

## DONIESIENIA NAUKOWE – RESEARCH REPORTS

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### **ANALYSIS OF RELATIVE MACHINABILITY INDEXES OF WOOD PARTICLE BOARDS BONDED WITH WASTE THERMOPLASTICS**

*The paper presents original data concerning one aspect of the machinability of special, wood particle boards bonded with waste thermoplastics. The study focused on the measurement of drilling torque and thrust force. The classic idea of machinability indexes was used. The experimental plastic particle boards (with a nominal density of 650 kg/m<sup>3</sup>) were made of industrial grade core-layer pine wood particles and three different waste thermoplastics: polyethylene, polypropylene and polystyrene. Three different proportions of plastic contents were used: 30, 50 and 70%. The machinability of the boards was tested in relation to commercially-produced materials: standard medium-density fibreboard (MDF) and standard particle board (with nominal densities: 750 and 650 kg/m<sup>3</sup>, respectively). Data presented in the paper suggest that the machinability of wood particle boards bonded with waste thermoplastics, especially waste polyethylene, is particularly good, not only in relation to standard particle boards, but even in relation to standard MDF.*

**Keywords:** wood-plastic composites, waste thermoplastics, machinability

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## Introduction

Nowadays, wood-plastic composites (WPC) are mass produced materials made of wood (fibres, flour, chips etc.) and, most popularly, of thermoplastics. It is generally known that the workability of WPC is reasonably good but there is a lack of quantitative data concerning their machinability indexes. Previous studies of WPC machinability [Buehlmann et al. 2001; Somsakova et al. 2012] are inadequate from this point of view.

The paper presents original data concerning one aspect of the machinability of special, wood particle boards bonded with waste thermoplastics. The study focused on the measurement of drilling torque and thrust force. The classic idea of machinability indexes [Globocki et al. 2009] was used.

The basic aim of the study was to analyze the machinability of wood particle boards bonded with waste thermoplastics in relation to commercially-produced materials: standard medium-density fibreboard (MDF) and standard particle board.

## Materials and methods

The experimental plastic particle boards (with a nominal density of 650 kg/m<sup>3</sup>) were made of industrial grade core-layer pine wood particles and three different waste thermoplastics: polyethylene (PE), polypropylene (PP) and polystyrene (PS). The boards were made following the procedure developed by Borysiuk et al. [2008], and hence 16-mm thick boards were prepared. The pressing parameters were as follows: maximum unit pressure 2.5 MPa, temperature 200°C, pressing time 10 min. The boards were cooled under pressure for 15 min. Three different proportions of plastic contents were used: 30, 50 and 70%. Consequently, the machinability of nine variants of plastic particle boards was tested.

The machinability of the boards was tested in relation to commercially-produced materials which were the objects of an earlier study [Podziewski, Górski 2011], standard medium-density fibreboard (MDF) and standard particle board (with nominal densities of 750 and 650 kg/m<sup>3</sup> respectively).

In all the cases, the drilling process was carried out by means of a standard CNC machine tool (Busellato JET 130) and a standard PCD drill (10mm, Leitz 91193). Three spindle speeds (3000, 6000 and 9000 rpm) and five values of feed per revolution (0.1; 0.15; 0.20; 0.25; 0.3 mm) were used. Consequently, fifteen variants of cutting parameters were taken into account.

The basis of the machinability assessment was the monitoring of the drilling torque (M) and of the thrust force (F), therefore an adequate measuring system (Kistler 9345A, Kistler 5073A) and data acquisition system (NI PCI 6034E, NI LabVIEW) were used.

Adopting commercial MDF as the universal, reference wood-based material, two relative machinability indexes ( $MI_M$  and  $MI_F$ ) were defined:

$$MI_M = (M_{MDF}/M_i) \quad (1)$$

$$MI_F = (F_{MDF}/F_i) \quad (2)$$

where:  $M_{MDF}$ ,  $F_{MDF}$  – mean values of drilling torque and thrust force observed when drilling in MDF (all of the fifteen variants of cutting parameters were taken into account);

$M_i$ ,  $F_i$  – analogue values observed when drilling in the  $i$ -th material (i.e. the particular material tested for its machinability, which was then compared with the machinability of MDF).

The experimental data related to the machinability indexes were analyzed by means of a special software package – STATISTICA 10 (StatSoft Inc.). The analysis was carried out using the standard method of variance analysis (multi-factor ANOVA).

The general characteristics of MDF, as the reference material, were determined in experimental way according to the adequate standards. The basic properties of MDF were as follows: tensile strength [EN 319] – 0.57 MPa, bending strength [EN 310] – 40 MPa, modulus of elasticity [EN 310] – 4020 MPa, swelling in thickness after immersion in water [EN 317] – 8%.

## Results and discussion

The values of the relative machinability indexes, based on the measurement of drilling torque and thrust force, are illustrated in fig. 1 and fig. 2, respectively. It should be noted that the values of both indexes proved to be relatively high for all the special plastic particle boards, especially in relation to the standard wood particle board. This is a very important fact since the lower the drilling torque, the lower the cutting power (i.e. lower energy costs). Moreover, the lower the thrust force, the lower the risk of drill buckling or breakage, which are common problems observed for small hole drilling, especially for high feed rates. From this point of view, the best of the tested materials were the wood particle boards bonded with polyethylene waste (PE). At any rate, the more polyethylene, the better the machinability (at least in the tested range of percentage content). The statistical significance ( $p$ -value below 0.01) of this conclusion was based on the standard method of variance analysis (multi-factor ANOVA). The use of polypropylene (PP) or polystyrene (PS) as bonding components of the boards also had a positive, but much less spectacular effect. In this case, the increase in the plastic content from 30 to 70%, had no statistically significant effect on the machinability indexes.

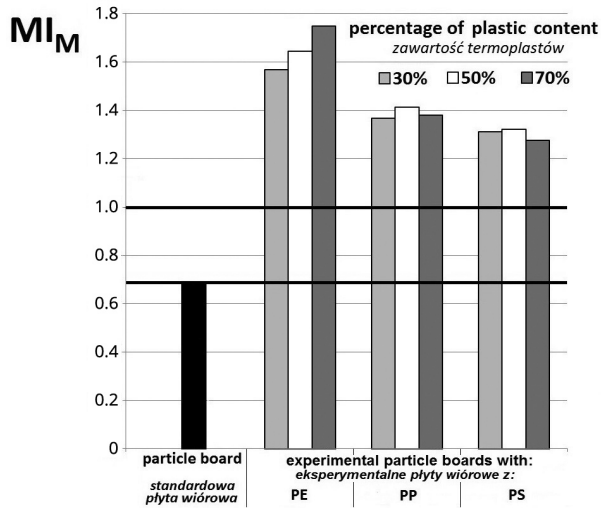


Fig. 1. Values of relative machinability index based on measurement of drilling torque ( $MI_M$  – machinability index defined in the text by means of formula 1, PE – polyethylene, PP – polypropylene, PS – polystyrene)

Rys. 1. Wartości względnego wskaźnika skrawalności związanego z momentem obrotowym skrawania ( $MI_M$  – wskaźnik skrawalności zdefiniowany w tekście za pomocą wzoru 1, PE – polietylen, PP – polipropylen, PS – polistyren)

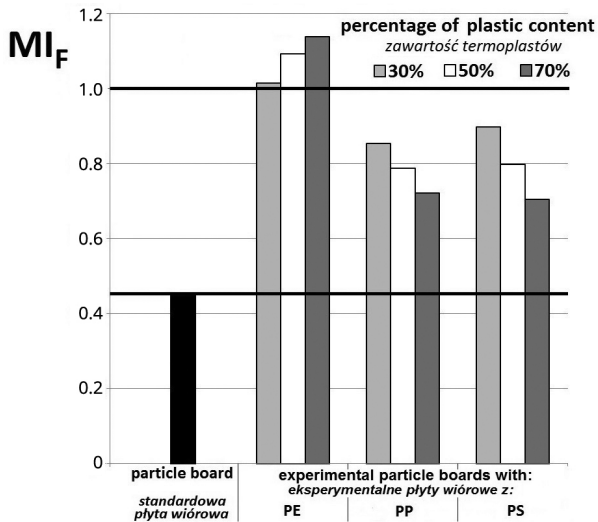


Fig. 2. Values of relative machinability index based on measurement of thrust force ( $MI_F$  – machinability index defined in the text by means of Formula 2, PE – polyethylene, PP – polypropylene, PS – polystyrene)

Rys. 2. Wartości względnego wskaźnika skrawalności związanego z siłą osiową ( $MI_F$  – wskaźnik skrawalności zdefiniowany w tekście za pomocą wzoru 2, PE – polietylen, PP – polipropylen, PS – polistyren)

## Conclusions

The data presented above suggest that the machinability of wood particle boards bonded with waste thermoplastics, especially waste polyethylene, is particularly good not only in relation to standard particle boards, but even in relation to standard MDF.

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## List of standards

- EN 310** [1993]: Wood-based panels: Determination of modulus of elasticity in bending and of bending strength
- EN 317** [1993]: Particle boards and fibreboards: Determination of swelling in thickness after immersion in water
- EN 319** [1993]: Particle boards and fibreboards: Determination of tensile strength perpendicular to the plane of the board

# ANALIZA WZGLĘDNYCH WSKAŹNIKÓW SKRAWALNOŚCI PŁYT WIÓROWYCH SPAJANYCH TERMOPLASTAMI POUŻYTKOWYMI

## Streszczenie

Kompozyty drewnopochodne określane jako WPC (*wood-plastic composites*) zawierają zwykle cząstki drewna (w formie wiórów, włókien, mączki) spojone za pomocą najpopularniejszych termoplastów. Ogólnie wiadomo, że obrabialność takich kompozytów jest

całkiem dobra, ale problemem jest brak jakichkolwiek danych ilościowych dotyczących ich wskaźników skrawalności. Wcześniejsze badania skrawalności WPC są całkowicie niewystarczające z tego punktu widzenia. Niniejszy artykuł prezentuje oryginalne dane na temat jednego z aspektów skrawalności specjalnych płyt wiórowych spajanych za pomocą termoplastów odpadowych. Badania koncentrowały się na pomiarze momentu obrotowego wiercenia i siły osiowej. Podczas interpretacji wyników wykorzystano klasyczną koncepcję wskaźników skrawalności względnej. Płyty eksperymentalne (o nominalnej gęstości  $650 \text{ kg/m}^3$ ) były wykonywane z przemysłowych, przeznaczanych na warstwę wewnętrzną, wiórów sosnowych oraz z trzech różnych termoplastów użytkowych. Wykorzystywano przy tym trzy różne udziały procentowe tworzyw sztucznych: 30, 50 i 70%. W konsekwencji testowano skrawalność dziewięciu różnych wariantów płyt. Badano skrawalność tych płyt w odniesieniu do materiałów komercyjnych – standardowej płyty MDF oraz standardowej płyty wiórowej (o nominalnych gęstościach wynoszących odpowiednio:  $750$  i  $650 \text{ kg/m}^3$ ). Uzyskane dane eksperymentalne sugerują, że skrawalność płyt wiórowych spajanych termoplastami użytkowymi (zwłaszcza polietylenem) jest naprawdę dobra nie tylko w odniesieniu do standardowych płyt wiórowych, ale nawet w odniesieniu do standardowej płyty MDF.

**Słowa kluczowe:** kompozyty drewno-tworzywo sztuczne, termoplasty odpadowe, skrawalność

## Acknowledgements

All the experiments presented in the paper were financed by the National Science Centre in Poland, grant No. N N309 007537 (“Machining of wood based materials” 2009-2013).