THE EFFECT OF FULL-CELL IMPREGNATION OF PINE WOOD (*PINUS SYLVESTRIS* L.) ON THE FINE DUST CONTENT DURING SAWING ON A FRAME SAWING MACHINE

Kazimierz A. Orlowski[1] – Daniel Chuchala[1] – Ladislav Dzurenda[2]

Abstract

In this paper the results of the analysis of the effect of the impregnation treatment of pine wood on the granularity of sawdust from the sawing process on the frame sawing machine PRW 15M are presented. Granulometric analyses of chips from impregnated and unimpregnated pine wood implies that the impregnation of pine wood does not affect the size and structure of the sawdust produced. A major ≈ 95% share of the formed chips is the coarse and thick coarse fractions at a grain range of 125 μm to 2 mm. The slight difference is in the fraction of the fine fraction with a particle size of 32 - 125 μm. While the share of pine wood sawdust of unimpregnated wood is between 0.48 and 0.8%, and of the impregnated wood pine wood is 0.68 - 1.1%. This fact does not affect the efficiency of separation in fabric filters and the technological use of sawdust in the production of briquettes and pellets.

Key words: *sawdust, impregnation of wood, pine wood, sawing process, frame sawing machine*

INTRODUCTION

The increasing interest in sawdust, as a secondary raw material, in the last years, requires a proper specification of its physical properties as follows: granularity, geometric shapes and size of sawdust chips. The shape, dimensions and amount of chips depend on the form, physical and mechanical properties of the sawed wood (Beljo Lučič et al. 2009; Dzurenda et al. 2009; Dzurenda et al. 2010; Dzurenda and Orlowski 2010, 2011, 2011 a, Fujimoto et al. 2011), as well as on the shape, dimensions, and sharpness of the cutting blade, technical and technological conditions of the sawing process (Dzurenda et al. 2006; Hlásková et al. 2016; Pałubicki and Rogoziński 2016). On the contrary, Marková et al. (2018) examined granularity and size of sawdust chips not from the point of view of the further technological processes, however, they were interested in thermal parameters of beech wood dust.
Sawdust is characterized as poly-dispersion bulk material consisting of coarse and medium-coarse fractions (Hejma et al. 1981; Dzurenda 2009), i.e. bulk material with dimensions of grain over 0.3 mm, while the share of fine fractions with smaller dimensions of chips is not excluded. According to the classification parameters of bulk material described in STN 26 0070 standard, sawdust is classified as B-45UX, i.e. bulk material of fine granularity (0.5-3.5 mm), hygroscopic, low crisp and abrasive material with a tendency to crowd.

[1]Gdansk University of Technology, Narutowicza 11/12, 80-233 Gdansk, Poland
e-mail: korlowsk@pg.edu.pl, danchuch@pg.edu.pl
[2]Technical University in Zvolen, T. G. Masaryka 24, 960 53 Zvolen
e-mail: ladislav.dzurenda@tuzvo.sk

The full-cell impregnation of pine wood (*Pinus sylvestris* L.) influenced the resistance values and the accuracy of moisture content measurements (Konopka et al., 2018). For that reason, the aim of this work is to analyze the effect of the impregnation treatment of pine wood on sawdust granularity during the sawing process conducted on the frame sawing machine PRW15–M.

MATERIALS AND METHODS

Materials

The material used in the experiments was pine wood (*Pinus sylvestris* L.) impregnated and not impregnated. The wood to be used in the impregnation experiments (wood blocks b = 50 mm × H_p = 50 mm × L_p = 500 mm) was initially dried in industrial conditions until the relative moisture content was near the FSP. Next, they were full-scale impregnated in an autoclave in the industrial conditions. The impregnation process lasted 120 min, and the level of retention was 1.0 $dm^3/(m^3 \cdot min)$. The impregnation method is based on the technique that has been described in detail by Babiński (1992), called full-cell impregnation. The blocks were placed in the impregnation solution under atmospheric pressure. The first impregnation phase lasted 25 min in a vacuum of -0.8 bar. Thereafter, a pressure of 10 bar was maintained for 55 min. After a second impregnation phase when the pressure was reduced to atmospheric, the surplus of impregnation solution was removed from the autoclave. The final impregnation step, during of which the impregnation solution is sucked out of the lumens, was carried out in a vacuum of -0.8 bar and lasted 40 min (Konopka et al. 2018). A preservative KORASIT KS2 (Kurt Obermeier Gmbh&Co KG, D) which is chracterised as a water soluble, liquid, fixative, chromate and boron free wood preservative based on copper complex compounds and a highly effective quaternary ammonium compound, was applied. Concentrate and solution of Korasit KS2 have a deep blue colour. Nevertheless, impregnated wood takes on an olive green hue. The solution can be stained with Korasit® colour pastes. The concentration of the impregnate was 3.8 %.

The other blocks in the same dimensions (58 mm × 58 mm × 500 mm) were not impregnated.

Machine tool and tools

Tests were performed on the frame sawing machine PRW15M (Fig. 1) with a hybrid dynamically balanced driving system and elliptical teeth trajectory movement (Wasielewski and Orlowski, 2002) at the Department of Manufacturing Engineering and Automation (GUT, PL). The machine settings were as follows: number of strokes of saw frame per min (n_F), 685 spm; saw frame stroke (H_F), 162 mm; number of saws in the gang (n), 5; and average cutting speed (v_c), 3.69 $m \cdot s^{-1}$. The saw blades were sharp, with stellite tipped teeth: overall set (kerf width) (S_t), 2 mm; saw blade thickness (s), 0.9 mm; free length of the saw blade (L_0), 318 mm; tension stresses of saws in the gang (σ_N), 300 MPa; blade width (b), 30 mm; tooth pitch (P), 13 mm; tool side rake (γ_f), 9°; and tool side clearance (α_f), 14°. The only varying cutting parameter was feed speed, which was applied at two levels: $v_{f1} \approx 0.9$ $m \cdot min^{-1}$ and $v_{f2} \approx 1.72$ $m \cdot min^{-1}$. This corresponds to a feed per tooth (f_z) of ~0.105 mm and ~0.2 mm, respectively. Lamellae with thicknesses of 5 ± 0.2 mm were obtained as a result of the re-sawing process. The actual value of the feed per tooth were computed on the basis of the sawing time taken from the plots of time changes of electrical power consumption (Fig.2). The mean value of feed per tooth for a sash gang saw is calculated as:

$$\bar{f}_z = \frac{1000 \cdot v_f \cdot P}{n_{RP} \cdot H_{RP}} \qquad (1)$$

where: strokes number of the frame n_{RP} = 685 1/min, stroke of the frame H_{RP} = 162 mm, P = 13 mm is a tooth pitch, and v_f in m· min^{-1} is calculated as:

$$v_f = \frac{L_p}{60 t_c} \qquad (2)$$

where: L_p is length of the sample in m, and t_c is the real cutting time taken from the plot, e.g. Fig. 2.

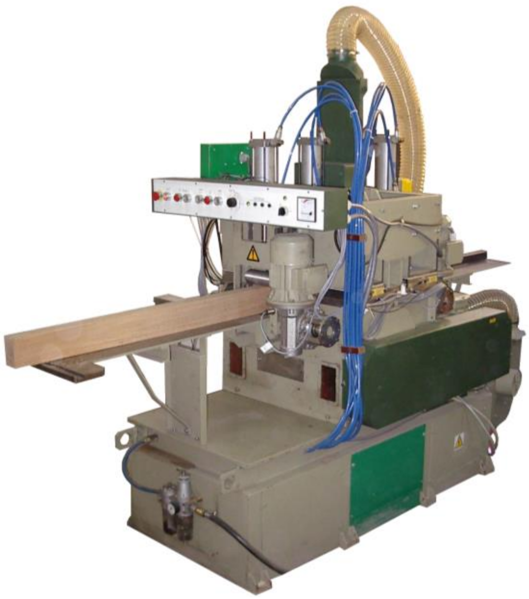


Figure 1. Narrow-kerf frame sawing machine (sash gang saw) PRW15–M

Sawdust collection and sieve analyses

For granulometric analyses, samples of pine sawdust (natural, not impregnated) and impregnated pine sawdust were taken isokinetically from the exhaust pipe of a frame sawing machine PRW-15 in accordance with a standard ISO 9096.

The moisture content of both types of dust samples was MC = 10%, and was determined by the weight method.

Sieve analysis was carried out on an automated vibratory screening machine Retsch AS 200 control; a set of control stainless steel sieves, diameter of sieve 200 mm, height 50 mm, diameter of sieve mesh 2 mm, 1 mm, 0.50 mm, 0.25 mm, 0.125 mm, 0.080 mm, 0.063 mm, and 0.032 mm. The residues on each sieves and bottom were weighed on a digital laboratory balance EP 200 (f. BOSCH) to an accuracy of 0.001 g. The sieving parameters were an amplitude 2 mm/(g), with an interval of 10 s, and a time of 20 min.

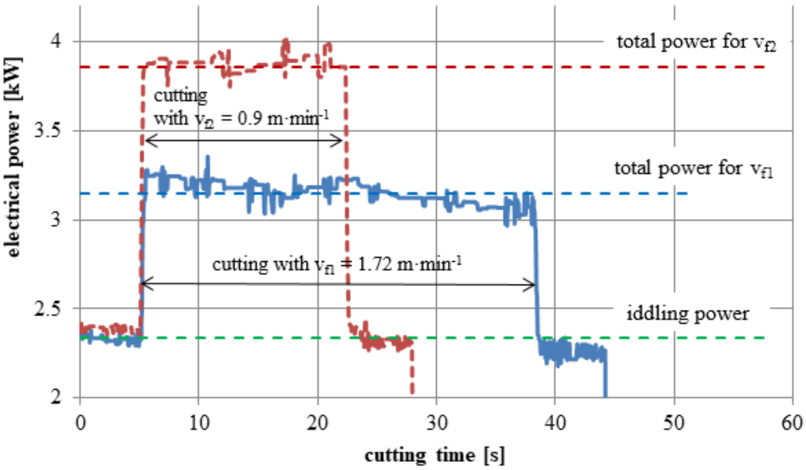


Figure 2. Time changes of electrical power consumption while sawing at two levels of feed speed v_{f1} and v_{f2} of impregnated samples

RESULTS AND ANALYSES

In Table 1 the symbols of samples, values of feed speeds v_f and feed per teeth f_z, which were used in the tests, are presented. The results of the sieve analysis - size distribution of the dry chips of untreated pine sawdust and dry impregnated pine are given in Table 2.

Table 1. Symbols of samples, feeding parameters and types of raw material

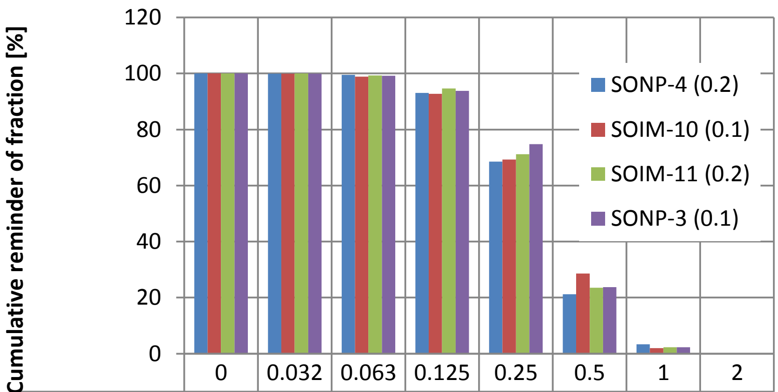
Symbol	feed speed v_f	feed per tooth f_z	kind of raw material
	$m \cdot min^{-1}$	mm	
SOIM-10	0.901	0.1058	impregnated
SOIM-11	1.717	0.2052	impregnated
SONP-3	0.898	0.1055	not impregnated
SONP-4	1.719	0.2049	not impregnated

Table 2. Granulometric analysis of sawdust from unimpregnated and impregnated and pine wood

Measure of sieve mesh [mm]	Mark of fraction	Representation of fractions in dry pine wood [%]			
		pine not impregnated wood		pine impregnated wood	
		SONP-3	SONP-4	SOIM - 10	SOIM - 11
2.000	coarse	2.29	3.31	1.97	2.26
1.000		21.44	17.87	26.61	21.29
0.500	medium coarse	51.02	47.38	40.68	47.70
0.250		19.11	24.47	23.49	23.36
0,125		5.34	6.47	6.15	4.71
0.063	fine	0.77	0.47	1.08	0.68
0.032		0.03	0.01	0.02	0.00
< 0.032		0.00	0.00	0.00	0.00

The majority ≈ 95% of the chips produced are thick and the chip share of the coarse fraction in the particle size range 125 microns to 2 mm. The slight difference is in the fraction of the fine fraction with a particle size of 32 - 125 μm. While the share of pine wood sawdust of unimpregnated wood is between 0.48 and 0.8%, whereas of the impregnated wood pine wood is 0.68 - 1.1%.

Figure 2 presents the cumulative histogram residue granularity plots of sawdust obtained during the sawing process of not impregnated and impregnated pine wood.



	0	0.032	0.063	0.125	0.25	0.5	1	2
SONP-4 (0.2)	100	99.99	99.52	93.03	68.56	21.18	3.31	0
SOIM-10 (0.1)	100	99.99	98.91	92.76	69.27	28.59	1.98	0
SOIM-11 (0.2)	100	100	99.32	94.61	71.25	23.55	2.26	0
SONP-3 (0.1)	100	99.97	99.2	93.86	74.75	23.73	2.29	0

Mesh size, mm

Figure 2. Histograms of residue of sawdust while sawing on the sash gang saw PRW15M, where: a) not impregnated pine, b) impregnated pine. Legend: close to the samples symbols in parentheses values of feed per tooth are provided

The obtained results show that the impregnation process practically does not affect the sawdust grain size when sawing on the frame sawing machine PRW-15M in the examined feed rate range. A slightly higher proportion of fine fraction of pine wood impregnated wood does not affect the efficiency of separation in fabric filters and the technological use of sawdust, e.g. for the production of briquettes and pellets.

CONCLUSIONS

Based on the carried out analyses, it can be concluded that:

- firstly, the sawdust of both the unimpregnated pine wood and impregnated pine wood, created in the sawing process on a frame sawing machine PRW15-M at a feed speed of v_f = 0.9-1.72 m·min^{-1}, consists of ≈ 95% of the chips with a grain size within the range from 125 μm to 2 mm;
- secondly, the slight difference is in the fraction of fine fraction with a particle size of 32 - 125 μm.
- eventually, the obtained results revealed that the impregnation process practically does not affect the sawdust granularity when sawing on the sash gang saw PRW-15M in the examined feed rate range; does not affect the efficiency of separation in fabric filters and the technological use of sawdust, e.g. for the production of briquettes and pellets.

ACKNOWLEDGMENTS

The authors would like to acknowledge Mr. Piotr Taube from the company Sylva Ltd. Co. in Wiele, Poland, for supplying materials for this work.

REFERENCES

BELJO LUČIČ, R., ČAVLOVIČ, A., DUKIČ, I., JUG, M., IŠTVANIČ, J., ŠKALJIČ, N., 2009. Machining propertirs of thermally modified beech-wood compared to steamed beech-wood. In: Woodworking technique. DENONA, Zagreb: 315-324.

BABIŃSKI, L. K., 1992. Impregnacja drewna metodą próżniową. Ochrona Zabytków 45/4(179): 360-368. (in Polish).

DZURENDA, L., WASIELEWSKI ,R., ORLOWSKI, K., 2006. Granulometric analysis of dry sawdust from the sawing process on the frame sawing machine PRW15M = Granulometrická analýza suchej piliny z procesu pílenia borovicového dreva na rámovej píle PRW-15M// Acta Facultatis Xylologiae Zvolen. -Vol. 48., nr 2 (2006):51-57.

DZURENDA, L., 2009. Sypká drevná hmota, vzduchotechnická doprava a odlučovanie. V-TU, Zvolen.

DZURENDA, L., ORLOWSKI, K., GRZEŚKIEWICZ, M., PAULINY, D., 2009. Sawdust size distribution analysis of thermally modified and unmodified oak wood sawed on the frame sawing machine PRW15-M// Annals of Warsaw University of Life Sciences-SGGW Land Reclamation. -., nr. Nr 68.

DZURENDA L., ORLOWSKI K., GRZEŚKIEWICZ M., 2010. Effect of thermal modification of oak wood on sawdust granularity = Utecaj termicke modifikacije na granulometrijski sastav piljevine// Drvna Industrija.Vol. 61., iss. 2.

DZURENDA, L., ORLOWSKI, K. (2010): Vplyv modifikácie dubového dreva technólogiou thermo-wood na zrnistosŤ piliny z procesov pilenia dreva na rámovej pile PRW 15M// W The 7th International Science Conference : Chip and Chipless Woodworking Processes 2010 : Proceedings of papers, September, 9-11. 2010, Terchová./ Zvolen: Technická Univerzita vo Zvolene, pp. 69-75

DZURENDA, L., ORŁOWSKI, K., 2011. The effect of thermal modification of ash wood on granularity and homogeneity of sawdust in the sawing process on a sash gang saw PRW 15-M in view of its technological usefulness. Drewno, Vol. 54, nr 186.

DZURENDA L., ORŁOWSKI K., 2011a. Influence of feed rate on the granularity and homogenity of oak sawdust obtained during the sawing process on the frame sawing machine PRW15M// Proceedings of the 4th International Science Conference Woodworking Techniques/ ed. Barcik S., Dvorak J. - Czech University of Life Sciences Prague, Univ Zagreb. Prague: Czech University of Life Sciences Prague, Czech Republic.

FUJIMOTO, K., TAKANO, T., OKUMURA, S., 2011. Difference in mass concentration of airborne dust during circular sawing of five wood-based materials. J Wood Sci 57: 149-154. https://doi.org/10.1007/s10086-010-1145-y

HEJMA, J. et al., 1981. Vzduchotechnika v dřevozpracovávajícím průmyslu. SNTL, Praha.

HLÁSKOVÁ, L., ROGOZINSKI, T., KOPECKÝ, Z., 2016. Influence of feed speed on the content of fine dust during cutting of two-side-laminated particleboards. Drvna Ind 67 (1): 9-15 (DOI: 10.5552/drind.2016.1417)

KONOPKA, A., BARAŃSKI, J., ORŁOWSKI, K., SZYMANOWSKI, K., 2018. The effect of full-cell impregnation of pine wood (Pinus sylvestris L.) on changes in electrical

resistance and on the accuracy of moisture content measurement using resistance meters. BioRes. 13(1): 1360-1371. (DOI: 10.15376/biores.13.1.1360-1371)
MARKOVÁ, I., LADOMERSKÝ, J., HRONCOVÁ, E., MRAČKOVÁ, E.,2018. Thermal parameters of beech wood dust. BioRes. 13(2), 3098-3109. (DOI: 10.15376/biores.13.2.3098-3109).
PAŁUBICKI, B., ROGOZIŃSKI, T., 2016. Efficiency of chips removal during CNC machining of particleboard. WOOD RESEARCH, Vol. 61, Number 5: 811-818.
WASIELEWSKI R., ORŁOWSKI K., 2002. Hybrid dynamically balanced saw frame drive. Holz als Roh- und Werkstoff 60(3):202–206.(DOI: 10.1007/s00107-002-0290-4).
KORASIT KS2 , 2017.
https://www.kora-holzschutz.de/fileadmin/assets/produkte/Technische-Merkblaetter_Englisch/Korasit_KS2_TM_CLP_2017-02_EN.pdf (accessed on 23 May, 2018).
ISO 3310-1, 2007. Test sieves. Technical requirements and testing. Part 1: Test sieves of metal wire cloth. International Organization for Standardization, Geneva, Switzerland.
ISO 9096: 2017. Stationary source emissions – Manual determination of mass concentration of particulate matter.
STN 26 0070, 1995. Klasifikácia a označovanie sypkých hmôt dopravovaných na dopravných zariadeniach. (In Slovak: Clasification and symbolization of bulk material transported on conveyor equipment).