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Drilling susceptibility of particleboard with *Cannabis sativa* L.

Podatność na wiercenie płyt wiórowych z udziałem *Cannabis sativa* L.

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Abstract

The study examined the susceptibility to drilling of chipboards made of hemp shives. The research included measuring the axial force and torque when drilling chipboards with different hemp content (0, 25, 50, 75, 100%). Two variants of cutting parameters were used in the tests (6000 rpm and feed per revolution 0.2 mm and 6000 rpm and feed per revolution 0.25 mm).

The results indicated that the share of hemp shives affects the value of the axial force and torque during drilling. However, an increase in the feed per revolution causes a significant increase in the axial force, but does not cause in a statistically significant effect in torque.

Streszczenie

W ramach pracy zbadano podatność na wiercenie płyt wiórowych z udziałem paździerzy konopnych. Badania obejmowały pomiar siły osiowej oraz momentu obrotowego podczas wiercenia płyt wiórowych różniących się udziałem konopi (0, 25, 50, 75, 100%). W badaniach zastosowano dwa warianty parametrów skrawania (6000 obr/min, a posuw na obrót 0,2 mm i 6000 obr/min, a posuw na obrót 0,25 m).

W oparciu o uzyskane wyniki można stwierdzić, że udział paździerzy konopnej wpływa w istotny statystycznie sposób na wartość siły osiowej oraz moment obrotowy podczas

wiercenia. Natomiast wzrost posuwu na obrót powoduje istotny wzrost siły osiowej, przy czym nie powoduje on zwiększenia momentu obrotowego.

Keywords: drilling, particleboard, hemp shives, axial force, torque

Słowa kluczowe: wiercenie, płyta wiórowa, paździerze konopna, siła osiowa, moment obrotowy

Introduction

The increasing demand for raw wood materials in the particleboard industry drives the need to seek new sources of lignocellulosic material. Some studies have been already conducted, among others, on grasses (Borysiuk and Laskowska 2009), willows (*Salix vimnalis* L.) (Warmbier et al. 2011) or giant miscanthus (Miscanthus giganteus) (Pawlak et al. 2018). Also, a great possibility has been seen in agricultural waste - material rich in lignocellulose such as hazelnut husk (Kowaluk and Kądziela 2014), corn cobs (Sekaluvu et al. 2014, Banjo Akinyemi et al. 2016), sunflower husk (Klimek et al. 2016), and apple wood or plum wood (Auriga et al. 2019).

Industrial hemp (*Cannabis sativa*) may be another promising alternative for the particleboard industry. It is widely cultivated for seeds and fibres. Stalks, when decorticated, give three fractions: long fibres, short fibres and woody core tissue called shives or hurds. Shives are a waste from the hemp industry's point of view. Hemp fibres have been studied for their reinforcement properties in building materials based on cement, hydraulic lime and gypsum binders (Placet 2009, Peyratout and Smith 2009, Murphy et. al. 2010, Dalmay et. al. 2010). The mechanical and physical properties of the composites showed a favourable effect of the fibres. The structure of hemp shives constitutes substantial potential for its use in particleboard production, but it requires thorough investigation.

Aim and scope

The aim of the research was to determine the influence of the share of hemp shives in three-layer particleboards on their susceptibility to drilling. The research included determining the axial force and torque when drilling particleboards with a mass fraction of hemp shives of 0, 25, 50, 75 and 100%. Two variants of feed per revolution of 0.2 mm were used during drilling tests.

Materials and Methods

Particleboards

Three-layer particleboards with hemp shives were used as the research material. The boards were made of industrial wood shavings and hemp shives. The mass fraction of hemp shives in the face and core layers was 0%, 25%, 50%, 75% and 100%. The control variant

consisted of boards made of industrial pine shavings only. Three-layer particleboards with a thickness of 16 mm and a density of 650 kg/m^3 were made.

Urea-formaldehyde resin Silekol 123 (UF) was used to gluing the particles during the manufacturing process. The hardener was a 10% solution of ammonium sulfate. The degree of gluing of the face layers was 10% and the core layer was 8%. The pressing time was 325 s, the temperature was 180°C and the maximum unit pressing pressure was 2.5 MPa. After production, the boards were air conditioned in a normal climate (20 ± 2°C, 65 ± 5% relative air humidity) for a period of not less than 7 days.

Drilling

Machinability tests were performed on a Busellato Jet 130 CNC machining center (Casadei-Busellato, Thiene, Italy). For through drilling (throughout the entire thickness of the board), a new single-point DPI drill with a polycrystalline diamond with a diameter of 8 mm (Leitz) was used.

Drillability was tested for two variants of cutting parameters:

- rotational speed 6000 rpm, feed speed 1.2 m/min and feed per revolution 0.2 mm,
- rotational speed 6000 rpm, feed speed 1.5 m/min and feed per revolution 0.25 mm.

The signals of axial force and torque during drilling were recorded with a Kistler 9345A piezoelectric force sensor (Kistler Group, Winterthur, Switzerland). The sampling frequency was 12 kHz. Ten repetitions were made for each variant.

Statistical analysis

The obtained results were submitted to statistical analysis in Statistica13 (TIBCO Software Inc. 2017). A multivariate analysis of variance (α = 0.05) was performed to determine the relation between variables, the type of these relations and the impact of selected factors on variables. Tukey test (α = 0.05) was used to compare the significance of differences of the individual values in homogenous groups.

Results

The results showed that in the case of a feed per revolution of 0.2 mm, the highest value of axial force during drilling was observed in boards made of 100% hemp shives. The axial force for this type of boards was 31.38 N and was 15.5% higher than in the case of drilling particleboards made of standard wood raw material (Table 1). It should be noted that, in general, the value of the axial force during drilling increases with the share of hemp shives in the boards.

For a feed per revolution of 0.25 mm, the highest value of axial force was observed for particleboards made with 75% hemp shives. It should be noted here that in this case there is no clear trend in relation between the share of hemp shives in the particleboard and the value of the axial force.

Table 1. Axial force and torque when drilling particleboards with hemp shives additive
Tabela 1. Siła osiowa oraz moment podczas wiercenia płyt wiórowych z udziałem paździerzy konopnych

Axial force (N)						
Feed per revolution	Share of hemp shives (%)					average
	0	25	50	75	100	
0,2	27,16^{a}	30,45^{ab}	28,76^{a}	30,90^{ab}	31,38^{abc}	29,73^{I}
0,25	33,54^{abcd}	38,07^{d}	35,97^{bcd}	39,34^{d}	37,78^{cd}	36,84^{II}
average	30,35^{A}	34,00^{AB}	32,35^{AB}	34,84^{B}	34,58^{B}	
Torque (Nm)						
	Share of hemp shives (%)					average
	0	25	50	75	100	
0,2	0,827^{ab}	0,840^{b}	0,837^{ab}	0,784^{ab}	0,822^{ab}	0,822^{I}
0,25	0,750^{a}	0,841^{b}	0,829^{ab}	0,799^{ab}	0,860^{b}	0,816^{I}
average	0,783^{A}	0,841^{B}	0,833^{AB}	0,791^{AB}	0,841^{B}	

a, b, c, d, A, B; I, II - homogeneous groups

In the case of the torque occurring during drilling, there is no clear relationship to the share of hemp shives in the particleboard. However, for a feed per revolution of 0.2 mm, the lowest torque value was observed for particleboards with a 75% share of hemp shives. In this case, there are no statistically significant differences in the torque during drilling for the tested particleboards.

The analysis of variance showed that the share of hemp shives and the feed per revolution had a statistically significant impact on the axial force during drilling (Table 2). However, the impact of hemp shives is insignificant, as evidenced by the percentage impact factor of 10%. It should be emphasized that the feed per revolution has a much greater impact on the value of the axial force during drilling (percentage influence factor 43%).

Table 2. Analysis of variance for the studied factors influencing the axial force and torque when drilling particleboards
Tabela 2. Analiza wariancji dla badanych czynników wpływających na siłę osiowa i moment obrotowy podczas wiercenia płyt wiórowych

Factor/interaction	Axial force		Torque	
	p	X	p	X
Share of hemp shives (SH)	0.0062	10.49	0.0088	16.38
Feed per revolution (FR)	0.0000	43.70	0.6283	0.26
SH x FR	0.9432	0.50	0.0644	10.33
Error		45.30		73.01

p - error probability, X - percentage influence of factors on the examined property of particleboards

In the case of drilling torque, only the proportion of hemp has a statistically significant effect. However, the torque value is influenced to a greater extent by factors not taken into account in this research, as evidenced by the high value of the percentage influence factor obtained for the error (73%).

Conclusion

Based on the research conducted, the following conclusions can be drawn:

1. The influence of the share of hemp shives in particleboards causes a slight increase in the axial force and torque during drilling, this influence is statistically significant.
2. An increase in the feed per revolution during drilling causes a statistically significant increase in the axial force when drilling the tested particleboards, while the effect of the feed per revolution does not have a statistically significant effect on the torque occurring during drilling.

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