INFLUENCE OF THE THICKNESS OF REMOVED LAYER ON GRANULOMETRIC COMPOSITION OF CHIPS WHEN MILLING OAK BLANKS ON THE CNC MACHINING CENTER

Adrián Banski – Richard Kminiak

Abstract

The paper deals with the production of chips in the process of milling oak blanks on a CNC machining center and their granulometric content. They present the results of the experiment in which was simulated milling process of oak blanks by end mill fitted with a replaceable carbide blade under standard conditions: feed speed vf = 1÷5 m.min^{-1} and thickness of the removed layer e = 1/3/5 mm.

The granulometric analysis suggests that more than half of the chips formed is a coarse fraction consisting of flat particles larger than 2 mm. Fraction of chips in grain ranges of 0.5 ÷ 2 mm are fibrous chips, the chin is significantly extended in one direction. Dust fractions below 500 μm formed isometric beads i.e chips having in all three directions about the same size. Inhalable dust particles below 125 μm are on average 0.92 ÷ 5.82%. It can be stated that there are no respirable dust particles with dimensions less than> 10 μm.

Key words: *milling on a CNC machining center, dustability, granulometric composition of chips, dust fraction, respirable particles.*

INTRODUCTION

CNC technology has become an integral part of the woodworking industry whether it is a piece or large-scale production. The range of used CNC machines is wide and the most commonly used are CNC machining centers.

During milling, the separated chips are formed into a rotating air stream. The mixture of rotating air and chips has so much energy that its significant part is not broken by the exhaust air, it hits the walls of the suction hood and falls into the work area of the concealed CNC machine.

Extruded chip is a polydispersible bulk material consisting of coarse, medium coarse and powder fractions (*Hejma et al., 1981, Horák, 1996, Očkajová a Banski, 2013 Dzurenda et al., 2010*). Wood dust with grain size ranging from 1 ÷ 500 μm is hygroscopic, low abrasive, explosive bulk. The proportion of dust particles depends on the properties of the processed raw material, the parameters of the tool as well as the technical and technological parameters of the machining process (*Dzurenda, 2002, Kučerka, 2010, Palmqvist a Gustafsson, 1999, Kopecký a Rousek, 2006*).

From a physiological point of view and according to conventions in the sense of international harmonization (USA - ACGIH, EPA a Európa - ISO, CEN, BMRC) fractions of dust below 100 μm *Tureková* (*2012*) broken down as follows:

- breathable (inhalable) weight fraction <100 μm,

Technical University in Zvolen, T. G. Masaryka 24, 960 53 Zvolen
e-mail: banski@tuzvo.sk, richard.kminiak@tuzvo.sk

- thoracic weight fraction $5 \div 10$ μm,
- tracheobronchial (respirable) weight fraction $2.5 \div 5$μm,
- High respirable weight fraction <2.5 μm.

Dust fraction (> 10 μm), as indicated *Buchancova* (*2003*), in the work environment, do not quickly adjust and in case of unprotected respiratory they are inhaled by humans. They are captured in the upper respiratory tract and together with mucus and activity of the rib cage epithelium move up into the nasopharynx, from where they can enter the digestive tract or eliminate them from the body by coughing. Problematic are mainly smaller particles ($0 < 5$ μm) – called. respirable fraction - remain in the air for a long time. They also penetrate into the lung alveoli, where they are phagocyticated by alveolar macrophages. They can remain deposited and cause local biological effects, or they can penetrate into blood and lymph.

Wood dust from beech and oak, as *Očkajová a Kučerka* (*2017*) states is considered to be toxic and is classified as a carcinogen 1st category. Dust with carcinogenic and mutagenic effects according to NV SR č. 83/2015 Z.z., which amends NV SR č. 356/2006 Z.z. on the protection of the health of workers from the risks related to exposure to carcinogens and mutagens at work, as amended NV SR č. 301/2007 Z.z. and the concentration of the toxic component of the aerosol must not exceed the technical guidelines for the given factor (5 mg/m3) (NV SR č. 301/2007 Z.z.; NV SR č. 471//2011 Z.z).

The aim of the article is to determine the granulometric composition of exhausted chips from the milling process of oak grooves on a CNC machining center in the range of commonly used combinations of technical and technological parameters.

MATERIAL AND METHODS

Characteristics of used material:

In the experiment were used furniture blanks of following parameters:
- wood species: European oak (Quercus robur)
- texture: tangential lumber
- dimensions: thickness h = 25 mm (± 0,5 mm), width w = 80 mm (± 0,5mm), length l = 500 mm (± 1 mm),
- moisture: w = 10% (± 2%).

Characteristics of used machinery:

The experiment was performed on a 5-axis CNC Machining Center SCM Tech Z5 (*Fig.1*) supplied by the company SCM – group, Rimini, Italy. The basic technical and technological parameters reported by the manufacturer are given in Tab. 1.

Characteristics of tool:

In the experiment was used end mill KARNED 4451 of diameter D = 16 mm fitted with a replaceable T10MG carbide blade from the manufacturer Karned Tools Ltd., Prague, Czech Republic (*Fig. 2*). Basic technical and technological parameters provided by the manufacturer are presented in *Tab. 2*.

Fig. 1. CNC machining center SCM Tech Z5 (*SCM Group, 2017*).

Tab. 1. Technical and technological parameters of CNC machining center SCM Tech Z5 (*SCM Group, 2017*).

| Technical parameters of CNC machining center SCM Tech Z5	
Useful desktop	x= 3,050 mm , y = 1,300 mm, z =300 mm
Speed X axis	$0 \div 70$ m.min^{-1}
Speed Y axis	$0 \div 40$ m.min^{-1}
Speed Z axis	$0 \div 15$ m.min^{-1}
Vector rate	$0 \div 83$ m.min^{-1}
Parameters of the main spindle	
electric spindle with HSK F63 connection	
Rotation axis C	640°
Rotation axis B	320°
Revolutions	$600 \div 24,000$ ot.min^{-1}
Power	11 kW 24,000 ot.min^{-1}
	7,5kW 10,000 ot.min^{-1}
Maximum tool diameter	D = 160 mm
	L = 180 mm
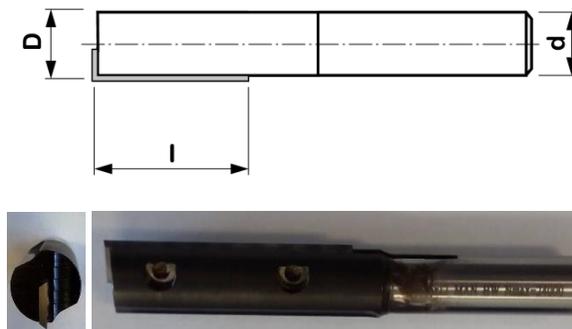
Fig. 2. End mill KARNED 4451 fitted with one replaceable carbide blade (D – cutting diameter, L – cutting length, d - diameter of the chucking shank)

Tab. 2. Technical and technological parameters of end mill KARNED 4451 fitted with one replaceable carbide blade (Karned Tools Ltd, 2017)

Miller	Working diameter D [mm]	Working length l [mm]	Diameter of the chucking shank d [mm]	Dimensions of used razor blades L x š x h [mm]	Blades material	
KARNED 4451	16	49,5	12	49.5 x 9 x 1.5	T10MG	
Classes of TIGRA	ISO CODE	US CODE	Binder%	Hardness		Bending strength
				HV10	HRA±0.2	N/mm^2	psi
T10MG	K10–K40	C3+	10.0	1,65	92.3	3,6	522.000

Milling process:

A milling cutter was fitted into the hydraulic clamp SOBO. 302680291 GM 300 HSK 63F from Gühring KG, Albstadt, Germany. Oak blanks were placed in a CNC machining center so that the longer side was in the X-axis and the shorter side was in the Y-axis. Oak blanks were clamped during the milling by mechanical clampers VCMC-S4 145x145x50 12-80 from J. Schmalz GmbH, Glatten, Germany. The milling process was carried out at constant operation speed of cutter n = 20,000 min^{-1} and changing thickness of the removed layer e = 1/3/5 mm and changing feeding speed from v_f = 1 m.min^{-1}to v_f = 5 m.min^{-1} (representing a maximum feeding speed recommended by the manufacturer of the tools).

Specimens for granulometric analysis of chips were removed isokinetically from the suction line of the CNC woodworking center in accordance with STN 9096 (83 4610): "Manual determination of the mass concentration of solid pollutants".

The granulometric composition of the chippings was detected by sieving. For this purpose, special sets of stacked sieves (2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm, 0.063 mm, 0.032 mm, and bottom) were placed on the Retsch AS 200c vibration stand of the Retsch AS 200c screening machine Retsh GmbH, Haan, Germany. The sizing parameters were in accordance with STN 153105 and STN ISO 3310-1, sessile interruption frequency 20 seconds, sieve deflection amplitude 2 mm.g-1, siting time t = 15 minutes, weight 50 g. The granulometric composition was obtained by weighing the percentages remaining on the sieves after sieving on a Radwag 510 / C / 2 electrical laboratory scale from Radwag Balances and Scales, Radom, Poland, with a weighing accuracy of 0.001 g. Sittings were performed on three samples for each wood.

RESULTS AND DISCUSSION

In the experiment were simulated conditions normal production practices. Thickness of the removed layer was set at 1, 3. 5 mm, which is a normal addition for the final machining of furniture blanks. The sliding speed was in the range of 1-5 m.min^{-1}, which is the commonly used sliding speed for machining wood. The results are presented in *Tab. 3* and graphically in *Fig. 3*.

Tab. 3. Granulometric composition of oak chips from the milling process on a CNC machining center.

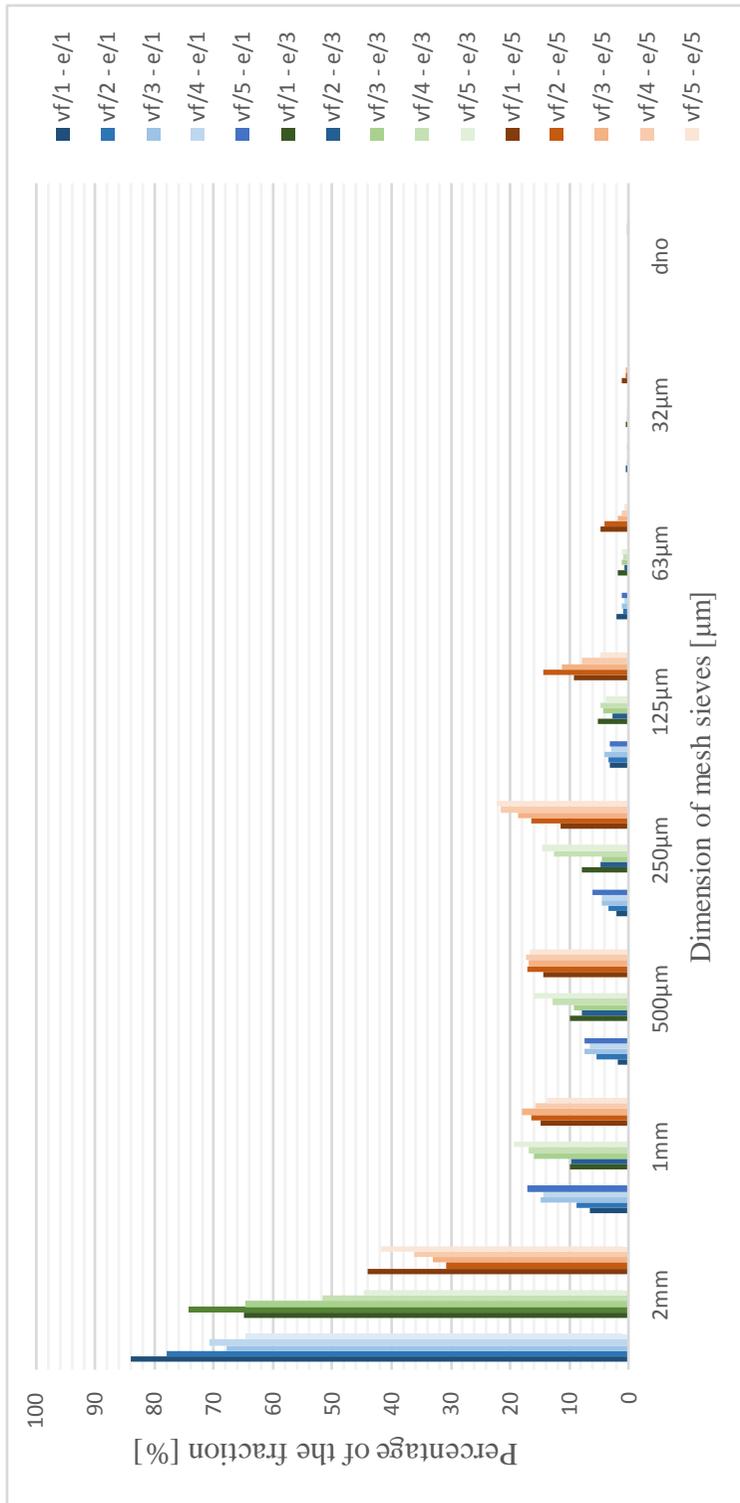| Thickness of removed layer e [mm]	Dimension of mesh sieves [μm]	Fraction designation	Percentage of the fraction [%]				
			Feed speed v_f [m.min^{-1}]				
			1 m.min^{-1}	2 m.min^{-1}	3 m.min^{-1}	4 m.min^{-1}	5 m.min^{-1}
1mm	2mm	coarse	84,01	77,9	67,88	70,84	64,72
	1mm		6,55	8,78	14,83	14,49	17,17
	500μm	medium coarse	1,72	5,32	7,36	6,53	7,44
	250μm		2,14	3,48	4,55	4,62	6,12
	125μm		3,2	3,36	4,08	2,83	3,24
	63μm	fine	1,96	1,03	1,12	0,62	1,09
	32μm		0,41	0,13	0,18	0,06	0,23
	> 32μm		0	0	0	0	0
3mm	2mm	coarse	64,95	74,1	64,77	51,72	44,83
	1mm		9,9	9,77	15,95	16,84	19,36
	500μm	medium coarse	9,87	7,83	9,12	12,82	15,96
	250μm		7,98	4,68	4,41	12,71	14,51
	125μm		5,1	2,75	4,36	4,75	3,84
	63μm	fine	1,78	0,71	1,13	0,95	1,18
	32μm		0,42	0,15	0,26	0,21	0,32
	> 32μm		0	0	0	0	0
5 mm	2mm	coarse	44,01	30,85	33,03	36,1	41,76
	1mm		14,9	16,36	17,93	15,74	13,75
	500μm	medium coarse	14,49	17,16	16,78	17,32	16,57
	250μm		11,57	16,5	18,59	21,51	22,33
	125μm		9,17	14,42	11,34	7,81	4,67
	63μm	fine	4,78	4,11	1,91	1,2	0,7
	32μm		1,04	0,56	0,4	0,32	0,22
	> 32μm		0	0	0	0	0

Fig. 3. Granulometric composition of chips from the milling process of oak blanks on a CNC machining center.

The majority share of resulting chips are fractions of dimensions greater than 2 mm. These chips belong to the category of flat chips, i.e., the length and width of the chips significantly exceed its thickness. Chip has the shape of trimming layers of milled wood. At lower feed speed, the chips were unbroken. With increasing feed speed, the intensity of break in chips increased.

Fractions of 2 mm to 500 μm belong to so-called " fibrous particles, i. to the particles with a significant extension in one direction.

Fractions below 500 μm can be characterized as isometric chips, i.e., splinters having approximately the same dimensions in all three directions.

The inhalable dust fraction particles with dimensions below 125 microns is formed by a proportion of 0,92÷5,82%, depending on thickness of the removed layer and feed speed.

The CNC machining center does not produce fractions of respirable fraction with dimensions less than 10 μm.

Effect of the thickness of removed layer

By increasing the size of the removed layer, the proportion of the fraction with a size above 2 mm is reduced. For the 1÷2 mm fraction there was no significant change in the percentage of the fraction. Increasing the size of the removed layer will cause an increase in the proportion of the fraction below 1 mm. The rationale for the phenomenon can be found in increasing the size of the trimming chips, which affects the force ratios in the chips, cracks are formed in the chips, and the chips are crushed into smaller pieces. It can be concluded addictionas a result of the larger slender ratio of chips there is a greater fragmentation of the chips.

This argument is supported by the basic literature dealing with the problem of wood processing. As say *Siklienka et al* (*2017*), *Lisičan* (*1996*), či *Nemec et al* (*1985*) cutting speed, feed speed as well as thickness of removed layer participate in the creation of the shape and dimensions of the cut layer. Increasing the size of the chips causes a change of character of chips creations, the particle becomes more fragmented.

In favor of the assumption says the change of fractions in changing the feed speed. Increasing the feed speed means increasing the feed rate on the tooth and increasing the thickness of trimming chips - changing the slender ratio of chips. Increasing the feed speed will result in a reduction in the proportion of the fraction with a size above 2 mm and, on the other hand, an increase in the fraction with a size below 1 mm

CONCLUSION

Based on our experiments, we can draw the following conclusions:
- most of the mixture of chips form chips with a size above 2 mm,
- dust particles (> 500 μm) make up 7.71 - 35.59%,
- inhalable dust particles (> 125 μm) make up 0.92 ÷ 5.82%,
- the occurrence of parts smaller than 32 microns and therefore respirable particles have not been proven.

It was shown dependence of particle size distribution of the chips to the chip slenderness ratio. Is valid, greater thickness of removed layer or feed speed, mean greater slenderness ratio and greater percentage of the smaller fractions of the chips.

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