ISSN 2176-5480

22nd International Congress of Mechanical Engineering (COBEM 2013)
November 3-7, 2013, Ribeirão Preto, SP, Brazil

INFLUENCE OF FORWARD SPEED AND GRANULOMETRY IN THE PROCESS OF TUBULAR SANDING OF THE WOOD *CORYMBIA CITRIODORA*

Demétrio Zacarias
Manoel Cléber de Sampaio Alves
Universidade Estadual Paulista/UNESP, Itapeva, São Paulo, Brazil.
manoel@itapeva.unesp.br

Fábio Henrique Antunes Vieira
Universidade Estadual Paulista/UNESP, Guaratinguetá, São Paulo, Brazil.
prof.fabio@live.com

Francisco Mateus Faria de Almeida Varasquim
Universidade Estadual Paulista/UNESP, Guaratinguetá, São Paulo, Brazil.
mateus1985@uol.com.br

Abstract. *As a method of surface preparation widely common in furniture industry, sanding precedes the coating process, whose function is to create uniform surfaces to evenly absorb the coating. The objective of this work is to analyze the average roughness and the consumed power during the tubular sanding of the wood Corymbia citriodora. Three forward speeds were used (13, 16 and 18 m/min), three sandpaper pairs with different granulometry (P80-P100, P80-P120 and P100 and P120) and one cutting speed (19,5m/s). The combination of sandpapers and forward speed had significant influence in the process. The set of sandpaper with low granulometry (P80-P100) provides a larger average roughness. It was also noticed that when the forward speed was increased, the average roughness was also increased. As to the consumed power there was not a uniform behavior.*

Keywords: *machining, sandpaper, roughness and consumed power.*

1. INTRODUCTION

Wood has become a high consumption material, especially the species from reforestation. As wood is an easy processing material, it can be used in construction, furniture industry, wood-based panels, shipbuilding, etc. It can be considered a heterogeneous material with different characteristics and properties within the same tree, and also from species to species. Due to this factor, the study of the sanding process for this material is complex and there is little research worldwide.

With the increasing demand of this material by logging industries, it is highly important to study the variables involved in the process of sawing and wood processing. The understanding of the processes enables optimal use of this material generating a better utilization and less waste.

In Brazil, the species *Corymbia citriodora* was introduced along with other species of Eucalyptus, with the initial objective of timber production. Nowadays, it is widely used for lumber production as well as production of charcoal, poles, fence posts and also great potential for using it in the furniture industry (VITTI, 2003).

The sanding process is one of the most common surface preparation methods in the furniture industry, which precedes the coating process. The purpose of sanding is to produce surfaces free of visible defects as well as create uniform surface to absorb the coating evenly (MOURA; HERNÀNDEZ, 2006). The properties and characteristics of the sanded surface differ from the surface obtained from planed. Sanding generates certain uniformity on the surface and reduces the influence of the anatomical structure of the wood that has vessels, pores and other geometric errors. Koch (1964) says that the sanding process should be divided into two labor stages. In the first stage (roughing) the wood should be prepared by reducing the surface roughness of the workpiece and the second one (sanding) prepares the wood for subsequent application of finishing materials.

The objective of this study was to analyze the results of roughness and consumed power in the process of tubular sanding of *Corymbia citriodora*, relating 3sandpaper grit sizes and 3 forward speeds.

2. THEORETICAL RATIONALE

The abrasive sanding process in the furniture industry remains one of the most "complex" processes, resulting in high cost. However, with the increased competition in the industry all over the world, which requires an increase in productivity, there seems to be a growing interest in wood sanding processes (RATNASINGAM and SCHOLZ, 2004).

There is little literature on wood sanding process worldwide, and there is no information on specific parameters in wood sanding and their interactions. Many industries use the same cutting parameters for different wood species. Gurau

ISSN 2176-5480

(2010) states that there are no approved guidelines in wood surface metrology on how to measure and objectively evaluate the surface quality. Also, there is no standard method and specific computer programs that are used only for wood.

When the machining of a workpiece is performed in a perpendicular to the fibers way, the finishing process becomes necessary, mainly if it is machined using a lathe. Then a tubular sanding machine is used for finishing. The tubular sanding, unlike the plane sanding, is done in parts with cylindrical shape, from a machining with perpendicular cut to the wood fibers. This type of sanding involves a cutting speed provided by the sanding rotation in heads, and it also has treadmills that when increasing its inclination angle, increases the forward speed of the cylindrical part. This type of sanding is often used for turnery parts, as furniture components and tool handles.

According to Gurau *et al.* (2004) the main method for evaluating the surface quality is the roughness. Therefore, the enhanced study of this effect of surface roughness leads to optimized process of sanding. A large number of roughness measurement methods have been standardized for homogeneous materials, which cannot be applied to wood, because it is considered a heterogeneous material. The factors that could affect these roughness values are the anatomy of wood and also ripples caused by machining.

The quality of wood products is the combination of textures through various processes such as cutting, planing and sanding the parts. The sanding process generally determines the finish quality of a workpiece. Hendarto *et al*. (2006) present in their work that the quality of wood products is frequently characterized by surface irregularities or by roughness. And that an effective method to analyze the roughness of the wood is limited by the fact that the effect of the anatomical structure is a long way from being fully investigated. The main reason is the difficulty of distinguishing surface irregularities caused by the machining and wood anatomy.

Due to the need for controlling the sanding process, methods are being developed relating the input variables (sandpaper granulometry, cutting speed and forward speed), where it is possible to control these values, obtaining output variables such as roughness, acoustic emission, power consumption, among others, enabling a better understanding of the sanding process, with the goal of optimization.

In another work, Varanda (2010), using a tubular sanding system, obtained results in which the sandpaper with P100 and P120 grain size, for roughing and finishing, respectively, resulted in values of average roughness inferior to other sets of used sandpapers (P80-P100, P80-P120). According to Aguilera and Martin (2001) if the parameters to achieve a particular roughness are known, and if machining is performed with lower cutting forces, the cutting power can be reduced.

Saloni *et al.* (2005) conducted a study which emphasizes that the variables that can influence the power consumption are: width of cut, depth of cut, rotation speed of the cutting tool, the number of knives, forward speed and cutting guidance. Other factors such as grinding and cutting conditions are related to the tool used in the process. Samolej and Barcik (2006) state that generally, the higher the sandpaper grain size, the greater is the cutting power, and this varies for perpendicular and parallel to the fibers cuts.

3. EXPERIMENTAL SECTION

3.1. Preparation of samples

The wood samples from *Corymbia citriodora* trees were collected with a minimum diameter of 50 cm, with a mean age of 35 years and were taken, mostly, from the heartwood of them, with dimensions, on average, of 35 mm in diameter and 1200 mm in length.

The specimens were classified diametrically in the range from 34.4 to 35.5 mm (Fig. 1a). Then the length was standardized in 600 mm (Figure 1b).

ISSN 2176-5480

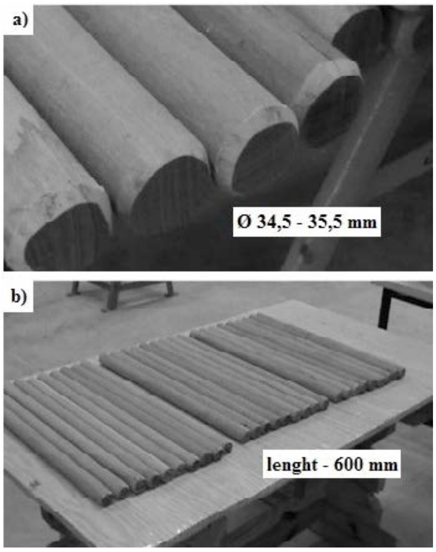

Figure 1. Preparation of the specimens.

Next, one end of the specimens was sanded, in a flat sander, eliminating edges, so that when subjected to sanding, it would avoid the breaking of sandpaper, as shown in Figure 1a.

The following step was to submit the specimens to the tubular sander with two P80 sanding weight (for roughing), to standardize the surface characteristics before the tests. After performing all the steps described earlier, the specimens were with uniform surface dimensions and characteristics, allowing the tests.

3.2. Conducting the tests

The test bench was composed of a double tubular sander with feed belt (Eagle™, model LPD 3200) a data acquisition central and control panel of the equipment, as shown in Figure 2a.

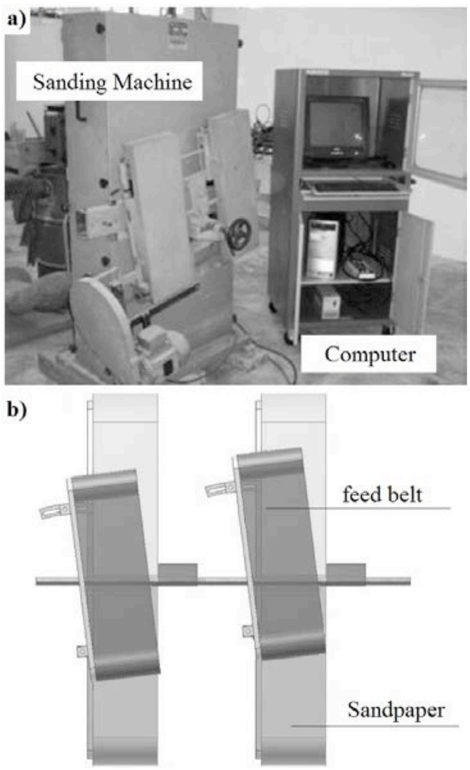

Figure 2. Test bench.

In the sanding process, abrasive aluminum oxide sandpapers were used, with granulometry P80, P100 and P120, in combinations P80-P100, P80-P120 and P100-P120 (the first sandpaper for roughing and the second one for finishing). Concerning the forward speeds the values of 13, 16 and 18 m/min were used. Figure 2b shows the traction system by rubber treadmill, with forward speed controlled by the inclination of it, which was measured with an optical tachometer.

To acquire the data of the consumed cutting power, a data acquisition system was performed consisting of a computer with National Instruments™ data acquisition board, model PCI-6220 and the Ward™ current transducer, model TRX-I/U, whose signal was captured by the data acquisition board and saved during the tests.

The data acquisition was performed using LabView™ software, version 7.1, and the data processing obtained in the tests was performed with Matlab™ software, version 6.5.

The experimental design was completely randomized in a factorial 3 x 3 x 3 (forward speeds x sandpaper sets x repetitions for each sanction) resulting in 27 trials. For the values obtained in real time, 200 points per second were acquired. These data were stored in files generated by LabView™ software and processed by handlers of Matlab™ software.

3.3. Physical testing and analysis of average roughness "Ra"

After the tests, the specimens were sectioned for the analysis of surface quality (roughness). From each specimen, three core samples were taken. Then, two of them were used for analyzes of basic and apparent density, and one of them was used for the measurement of roughness. The apparent density of the specimens was determined according to NBR 7190 (ABNT, 1997). The samples for measurement of roughness were carefully handled during the sectioning; avoiding beats that could affect the results of the roughness after sanding. They were subjected to measurement of surface roughness using a Taylor Robson™ rugosimeter, model Surtronic 25+.

The roughness parameter used was the average roughness "Ra", because it fits better when studying wood surface finishing (GURAU *et al.,* 2004), given that the sanding process does not produce periodic marks as in conventional machining processes (turning, milling, planing, etc.). The adopted sampling length was 2.5 mm (cut-off), according to the value suggested by NBR 6405 (ABNT, 1988). The length measurement (lm) for 2.5 mm cut-off was 12.5 mm, resulting in an average of five values obtained by measurement. The range adopted in the rugosimeter was 300 µm and the adopted filter was a Gaussian one.

Six measurements of average roughness (Ra) were performed for each specimen. Then the mean and standard deviation of 27 measurements were calculated, for each one of the nine combinations.

4. RESULTS AND DISCUSSIONS

Table 1 presents the average basic density (D_{bm}) and apparent (D_{apm}, 12%), with standard deviation (s.d.) and number of samples (N). The values found are similar to those found in the literature for Corymbia *citriodora*.

Table 1. Average basic and apparent density for *Corymbia citriodora*.

	D (kg.m-3)	s.d.	N
$D_{apm,12\%}$	959.07	136.76	30
D_{bm}	731.67	65.44	30

Table 2 shows the values of average roughness (Ra) obtained in microns (µm) for three forward speeds (F.S) and varying the sandpaper pairs with different granulometry (P80-P100, P80-P120, P100-P120). Analysis of variance was performed and Tukey test (α = .05).

Table 2. Obtained values of average roughness (Ra) in microns (µm).

	F.S. 13 m/min			F.S. 16 m/min			F.S. 18 m/min		
	80-100	80-120	100-120	80-100	80-120	100-120	80-100	80-120	100-120
Mean	7.87a	6.41b	6.31b	8.88a	7.18b	6.49b	8.44a	7.62ab	7.24b
s.d.	1.45	0.58	0.61	1.05	0.81	0.68	1.60	1.23	0.95

The pair of sandpapers that provided the highest values of average roughness was P80-P100. This is due to the fact of larger grains which machined the wood in a rougher way, causing greater "scratches". It was also observed that with the increased forward speed, there was also an increase on the value of the average roughness. With lower forward speed, the abrasive grains pass through the same point repeatedly, providing a more uniform surface.

Table 3 shows the obtained values of the consumed power in kilowatts (kW) for the 3 forward speeds with variations of the pairs of sandpaper with different granulometry. The analysis of variance and the Tukey test (α = .05) were performed.

Table 3. Obtained values of the consumed power in kilowatts (kW).

	F.S. 13 m/min			F.S. 16 m/min			F.S. 18 m/min		
	80-100	80-120	100-120	80-100	80-120	100-120	80-100	80-120	100-120
Mean	3.41a	2.27b	2.35b	3.71a	4.78b	4.20c	3.49a	3.75ab	4.27c
s.d.	0.09	0.15	0.14	0.15	0.29	0.07	0.14	0.47	0.07

Regarding the obtained values of consumed power, there was no uniform behavior with the variation of the pairs of sandpapers, but it was noticed that there was a significant influence on the variation of the granulometry.

5. ACKNOWLEDGEMENTS

This work was supported by CNPq, CAPES and FAPESP.

6. REFERENCES

Aguilera, A.; Martin, P., 2001. Machining qualification of solid wood of Fagus silvatica L. and Picea excelsa L.: cutting forces, power requirements and surface roughness. Holz als Roh – und Werkstoff, v.59, n.6, p.483-488.

Associação Brasileira de Normas Técnicas. NBR 7190: Projeto de estruturas de madeira. Rio de Janeiro, 1997.

Associação Brasileira de Normas Técnicas. NBR 6405: Rugosidades de superfícies. Rio de Janeiro, 1988.

Gurau, L., 2010. An objective method to measure and evaluate the quality of sanded wood surfaces. In: The Final Conference Of Cost Action, 53, Edinburgh.

Gurau, L.; Mansfield-Willians, H.; Irle, M., 2004. Processing roughness of sanded wood surface. Holz als Roh - und Werkstoff, v.63, n. 1, p. 43-52.

Hendarto, B.; Shayan, E.; Ozarska, B.; Carr, R., 2006. Analysis of roughness of a sanded wood surface. International Journal of Advanced Manufacturing Technology, v. 28, p. 775–780.

Koch, P., 1964. Wood Machining Process. New York: Ronald Press Company, 530p.

Moura, L. F.; Hernández, R. E., 2006. Effects of abrasive mineral, grit size and feed speed on the quality of sanded surfaces of sugar maple wood. Wood Science And Technology, Springer-Verlag, v. 40, n. 6, p.517-530.

Ratnasingam, J.; Scholz, F., 2004. Optimizing the abrasive sanding process of rubberwood (Hevea brasiliensis). Holz als Roh - und Werkstoff. v.62, n. 4, p. 411-418.

Saloni, D. E.; Lemaster, R. L.; Jackson, S. D., 2005. Abrasive machining process characterization on material removal rate, final surface texture, and power consumption for wood. Forest Products Journal, v.55, n. 12, p.35-52.

Samolej, A.; Barcik, S., 2006. Influence of Specific Pressure on Cutting Power and Wood Removal by Disc Sander. Drvna Industrija. v.57, n.1, p.5-11.

Varanda, L. D., 2010. Influência da Velocidade de Corte e da Granulometria das Lixas na Qualidade de Peças de Eucalyptus grandis Processadas Através do Lixamento Tubular. 83p. Trabalho de Conclusão de Curso (Graduação em Engenharia Industrial Madeireira) – Universidade Estadual Paulista do Campus de Itapeva.

Vitti, A. M. S. ; Brito, J. O., 2003. Óleo Essencial de Eucalipto. *Documentos Florestais*. Universidade de São Paulo – Escola Superior de Agricultura "Luiz de Queiroz". n.17.

7. RESPONSIBILITY NOTICE

The author(s) is (are) the only responsible for the printed material included in this paper.