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Susceptibility of drilling particleboard with share of hemp shives

Podatność na obróbkę wierceniem płyt wiórowych z udziałem paździerzy konopnych

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Abstract

The influence of the share of hemp shives in individual layers of the three-layer particleboard on its susceptibility to drilling was investigated. Seven variants of three-layer particleboards were produced with the share of 0, 10 and 25% hemp shives in either the face or core layer, as well as in the face and core layers, respectively. The particleboards were examined for the axial force and torque that occurs during drilling.

The obtained results allow to conclude that both the share of hemp shives and the layer in which this share occurs significantly affect the value of the axial force and torque during drilling. It should be marked, that a significant influence on the axial force and torque occurred only when 25% share of hemp shives was at the same time in the face and core layers of the particleboard.

Streszczenie

Zbadano wpływ udziału paździerzy konopnych w poszczególnych warstwach trójwarstwowej płyty wiórowej na jej podatność na wiercenie. Wytworzono siedem wariantów trójwarstwowych płyt wiórowych z 0, 10 i 25% udziałem paździerzy konopnych odpowiednio w: warstwach zewnętrznych, warstwie wewnętrznej i warstwach zewnętrznych i wewnętrznej. Dla wytworzonych płyt wiórowych zbadano siłę osiową oraz moment skręcający występujące podczas wiercenia.

Uzyskane wyniki pozwalają stwierdzić, że zarówno udział paździerzy konopnych jak i warstwa, w której ten udział występuje, w sposób istotny wpływają na wartość siły osiowej oraz momentu obrotowego podczas wiercenia. Należy przy tym zaznaczyć, że istotny wpływ na siłę osiową i moment obrotowy widoczny jest dopiero przy 25% udziale paździerzy konopnych w płycie wiórowej w warstwach zewnętrznych i wewnętrznej.

Keywords: drilling, particleboards, hem shives

Słowa kluczowe: wiercenie, płyty wiórowe, paździerze konopne

Introduction

The developing wood industry and the limited availability of wood raw materials on the market make it necessary to look for new sources of raw materials for the production of particleboards. Therefore, a number of studies aimed at the use of alternative lignocellulosic raw materials in the production of particleboards constantly increase. These studies, among others, include: willows (*Salix vimnalis* L.) (Warmbier et al. 2011), giant miscanthus (*Miscanthus giganteus*) (Pawlak et al. 2018), grasses (Borysiuk and Laskowska 2009). Moreover, there have been attempts to utilize a lignocellulosic biomass, which is an agricultural waste. Research on agricultural waste biomass concerned the application of corn cobs (Sekaluvu et al. 2014, Banjo Akinyemi et al. 2016), sunflower husk (Klimek et al. 2016), hazelnut husk (Kowaluk and Kądziela 2014), and apple wood or plum wood (Auriga et al. 2019).

An interesting alternative for the particleboard industry seems to be Cannabis sativa, which is more and more willingly cultivated in recent years in Europe. Industrial hemp is grown primarily to obtain the seeds for the production of oils and fiber, which is extremely strong and durable. Decortication of the stalks leads to three main fractions: long fibres, short fibres and woody core tissue. The woody core part of the hemp stalk called shives or hurds is considered as a waste in the hemp industry. Many authors have studied the use of hemp fibres as reinforcement for building materials based on cement, hydraulic lime and gypsum binders (Placet 2009, Peyratout and Smith 2009, Murphy et. al. 2010, Dalmay et. al. 2010). They have studied the effect of hemp fibers on the physical and mechanical properties of the fibre composites. Therefore, studies on the utilization of hemp shives are still valid and need supplementation.

Aim and scope of work

The aim of the study was to determine the influence of the share of hemp shives in three-layer particleboards on the susceptibility to drilling. The scope of the work included the determination of the axial force and the torque occurring during the drilling of particleboards with the share of 0, 10% and 25% of hemp shives in the face or core layers, as well as in the face and core layers, respectively.

Materials and Methods

Particleboard

As part of the research, three-layer particleboards with a density of 650 kg/m^3 and a mass fraction of hemp shives at the level of 0%, 10%, and 25% were used. The hemp shives were added to the core and/or face layers in a manner that presents Table 1. The assumed thickness of the panels was 16 mm, the degree of gluing of the face layers 10%, and the core layer 8%. The share of face layers in the board was 35%. UF (Silekol 123) urea-formaldehyde resin was used to seal the particles. The process of pressing the carpets was carried out on a one-shelf press with the 180°C pressing temperature, the maximum unit pressing pressure of 2.5 MPa, pressing time 325 s.

The particleboards produced for the tests were seasoned for 7 days in under standard conditions (20 ± 2°C and 65 ± 5% relative air humidity).

Table 1. Variants of the tested particleboards and their mechanical and physical properties
Tabela 1. Warianty badanych płyt wiórowych i ich właściwości mechaniczne i fizyczne

Variant	Core layer	Face layers	Share of hemp shives (%)	Density (kg/m^3)	MOE (N/mm^2)	MOR (N/mm^2)
A	-	-	0	651	1835	11.05
B	-	X	10	639	1650	9.91
C	-	X	25	646	1695	9.87
D	X	-	10	646	1823	10.70
E	X	-	25	641	2020	12.68
F	X	X	10	650	1795	11.03
G	X	X	25	634	2071	12.75

Drilling

For the machinability tests of particleboards Busellato Jet 130 CNC machining center (Casadei Busellato, Thiene, Italy) was used. For drilling through holes (across the entire thickness of the board) was used a new 8 mm DPI single-edge polycrystalline diamond drill bit , (Leitz, GmbH and Co. KG, Stuttgart, Germany). The following drilling parameters were set: rotational speed 6,000 rpm, feed speed 1.2 m/min., feed per revolution 0.2 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 statistical analysis of the results was carried out in the Statistica13 (TIBCO Software Inc. 2017). In order to show the relation between variables, the type of these relations and the impact of selected factors on variables a multivariate analysis of variance with α = 0.05 was used in the statistical analysis. In order to compare the significance of differences of the individual values, homogeneous groups were used based on the Tukey test (α = 0.05).

Results and Discussion

The results shows that the highest value of the axial force and torque during drilling were noted for particleboards when a 25% share of hemp shives in the face and core layers. The axial force for the boards manufactured under this variant was 42.62 N and the torque 0.252 Nm (Figs 1 and 2). On the other hand, the lowest value of the axial force and torque were characteristic for the panels made with a 10% share of hemp shives in the core layer.

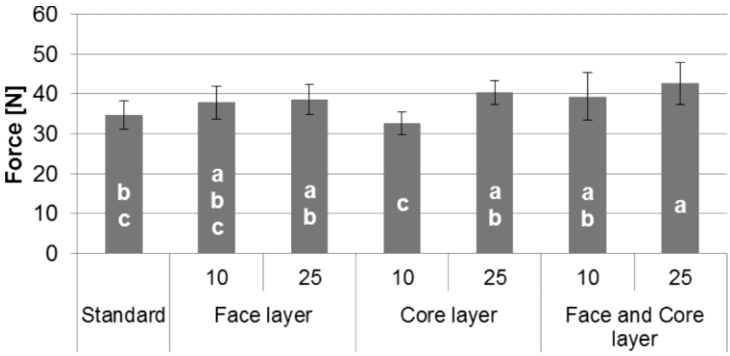

Fig. 1. Results of the axial force during drilling test for the manufactured particleboards
Rys. 1. Wyniki pomiaru siły osiowej podczas wiercenia badanych płyt wiórowych

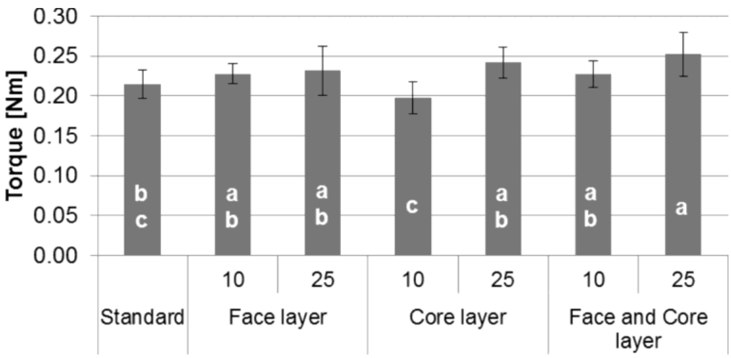

Fig. 2. Results of the torque moment during drilling test for the manufactured particleboards
Rys. 2. Wyniki pomiaru momentu skręcającego podczas wiercenia badanych płyt wiórowych

The statistical analysis of the obtained results revealed that only the panels with a 25% share of hemp shives in the face and core layers had significantly higher values of the axial force and torque, compare the panels made without hemp shives (Table 2).

In the case of susceptibility to machining, the main factor affecting the value of cutting resistance is the density of the produced wood materials (Wilkowski et al. 2014). Moreover, Kowaluk et al. (2018) report that in the case of apple and plum wood particleboards, an increase in the axial force and torque is visible along with an increase in the density of the particle boards tested. When analyzing the obtained results of the axial force and torque, it should be emphasized that the difference in the densities of the plates made within the various variants has not exceed 3% (Table 1).

The analysis of variance revealed that the share of hemp shives and the layer to which hemp shives were added had a statistically significant influence on the value of the axial force during drilling (Table 2). However, the value of the percentage coefficient of the influence of these factors indicates that together they only contribute 27.6% to the value of the axial force during drilling. It should be noted that the percentage impact factor for error in this case was almost 65%. This means that the axial force occurring during drilling is largely affected by factors that were not included in the analysis.

Table 2. Analysis of variance for selected factors and interactions between factors affecting the axial force during drilling
Tabela 2. Analiza wariancji dla wybranych czynników i interakcji pomiędzy czynnikami wpływającymi na siłę osiową przy wierceniu

Factor / interaction	SS	Df	MS	F	p	X
Layer	201.76	2	100.88	5.45	0.0070	13.02
Share	226.57	1	226.57	12.23	0.0010	14.62
Layer*share	121.13	2	60.56	3.27	0.0457	7.82
Error	1000.28	54	18.52			64.55

SS - sum of squared deviations from the mean value, Df - number of degrees of freedom, MS - mean square of deviations (MS = SS/Df), F - test value, p - error probability, X - percentage influence of factors on the examined property of particleboards

The torque during drilling results revealed a similar dependency as in the case of axial force, both the share and the layer to which the hemp shives were added significantly affected the torque value (Table 3). It should be noted, however, that for torque the share of the hemp shives in the boards had a much greater impact than the layer to which the hemp shives were added.

Table 3. Analysis of variance for selected factors and interactions between factors affecting the drilling torque during drilling
Tabela 3. Analiza wariancji dla wybranych czynników i interakcji pomiędzy czynnikami wpływającymi na moment obrotowy przy wierceniu

Factor / interaction	SS	Df	MS	F	p	X
Layer	0.0041	2	0.0020	4.268	0.0190	9.52
Share	0.0088	1	0.0088	18.46	0.0001	20.58
Layer*share	0.0042	2	0.0021	4.348	0.0177	9.69
Error	0.0259	54	0.0005			60.20

SS - sum of squared deviations from the mean value, Df - number of degrees of freedom, MS - mean square of deviations (MS = SS/Df), F - test value, p - error probability, X - percentage influence of factors on the examined property of particleboards

The percentage factor of the influence of the factor which is the share of hemp shives was 20% and was twice as high as for the factor layer to which the hemp chaff was added (9.5%) (Table 3). As in the case of the axial force and in the case of the torque, the percentage error coefficient was over 60%. This proves that in the case of torque factors, that were not included in the conducted tests, had greater impact too.

Conclusions

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

1. The share of hemp shives in the particleboards has a statistically significant influence on the axial force and torque during drilling. However, this significance is visible only when a 25% share of hemp shives in the particleboard in the face and core layers.
2. The board's layer to which hemp shives were added has a statistically significant influence on the axial force and torque during drilling. The presence of the material in the face and core layers had the greatest impact.

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