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Chip grain size from the process of machining steamed and unsteamed alder wood on a cnc machining center and assessment of separation results

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Abstract: The paper discusses the particle size of the chips formed in the process of machining unsteamed and steamed alder wood on a CNC machining center. From the granulometric analysis of the chips, it follows that the average share of the coarse fraction of the chips created from unsteamed alder wood is 66.0% and steamed alder wood is 62.9%. The representation of medium-coarse fractions of alder wood with dimensions of 1.0-0.125 μm in unsteamed wood is 29.5% and steamed by 32.7%. Dust fractions with dimensions below 125 μm in unsteamed alder wood account for 4.5% and in steamed alder wood 4.4%. Chips of non-steamed or steamed alder wood with dimensions below 32 μm were not measured, so it can be concluded that no respirable dust particles with dimensions below < 10 μm are formed. Changes in the physical and mechanical properties of steamed alder wood are manifested by a decrease in the coarse fraction above 2 mm and an increase in the fraction of chips 0.125 to 2000 μm. For the separation of chips, both unsteamed and steamed alder wood, from the transport air, fabric filters and filter fabric Finet PES 4 are suitable, the separation limit of which is smaller than the size of the smallest chips formed in the milling process: a_{MO} = 7 μm <<< amin = 32 μm.

Key words: *alder wood, steaming, CNC machining center, granulometric composition of chips, filter technique.*

INTRODUCTION

CNC woodworking technologies have become an integral part of the woodworking industry. The range of CNC machines used is wide, and CNC machining centers are among the most used in secondary wood processing operations. The chip created from the milling process in the CNC machining center is a polydisperse loose mass of different grain size from coarse, medium coarse and dust fractions: *Kminiak – Dzurenda (2018), Očkajová et al. (2020).* The representation of individual fractions from CNC milling processes depends on the properties of the processed raw material, the tool parameters, as well as the technical-technological parameters of the machining process. Coarse and medium-thick chips formed by milling on CNC centers, as stated in the works: *Banski – Kminiak (2018), Kminiak et al. (2020, Dzurenda 2022),* have a fibrous shape, the length of which is several times greater than the width and thickness. Fine fractions with dimensions less than 125 μm are isometric chips that are approximately the same size in all three dimensions.

Wood dust with a grain size in the range of 1 ÷ 500 μm (*Hejma et al. 1981*, *Dzurenda 2002*, *Dzurenda et al.*, *2010*) is a hygroscopic, slightly abrasive, explosive bulk material.

From the aspect of the impact of dust particles with dimensions below 100 μm on the human respiratory system, dust particles are divided into:

- respirable (inhalable) mass fraction < 100 μm,
- thoracic 5 ÷ 10 μm,
- tracheobronchial (respirable mass fraction) 2.5 ÷ 5μm,
- highly respirable mass fraction < 2.5 μm.

Particles of the dust fraction (> 10 μm), as reported by Buchancova (2003), in the working environment they do not sediment quickly and are inhaled by humans if the respiratory tract is not protected.

They are caught in the upper parts of the respiratory tract and, together with mucus and the activity of the ciliated epithelium, move to the nasopharynx, from where they can enter the digestive tract or be eliminated from the body by coughing. Smaller particles (0 < 5 μm) are particularly problematic - the so-called respirable fraction. They penetrate into the lung alveoli, where they are phagocytosed by alveolar macrophages. Here they can remain deposited and cause local biological effects, or they can penetrate into the blood and lymph.

Recently, the attention of research in the field of thermal treatment of wood is focused on steaming with saturated water vapor for the purpose of targeted wood color into non-traditional shades of wood *Trebula (1986), Tolvaj et al. (2009), Dzurenda (2018), Dzurenda - Dudiak (2022)* which a wider space is created for designers and constructors to use the excellent mechanical properties of alder wood in other colors and shades without its surface treatment by staining or dyeing. By steaming alder wood with saturated steam at a temperature of t = 135 °C for a period of τ = 9 hours. the white-gray color with a yellow tinge changes to a dark brown-gray color. After drying, steamed alder wood is used as a construction material and is mechanically processed by milling cutters on CNC machining centers.

The aim of the work is to compare the grain size of steamed alder wood chips with non-steamed alder wood chips created in the milling process on the SCM Tech Z5 CNC machining center under the same machining conditions and to assess the suitability of the Finet PES 4 filter fabric for capturing chips extracted from transport air in the fabric filter FR - SP 50/4.

MATERIALS AND METHODS

Material: alder wood was processed in the experiment in the form of blanks:
- unsteamed alder wood with dimensions: 50 x 80 x 500 mm,
- steamed alder wood with saturated water steam at a temperature of t = 135 °C for a period of τ = 9 hours. with dimensions: 50 x 80 x 500 mm,
- wood moisture of steamed and unsteamed blanks w = 10 ± 2%.

CNC machining center: the experiment was carried out on a 5-axis CNC machining center SCM Tech Z5 (Figure 1). Milling of the blanks was carried out with a single-blade end mill with the type designation KARNED 4451 from the manufacturer Karned Tools s.r.o., Prague, Czech Republic. A reversible knife HW 49.5/9/1.5 made of T10MG sintered carbide was installed in the end mill. Technological conditions of milling:

- cutter speed n = 20,000 min^{-1},
- feed speed v_f = 2 $m.min^{-1}$, v_f = 4 $m.min^{-1}$ and v_f = 6 $m.min^{-1}$,
- when removing e = 1 mm, e = 3 mm, e = 5 mm.

Fig. 1. CNC machining center SCM Tech Z5

Sampling for granulometric analysis: Chips from the workspace of the CNC machining center were extracted with a STILER model FM 470 local extraction source with a filter bag made of Finet PES 4 filter fabric with a limit of fractional separation a_{MO} = 7 μm.
The granulometric composition of the chips was determined by sieving. For this purpose, a special set of stacked sieves (2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm, 0.063 mm, 0.032 mm and bottom) was used, placed on the vibrating stand of the Retsch AS 200c sieving machine from the company Retsh GmbH, Germany. The parameters of the Retsch AS 200c sieving machine were set for sieving at a sieving interruption frequency of 20 seconds, sieving time τ = 15 minutes, weight 50 g. The granulometric composition was obtained by weighing the fractions remaining on the sieves after sieving on a Radwag 510/C/2 electric laboratory balance from the company: Radwag Balances and Scales, Radom, Poland, with a weighing accuracy of 0.001 g. Sieving was performed on three samples for each chip taken.

RESULTS AND DISCUSSION

Deposit of chips created in the process of processing steamed alder wood with saturated water steam at a temperature of t = 135 °C for a period of τ = 9 hours. on a CNC machining center at removal e = 3 mm and feed speed v_f = 4 m.min^{-1} is shown in Fig. 2.

Fig. 2. A look at the chips from milling beech wood at the CNC machining center

The results of sieve analyzes of the chips created for the sliding speeds $v_f = 2$ m.min^{-1}, $v_f = 4$ m.min^{-1} and $v_f = 6$ m.min^{-1} and chip removal e = 1 mm, e = 3 mm, e = 5 mm for unsteamed and steamed alder wood are listed in Table 1.

Table. 1. Granulometric composition of chips from the milling process of unsteamed and steamed alder wood on a CNC machining center.

Removal *e* [mm]	Dimensions sieve mesh	Factions	Percentage representation of the chips fraction [%]					
			Unsteamed alder wood			Steamed alder wood		
			The feed rate v_f [m.min^{-1}]			The feed rate v_f [m.min^{-1}]		
			2 m.min^{-1}	4 m.min^{-1}	6 m.min^{-1}	2 m.min^{-1}	4 m.min^{-1}	6 m.min^{-1}
1 mm	2 mm	thick	62.30	60.43	59.18	46.89	48.63	43.71
	1 mm		12.08	12.00	11.49	22.58	19,03	21.37
			74.38	**72.43**	**70.67**	**69.47**	**67.66**	**65.08**
	500 µm	medium thick	9.42	8.66	8.49	11.20	14.15	16.10
	250 µm		5.13	6.25	8.18	7.70	6.08	9.22
	125 µm		4.28	7.38	8.13	5.25	5.40	4.76
			18.83	**22.29**	**24.8**	**24.15**	**26.48**	**30.08**
	63 µm	**gentle**	5.01	4.11	4.22	4.70	4.21	3.47
	32 µm		1.78	1.18	0.31	1.68	2.65	1.37
	< 32 µm		0.00	0.00	0.00	0.00	0.00	0.00
			6.79	**5.28**	**4.53**	**6.38**	**5.86**	**4.84**
3 mm	2 mm	thick	58.18	55.24	52.27	39.10	36.14	32.25
	1 mm		10.60	9.57	11.08	25.12	27.36	29.70
			68.78	**64.81**	**63.35**	**64.22**	**63.5**	**61.99**
	500 µm	medium thick	8.31	12.35	10.35	16.71	17.35	18.57
	250 µm		7.60	10.73	7.73	9.31	9.95	11.98
	125 µm		7.25	8.61	6.72	4.95	5.24	4.74
			23.16	**31.69**	**24.80**	**30.97**	**32.54**	**35.29**
	63 µm	gentle	4.70	2.98	2.63	3.21	2.67	1.72
	32 µm		1.36	0.52	0.71	1.60	1.29	1.00
	< 32 µm		0.00	0.00	0.00	0.00	0.00	0.00
			6.06	**3.50**	**3.34**	**4.81**	**3.96**	**2.72**
5 mm	2 mm	thick	30.19	41.03	37.69	26.36	27.53	28.00
	1 mm		21.13	18.73	19.97	33.51	30.00	28.11
			61.32	**59.76**	**57.66**	**59.87**	**57.53**	**56.11**
	500 µm	medium thick	17.23	10.75	20.92	19.41	18.27	17.34
	250 µm		10.86	18.80	12.49	11.16	16.61	16.93
	125 µm		7.10	8.10	6.70	5.83	4.71	7.20
			35.29	**37.65**	**40.11**	**36.4**	**39.59**	**41.47**
	63 µm	gentle	2.83	2.21	1.84	2.03	2.42	2.06
	32 µm		0.56	0.38	0.39	1.70	0.46	0.36
	<32 µm		0.00	0.00	0.00	0.00	0.00	0.00
			3.39	**2.59**	**2.23**	**3.73**	**2.88**	**2.42**

In Fig. 3 and Fig. 4 shows the representation of the proportions of coarse, medium and fine fractions of chips from milling unsteamed and steamed alder wood, depending on the feed rate and removal rate on the SCM Tech Z5 CNC machining center.

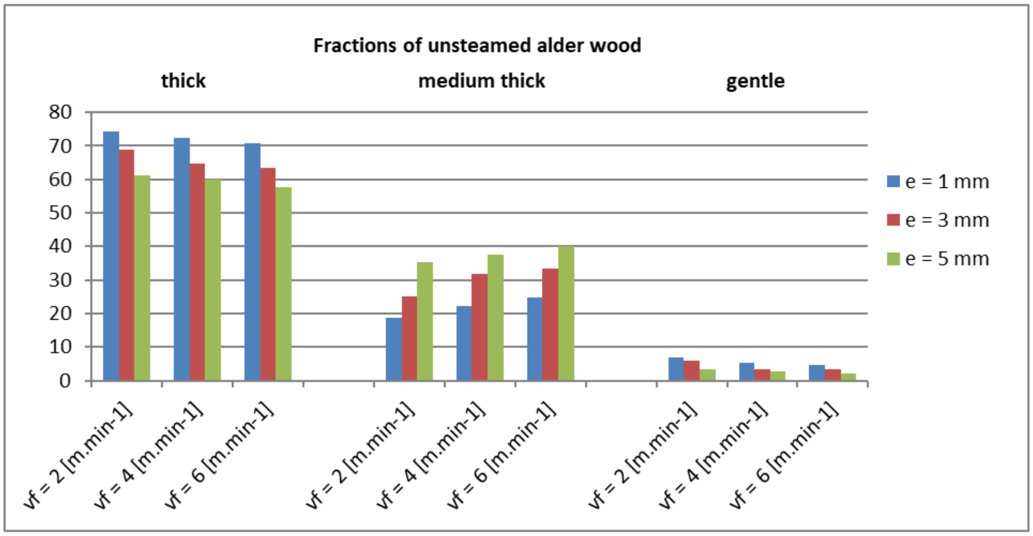

Fig. 3. Comparison of thick, medium thick and gentle fractions of unsteamed alder wood depending on milling feed rate and removal.

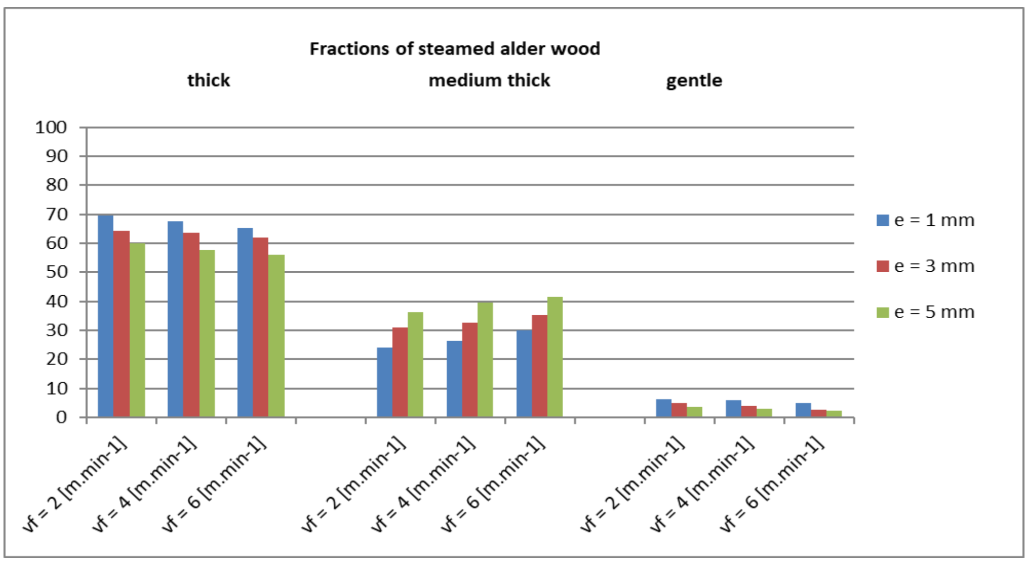

Fig. 4. Comparison of thick, medium thick and gentle of steamed alder wood as a function of milling feed rate and removal.

From the analysis of the size of the chips formed in the milling process on the SCM Tech Z5 CNC machining center presented in Table 1, Fig. 3. and 4. it follows that the majority share in the formed loose wood matter, both in unsteamed and steamed alder wood, are chips of the coarse fraction. The average representation of the coarse fraction of chips from the milling of non-steamed alder wood is 66%, and for steamed wood this fraction is about 3.1% lower. The proportions of this fraction of chips in both types of alder wood decrease with the growth of removal and increase of the sliding speed.

The average representation of the medium-coarse fraction of chips with dimensions of 0.125 - 1.0 mm in non-steamed alder is 29.5% and in steamed alder wood 32.7%.

Dust fractions with dimensions below 125 μm are represented to the smallest extent in the created loose wood mass. The average representation of the dust fraction from unsteamed alder wood is 4.5% and from steamed alder wood 4.4%.

Chips of both unsteamed and steamed alder wood with dimensions below 32 μm were not measured, so it can be concluded that no respirable dust particles with dimensions below < 10 μm are formed.

Based on a comparison of the separation limit of the a_{MO} filter fabric Finet PES 4 and the size of the smallest chips of the extracted amine sawdust, it can be concluded: a_{MO} = 7 μm <<< amine = 32 μm i.e., that on the Finet PES 4 filter fabric in the fabric filter FR-SP 50/4, all extracted chips are captured and separated from the transport air *Kminiak – Banski (2018).*

CONCLUSION

Based on the conducted experiments, we can draw the following conclusions about the influence of the thermal treatment of alder wood with saturated water steam at a temperature of t = 135 °C on the granulometric composition in the process of milling steamed alder blanks on the SCM Tech Z5 CNC machining center:

- The majority 62.9% share of chips from milling of steamed alder wood are chips of the coarse fraction with dimensions above 1 mm. For unsteamed wood, the share of the coarse fraction is 3.1% higher
- Chips of the medium-coarse fraction with dimensions of 1 - 0.125 μm of steamed alder wood make up 32.7% and unsteamed alder wood 32.7%.
- The share of the dust fraction of chips from milling steamed alder wood is 4.4% and unsteamed alder wood 4.5%.
- The occurrence of parts of the dust fraction with dimensions below 32 μm and thus respirable particles has not been proven.
- Since the limit of fractional separation of the Finet PES 4 filter fabric is a_{MO} = 7 μm and the grain size of the smallest particles of extracted chips is amine ≥ 32 μm, then it can be concluded that the filter fabric meets the requirements for the separation of extracted chips

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Streszczenie: Rozmiar wiórów z procesu obróbki drewna olchowego parowanego i nieparowanego na centrum obróbkowym cnc oraz ocena warunków rozdzielania.

W pracy omówiono ziarnistość wiórów powstających w procesie obróbki drewna olchowego nieparzonego i parzonego na centrum obróbczym CNC. Z analizy granulometrycznej zrębki wynika, że średni udział frakcji grubej zrębki powstałej z nieparzonego drewna olchowego wynosi 66,0%, a parzonego drewna olchowego 62,9%. Udział frakcji średniogrubych drewna olchowego o wymiarach 1,0-0,125 µm w drewnie nieparzonym wynosi 29,5%, a parzonym 32,7%. Frakcje pyłu o wymiarach poniżej 125 µm w drewnie olchy nie parzonej stanowią 4,5%, aw drewnie olchy parzonej 4,4%. Nie mierzono wiórów drewna olchowego nie parzonego lub parzonego o wymiarach poniżej 32 µm, można więc stwierdzić, że nie tworzą się pyły respirabilne o wymiarach poniżej 10 µm.

Zmiany właściwości fizycznych i mechanicznych parzonego drewna olchowego przejawiają się spadkiem frakcji grubej powyżej 2 mm i wzrostem frakcji wiórów od 0,125 do 2000 µm.

Do separacji zrębków zarówno nieparzonego jak i parzonego drewna olchowego z powietrza transportowego nadają się filtry tkaninowe i włóknina filtracyjna Finet PES 4, których granica oddzielania jest mniejsza od wielkości najmniejszych wiórów powstałych w procesie frezowania: a_{MO} = 7 µm <<< amina = 32 µm.

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