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Relationship between machining conditions and feed force during drilling in some wood-based materials

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Abstract: *Relationship between machining conditions and feed force during drilling in some wood-based materials.* The article describes the effect of the feed speed and the cutting speed on the feed force during drilling in: raw MDF, raw particleboard, laminated particleboard and plywood. The feed force signal was measured and recorded. The results were analyzed using multi-factor ANOVA. The analysis confirmed the statistical significance of the considered factors. However the effect of spindle speed was practically negligible in contrast to the type of material and feed rate.

Keywords: cutting speed, feed force, drilling, wood-based materials

INTRODUCTION

In the wood industry, especially in wood-based materials processing, drilling is a very common technological process. Parameters of cutting, especially feed per revolution, may affect cutting resistance [Staniszewska, Zakrzewski 2002, Orlicz 1988]. Experimental determination of cutting forces is important from scientific and from practical point of view. One of the reasons is the fact that values of cutting forces can be a source of information about the relative machinability rate of different wood-based materials.

MATERIALS AND METHODS

Tests were carried out with the use of standard CNC machine-tool (BUSELLATO Jet 130). The tool was 10 mm diameter Leitz drill (ID NR:091193) with one diamond polycrystalline (PCD) cutting edge (Fig.1). The holes were drilled in following wood-based materials (Fig.2):

1 - raw MDF,
2 - raw particleboard,
3 - laminated particleboard,
4 – plywood.

Measuring of feed force was realized by piezoelectric sensor mounted in a special platform (Fig.3). The platform used by Czarniak and Górski [2009] was modified for different shaped samples.

Experimental procedures were the same as in previous tests [Podziewski, Górski 2010]. For each material five different feeds per revolution (0,1 mm, 0,15 mm, 0,2 mm, 0,25 mm, 0,3 mm) and three different spindle speeds (3000 rpm, 6000 rpm and 9000 rpm) were used. Total number of hols was 300 for each material.

Influence of feed per revolution, material type and spindle speed on axial force were tested by means of standard analysis of variance (ANOVA). Tab.1. shows the assignment of conventional levels for the considered factors. ANOVA allowed to evaluate the statistic significance of mentioned above factors. Moreover the percentage contribution of relative significance of each factor was estimated, using following equation:

$$Q_X = (100\ SS_X)/SS_T \qquad (1)$$

where:
Q_X [%] - percentage contribution of factor X,
SS_X - sum of squares deviations due to factor X,
SS_T - total sum of squares deviations.

Tab 1. Assignment of levels for the considered factors for ANOVA

Factors	**Levels of factors**				
	1	**2**	**3**	**4**	**5**
Material	raw MDF	raw particleboard	laminated particleboard	plywood	
Spindle speed	3000rpm	6000rpm	9000rpm		
Feed per revolution	0,1 mm	0,15 mm	0,2 mm	0,25 mm	0,3 mm

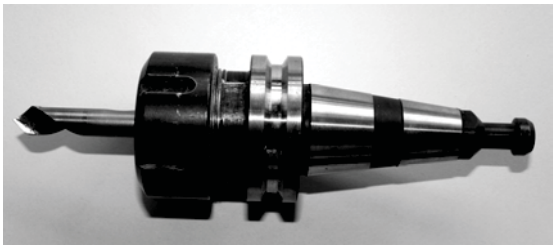

Fig. 1. LEITZ drill used in tests

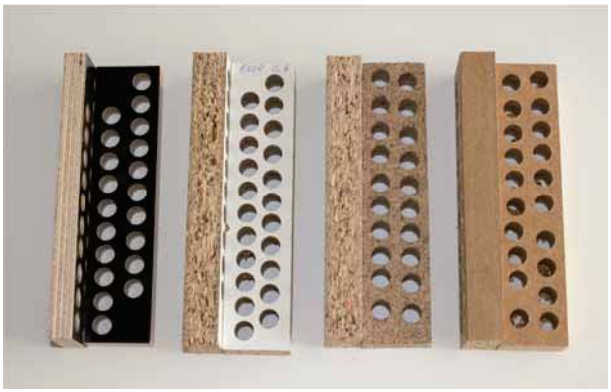

Fig. 2. Samples of tested materials

Fig. 3. Sample fastened in measuring platform.

RESULTS AND DISCUSSION

Results of ANOVA are shown in Tab 2. The p-value for every considered factor came out lower than 0,01. It means that effect of each factor is statistically significant. But relative rate of contribution, estimated according to equation (1), shows that only material and feed per revolution can be considered as really important. The effect of spindle speed on feed force has only 0,5% significance rate. This effect is only symbolic or even negligible. Therefore the results of measurements of feed force for different spindle speeds were averaged by arithmetical mean and presented in Fig.4.

Tab 2. Results of ANOVA test and percentage contribution (Q) calculations.

Variation source	Sum of squares (SS)	Degree of freedom (DOF)	F-ratio (F)	p-value (p)	Percentage contribution (Q)
material	1443003	3	4540,4	< 0,01	75,12 %
spindle speed	9429	2	44,5	< 0,01	0,49 %
feed per revolution	347740	4	820,6	< 0,01	18,10 %
Error	120877	1141			6,29 %
Total	1921049				100 %

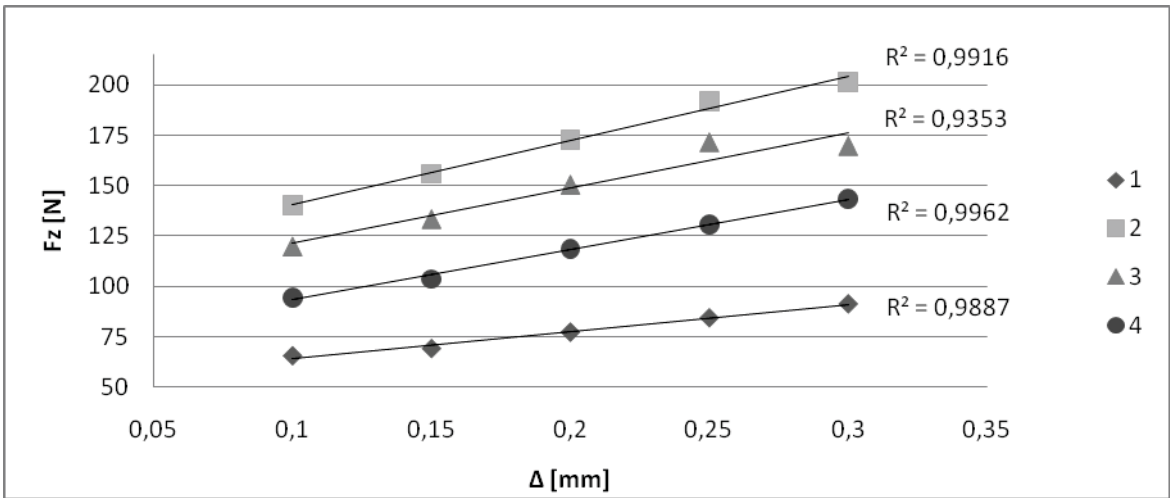

Fig. 4. Relationship between feed per revolution (Δ) and feed force (Fz) for all tested materials (1- raw MDF, 2- raw particleboard, 3- laminated particleboard , 4- shuttering plywood)

Coefficient of determination (R^2) values are presented in Fig 4. and linear trend equations in Tab 3. Following equations are valid in tested range of feeds.

Tab 3. Linear trend equation calculated for materials.

Sample material.	**Linear trend equation**
raw MDF	y = 134,42x + 50,657
raw particleboard	y = 316,44x + 109,19
laminated particleboard	y = 274,12x + 94,097
plywood	y = 249,87x + 68,178

CONCLUSIONS

Results of tests allow to formulate following conclusions.

1. The effect of spindle speed on feed force was practically negligible.
2. Directly proportional relationship between feed per revolution and feed force for each tested material was observed.

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Streszczenie: *Zależność między warunkami skrawania a siłą posuwu w czasie wiercenia w wybranych materiałach drzewnych.* W artykule opisano wpływ prędkości posuwu na siłę posuwu podczas wiercenia w surowej płycie MDF, surowej płycie wiórowej, laminowanej płycie wiórowej oraz sklejce szalunkowej. W czasie wiercenia rejestrowano sygnał siły posuwu. Wyniki badań przeanalizowano przy pomocy analizy wariancji ANOVA. Stwierdzono, że wpływ prędkości obrotowej wrzeciona był praktycznie pomijalny. Decydujące znaczenie miał natomiast rodzaj materiału obrabianego i posuw na obrót.

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