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MDF - machinability during drilling

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Abstract: *MDF - machinability during drilling.* Two criteria of machinability during drilling of MDF were considered. The article describes analysis of two indicators connected with quality aspect of machinability (external and internal type) and two connected with cutting forces during drilling (feed force and torque). The results were analysed statistically. The influence of feed per revolution and place of observation on the quality turned out quite different for internal and external type of indicator. Effect of feed per revolution on the cutting forces was linear.

Keywords: machinability, quality, cutting force, drilling, MDF

INTRODUCTION

MDF (Middle Density Fiberboard) is one of the most popular materials used in the furniture industry [Davim, Clemente, Silva 2008]. The material is designed to eliminate the disadvantages of a natural timber, it is almost isotropic (has a tendency to delaminate when screwing into the edge of the board) and structural defect free. Its machinability, defined as the easiness of cutting process, can be specified using wide range of different criteria and indicators [Górski, Podziewski, Szymanowski 2010; Podziewski, Górski 2012]. The machinability during drilling criteria depends on the subjective point of view but the most commonly the most important are quality of machining and cutting forces. The results of experimental study of these aspects are presented in this paper.

MATERIALS AND METHODS

The samples of commercially available MDF were tested - its basic, physical properties are presented in tab.1.

Table.1. Some mechanical and physical properties of MDF which machinability was tested

Density	IB (EN-319)	Swelling after 24h (EN-317)	MOR (EN-310)	MOE (EN-310)
746,2 [kg/m^3]	0,48 [N/mm^2]	19 [%]	34 [MPa]	4180 [MPa]

Tests were carried out with the use of standard CNC machine (BUSELLATO Jet 130). The tool was 10 mm diameter Leitz drill with one cutting edge made of PCD. Tests were conducted with seven variants of feed per revolution: 0,1 mm; 0,15 mm; 0,2 mm, 0,25 mm; 0,3 mm, 0,5 mm; 0,7 mm. Spindle speed was set to 6000 rpm. Tested material was fixed to the CNC machine with special clamp featuring piezoelectric sensor. Sensor was connected to PC computer, allowing the measurement and recording of feed force and torque signals. Signals were then analyzed using LabView environment.

After drilling, holes were photographed and on this base a quality of drilling was analyzed. Two following types of quality indicators (based on were determined:

$$A = \frac{D\max - D}{2}$$

$$B = \frac{D - D\min}{2}$$

where:
A, B – two different (external and internal type) drilling quality indicators,
Dmax – a diameter of a circle covering total damaged area which were observed outside a hole,
Dmin – a diameter of a circle covering a real hole (this diameter was generally less than the nominal diameter because of damages which were observed inside the hole),
D - nominal diameter of the hole.

The above defined parameters were observed and analyzed at the entry and also at the exit of the drill.

RESULTS AND DISCUSSION

The effect of feed per revolution on the A and B type quality indicators is shown on figs. 1 and 2.

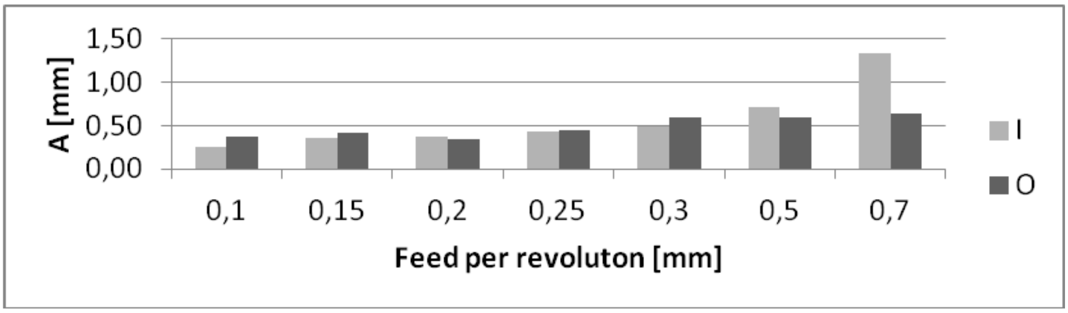

Figure. 1. Effect of a feed per revolution on the external quality indicator A[mm] which was determined at the entry (I) and also at the exit (O) of the drill

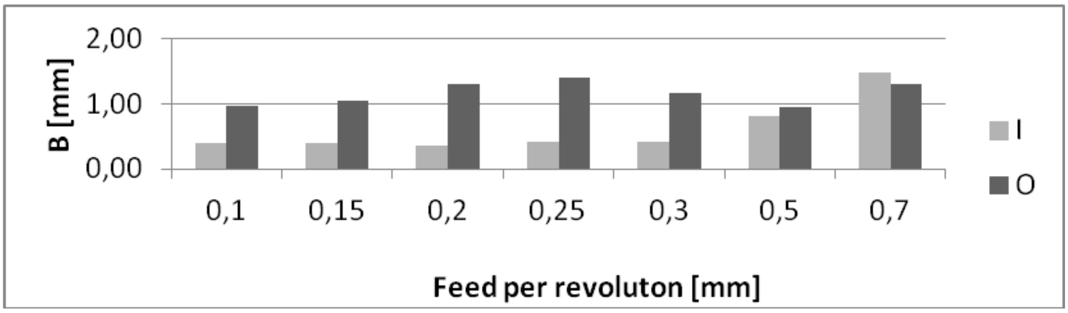

Figure 2. Effect of a feed per revolution on the internal quality indicator B[mm] which was determined at the entry (I) and also at the exit (O) of the drill

The ANOVA results for the A indicator are shown in Tab.2 and results for the B indicator are in Tab.3. The p-value indicates the statistical significance level. Charts in following figures present the average effect of the observation place construed as the entry (I) and the exit (O) of the drill (Fig. 3) and feed per revolution (Fig. 4) on the value of the quality indicators – A indicator on the left and B indicator on the right.

Table.2: ANOVA results for the A indicator

	Sum of Squares	Degree of Freedom	Mean Square	F test	p value	significance rate ω^2
Intercept.	72,54	1	72,54	1747,90	<0,05	
O/I	0,13	1	0,13	3,06	0,08	
Feed	27,33	6	4,55	109,74	<0,05	76,27%
O/I*Feed	0,35	6	0,06	1,42	0,21	
Error	8,13	196	0,04			

Table 3. ANOVA results for values of the B indicator

	Sum of Squares	Degree of Freedom	Mean Square	F test	p value	significance rate ω^2
Intercept.	142,30	1	142,30	2328,94	<0,05	
O/I	23,84	1	23,84	390,12	<0,05	59,31%
Feed	2,06	6	0,34	5,62	<0,05	4,22%
O/I*Feed	2,15	6	0,36	5,87	<0,05	4,46%
Error	11,98	196	0,06			

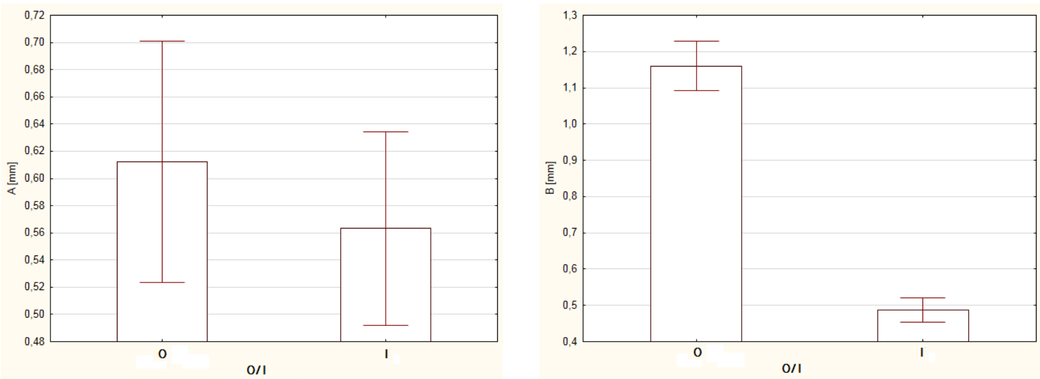

Figure 3. Effect of a place of observation - the entry (I) and the exit (O) of the drill - on the external quality indicator A[mm] (left diagram) and internal quality indicator B[mm] (right diagram)

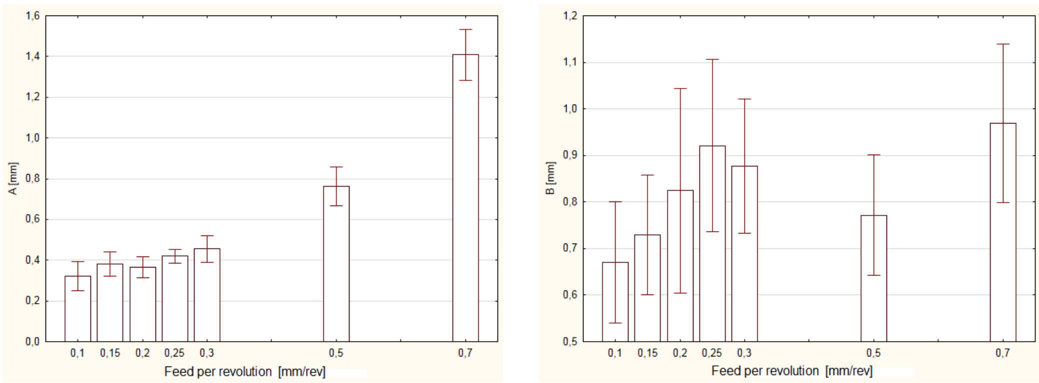

Figure 4. Effect of feed per revolution on the external quality indicator A[mm] (left diagram) and internal quality indicator B[mm] (right diagram)

The data presented in Tab. 2 shows that one of the considered factors turned out to be statistically significant. The significance rate of the factor (ω^2) in terms of their percentage contribution were estimated and it was found that the value of feed per revolution explained more than 76% of the total variation of the A quality indicator (Fig.5 left chart).

The results of ANOVA for the B indicator are presented in Tab.3. Both factors and their interaction turned out to be statistically significant. It was found that the value of feed per revolution explained only 4,2 % of the total variation of the B quality indicator and the more important factor was place of observation (Fig.5 right chart).

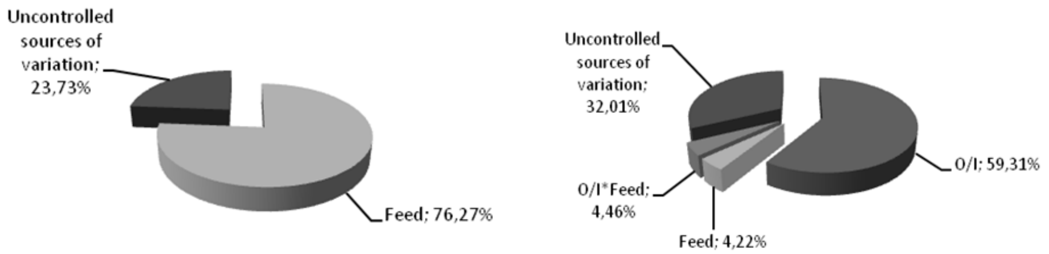

Figure 5 Graphical interpretation of ω^2 from Tab. 2 (left diagram) and from Tab. 3 (right diagram)

The results of measurements of feed force and torque are presented in Fig.6 and Fig. 7. Influence of feed per revolution on both components of cutting force exhibits a linear relationship (coefficient of determination R^2 is respectively 0.99 and 0.95)

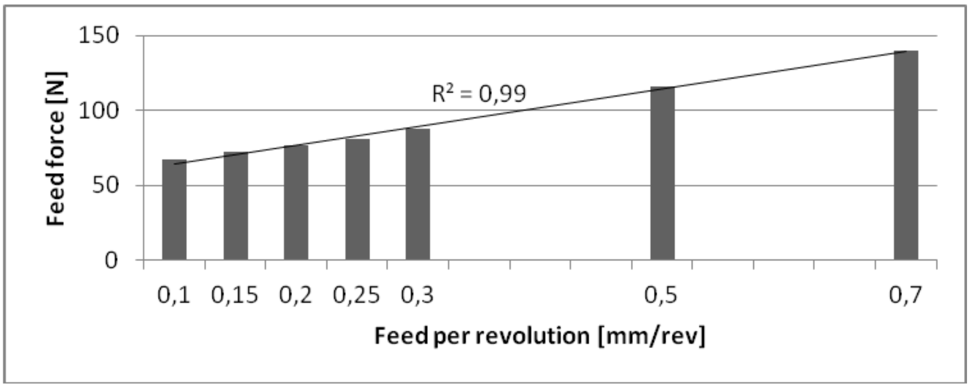

Figure 6. Effect of a feed per revolution on the feed force.

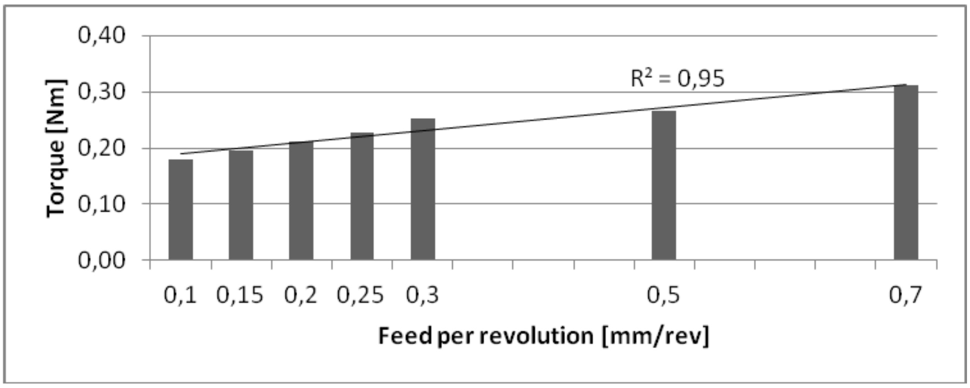

Figure 7. Effect of a feed per revolution on the drilling torque.

CONCLUSIONS

Effect of feed per revolution and place of observation on the quality of drilling MDF is quite different for internal and external kind of quality. For external quality indicator A place of observation had no significant effect and higher feed rate gave lower quality. In the case of the second type of indicator - internal - effect of feed rate was rather weak (but statistically significant) Place of observation on the opposite had larger influence, quality at the entry of the drill was much better than on the other side.

It was no surprise that the impact of feed per revolution on the feed force and torque had a strongly linear relationship. The presented values of the two components of the cutting forces characterize one of the important aspects of MDF machinability.

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Streszczenie: *MDF - podatność na wiercenie.* Rozpatrzono dwa kryteria podatności na wiercenie MDF. Artykuł przedstawia wyniki badań oraz wartości dwóch wskaźników związanych z jakością (typ zewnętrzny i wewnętrzny) oraz dwóch związanych z siłami skrawania (siła posuwu i momentu obrotowego skrawania). Wyniki poddano analizie statystycznej. Wpływ posuwu na obrót i miejsca obserwacji na jakość okazał się zupełnie inny dla wewnętrznego i zewnętrznego typu wskaźnika. Wpływ posuwu na obrót na siły skrawania miał charakter liniowy..

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