*3*	*1382,1*	*0,004*^{NS}	*1,00*
Cultivar	*19982,9*	*9*	*2220,3*	*0,006*^{NS}	*1,00*
Nominal thickness	*20,8*	*1*	*20,8*	*0,000* ^{NS}	*1,00*
*Station*Cultivar*	*10846,1*	*27*	*401,7*	*0,001* ^{NS}	*1,00*
Station Nominal thickness*	*967,5*	*3*	*322,5*	*0,001* ^{NS}	*1,00*
Cultivar Nominal thickness*	*3020,2*	*9*	*335,6*	*0,001* ^{NS}	*1,00*
*Station*Cultivar* Nominal thickness*	*8449,7*	*27*	*313*	*0,001* ^{NS}	*1,00*
Error	*350209,1*	*1*	*350209,1*		

SS :The sum of squares due to the source ; DF :Degrees of freedom in the source
MS :The mean sum of squares due to the source ; F :The F-statistic ; P :The P-value
NS : no significant variance

Despite of the inobservance of any significant effect and because of the deficiency of the method to evaluate woolly surfaces, we take the liberty of compare stations and cultivars for this defect (Figure 15 and 16). Considering cultivars, some tendencies appear allowing the establishment of 3 classes:

- Cultivars generating very few woolly surfaces (I 214; Dorskamp);
- Cultivars generating high quantities of woolly surfaces (Raspalje, Blanc du Poitou, Fritzi Pauley);
- Intermediate cultivars (Robusta, Flevo, Ghoy, I 45-5, Beaupré).

The quite high ratio of veneer affected by woolliness (65% of all the veneers measured) can be explained by the very high moisture content of the bolts before peeling because of a long storage of few months into a water tank. According to professionals, the defect increase with moisture content.

3.3 Thickness uniformity

First of all, it appears that veneer thickness maximum deviation never exceed 0.04 mm and 0.1 mm respectively for nominal thicknesses of 1.4 and 3 mm. These values are widely into the 5% range recommended by US Product Standard [12] andso peeling quality is very good whatever the cultivar and the station may be.

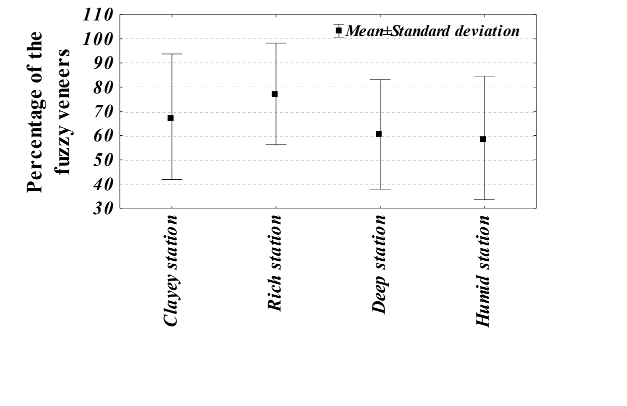

Figure 15: Variation of the fuzzy veneer percentage according to the station type.

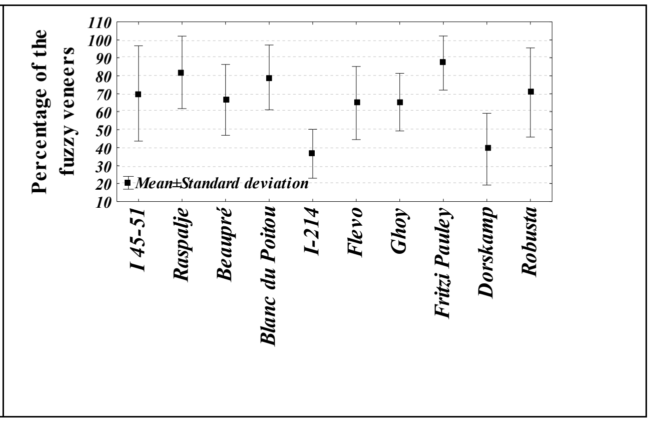

Figure 16: Variation of the fuzzy veneer percentage according to the cultivars.

Because the absolute value of the veneer thickness is here a less important quality requirement than its variability, we have calculated the thickness coefficient of variation (CoV) for each veneer sheet (Table 2). The ANOVA conducted on this criterion doesn't show any significant effect: the thickness variations are always very weak and there is obviously no cultivar, no station and no radial position effect when peeling poplar.

Table 2: *Results of ANOVA per nominal thicknesses for coefficient of variation of veneer thickness*

	1,4 mm					3mm				
	SS	DF	MS	F	P	SS	DF	MS	F	P
Station	1.15	3	0.38	0.17 NS	0.92	5.62	3	1.87	0.17 NS	0.92
Cultivar	1.26	9	0.14	0.06 NS	1.00	1.88	9	0.21	0.02 NS	1.00
Radius (Veneer position)	0.74	27	0.03	0.01 NS	1.00	0.83	27	0.03	0.00 NS	1.00
Station*Cultivar	4.79	27	0.18	0.08 NS	1.00	21.4	27	0.79	0.07 NS	1.00
Station*Radius	3.8	81	0.05	0.02 NS	1.00	3.83	81	0.05	0.00 NS	1.00
Cultivar*Radius	6.44	243	0.03	0.01 NS	1.00	10.98	243	0.05	0.00 NS	1.00
Station*Cultivar*Radius	27.18	729	0.04	0.02 NS	1.00	35.68	729	0.05	0.00 NS	1.00
Error	18066.71	7841	2.30			85278.82	7841	10.88		

SS : The sum of squares due to the source ; DF : Degrees of freedom in the source
MS : The mean sum of squares due to the source ; F : The F-statistic ; P : The P-value
NS : No significant variance

As can be seen in figure 17, mean thickness CoV is higher on 1.4 mm thick veneers (mean value = 3.85%) than on 3 mm thick ones (mean value = 2.54%). The dispersion of thickness CoV is also higher on thin veneers compared to thicker ones. These results are in accordance with those usually observed on homogeneous wood: the thinner the veneer is, and more difficult it is to maintain its thickness regularity [13]. The forces equilibrium between rake face and clearance face of the tool being more easily disturbed by local wood specificities (density, defects, …) when peeling thin veneer generating lower cutting forces.

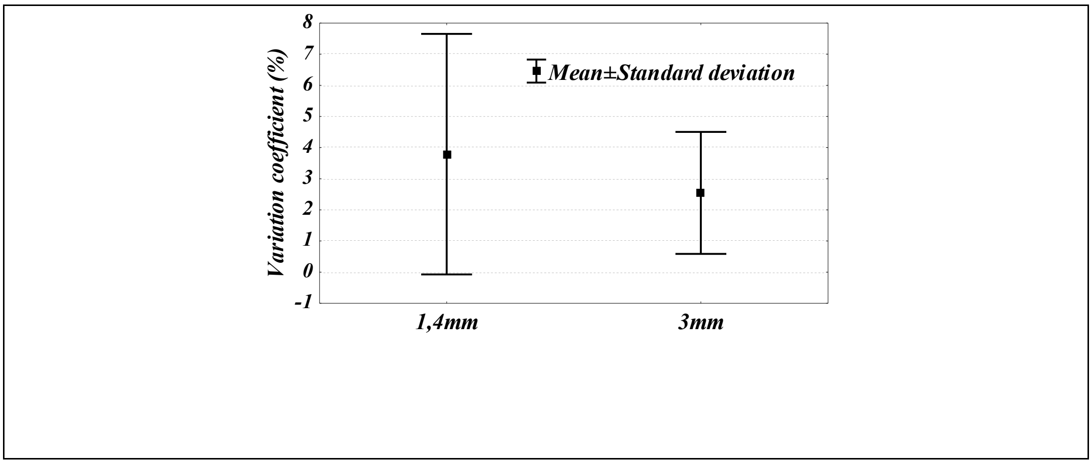

Figure 17: Evolution of the coefficient variation according to the nominal thickness.

3.4 Roughness

The ANOVA for roughness criterion just shows significant effects of station*cultivar interaction and of cultivar (Table 3). However these two effects just explain a very weak percentage of the total variance (3.4% compared to the 94.25% due to non-controlled factors). Cultivar classification change a bit with the stations (Figure 18). The mean roughness for all the cultivars is included into the range 124-330 mm of water. The inter-cultivars variability seems more marked in the clayey and rich stations. The veneers presenting the best surface quality whatever the station have been obtained with Blanc du Poitou, Beaupré, Raspalje and Fritzi Pauley.

On the whole, veneers are never very rough, even those presenting wooly surfaces. It could be due to the very thin vessels of poplar wood but also to an experimental bias introduced by using the "leakmeter".

Table 3:*Results of ANOVA for roughness.*

	SS	DF	MS	F	P	R^2
(1)Station	*279445*	*3*	*93148,30*	*0,85^{NS}*	*0,47*	*0,07*
(2)Cultivar	***2571437***	***9***	***285715,20***	***2,61****	***0,01***	***0,66***
(3)Nominal thickness	*17391*	*1*	*17391,50*	*0,16^{NS}*	*0,69*	*0,00*
(4)Radius (Veneer position)	*23020*	*6*	*3836,70*	*0,03^{NS}*	*1,00*	*0,01*
(5)Veneerside (Loose/Tight)	*8280*	*1*	*8280,30*	*0,08^{NS}*	*0,78*	*0,00*
Station*Cultivar	***10698639***	***27***	***396245,90***	***3,61******	***0,00***	***2,74***
Station* Nominal thickness	*115726*	*3*	*38575,30*	*0,35^{NS}*	*0,79*	*0,03*
Cultivar*Nominal thickness	*103404*	*9*	*11489,40*	*0,10^{NS}*	*1,00*	*0,03*
Station*Radius	*139144*	*18*	*7730,20*	*0,07^{NS}*	*1,00*	*0,04*
Cultivar*Radius	*504814*	*54*	*9348,40*	*0,09^{NS}*	*1,00*	*0,13*
Nominal thickness*Radius	*25516*	*6*	*4252,70*	*0,04^{NS}*	*1,00*	*0,01*
Station*Side	*6138*	*3*	*2045,90*	*0,02^{NS}*	*1,00*	*0,00*
Cultivar*Side	*65974*	*9*	*7330,50*	*0,07^{NS}*	*1,00*	*0,02*
Nominal thickness*Side	*1189*	*1*	*1189,20*	*0,01^{NS}*	*0,92*	*0,00*
Radius*Side	*21953*	*6*	*3658,90*	*0,03^{NS}*	*1,00*	*0,01*
Station*Cultivar*Nominal thickness	*802507*	*27*	*29722,50*	*0,27^{NS}*	*1,00*	*0,21*
Station*Cultivar*Radius	*1392231*	*162*	*8594,00*	*0,08^{NS}*	*1,00*	*0,36*
Station*Nominal thickness*Radius	*162329*	*18*	*9018,30*	*0,08^{NS}*	*1,00*	*0,04*
Cultivar*Nominal thickness*Radius	*523460*	*54*	*9693,70*	*0,09^{NS}*	*1,00*	*0,13*
Station*Cultivar*Side	*157652*	*27*	*5839,00*	*0,05^{NS}*	*1,00*	*0,04*
Station*Nominal thickness*Side	*26500*	*3*	*8833,40*	*0,08^{NS}*	*0,97*	*0,01*
Cultivar*Nominal thickness*Side	*19490*	*9*	*2165,60*	*0,02^{NS}*	*1,00*	*0,00*
Station*Radius*Side	*59833*	*18*	*3324,10*	*0,03^{NS}*	*1,00*	*0,02*
Cultivar*Radius*Side	*241619*	*54*	*4474,40*	*0,04^{NS}*	*1,00*	*0,06*
Nominal thickness*Radius*Side	*10356*	*6*	*1726,00*	*0,02^{NS}*	*1,00*	*0,00*
1*2*3*4	*2139536*	*162*	*13207,00*	*0,12^{NS}*	*1,00*	*0,55*
1*2*3*5	*142833*	*27*	*5290,10*	*0,05^{NS}*	*1,00*	*0,04*
1*2*4*5	*878903*	*162*	*5425,30*	*0,05^{NS}*	*1,00*	*0,22*
1*3*4*5	*109055*	*18*	*6058,60*	*0,06^{NS}*	*1,00*	*0,03*
2*3*4*5	*349038*	*54*	*6463,70*	*0,06^{NS}*	*1,00*	*0,09*
1*2*3*4*5	*893762*	*162*	*5517,10*	*0,05^{NS}*	*1,00*	*0,23*
Error	*368505641*	*3361*	*109641,70*			*94,25*

SS : The sum of squares due to the source ; DF : Degrees of freedom in the source
MS : The mean sum of squares due to the source ; F : The F-statistic ; P : The P-value
R^2: Coefficient of determination
****: Significant variance at 0,1% level.*
** : Significant variance at 5%.*
NS : Non significant variance

3.5 Lathe checking occurence

According to the ANOVA (Table 4), there is no significant effect for this defect. In fact, the mean values for the four stations are nearly the same as for the cultivars (Figure 19), whatever the nominal veneer thickness. The values of lathe checking criteria are always very low and around 20 mm of water. It is true that lathe check were never very pronounced even when peeling in 3 mm thick but, obviously, the method of measurement, although very convenient to quickly qualify a big number of veneers, must be improved.

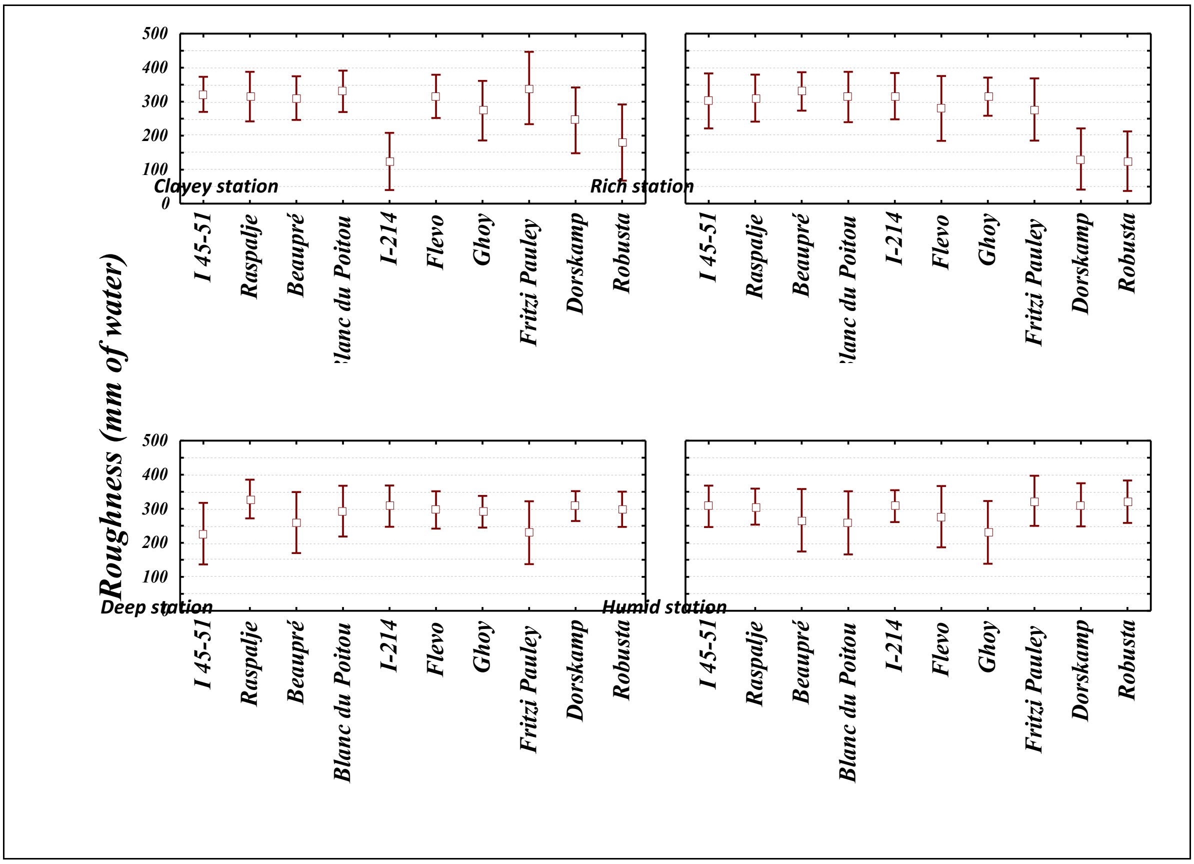

Figure18: Roughness variation according to the cultivars in the four stations.

Table 4: Results of ANOVA for lathe checking occurrence

	SS	*DF*	*MS*	*F*	*P*
(1)Station	*12267*	*3*	*4089,02*	*0,39*NS	*0,76*
(2)Cultivar	*131985*	*9*	*14664,95*	*1,42* NS	*0,18*
(3)Nominal thickness	*2383*	*1*	*2382,96*	*0,23* NS	*0,63*
(4)Veneer (Radial position)	*43877*	*6*	*7312,88*	*0,71* NS	*0,64*
Station*Cultivar	*315344*	*27*	*11679,42*	*1,13* NS	*0,30*
Station*Nominal thickness	*52965*	*3*	*17655,15*	*1,70* NS	*0,16*
Cultivar*Nominal thickness	*38963*	*9*	*4329,26*	*0,42* NS	*0,93*
Station*Veneer	*119664*	*18*	*6648,00*	*0,64* NS	*0,87*
Cultivar*Veneer	*483296*	*54*	*8949,93*	*0,86* NS	*0,75*
Nominal thickness*Veneer	*20709*	*6*	*3451,53*	*0,33* NS	*0,92*
Station*Cultivar*Nominal thickness	*285677*	*27*	*10580,62*	*1,02* NS	*0,43*
Station*Cultivar*Veneer	*1757546*	*162*	*10849,05*	*1,05* NS	*0,33*
Station*Nominal thickness*Veneer	*218094*	*18*	*12116,36*	*1,17* NS	*0,28*
Cultivar*Nominal thickness*Veneer	*698164*	*54*	*12928,95*	*1,25* NS	*0,11*
1*2*3*4	*1788031*	*162*	*11037,23*	*1,07* NS	*0,28*
Error	*17412252*	*1681*	*10358,27*		

SS : The sum of squares due to the source ; DF : Degrees of freedom in the source
MS : The mean sum of squares due to the source ; F : The F-statistic ; P : The P-value
NS : no significant variance

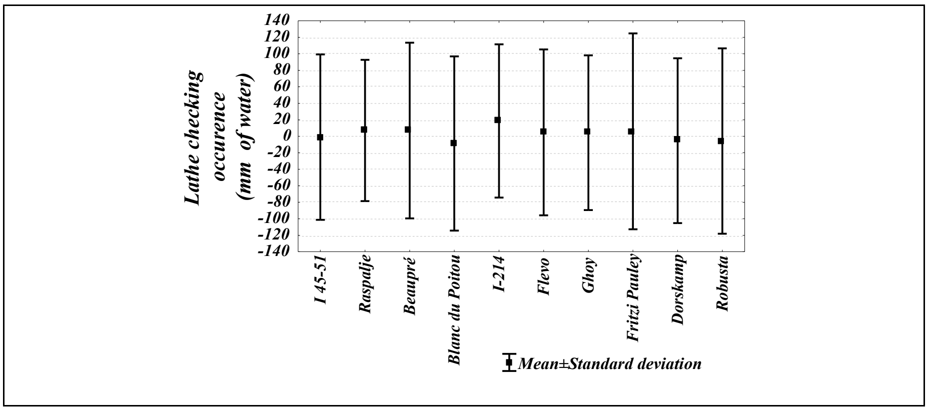

Figure 19: Variation of the lathe-checking occurrence according to the cultivars.

Conclusion

This study clearly shows that:

- It is not necessary to use specific peeling parameter for each cultivar: "poplar" settings are valid for all the cultivars.
- The quality of poplar veneers is always high, whatever the cultivar is
- No cultivar effect has been revealed both considering cutting forces or veneer quality, except for veneer roughness. No station effect has been detected for any veneer quality criteria but the more pronounced veneer defect is always "wolly surfaces".

However, these results should be considered carefully. They just show global tendencies, for two main raisons:

- The methods used for veneer quality assessment are perfectible, especially those developed for wooly surfaces, roughness and lathe checks measurements. New methodologies are under development using scanners;
- In order to obtain all the cultivar in the 4 stations, the logs should has been sampled in 13 different sites, inducing that in some case a "site effect" could have hidden "station effect".

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