

EFFICIENCY OF CHIPS REMOVAL DURING CNC MACHINING OF PARTICLEBOARD

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ABSTRACT

The results of testing of chips extraction system efficiency during CNC milling of particleboards were presented in this paper. Experimental machining was performed using the 3-axis CNC router Weeke Venture 108M and a standard diamond tipped, newly sharpened shank-type router bit. As a material the market size (2200×1250×18 mm) laminated particleboards with density of 649 kg.m⁻³ were used. The efficiency of chips extraction system of the CNC machine depends on the mode of milling. For pocketing nearly 100 % of chips were removed successfully while for through-milling it was only 87 %. The extraction system worked with very high efficiency regarding chips smaller than 0.1 mm. The chips extraction efficiency decreases for larger and heavier chips.

KEYWORDS: CNC machining; particleboard; chips extraction.

INTRODUCTION

Quantity, dimensional and shape characteristic of chips formed by machining are very variable and depend on many factors. The most important factors are: Type of worked material, processing technology, and machining parameters. Content of dust particles and bigger particles in the whole mass of chips strongly depends on these factors. This dependence also applies to the

smallest particles which, when dispersed in the air, pose the greatest risk to health of workers (inhalable particles) (Rautio et al. 2007, Dutkiewicz and Prażmo 2008, Beljo-Lučić et al. 2011, Hlásková et al. 2015). Also machine type and method of processing are factors determining the dust concentration in the air (Kos et al. 2004). The zone of waste creation on various machines which should be covered by the operation of an exhaust device may vary depending on type of the tool and shape of the workpiece. For simple woodworking machines it is quite easy to design a suction hood since the chips tend to form and move in a repetitive manner. Removal of chips is more difficult when the working zone is large and direction of relative movement between the tool and a workpiece is variable during processing is an additional obstacle in effective chip extraction. Such case occurs in most CNC machines used in the woodworking industry (Varga et al. 2006). The dispersion of chips in different directions (also due to high rotational speed of the tool) in the cutting zone is very unfavorable in this respect. When the movement of chips created during machining does not coincide with the direction of movement of the air suction by an extraction system many of them remain not removed.

Processing of wood composites is known to cause the creation of significant amounts of small dust particles (Palmqvist and Gustafsson 1999, Chung et al. 2000, Fujimoto et al. 2011). This is due to the fact that composites are made of wood, which has previously been splitted. Machining by cutting tools is in this case the secondary fragmentation of wood tissue. Perhaps this phenomenon may be intensified by temperature influence during chipboard production. Wood exposed to elevated temperature seems to produce finer sawdust while machining (Dzurenda and Orłowski 2011). Problem with chips exhausting concerns also bigger particles since they require higher air velocity to be hovered. Untaken chips fall down polluting the machine and floor around it increasing a risk of fire, or operator slipping. The contamination of a machine table may also lead to machining quality decrease e.g. by workpiece positioning problems with under pressure clamping. For this reason, the removal of chips in the CNC centers is reported by industry as an important problem.

The objective of the present research was to evaluate the efficiency of chips extraction during CNC milling of laminated practiceboards in both pocketing and through-milling.

MATERIAL AND METHODS

In order to achieve the goal defined above it was decided to perform a machining process and assess the mass share of unremoved chips left in the neighbourhood of machine comparing to a total mass of chips produced. The efficiencies of chips removal for both cases described below were then derived as:

$$E = \frac{m_e}{m_t} \cdot 100 = \frac{m_t - m_r}{m_t} \quad (\%)$$

where: m_e – mass of extracted chips,
 m_t – total mass of chips produced,
 m_r – mass of residual, non-extracted chips.

The machining was performed on industrial, full size, 3-axis CNC router Weeke Venture 108M from Homag Group (Germany). The machine was equipped with console table and under-pressure clamps for fixing the workpiece. The router was connected to a central exhaustion system of Nederman company (Germany) by a connection pipe of diameter 200 mm. In order to

determine the flow parameters of the air removed from the cutting area a dynamic pressure in the central axis of pipe was measured with use of a differential micromanometer CMR 10 (producer: ZAM Kęty, Poland). Three measurements have given the medium dynamic (differential) pressure 225 Pa which was an equivalent of a maximal air velocity $19.4 \text{ m}\cdot\text{s}^{-1}$ and theoretical volumetric air flow $2189 \text{ m}^3\cdot\text{h}^{-1}$ in the center axis of the pipe. It was assumed on the basis of Dolny (1999) that the average values of these parameters in exhaustion tube was 85 % of their maximal values e.i. the average air flow $1861 \text{ m}^3\cdot\text{h}^{-1}$ and the air velocity $16.5 \text{ m}\cdot\text{s}^{-1}$. According to machine producer recommendations the air flow should be at least $3170 \text{ m}^3\cdot\text{h}^{-1}$, but in industrial conditions this requirement is rarely fulfilled. Also Rautio et al. (2007) have used the air velocity between 15.5 and $18.8 \text{ m}\cdot\text{s}^{-1}$ which was similar that of current experiment. The suction hood geometry is shown in the Fig. 1. It was equipped in the bottom part with the sealing brushes. The air velocities field in the hood was not mapped.

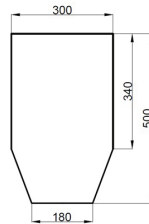


Fig. 1: The suction hood cross-section geometry.

As a material for machining and therefore for chips production two market size ($2200\times 1250\times 18 \text{ mm}$) laminated particleboards were used. The average density of the boards was $649 \text{ kg}\cdot\text{m}^{-3}$.

For performing the experimental machining of particleboards a standard diamond tipped, newly sharpened shank-type router bit (Leuco Diamax, Germany) was used (Fig. 2). The cutting diameter was 18 mm, total tool length $L_t = 95 \text{ mm}$ and working length $L_w = 28 \text{ mm}$. The cutters set-up in the tool reveals zones having one or two teeth on the perimeter. It causes two different feed-per-tooth values. However since the double teeth zones are significantly smaller, just to ensure overlapping, for further analysis the tool was assumed to have only one tooth per rotation. For cutting parameters used in the experiment the rotational speed was 18 000 rpm and the feed speed $5 \text{ m}\cdot\text{min}^{-1}$. It gives feed-per-tooth equal 0.28 and 0.14 mm depending on zone of the tool.

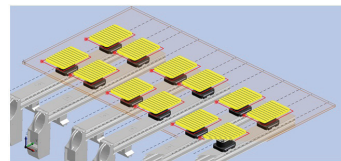
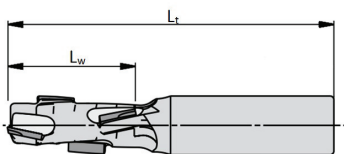


Fig. 2. Cutting tool used in experiment (source: www.leuco.com). Fig. 3: Machining pattern for pocketing the particleboard.

Machining of both chipboards had the same pattern. First the pocketing of 12 pockets $200\times 300\times 12.4 \text{ mm}$ each were performed. With each rectangle path (Fig. 3) of the tool inside the pocketed the router bit was moved by 80 % of its diameter what leads to the conclusion that the cutting layer thickness was in that case 14.4 mm.

The second operation was through-milling used often in nesting or edging of wood-based materials. In the experiment two entire panels were changed into the chips except for 12 rectangular blocks 225×325×18 mm per panel surrounding the pocket made in previous step. In this case the tool path was shifted by a tool diameter (18 mm) in each pass so the cutting layer thickness equaled 18 mm. The most important cutting parameters are collected in the Tab. 1.

Tab. 1: Cutting parameters of pocketing and through-milling used in experiment.

			Pocketing	Through-milling
Number of teeth	z		2 / 1	
Feed speed	f	m.min ⁻¹	5	
Rotational speed	n	min ⁻¹	18000	
Feed per revolution	fr	mm	0.28	
Feed per tooth	ft	mm	0.28	
Uncut chip thickness	b	mm	14.4	18
Cutting width	b	mm	12.4	18
Cutting diameter	D	mm	18	
Medium chip thickness	g	mm	0.25	0.28
Volume removal ratio	\dot{v}	cm ³ .s ⁻¹	14.9	27.0
Mass removal ratio	\dot{m}	g.s ⁻¹	9.6	17.5

Additionally a particle size analysis of the chips obtained was performed. It was done by the sieving method using electromagnetic sieve apparatus type AS 200 Digit (Retsch, Germany) with the set of sieves comprising the sieves of aperture size 1000, 500, 250, 125, 63 and 32 μm . Sieves were arranged in such a way that the sieve with the aperture size 1000 μm was placed on the top, and the sieve with the smallest aperture size on the bottom of the set. The particles passing thru the smallest aperture sieve have fallen to the bottom collector and was denoted in the result section as "0" particle size. The whole set of sieves were subjected to vibrations (amplitude 1.5 mm, duration 20 min). The masses of fractions isolated on the sieves were determined using the laboratory scales Radwag (Poland) with the weighing accuracy of 0.001 g. The average of three measurements was accepted as a result.

RESULTS AND DISCUSSION

Pocketing

Chips produced during pocketing were removed efficiently. A negligible amount (0.03 %) of all chips created during the pocketing were left over by the exhaustion system only in the corners of pockets (Fig. 4). This happened only in the pockets located near to the edge of board. In the shown case the distance a was equal 85 mm what, comparing to dimensions of the exhaustion hood in Fig. 1, gives an explanations why not all chips were removed. When the suction hood was significantly extending out of the panel's surface during routing of the pocket a significant clearance was created in the hood changing the air stream inside of it. The brushes usually sliding on the panel face homogenize the air stream around the spindle ensuring hovering of particles. When mentioned clearance of the hood occurs the air flows mostly through it and on the other side of the hood the air velocity dramatically decreases causing loss of chips removal efficiency. Obviously the problem occurred only in the area over which the suction hood was not traversing

any more. In other cases the suction effectiveness increased again after closing the clearance removing particles.

But still, for the outer regions of panels the remaining amount of chips was negligible. We may conclude that in general there was no problem in CNC pocketing of laminated particleboard.

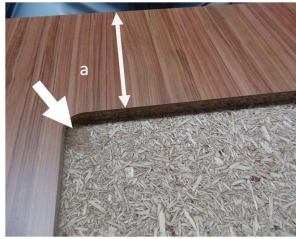


Fig. 4: Chips left over during CNC pocketing in pocket located close to panel's edge.

Through-milling

In through-milling process the chips exhaustion efficiency was definitively lower than in pocketing and was equal 87 %. It means that 13 % of chips produced during milling of two sheets of particleboard were left over on the router table or under it. In this case it was 5.9 kg of chips out of 43.7 kg produced in this second stage. This amount is very significant (Fig. 5) considering how much effort it has to be put to clean the machine and its surround in order to ensure setting up the CNC center for the next operation, proper fixing of next stock, avoid slipping of an operator, fulfilling anti-fire requirements in the site etc.

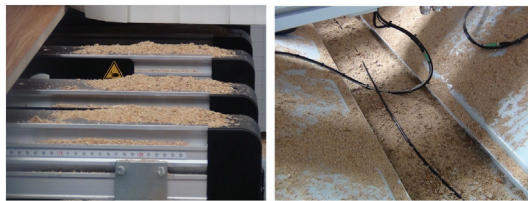


Fig. 5: Unremoved chips on the machine during CNC machining of particleboard.

The reason of this efficiency decrease was the same as described before for the pocketing operations. In this case however the tool goes through whole thickness of material and extends under it. It causes the kerf occurring right after the tool passage which opens the space previously closed in the suction hood by the brushes. It takes place especially in the nesting operations. The gaps in the panel may become even bigger when larger wastes of material cut out from the panel fall down under the console table in CNC router (it was not the case in current experiment). Such clearances reconfigure the air stream as described in pocketing chapter. In the process of edging of the panel (milling around to achieve straight or curved edge) the suction hood extends permanently out of the panel. Moreover in case of routing through hole panel thickness a part of chips is evacuated at the bottom side of board and the suction system located over the panel has poor chances to intercept them. Results of Troger (2004), who was investigating nesting process, seem to confirm this theory. When machining zone is closed by a table itself or MDF base board from the down side the effectiveness of chip exhaustion is nearly 100 % for $n=18\ 000$ rpm (used in current research). According to this investigation the rotational speed increase causes decrease of chip removal effectiveness below 70 %.

Particle size analysis of the chips was performed after machining. Size distribution of particles obtained is presented in Fig. 6. Comparing to the results shown by Rogoziński and Očkajová (2013) for particleboard milling, here the mass distribution is shifted to the direction of smaller particles. This is probably due to higher cutting speed used in present research. This might be also influenced by the tool type used and its areas double covered by teeth, leading to decreasing the chip thickness. Analogical differences occur comparing to the results of Rogoziński et al. (2015).

Distribution of particles left over around the machine (not removed by the extraction system) is presented in Fig. 7. It is clear that for unremoved chips the higher shares are in case of bigger particles and there are practically no smaller chips fractions (chips smaller than 0.063 mm were less than 0.5 %). It is not surprising since the smaller particles are easier to carry by a suction system.

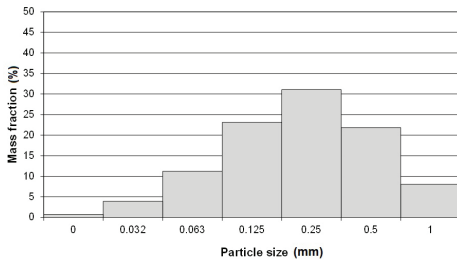


Fig. 6: Particle size distribution of overall chips produced.

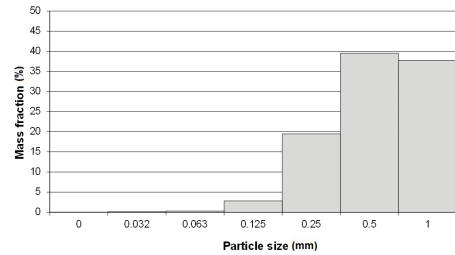


Fig. 7: Particle size distribution of chips not removed by exhaustion system.

This is well illustrated in the Fig. 8 which shows the efficiency of chips removal for different chips sizes comparing to general size distribution of overall mass of chips created in laminated particleboard CNC milling. The problem with removing the chips starts at the particles size around 0.1 mm (below the efficiency is close to 100 %) and intensifies with bigger chips. For 1 mm chips size the extraction efficiency had a very poor value of 40 %.

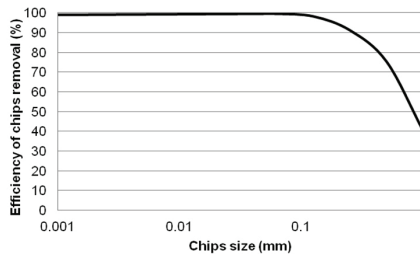


Fig. 8: Effect of chips size on chips removal efficiency.

CONCLUSIONS

After performing the tests of the chips removal efficiency during CNC machining of particleboard it may be concluded that the efficiency highly depends on the operation type realized by CNC center as well as the machining pathway. For pocketing the amount of chips

remained on the panel after routing was negligible and therefore the exhaustion efficiency was near 100 %. For through-milling however it was on the level of 87 % which was not satisfying.

In the research also the particle size analysis of the chips were performed. It has shown that the chips left over on the machine and around it were not smaller than 0.1 mm. The efficiency of chips removal was decreasing with chips size increase.

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