TRIESKOVÉ A BEZTRIESKOVÉ OBRÁBANIE DREVA 2024

CHIP AND CHIPLESS WOODWORKING PROCESSES 2024

Vedecký časopis // Scientific journal

TECHNICKÁ UNIVERZITA VO ZVOLENE // TECHNICAL UNIVERSITY IN ZVOLEN
DREVÁRSKA FAKULTA // FACULTY OF WOOD SCIENCES AND TECHNOLOGY
KATEDRA OBRÁBANIA DREVA // DEPARTMENT OF WOODWORKING

Technická univerzita vo Zvolene // Technical University in Zvolen
Drevárska fakulta // Faculty of Wood Sciences and Technology
Katedra obrábania dreva // Department of Woodworking

TRIESKOVÉ A BEZTRIESKOVÉ OBRÁBANIE DREVA 2024

CHIP AND CHIPLESS WOODWORKING PROCESSES 2024

Vedecký časopis // Scientific journal

drevársky kongres

Trieskové a beztrieskové obrábanie dreva (ISSN 2453-904X (print), ISSN 1339-8350 (online)) je vedecký časopis uverejňujúci recenzované pôvodné vedecké práce, z oblasti technického a technologického výskumu trieskového delenie a obrábanie dreva, procesu tvorby triesky, kvality vytváraného povrchu a fyzikálno-mechanických vlastnostiach triesky. Súčasťou zamerania časopisu je i problematika termickej a hydrotermickej úpravy drevnej hmoty teplom a realizácie týchto procesov. Časopis vychádza s dvojročnou periodicitou v elektronickej a printovej forme.

Chip and chipless woodworking processes (ISSN 2453-904X (print), ISSN 1339-8350 (online)) is a scientific journal publishing the reviewed original scientific works focusing on the technical and technological research of chip separation and wood processing, the process of making chips, the quality of created surface as well as the physico-mechanical chips characteristics. The journal focuses also on the issue of thermal and hydrothermal modification of the wood pulp by heat and how these processes are realized. The journal is published in a twoyear periodicity in an electronic and a print form.

Redakcia/Editorial office
Technická univerzita vo Zvolene/ Technical university in Zvolen
Drevárska fakulta/ Faculty of Wood Sciences and Technology
Katedra obrábania dreva/ Departmen of Woodworking
T. G. Masaryka 24
960 01 Zvolen

Vydavateľ/Publisher
Technická univerzita vo Zvolene/Technical university in Zvolen,
T. G. Masaryka 24
960 01 Zvolen, IČO 00397440, 2024
Náklad (Circulation) 80 výtlačkov, rozsah (Pages) 220 strán
Tlač (Printed by) Vydavateľstvo Technickej univerzity vo Zvolene.
Vydanie I. – september
Periodikum s periodicitou raz za dva roky. Za vedeckú úroveň tejto publikácie zodpovedajú autori.

ISSN 2453-904X (print), ISSN 1339-8350 (online)

CONTENTS

CHIP AND CHIPLESS WOODWORKING PROCESSES, 14(1): 135–142, 2024
Zvolen, Technical University in Zvolen, ISSN 1339-8350 (online), ISSN 2453-904X (print)

COMPARISON OF PARTICLES FROM THE SANDING PROCESS OF SPRUCE AND OAK ON A NARROW BELT SANDER

Martin Kučerka – Lukáš Adamčík – Martin Júda – Richard Kminiak – Alena Očkajová

Abstract

The paper deals with the microscopic analysis and comparison of particles from the sanding process of spruce and oak on a narrow belt sander. The values of all sizes obtained from the microscope measurements ranged over a wide range of all sizes between 3-1000 μm. Chips with sizes < 100.0-10.0 μm were the most prevalent, accounting for 50% and 47% of the total sizes present in the oak and spruce samples, respectively. The presence of chips <10.0 μm in size was present in oak samples 37% and in spruce samples 33% of the total number of chips. Chips of larger sizes were present in 13 % of the oak samples and 20 % of the spruce samples. The study of sizes below <10.0 μm showed that, based on medians, the most frequently occurring splinter size was 5.43 μm diameter for both species equally. In both samples, the sizes ranged from 3.43 to 9.71 μm. The study of dimensions below <100.0-10.0 μm showed that the most frequently occurring dimensions based on medians were chips with a diameter of approximately 30 μm for oak and chips with a diameter of approximately 28 μm for spruce.

Key words: *oak, spruce, microscopic analysis, sanding process, narrow belt sander*

INTRODUCTION

Sanding wood is a seemingly simple process, but there is a complex science behind it. It involves interesting processes that lead to the formation of chips and dust, which also affects the final surface of the wood (ČistéDrevo.sk 2023). When wood is sanded, abrasive particles are used to remove material from the surface of the wood. These particles on the sanding belt move across the surface of the wood to cut away small pieces of wood (Sydor et al. 2021). The size of these fragments depends on the type of abrasive material, its grain size and the force of pressure exerted on the abrasive tool. Splinters are larger fragments of wood that are produced when sanding with coarser grits or when too much pressure is applied. They can vary in shape and size from small flakes to coarser-grained wood particles. Wood sanding dust is made up of fine wood particles that are removed from the surface (Chuchala et al. 2024). Its volume and composition depend on the type of wood, the sanding material and the grain size. Dust can pose a health hazard, so it is important to use personal protective equipment when sanding.

Matej Bel University, Tajovského 40, 974 01 Banská Bystrica
Technical University in Zvolen, T. G. Masaryka 24, 960 01 Zvolen
e-mail: martin.kucerka@umb.sk; xadamcikl@is.tuzvo.sk; xjuda@is.tuzvo.sk; alena.ockajova@umb.sk; richard.kminiak@tuzvo.sk;

Wood sanding is a widely used process in the woodworking industry, employed to smooth out the surface of wood and prepare it for finishing, painting, or other applications. Despite its widespread use, the mechanics of wood sanding remain not fully understood, and the optimization of this process is still an active area of research. The quality of the finished surface produced by sanding is heavily dependent on a complex interplay of factors, including the type and grit of sandpaper used, the pressure and speed of sanding, and the properties of the wood itself (Meraj 2023; Jenkins 2023). Recent studies have shown that the properties of wood can play a significant role in determining the effectiveness of sanding (Adamčík et al. 2023). For example, woods with higher densities tend to be more resistant to abrasion and require more aggressive sanding techniques (Čunderlík 2009). Additionally, the presence of defects such as knots or splits can significantly affect the sanding process and impact the quality of the finished surface (Gaff et al. 2015; Barcík et al. 2014). Despite these challenges, advancements in sanding technology have led to significant improvements in efficiency and quality (Sydor et al. 2021; Rogoziński 2018; Rogozinski a Dolny 2004). The development of new types of sandpaper, such as diamond-coated and ceramic-coated papers, has enabled more effective removal of wood fibers and improved surface finish (Warguła et al. 2023). Furthermore, advances in robotics and automation have enabled more precise control over the sanding process, allowing for improved consistency and reduced waste (Jenkins 2023).

Sanding is basically the work of several cutting wedges (sanding grains) working in a groove. The basic strength properties of the wood involved in chip formation are bending strength (when the chip is bent by the cutting wedge face), tension along the grain (on the inside of the chip - facing the cutting wedge face) and pressure along the grain (on the outside of the chip), tension perpendicular to the grain in front of the cutting edge in the case of longitudinal cutting (sanding), and shear strength is also involved in some way.

Many authors are focused on parameters that influence granularity and shape of created particles. They point out particles smaller than 0.1 mm - hazardous for working environment, particles smaller than 0.01 mm - hazardous for working staff. Among the observed parameters belong processed material - hard and soft wood (Dzurenda a Očkajová 2003; Očkajová et al. 2006), juvenile wood, thermally modified wood (Dzurenda et al. 2010), frozen and unfrozen wood, way of machining - sawing, planning, sanding (Porankiewicz et al. 2010), cutting conditions, feed speed, tool geometry (Očkajová et al. 2006), cutting direction (Dzurenda et al. 2008).

In this paper, we analyzed and compared particles by microscopic analysis from the sanding process of coniferous (spruce) and deciduous (oak) wood on a narrow belt sander. We found that chips with sizes <100.0-10.0 μm were the most prevalent, accounting for 50% and 47% of the total sizes present in the oak and spruce samples, respectively. The presence of chips with size <10.0 μm was present in oak samples 37% and in spruce samples 33% of the total number of chips. The study of sizes below <10.0 μm showed that, based on medians, the most frequently occurring size of splinters was 5.43 μm diameter equally for both tree species. In both samples, the sizes ranged from 3.43 to 9.71 μm. The study of dimensions below <100.0-10.0 μm showed that the most frequently occurring dimensions based on medians were chips with a diameter of approximately 30 μm for oak and chips with a diameter of approximately 28 μm for spruce. The final objective is to evaluate the results obtained in terms of the sanding on the narrow belt sander and the type of wood species.

MATERIAL AND METHODOLOGY

Experimental samples
For analyzing the dimensions of dust particles, two species of wood were used - Norway spruce (*Picea abies* L.) and summer/winter oak (*Quercus petraea*) with an equilibrium moisture content of 8 to 10%. The dust particles were taken from the sanding process with a belt sander with P80 grit. The fraction was subsequently subjected to particle size analysis.

Machinery
Narrow belt sander JET JSG-96, cutting speed 10 $m \cdot s^{-1}$, sanding belt HIOLIT XO P80 sanding belt grit 80, individual pressure of the wood sample on the sanding belt, laboratory experiments. A sharp sanding belt was used for each wood species.

Digital particle analysis
Dust particles from the collected fraction were analyzed by optical method on a Keyence VHX-7000 digital microscope. The particles were uniformly deposited on a slide that can be placed in XYθ a motorized stage in the microscope. The uniformity of particle deposition was achieved by applying the particles with a laboratory double-sided spoon to a sieve that was placed over the slide and then passing them through a 125 μm mesh. This methodology avoided coagulation of the small dust particles during their deposition on the glass (the coalescence of the particles under the microscope would have made it impossible to analyses the particles individually). Subsequently, a 10 × 10 mm area was scanned at 100× objective magnification. The analysis on the VHX-7000 microscope works on the principle of illuminating the slide with dust particles using a high-intensity bottom illumination. The size of the particles and their area is then digitally calculated based on the different brightness of the particle (dark, opaque, casting a shadow across the objective, which is recorded by the digital camera) and the surroundings (transparent glass). Two main particle dimensions were determined as part of the analysis: the maximum diameter (the largest dimension of the particle in two-dimensional XY space) and the minimum diameter (the smallest dimension of the particle in two-dimensional XY space). In addition, particle area, circumference and circularity were also analyzed. These data were then processed with the statistical software STATISTICA 14 (TIBCO Software Inc., Palo Alto, California), using descriptive statistics (arithmetic mean, standard deviation, maximum and minimum values). The total number of scans for oak and spruce wood was 30. A total of more than 62 000 pieces of dust particles were analyzed.

RESULTS AND DISCUSSION

In the first step, the outliers of the measurement were removed, and the measurement was repeated. Subsequently, descriptive statistics were performed, in which the following data were determined: average maximum diameter, average minimum diameter and slimness ratio as the ratio between the maximum diameter and the minimum diameter. Tab. 1 shows that the spruce chips were larger in sample. The slimness ratio also indicates that the spruce chip has a more elongated shape, i.e., the maximum diameter (length) is larger.

Table 1 Average dimensions and slimness ratio for oak and spruce chips. The data in parentheses represent the standard deviation

Type of Wood	Average Max. Diameter [μm]	Average Min. Diameter [μm]	Slimness Ratio
Oak	41,07 (55,02)	22,20 (30,4)	1,85
Spruce	56,19 (73,47)	25,90 (35,3)	2,17

The analysis of individual dust particles was then carried out using a digital microscope. Based on the established methodology, the microscope divided the particles into fractions over 100 micrometers, under 100 micrometers and under 10 micrometers. For each fraction, the average values of the maximum diameter and the minimum diameter as well as the slimness ratio were again measured (Tab. 2). The table shows that the length of the chip (expressed by the maximum diameter) is greater in each fraction for spruce wood. At the same time, the slimness ratio within the individual fractions is again proof that spruce chips are longer than oak chips.

Table 2 Average dimensions and slimness ratio for oak and spruce chips in individual sieved fractions. The data in parentheses represent the standard deviation

Type of Wood	Size range [μm]	Average Max. Diameter [μm]	Average Min. Diameter [μm]	Slimness Ratio
Oak	>100.0	157,25 (63,60)	85,22 (33,6)	1,85
Oak	<100.0	38,06 (25,36)	20,85 (16,2)	1,82
Oak	<10.0	5,54 (1,89)	2,53 (1,1)	2,19
Spruce	>100.0	178,73 (72,02)	79,62 (40,2)	2,24
Spruce	<100.0	39,06 (27,13)	19,26 (17,3)	2,03
Spruce	<10.0	5,65 (1,91)	2,51 (1,1)	2,26

Analyzing data of sizes for normality with the Shapiro-Wilk test showed a non-normal distribution. Due to the non-homogeneity of variance, the standard parametric ANOVA tests cannot be used. Thus, the nonparametric analysis of variances Kruskal-Wallis one-way ANOVA was used. The presented numbers were calculated based on the confidence factor of 95%. The presented results were calculated with the statistic software STATISTICA 14 (TIBCO Software Inc., Palo Alto, California).

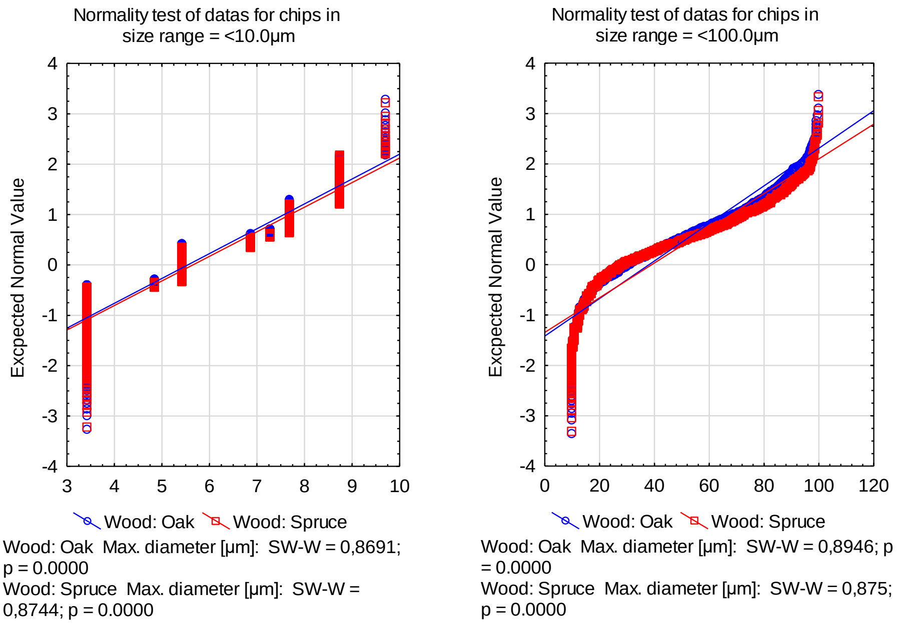

Fig. 1 Test for normality of dates for sizes in size range <10μm and <100μm for Oak and Spruce samples

Obtained values of all sizes from automatic measurement by microscope ranged widely across all sizes in between 3-1000μm. For easier interpretation and fitting to article aims here we used size ranges by <10.0μm, by <100.0μm, and by size range >100.0μm. Size range <10.0μm representing all sizes between <10.0-0.0μm, <100.0-10.0μm representing all sizes below <100.0-10.0μm and size range >100.0μm represents all chip sizes above this size limit. This chip size range distribution is shown in a histogram, which represents size ranges and their percentual distribution by numerical observed chip sizes obtained by digital automatic microscope measuring.

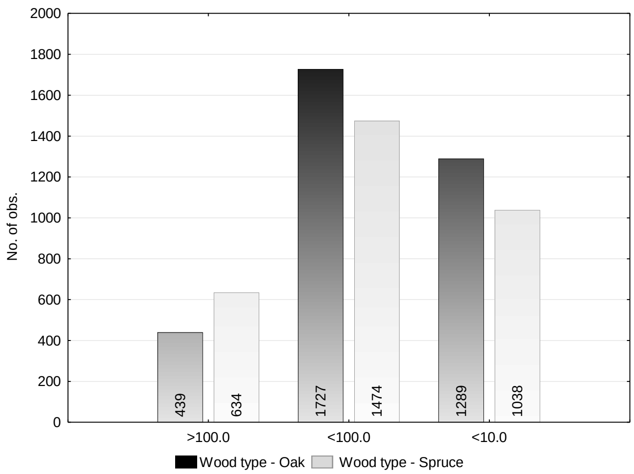

Fig. 2 Chip size distribution by size ranges with respect to total present amounts of sizes

Histogram is showing the observed number in analyzed screen of sizes. Based on observed results the most distributed chips were in sizes <100.0-10.0µm, which for Oak samples presented by 50% and in Spruce samples by 47% of the total present sizes. The presence of chips in sizes <10.0µm were present in Oak samples by 37% and in Spruce samples by 33% from the total chip sizes. The chips of higher sizes were found by 13% in Oak samples and by 20% in Spruce samples. Comparing those percentual results based on post-hoc test showed differences on p level for <10.0µm (p=0.3) and for <100.0µm (p=0.7). These results pointing on difference, but without significant differences and thus, based on obtained results samples showed there is no significant difference between the content of chips in sizes <100.0µm and <10.0µm between Oak and Spruce wood.

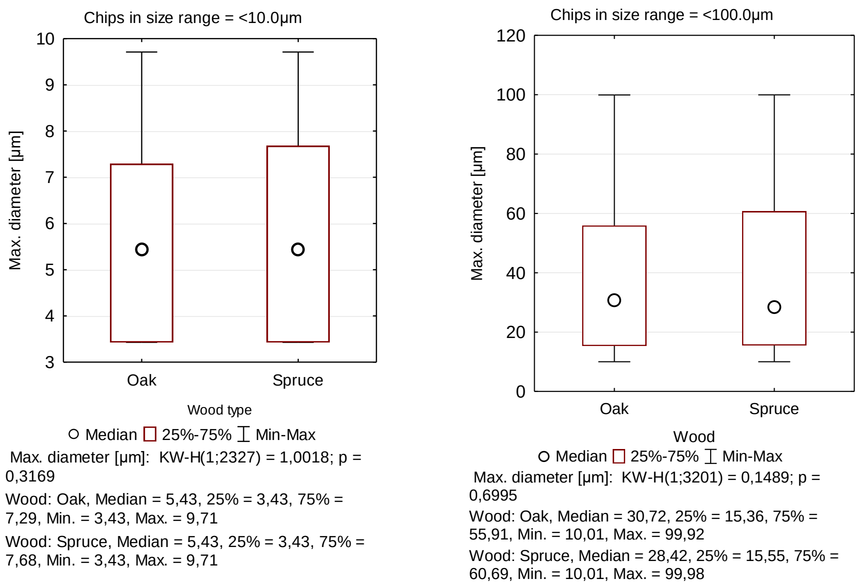

Fig. 3 Difference in amounts of chips in size <100.0-10.0µm and <10.0-0.0µm for oak and spruce

Studying the sizes below <10.0µm showed that based on medians most occurring size of chips is diameter size 5,43µm equally for both materials. In both samples the sizes ranged from 3,43-9,71µm. Studying the sizes below <100.0-10.0µm showed that most occurring size based on medians were chips for Oak wood in approximately diameter of size 30µm and for Spruce wood chips approximately in diameter of size 28µm.

CONCLUSION

The results show that microscopic analysis of particles from the sanding process of spruce and oak wood on a narrow belt sander yielded interesting findings. The particle size values obtained ranged over a wide range from 3 to 1000 µm. Particle sizes <100.0-10.0 µm were the most frequent, accounting for 50 % and 47 % of the total sizes present in the oak and spruce samples, respectively. Splinters smaller than 10.0 µm accounted for 37 % of oak samples and 33 % of spruce samples. Larger chips were present in 13 % of the oak samples and 20 % of the spruce samples. The average size of chips below 10.0 µm was the same for both species, 5.43 μm. Dimensional analysis below <100.0-10.0 μm showed that the most common sizes were approximately 30 μm for oak and 28 μm for spruce.

Acknowledgments: This experimental research was carried out under the grant project VEGA 1/0323/23 "Vplyv vybraných faktorov na kvalitatívno-kvantitatívne charakteristiky drevného prachu v pracovnom ovzduší pri opracovaní dreva elektrickým ručným náradím "

LITERATURE

ADAMČÍK, Lukáš, Richard KMINIAK, Michal DUDIAK a Adrian BANSKI, 2023. The Impact of Abrasive Grit Size on Roughness of Sanded Beech Wood Surface. Annals of WULS, Forestry and Wood Technology [online]. 2023, roč. 121, s. 51–60 [cit. 15.7.2024]. ISSN 1898-5912, 2719-6518. Dostupné na: doi:10.5604/01.3001.0053.8636

BARCÍK, Š., M. GAŠPARÍK, A. HOUSKA, E. RAZUMOV a M. SEDLECKÝ, 2014. Vliv technologických faktorů na kvalitu opracování povrchu při frézování termicky modifikovaného dřeva. V: Chip and Chipless woodworking processes: Trieskové a beztrieskové obrábanie dreva. Zvolen: Technická univerzita vo Zvolene, s. 11–22. ISBN 978-80-228-2658-7.

ČISTÉDREVO.SK, 2023. Ako na správne brúsenie dreva | ČistéDrevo.sk. cistedrevo.sk [online] [cit. 15.7.2024]. Dostupné na: https://www.cistedrevo.sk/navody/ako-na-spravne-brusenie-dreva/

ČUNDERLÍK, Igor, 2009. Štruktúra dreva [online]: Zvolen: Technická univerzita vo Zvolene [cit. 19.10.2021]. ISBN 978-80-228-2061-5. Dostupné na: https://www.library.sk/arl-sldk/sk/detail-sldk_un_cat-0038328-struktura-dreva/

DZURENDA, L., M. KUČERKA a A. BANSKI, 2008. Vplyv techniky na kvalitu deleného a obrábaného dreva. 1. vyd. Zvolen: Technická univerzita vo Zvolene. 2/2008/B. ISBN 978-80-228-1923-7.

DZURENDA, Ladislav a Alena OČKAJOVÁ, 2003. Rozmerová analýza drevného prachu smreka, borovice a duba z procesu rovinného brúsenia. V: Obrábanie a spájanie dreva. Zvolen: ES TU, s. 53–57. ISBN 80-228-1270-6.

DZURENDA, Ladislav, Kazimierz A. ORLOWSKI a M. GRZESKIEWICZ, 2010. Effect of Thermal Modification of Oak Wood on Sawdust Granularity. Drvna Industrija [online]. 2010, roč. 61, č. 2, s. 89–94 [cit. 15.7.2024]. Dostupné na: https://drvnaindustrija.com/archive/volume-2010-issue-2/effect-of-thermal-modification-of-oak-wood-on-sawdust-granularity/

GAFF, M., M. KVIETKOVA, M. GASPARIK, L. KAPLAN a Š. BARCIK, 2015. Effect of Selected Parameters on the Surface Waviness in Plane Milling of Thermally Modified Birch Wood. Bioresources. 2015, roč. 10, č. 4, s. 7618–7626. ISSN 1930-2126.

CHUCHALA, Daniel, Tomasz ROGOZIŃSKI, Kazimierz A. ORLOWSKI, Marta PĘDZIK, Luďka HANINCOVÁ a Olafur EGGERTSSON, 2024. Granulometric characterization of Arctic driftwood sawdust from frame sawing process. Industrial Crops and Products [online]. 2024, roč. 213, s. 118448 [cit. 4.4.2024]. ISSN 09266690. Dostupné na: doi:10.1016/j.indcrop.2024.118448

JENKINS, Steve, 2023. Sanding wood: What you need to know to get the best finish. Homebuilding & Renovating [online] [cit. 15.7.2024]. Dostupné na: https://www.homebuilding.co.uk/advice/sanding-wood

MERAJ, Md, 2023. How to Sand Wood: Expert Tips for Perfect Finish. Wood Working Advisor [online] [cit. 15.7.2024]. Dostupné na: https://woodworkingadvisor.com/how-to-sand-wood/

OČKAJOVÁ, Alena, 1999. Sand belt running time and its wear. 1999, s. 9–13.

OČKAJOVÁ, Alena, Adrián BANSKI a Ján RONČKA, ed., 2006. Dust in Woodworking Plants and Possibilities of its Reducing. V: Alena OČKAJOVÁ, Adrián BANSKI a Ján RONČKA, ed. Jubilee Scientific Conference: Manufacturing Engineering in Time of Information Society. Gdansk: Gdansk University of Technology, s. 255–260. ISBN 83-88579-61-4.

OČKAJOVÁ, Alena, Martin KUČERKA, Richard KMINIAK, Ľuboš KRIŠŤÁK, Rastislav IGAZ a Roman RÉH, 2020. Occupational Exposure to Dust Produced when Milling Thermally Modified Wood. International Journal of Environmental Research and Public Health [online]. 2020, roč. 17, č. 5, s. 1478 [cit. 11.4.2021]. ISSN 1660-4601. Dostupné na: doi:10.3390/ijerph17051478

OČKAJOVÁ, Alena, Mikuláš SIKLIENKA a Štefan BARCÍK, 1999. Physico-mechanical phenomenons in sanding process of natural and modified wood. V: Proceedings of the 14 th International Wood Machining Seminar Paris, Epinal, Cluny. s. 691–700. 12-19. September. ISBN 978-2-87614-362-3.

PORANKIEWICZ, Boleslaw, Adrian BANSKI a Grzegorz WIELOCH, 2010. Specific resistance and specific intensity of belt sanding of wood. BioResources [online]. 2010, roč. 5, č. 3, s. 1626–1660 [cit. 19.10.2021]. ISSN 1930-2126. Dostupné na: https://ojs.cnr.ncsu.edu/index.php/BioRes/article/view/BioRes_05_3_1626_Porankiewicz_BW_Spec_Resist_Belt_Sanding

ROGOZINSKI, T. a S. DOLNY, 2004. Influence of moisture content on the apparent densities of dust from sanding of alder wood. V: Trieskové a beztrieskové obrábanie dreva ´04. Zborník prednášok z MVK. s. 205–208.

ROGOZIŃSKI, Tomasz, 2018. Pilot-scale study on the influence of wood dust type on pressure drop during filtration in a pulse-jet baghouse. Process Safety and Environmental Protection [online]. 2018, roč. 119, s. 58–64 [cit. 19.10.2021]. ISSN 0957-5820. Dostupné na: doi:10.1016/j.psep.2018.07.016

SYDOR, Maciej, Radosław MIRSKI, Kinga STUPER-SZABLEWSKA a Tomasz ROGOZIŃSKI, 2021. Efficiency of Machine Sanding of Wood. Applied Sciences [online]. 2021, roč. 11, č. 6, s. 2860 [cit. 15.7.2024]. ISSN 2076-3417. Dostupné na: doi:10.3390/app11062860

WARGUŁA, Łukasz, Dominik WILCZYŃSKI, Bartosz WIECZOREK, Teijo PALANDER, Łukasz GIERZ, Carla NATI a Maciej SYDOR, 2023. Characterizing Sawdust Fractional Composition from Oak Parquet Woodworking for Briquette and Pellet Production. Advances in Science and Technology. Research Journal [online]. 2023, roč. 17, č. 5, s. 236–247. ISSN 2080-4075, 2299-8624. Dostupné na: doi:10.12913/22998624/172534