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Roughness study on homogeneous layer panels manufactured from treated wood waste

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ABSTRACT. Natural resource exploration is growing, highlighting woods and joinery waste, wood industries and the like. This study presents homogeneous particleboard (PPH) roughness characterization manufactured from treated wood waste. Normative document with values of Brazilian Technical Standard Association ABNT NBR 8404 (1984), was adopted as a reference. The results show that the manufactured PPH showed roughness class N 10, with roughness values (Ra) of less than 12.5 microns.

Keywords: roughness, particleboard, wood, waste.

Estudo da rugosidade em painéis de camada homogênea fabricados com resíduos de madeira tratada

RESUMO. A exploração de recursos naturais é crescente, com destaque para os resíduos de florestas, de marcenarias, indústrias madeireiras e afins. Este estudo apresenta a caracterização de rugosidade de painéis de partículas homogêneos (PPH) fabricados com resíduos de madeira tratada. Adotou-se como referência o documento normativo com os valores da Associação Brasileira de Normas Técnicas, ABNT NBR 8404 (1984). Os resultados apresentados mostram que os PPH fabricados apresentaram classe de rugosidade N 10, com valores de rugosidade (Ra) inferiores a 12,5 μm.

Palavras-chave: rugosidade, painéis de partículas, madeira, resíduos.

Introduction

Kollmann, Kuenzi, and Stamm (1975), Maloney (1977) and American National Standards Institute A208.1 (ANSI, 1999) report that particleboard definition depends on particles types, board structure, resin and manufacture equipment. A wide sizes and shapes variety of raw materials and particles may be used.

Particleboard is manufactured from lignocellulosic materials (usually wood) with synthetic resin or other suitable resin and glued together under heat and pressure in a hot press. Others materials may be added during manufacture in order to improve certain properties. The standard *Associação Brasileira de Normas Técnicas* NBR 14810 (ABNT, 2013) defines medium density particleboard, with density between 551 and 750 kg m^{-3}, a panel manufactured from wood particles bonded with thermosetting synthetic resin, which are consolidated under action together of heat and pressure.

Wood-based panels have been widely used around the world in various segments of the timber industry. Thus, alternative raw materials, as various types of agro-industrial wastes, have been investigated like studies by (Ashori & Nourbakhsh, 2008; Girods et al., 2009; Guler, Copur, & Tascioglu, 2008; Fiorelli, Rocco Lahr, Nascimento, Savastano Junior, & Rossignolo, 2011; Fiorelli et al., 2012).

The standard *Associação Brasileira de Normas Técnicas* NBR ISO 4287 (ABNT, 2002) defines surface roughness and geometric parameters used in determining the roughness. The obtained profile parameter was the arithmetic mean deviation of the assessed profile, defined as Ra and expressed in microns (μm), according to the standard *Associação Brasileira de Normas Técnicas* NBR ISO 4287 (ABNT, 2002). Ra is the main parameter of the surface roughness profile.

By the importance of the roughness analyses in particleboards, this study proposed homogeneous particleboard (PPH) manufactured evaluation from

different densities and reutilizing treated wood waste to evaluate roughness after circular saw cuttings, it is important to study the roughness of the panels in the end of introduction

Material and methods

Shavings from *Eucalyptus* sp. and *Pinu*s sp. treated wood were classified as shown in Figure 1. The greater shavings dimension was 2.8 mm. The shavings were mixed with two resins: urea formaldehyde and castor oil based polyurethane. Panels were made with nominal thickness of 10 mm with nominal dimensions of 400 × 400 mm and densities of 0.6, 0.8 and 1.0 g cm^{-3}. In mixer supplies were homogenized and, at continuation, a mold received mixture which was transferred to hot press (Figures 1 and 2).

Figure 1. Shavings classification.

Figure 2. Mold, mattress and hot press.

Cutting methodology

Panels cutting methodology included as basis Brazilian standard *Associação Brasileira de Normas Técnicas* NBR 6162 (ABNT, 1989). Circular saws used are described in Table 1; PPHs cutting speed was 58.98 m min^{-1}., and forward speed per tooth in saws were Z48 = 0.35 mm; Z96 = 0.17 mm; Z108 = 1.55 mm. From Table 1, TS is the Saw type; D is the Saw diameter, Z is the Sooth number and TD is the Tooth types and angle.

Table 1: Circular saws for wear testing.

TS	D	Z	TD
	350	96	RT
Wide circular saw	350	48	ED
	350	108	RT

Cutting number consisted of 2040 strips (Figure 3), in different densities and resin utilized. Cutting were randomly selected and divided into groups of *Pinus* sp., *Eucalyptus* sp. and resins urea formaldehyde and castor oil based polyurethane. From selection was measured roughness with Taylor Robsow Surtronic equipment.

Roughness testing

Mean roughness is defined as absolute values arithmetic mean of removal ordered (yi), of roughness profile points in relation to mean line, within measurement pathway (lm). Specimens for this analysis presented 350 mm in length, with a width ranging from 100 to 120 mm. Roughness testings were performed at University of Sao Paulo State, Unesp, Itapeva *Campus*, as illustrated in Figure 4.

In Table 3 are described roughness values according to Brazilian standard *Associação Brasileira de Normas Técnicas* NBR 8404 (ABNT, 1984), which were used as results comparison parameters.

Statistical analysis

Factors and experimental levels investigated in obtaining cutting roughness values [Ra (μm)] of homogeneous particleboard manufactured were Wood Species [Specie], varying between *Pinus* (Pinus) and *Eucalyptus* (Euca.), and adhesive type [Adhes.], consisting of castor oil based polyurethane resin (PU) and urea formaldehyde (UF). Two levels of two factors combination resulted in a full factorial design with four treatments (Tr), clarified in Table 4.

For each of four experimental treatments delineated were manufactured 8 homogeneous particleboards, being removed two samples from each panel, in a total of 64 specimens tested in roughness cutting values (Ra) obtaining.

Figure 3. Strips cutting.

Figure 4. Rugosimeter device to verify roughness of PHPM.

Table 3. Roughness reference values in accordance with Brazilian standard *Associação Brasileira de Normas Técnicas* NBR 8404 (ABNT, 1984).

Roughness class	Roughness Ra (μm)
N12	50
N11	25
N10	12.5
N09	6.3
N08	3.2
N07	1.6
N06	0.8
N05	0.4
N04	0.2
N03	0.1
N02	005
N01	0.025

Table 4. Experimental treatments delineated in homogeneous particleboard manufacturing.

Treatments (Tr)	Specie		Adhesive	
	Pinus	*Eucalyptus*	PU	UF
Tr1	X		X	
Tr2	X			X
Tr3		X	X	
Tr4		X		X

In order to investigate isolated factors effect [Specie; Adhes.] and interaction between them [Specie × Adhes] on cutting roughness values was used variance analysis (ANOVA), considered at 5% significance level (α). Equivalency between treatment means was considered as null hypothesis (H_0), and no equivalence between means (at least two treatments) as alternative hypothesis (H_1). By ANOVA formulation, evaluated by Minitab® software version 14, P-value lower than significance level (P-value < 0.05) implies to reject null hypothesis (at least one treatments mean differs from the others), accepting it in otherwise (the treatments means are equivalent). To validate Anova were tested normality in cutting roughness values distribution, with help of Anderson-Darling test (AD), variance homogeneity with Bartlett (Bt) and Levene (Le) tests and waste independence by means of waste versus order graph.

Accused significance of isolated factors on cutting roughness values, in sequence was used multiple comparison Tukey test (contrast test between means) enabling to group factor significant levels. From Tukey test, A indicates highest mean group, B is the second highest mean group and so on, same letters implied treatments with equivalent means. In case of significant interaction between factors, interaction between factors graphic was used as an auxiliary way to interpret interaction effects.

Results and discussion

Table 5 shows mean values, variation coefficients (*CV*) along with smaller (Min.) and with bigger

(Max.) roughness values related to fabricated panels according four delineated experimental treatments.

Table 5. Results obtained from cutting roughness from fabricated panels according four delineated experimental treatments.

Treatments	Ra (μm)	CV (%)	Min. (μm)	Max. (μm)
Tr1	5.20	14.66	3.80	6.40
Tr2	6.15	13.94	4.80	7.53
Tr3	5.98	17.14	4.20	8.80
Tr4	6.68	20.50	4.53	9.73

Rolleri and Roffael (2010) studied the surface roughness of particleboards produced from wood particles and urea formaldehyde resin and obtained Ra roughness values in the range of 5.2 to 11.2 μm. Their roughness results are similar to this study.

Tabarsa, Arshorie, and Gholamzadeh (2011) evaluated the roughness of particleboard made with sugarcane bagasse and urea formaldehyde resin and found roughness Ra of between 10 and 25 μm. The roughness results reported by these authors are superiors to those found in this study.

Varanda, Alves, Gonçalves, and Santiago (2010) evaluated the roughness of *Eucalyptus grandis* wood pieces submitted to sanding and found an average roughness value of 7.4 μm, after sanding. The results of Varanda et al. (2010) are similar to the results of this study roughness.

Statistical analysis positive results obtained were demonstrated. Figure 5 shows cutting roughness mean values graph from four experimental treatments investigated.

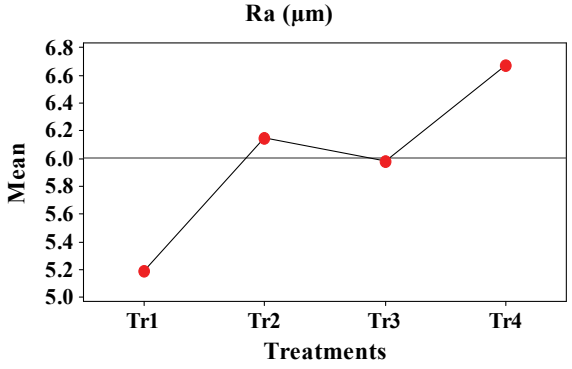

Figure 5. Cutting roughness mean values of manufactured panels. Tr1 - *Pinus* wood and PU adhesive; Tr2 - *Pinus* wood and UF adhesive; Tr3 - *Eucalyptus* wood and PU adhesive; Tr4 - *Eucalyptus* wood and UF adhesive.

Figure 6 presents Anova tests validation results on cutting roughness values. By means of P-values (> 0.05) found for both tests, cutting roughness values have normal distribution, variances homogeneity and waste independence, validating Anova model.

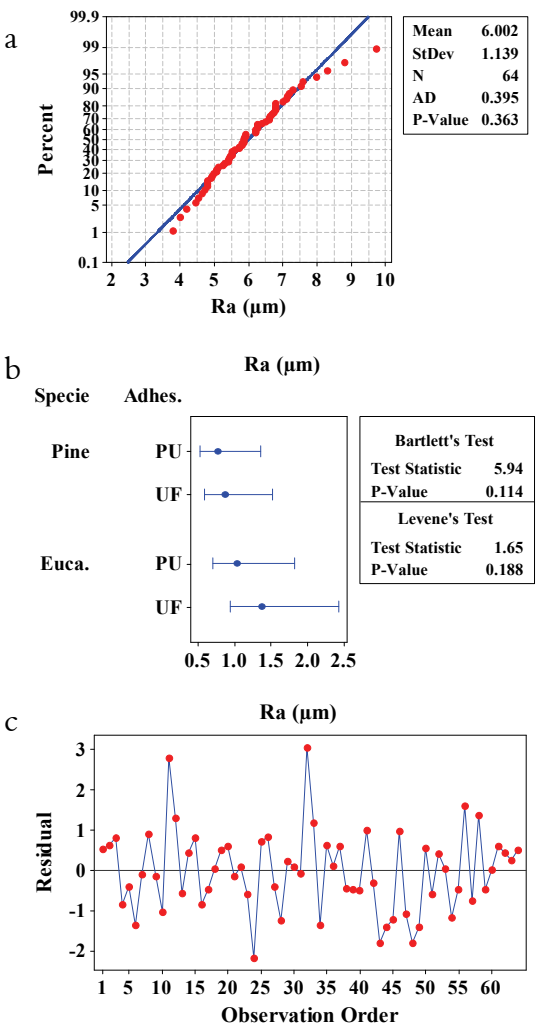

Figure 6. Anova validation test results of cutting roughness values: normality test (a), variance homogeneity test (b) and waste independence (c).

Table 6 shows Anova results on panel cutting roughnesses values, where DF represents freedom degrees, Seq SS squares sum, Adj SS the set squares sum, Adj MS set mean square and F Fisher's statistics.

Table 6. Anova results on the cutting roughnesses values.

Source	DF	Seq SS	Adj SS	Adj MS	F-value	P-value
Specie	1	6.910	6.910	6.910	6.51	0.013
Adhes.	1	10.898	10.898	10.898	10.27	0.002
Specie×Adhes.	1	0.277	0.277	0.277	0.26	0.611
Error	60	63.644	63.644	1.061		
Total	63	81.730				

As observed in Table 6, the two individual factors were significant on panels cutting roughness values, same did not occur with the interaction between them, considered not significant by Anova. Table 7 presents tukey's test results of two factors considered significant, where $\bar{x}$ is the mean and *Ag.* groups formed.

Table 7: Tukey's test results on panels cutting roughness values.

Stat.	Specie		Adhesive	
	Pinus	*Eucalyptus*	PU	UF
Ra (μm) - $\bar{x}$	5.67	6.33	5.59	6.42
Ag.	B	A	B	A

From tukey's test results in Table 6, regarding wood species, *Eucalyptus* provided the greatest cutting roughness values, and with respect to adhesive, urea formaldehyde showed superior behavior compared to castor base polyurethane resin. Figure 7 shows graphs of the two factors main effects considered significant on the cutting roughness values.

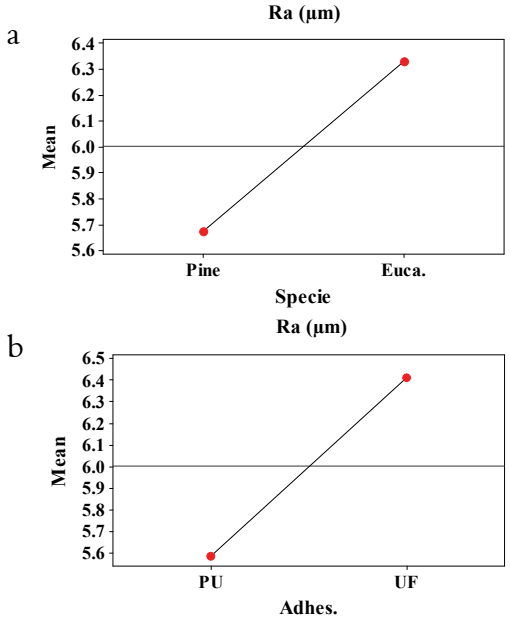

Figure 7. Graphs of Main effects on roughness values: wood species (a) and adhesive type (b).

Conclusion

Results obtained of this research allow concluding that:

- individual factors Specie and Adhesive were significant on roughness values of particleboards. The interaction between factors was considered not significant by Anova;

- particleboards produced with *Pinus* sp. particles presented roughness values (5.67 μm) lower than particleboards produced with *Eucalyptus* sp. particles (6.33 μm);

- particleboards produced with castor oil base polyurethane resin presented roughness values (5.59 μm) lower than particleboards produced with urea-formaldehyde resin (6.42 μm);

- Particleboards produced with urea-formaldehyde resin showed worse surface finish (Ra roughness greater value), still showed environmental problems in the use of this formaldehyde-based resin;

- roughness values of panels manufactured according to four experimental treatments delineated showed roughness class N 10, with roughness values (Ra) of less than 12.5 microns, according to *Associação Brasileira de Normas Técnicas* NBR 8404 (ABNT, 1984).

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References

Associação Brasileira de Normas Técnicas [ABNT]. (1984). *NBR 8404. Indicação do estado de superfícies em desenhos técnicos*. Rio de Janeiro, RJ: Associação Brasileira de Normas Técnicas.

Associação Brasileira de Normas Técnicas [ABNT]. (2013). *NBR 14810. Painéis de partículas de média densidade*. Rio de Janeiro, RJ: Associação Brasileira de Normas Técnicas.

Associação Brasileira de Normas Técnicas [ABNT]. (1989). *NBR 6162. Movimentos e relações geométricas na usinagem dos metais*. Rio de Janeiro, RJ: Associação Brasileira de Normas Técnicas.

Associação Brasileira de Normas Técnicas [ABNT]. (2002). *NBR ISO 4287. Especificações geométricas do produto (GPS) – Rugosidade: Método do perfil. Termos, definições e parâmetros*. Rio de Janeiro, RJ: Associação Brasileira de Normas Técnicas.

American National Standards Institute [ANSI]. (1999). *A208.1. Standard for particleboard.* Gaithersburg, US: American National Standards Institute.

Ashori, A., & Nourbakhsh, A. (2008). Effect of press cycle time and resin content on physical and mechanical properties of particleboard panels made from the underutilized low-quality raw materials. *Industrial Crops and Products, 28*(2), 225-230.

Fiorelli, J., Curtolo, D. D., Barrero, N. G., Savastano Junior, H., Pallone, E. M. J. A., & Johnson, R. (2012). Particulate composite based on coconut fiber and castor oil polyurethane adhesive: An eco-efficient product. *Industrial Crops and Products, 40*, 69-75.

Fiorelli, J., Rocco Lahr, F. A., Nascimento, M. F., Savastano Junior, H., & Rossignolo, J. A. (2011). Painéis de partículas à base de bagaço de cana e resina de mamona: produção e propriedades. *Acta Scientiarum.Technology, 33*(4), 401-406.

Girods, P., Dufour, A., Fierro, V., Rogaume, Y., Rogaume, C., Zoulalian, A., & Celzard, A. (2009). Activated carbons prepared from wood particleboard wastes: Characterization and phenol adsorption capacities. *Journal of Hazardous Materials, 166*(1), 491-501.

Guler, C., Copur, Y., & Tascioglu, C. (2008). The manufacture of particleboards using mixture of peanut hull (*Arachis hypoqaea* L.) and European Black pine (*Pinus nigra* Arnold) wood chips. *Bioresource Technology, 99*(8), 2893-2897.

Kollmann, F. P.; Kuenzi, E. W.; & Stamm, A. J. (1975). *Principles of wood science and technology: wood based materials* (Vol. 2). New York, US: Springer-Verlag.

Maloney, T. M. (1977). *Modern particleboard & dry-process fiberboard manufacturing*. San Francisco, US: Miller Freeman Publications.

Rolleri, A., & Roffael, E. (2010). Influence of the surface roughness of particleboards and their performance towards coating. *Ciencia Y Tecnologia, 12*(2), 143-148.

Tabarsa, T., Ashori, A., & Gholamzadeh, M. (2011). Evaluation of surface roughness and mechanical properties of particleboards panels made from bagasse. *Composites: Part B, 42*(5), 1330-1335.

Varanda, L. D., Alves, M. C. S., Gonçalves, M. T. T., & Santiago, L. F. F. (2010). A influência das variáveis do lixamento tubular na qualidade de peças de *Eucalyptus grandis*. *Cerne, 16*(supl.), 23-32.

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