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Impact of feed speed on the processing quality of seats on a multi-spindle drilling machine

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Abstract: *Impact of feed speed on the processing quality of seats on a multi-spindle drilling machine.* The study presents results of investigations on the effect of the feed speed on the state of seat edges and their dimensional-shape accuracy made on a multi-spindle drilling machine. In the course of the performed experiments, ten variants of feed spped comprising the entire range of the drilling machine settings were applied. The seats, 5 and 30 mm deep, were made in two wood species (beech and pine) in longitudinal and transverse directions to wood grain using two kinds of drilling bits of differing structure of the working part. The experiments showed that the employed feed speed affected the quality of seat execution and helped establishing favourable ranges of speeds from the point of view of the processed material, direction of drilling and the effectiveness of processes carried out on a multi-spindle drilling machine.

Keywords: multi-spindle drilling machine, feed speed, wood drilling, seat edge condition.

INTRODUCTION

The observed constructional development of woodworking machines makes it possible to obtain high efficiencies in fields of processing of wood and wood-derived materials. High efficiency, in turn, should ensure appropriate quality and accuracy of processed edges and surfaces which is associated with the choice of appropriate processing parameters. Wrong selection of machining parameters can result in processing defects and increase wear of cutting edges.

Basic kinds of processing are characterised by properly selected feed sppeds adjusted to machining conditions. In the case of drilling processing carried out with the assistance of a traditional multi-spindle drilling machine, the feed speed parameter is most frequently omitted and its value is set as a constant parameter, frequently – maximal. This is the result of the adopted assumption that, for this kind of processing, there is no need for feed speed selection and that this approach is one of the ways to increase output. The issue of increased efficiency is important bearing in mind the fact that in the drilling cycle conducted on a multi-spindle drilling machine, we can distinguish such stages as: approach of the bit to the processed material, proper drilling and return where the distance of the approach and return is frequently distinctly longer than the drilling depth.

In literature on the subject, studies associated with optimal choice of the feed speed in drilling operations are rare, especially those regarding drilling of solid wood with the assistance of a traditional multi-spindle drilling machine. The few available publications deal, in a general way, with the quality of seats made in wood-based materials (Taylor & Lemaster 2006; Davim et al. 2007). Catalogues of companies dealing in tools (Leitz-Lexicon 2009) specify feed sppeds in woodworking machines with possibilities of stepless regulation of spindle rotational spped. In the case of a multi-spindle drilling machine, this speed is constant.

The objective of the performed investigations was to analyse the influence of the feed speed on the results of the drilling process and, in this way, elaborate general recommendations regarding appropriate realisation of these processes. The impact of the feed speed on a number of factors was checked. In this study, the main focus was on the relationship between the feed speed and the quality of seat edges in processing of solid wood. In an earlier publication (Kowaluk et al. 2008), the authors presented the effect of the feed

speed on selected results of drilling of laminated chip boards and concluded that there was a clear relationship between the condition of seat edges made in chip boards covered with different kinds of laminates and the applied feed speed.

RESEARCH METHODOLOGY

Experiments were performed on a single-side, multi-spindle drilling machine with a working assembly consisting of 19 spindles arranged in one plane. The rotational speed of spindles amounted to n = 2800 min^{-1}. The feed motion of spindles was achieved using a double-sided, pneumatic servo with a working distance of 70 mm.

The drilling depth was set with the aid of a screw mechanism which controlled the operations of a separating valve which delivered air to the servo of the feed motion. The set depth of drilled seats was: 5 and 30 mm.

The feed speed (v_f) of the drill working assembly was regulated using a specially calibrated throttle valve. The following ten feed speeds were applied in experiments: 0.18; 0.27; 0.40; 0.60; 0.75; 0.92; 1.35; 1.99; 2.47 and 3.09 $m \cdot min^{-1}$, which were determined as mean values on the basis of numerous experiments.

Two types of uniform screw drill bits of 8 mm diameter, with the working part equipped in a cantering point and spurs and additional calibrating edges were used. Drill bits designated as W1 had cutters situated at the main cutting edge as well as a threaded shank and a centring point, while drill bits designated as W2 had cutters situated at the height of the additional calibrating edge and a cylinder shank with a bevel and a stop screw. The experimental drills were selected bearing in mind repeatability of linear and angle parameters of working parts.

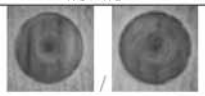
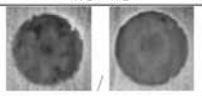
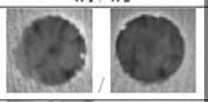
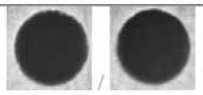
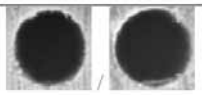
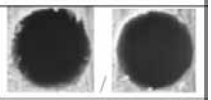
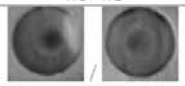
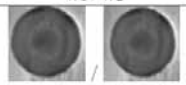
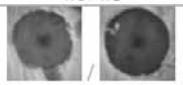
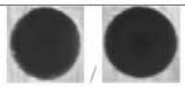
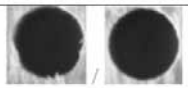
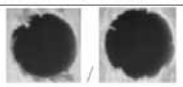
Two solid and dry wood species: beech and pine were selected for investigations and special samples with appropriately oriented grain were prepared.

Measurements and evaluation of the condition of the examined seat edges were carried out with the assistance of micrometric measuring equipment and microscopic methods using images registered with the aid of digital technique. The seat edge condition was represented by the number and form of fibre damages as well as the dimensional-shape accuracy analysis of the top part of seats.

RESULTS AND DISCUSSION

Table 1 shows images of the condition of seat edges made in pine wood in directions longitudinal and transverse to grain using the adopted feed speeds. The images refer to seats 5 mm and 30 mm deep made using two kinds of drill bits: W1 and W2. In the case of the longitudinal drilling direction for the applied feed speeds ranging from 0.18 – 0.92 $m \cdot min^{-1}$ seat edges did not show any damages and their quality was good. For feed speeds v_f = 1.35 and 1.99 $m \cdot min^{-1}$ satisfactory dimensional-shape quality and accuracy of seats was achieved despite small fibre damages covering 10-15% of the seat edge length. When feed speeds of v_f = 2.47 and 3.09 $m \cdot min^{-1}$ were applied, edges of the obtained seats were deformed with numerous damages and torn grain. The obtained irregular seat shapes limit technological usefulness of obtained seats.

Table 1. View of the condition of seat edges made in pine wood using the adopted feed speeds.

Seat depth [mm]	Feed speed [m · min^{-1}]									
	0,18	0,27	0,40	0,60	0,75	0,92	1,35	1,99	2,47	3,09
	Longitudinal direction									
	0,18 – 0,92*) W1 / W2 **)						1,35 - 1,99 W1 / W2		2,47 – 3,09 W1 / W2	
5										
30										
Seat depth [mm]	Transverse direction									
	0,18 – 0,75 W1 / W2						0,92 – 1,35 W1 / W2		1,99 - 3,09 W1 / W2	
5										
30										

*) Feed speed ranges for the repeated condition of seat edges.
**) W1/W2 representative picture of seats made using W1 and W2 drill bits

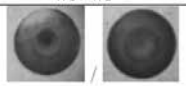
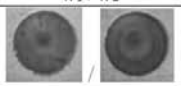
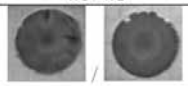
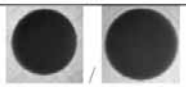
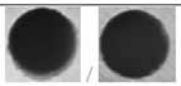
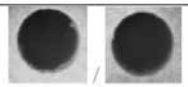
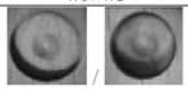
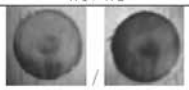
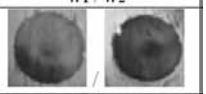
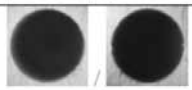
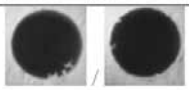
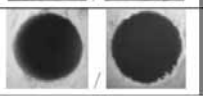
When seats in pine wood were drilled in transverse direction, the condition of seat edges was good for feed speeds ranging from 0.18 – 0.75 m · min^{-1}. Higher speeds caused increasingly greater damages of edges in the form of numerous torn fibres. Speeds v_f = 1.99 m · min^{-1} and higher yielded seats of unacceptable technological usefulness with numerous, deep grain raptures and edge damages.

The edge condition and dimensional-shape accuracy of the top part of seats made using W1 and W2 drill bits within the range of experimental feed speeds, both for the longitudinal and transverse directions of drilling, were similar.

The applied drilling depths of 5 mm and 30 mm did not affect significantly the condition of the obtained seats with the exception of the transverse direction of the feed speed 0.92 – 3.09 m · min^{-1} where a worse seat edge condition for 5 mm deep seats can be noticed.

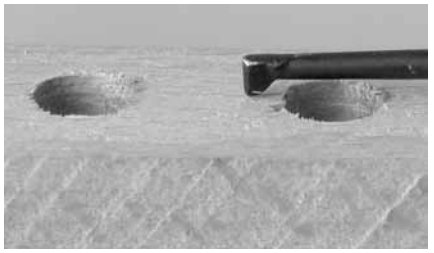
The edge condition of seats drilled in beech wood is presented in Table 2. The quality of seat edges for the analysed feed speeds 0.18 – 0.92 m · min^{-1} was described as good both for longitudinal and transverse directions of drilling in relation to wood fibres. For the feed speeds v_f = 1.35 and 1.99 m · min^{-1}, the state of seat edges was considered as good despite the occurrence of slight defects, primarily when drilling in the transverse direction. The v_f = 2.47 and 3.09 m · min^{-1} speeds for transverse direction resulted in serious damages of seat edges where numerous fibres were torn out and small deposits could be seen along edges causing seat deformation. In the case of the longitudinal direction, for the applied feed speeds of 2.47 and 3.09 m · min^{-1}, acceptable quality of seat edges was observed with only small damages and deposits. Relatively worse effects were obtained for seats 5 mm deep at v_f = 3.09 m·min^{-1}.

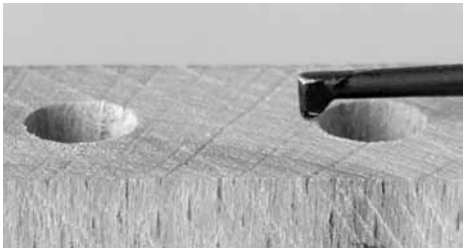
Table 2. View of the condition of seat edges made in beech wood using the adopted feed speeds

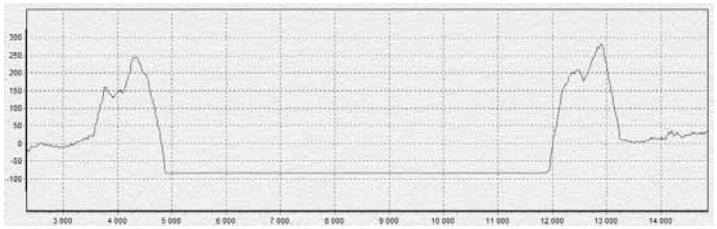
Seat depth [mm]	Feed speed [m · min^{-1}]									
	0,18	0,27	0,40	0,60	0,75	0,92	1,35	1,99	2,47	3,09
	Longitudinal direction									
	0,18 – 0,92*) W1 / W2 **)						1,35 - 1,99 W1 / W2		2,47 – 3,09 W1 / W2	
5										
30										
Seat depth [mm]	Transverse direction									
	0,18 – 0,92 W1 / W2						1,35 – 1,99 W1 / W2		2,47 - 3,09 W1 / W2	
5										
30										

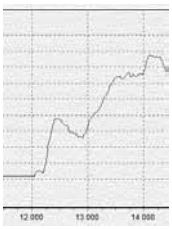
*) Feed speed ranges for the repeated condition of seat edges.
**) W1/W2 representative picture of seats made using W1 and W2 drill bits

An attempt was made for seats made in beech wood to measure the height of the occurred deposits and the depth of damages of seat edges employing the profilometer method. The problem will be discussed in a more comprehensive manner in a separate publication. The obtained measurement and selected results are presented in Figure 1.









Material	v_f = 2,47 m · min^{-1}		v_f = 3,09 m · min^{-1}	
	Damages			
	maximum height [μm]	*maximum depth [μm]*	*maximum height [μm]*	*maximum depth [μm]*
Beech wood *transverse direction*	320	420	> 480	> 480
Beech wood *longitudinal direction*	20	-	50	-

Fig. 1. Measurements of heights and depth of damages of seat edges in beech wood and example results

In the case of all beech wood combinations, no significant differences were observed regarding the quality of seats made using W1 and W2 drill bits.

The 5 mm and 30 mm depth of seats in beech wood did not affect in a significant way the state of their edges; only in the case of the transverse direction for feed speeds ranging from 1.35 – 3.09 m · min^{-1}, worse condition of edges could be observed for seats of 5 mm depth. For 0.18 and 0.27 m · min^{-1} feed speeds in the case of seats 30 mm deep made mainly using W2 bits, burns of inner seat surfaces were noticed.

CONCLUSIONS

Table 3 presents the examined ranges of feed speeds from the point of view of the quality of seats drilled in beech and pine wood with the assistance of a multi-spindle drilling machine determined on the basis of the performed investigations.

Table 3. Investigated feed speed ranges of multi-spindle drilling machine in aspect the quality of seats

Material	v_f [m · min^{-1}]									
	0,18	0,27	0,40	0,60	0,75	0,92	1,35	1,99	2,47	3,09
Beech wood transverse direction			w	x	x	x	x	w		
Beech wood longitudinal direction			w	x	x	x	x	x	x	w
Pine wood transverse direction			w	x	x	x	w			
Pine wood longitudinal direction			w	x	x	x	x	w		

x – favourable v_f ranges

w – conditional, favourable v_f ranges

Values v_f = 0.18 and 0.27 m · min^{-1} presented in Table 3 guarantee the appropriate quality of the drilled seats but they are not recommended due to overheated tools during the operation and occurring burns inside seats. The v_f = 0.40 m · min^{-1} speed was considered as a limiting value with regard to the efficiency of the drilling process.

The observed better quality of seats made in the longitudinal direction and worse of those made in transverse direction using drill bits with centring points and cutters was somewhat surprising.

On the basis of the performed investigations, the range of feed speeds 0.60 – 1.35 m · min^{-1} should be considered as recommendable to obtain good quality seats in solid wood using multi-spindle drilling machines.

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Streszczenie. *Wpływ prędkości posuwu na jakość gniazd na wiertarce wielowrzecionowej.* W pracy przedstawiono badania wpływu prędkości posuwu na stan krawędzi i dokładność wymiarowo kształtową gniazd wykonywanych na wiertarce wielowrzecionowej. W realizacji badań zastosowano dziesięć wariantów prędkości posuwu obejmujących cały zakres możliwości nastaw wiertarki. Gniazda o głębokościach 5 i 30 mm wykonywano w dwóch gatunkach drewna (buk i sosna) w kierunku wzdłużnym i poprzecznym do włókien, za pomocą dwóch rodzajów wierteł o zróżnicowanej budowie części roboczej. Stwierdzono wpływ prędkości posuwu na jakość wykonywanych gniazd oraz ustalono korzystne zakresy prędkości w ujęciu obrabianego materiału, kierunku wiercenia i wydajności procesów realizowanych na wiertarce wielowrzecionowej.

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