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The influence of temperature on selected strength properties of furniture particleboard

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Abstract: *The influence of temperature on selected strength properties of furniture particleboard*. As a part of the study, the influence of temperature on selected properties of furniture particleboard was tested. P2 type industrial particleboards in three finishing options: raw boards (1), boards covered with melamine film in white (2) and black (3) (10 samples per variant) have been subjected to temperatures from -20°C to +120°C, at 10°C intervals. The Time of exposure for individual temperatures was 7 days. MOR, MOE and IB were determined for tested boards. It has been shown that temperatures above 50°C have a negative effect on strength properties of boards. A large decrease in all tested parameters was observed in the temperature range from +60°C to +120°C. It was also noted that finishing boards with melamine film did not improve their durability.

Keywords: furniture particleboard, temperature, strength properties

INTRODUCTION

The conditions of use show a significant impact on the properties of wood-based panels that are the basic component of many products, e.g. furniture. Poland is the third largest exporter of furniture in the world, after China and Germany. In 2018, Poland exported furniture worth PLN 45.6 billion (www.biznesmeblowy.pl). In terms of categories, most of furniture produced in Poland is used in table rooms and living rooms, bedroom furniture and kitchen furniture (https://businessinsider.com.pl). One of the basic raw materials used in production of furniture is three-layer particleboard (type P2 according to EN 312:2011) covered with melamine film. In 2018, a total of 4.85 million m^3 of particleboard was produced in Poland (http://www.fao.org). During use, furniture particleboard may be exposed to changing environmental conditions: relative air humidity and temperature. Kozakiewicz and Matejak (2013) report, among others, that in facilities, especially in summer, there is a high probability of subjecting equipment elements to temperatures above 40°C.

The first research on the effect of temperature on lignocellulosic materials was mainly focused on solid wood. At the beginning of 20th century, Baumann (1922) and Vorreiter (1938) showed that frozen wet wood has greater strength when compared to wood with a positive temperature. Kollmann (1940 and 1942) stated that irrespective of humidity, wood at 20°C has about 30 to 50% lower compressive strength along fibres when compared to wood at -42°C. At the same time, he showed that with temperature increasing in the range from -200°C to +200°C, wood's resistance to forced shape changes decreases and its compressive strength along fibres is also reduced. Similar results were obtained by Kozakiewicz (2010) examining, among others, effect of temperature in the range from -40°C to +80°C on compressive strength along fibres of selected types of wood of various density and anatomical structure. He also showed that with changes in temperature typical for closed spaces (temperature changes in domestic utility rooms), i.e. between +7°C and +38°C, changes in strength can be considered insignificant. An increase in temperature also negatively affects the properties of wood materials (Bekhta *et al.* 2003). Authors stated, among others, that temperature changes from +20°C to +140°C (at 20°C intervals) with 1.0 hour of exposure time to a given temperature affects the reduction of MOR by a maximum of 40% for particleboard, 37% for MDF and 30% for OSB. The observed changes were linear. In turn, Sonderegger and Niemz (2006), subjecting wood materials to 1.5 hours exposure to temperature in the range from -20°C to +60°C (at 20°C intervals) showed that the smallest decrease in strength parameters (MOR and MOE) was recorded for plywood (respectively 12 and 14%) and the largest for blockboards (39 and 46%, respectively). As a result of research, particleboard was characterized by a decrease in MOR of 26% and a MOE in the range of 37 to 43% (for boards with a thickness of 16 and 18 mm). Ayrilmis *et al.* (2010) examining the mechanical properties of plywood, OSB and MDF exposed for 48 hours to temperature in the range of -30°C to +30°C (at 10°C intervals), found a decrease in their strength, with the largest changes observed in the temperature range from -10°C to +10°C. Borysiuk *et al.* (2018) examining MFP boards found that an increase in temperature in the range of -20°C to +120°C causes a decrease in MOR by an average of 30% and a decrease in MOE by an average of 26%.

The aim of the work was to determine the influence of temperature on strength properties of industrial furniture particleboard (type P2). The scope of work included exposure of boards to temperatures in the range of -20°C to +120°C (at 10°C intervals) during 7 days. The particleboard used in this study was in three variants of finish: raw boards (1), boards covered with melamine film in white (2) and in black (3).

MATERIALS AND METHODS

The study was conducted with the use of industrial furniture particleboard (type P2) in three different finishes: raw boards – PB, boards covered with melamine film in white – PB_w and black – PB_b. Boards covered with melamine film differed only in colour. They were characterized by a nominal thickness of 18 mm and an average density: 674 kg/m^3 for raw panels and 720 kg/m^3 for panels covered with melamine film.

Samples of boards with dimensions of 50 mm by 300 mm (10 for each variant) were exposed to temperatures between -20°C and +120°C at 10°C intervals (15 temperature variants in total). Samples were exposed to the specified temperature for 7 days. Each time the process was carried out at normal pressure without controlling relative air humidity. Immediately after exposure to temperatures samples were tested:

- MOR and MOE – in accordance with standard EN 310:1994. The length of the specimens for test was 300 mm – not 360 mm plus 50 mm, as it should be done according to standard. The span between the supports during tests was 280 mm;
- IB – in accordance with the standard EN 319:1999.

To compare the obtained results of strength properties, one-factor analysis of variance (ANOVA) was carried out using Statistica 13.1 software.

RESULTS AND DISCUSSION

Results of the research are presented in Fig. 1, 2 and 3. Generally it can be stated, that increase of temperature has the effect on decrease in strength properties of particleboards type P2. Analogous dependency was noted by many authors (among others Bekhta *et al.* 2003, Sonderegger and Niemz 2006, Ayrilmis *et al.* 2010, Kulman *et al.* 2015, Borysiuk *et al.* 2018) in relation to other wood materials, which was also presented in the introduction. The dependencies obtained as a part of the study are linear (R^2 in the range from 0.5037 to 0.9392). It confirms data presented by Bekhta *et al.* (2003). Both in case of MOR and MOE, the largest decrease in value (for temperatures in the range from -20°C to +120°C) was recorded for boards finished with melamine film (Fig. 1 and Fig. 2). It was from 44% to 50% for MOR and from 36% to 49% for MOE for PB_w and PB_b boards. For raw particleboard (PB), the decrease in MOR and MOE in the full range of tests was 31% and 27%, respectively. These values generally are comparable to data given in the literature for particleboard (Bekhta *et al.* 2003, Sonderegger and Niemz 2006, Borysiuk *et al.* 2018). It should be noted, however, that literature data usually refers to other types of particleboard exposed to temperatures in narrower ranges of temperature variations and significantly shorter exposure times. In the temperature range most commonly found in utility rooms, i.e. +10°C ÷ +30°C, slight fluctuations in strength values were observed for both raw (PB) and melamine film finished boards (PB_w and PB_b). PB_w and PB_b boards in the same temperature range were generally characterized by greater variability of strength parameters in relation to PB boards. At -20°C ÷ +50°C, the differences between selected MOR values of the tested boards are statistically significant – it can be specified in this range: 4 homogeneous groups of MOR values for PB boards, 3 homogeneous groups of MOR values for PB_w boards and 2 groups of homogeneous values MOR for PB_b boards (table 1). Similarly, in case of MOE, in temperature range -20°C ÷ +50°C, statistically significant differences between selected values were noted – it can be specified in this range: 5 groups of homogeneous MOE values for PB boards and 2 groups of homogeneous MOE values for boards PB_w and PB_b (table 1). It should be noted that in this temperature range all boards (type P2) meet the requirements of EN 312:2010 regarding MOR (above 11 N/mm^2). Regarding MOE, tested boards met the requirements of above standard (above 1600 N/ mm^2) in the entire tested temperature range (-20°C ÷ +120°C). A clear decrease in MOR and MOE values for tested boards was recorded at temperatures above +50°C. It is worth adding that the differences in MOR and MOE values of tested boards in the temperature range +60°C ÷ +120°C are generally not statistically significant (table 1). Kulman *et al.* (2015) while examining the influence of temperature in the range of +20°C ÷ +80°C on MDF properties showed significantly greater decreases in MOR and MOE values than in case of tested particleboards in the same temperature range.

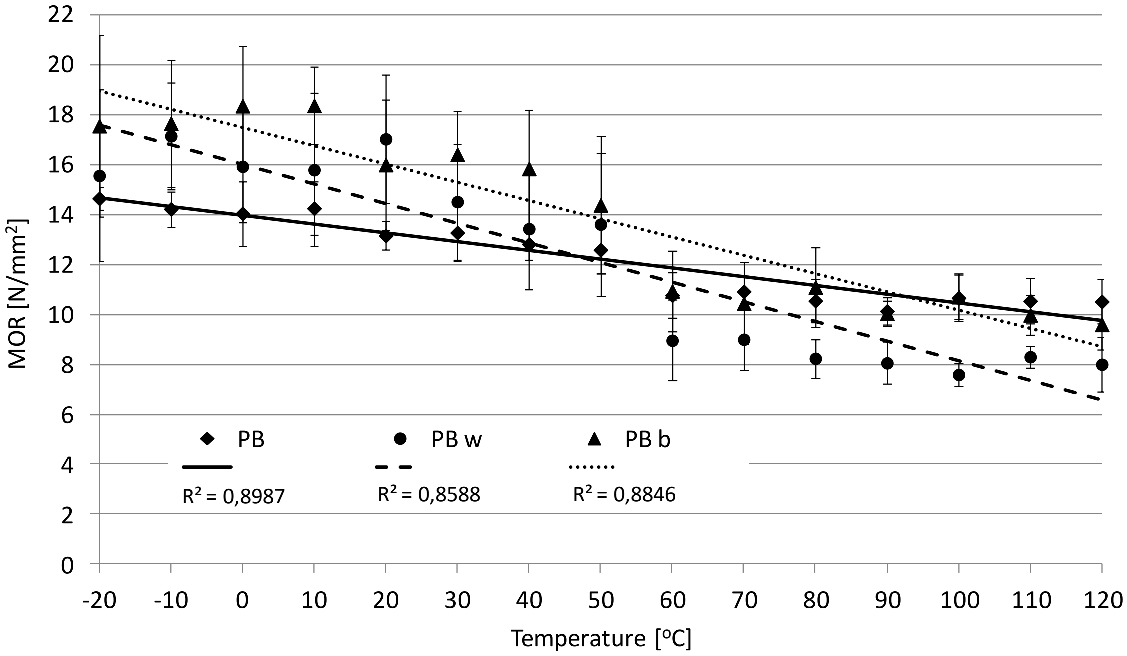

Figure 1. Dependence of particleboards MOR on the exposure temperature

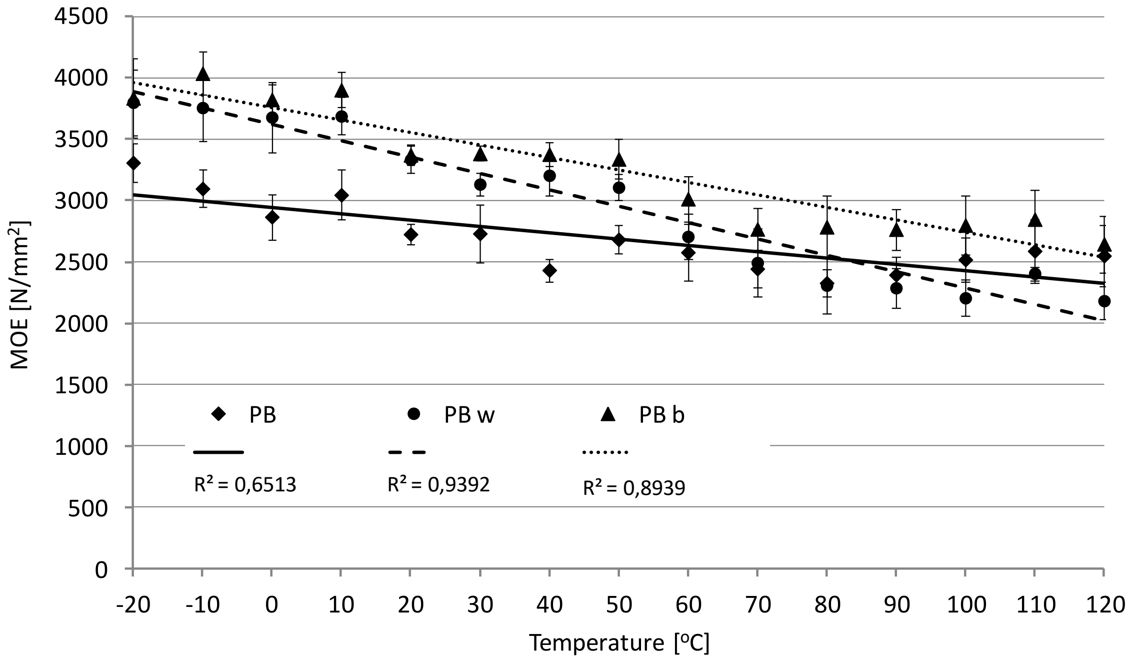

Figure 2. Dependence of particleboards MOE on the exposure temperature

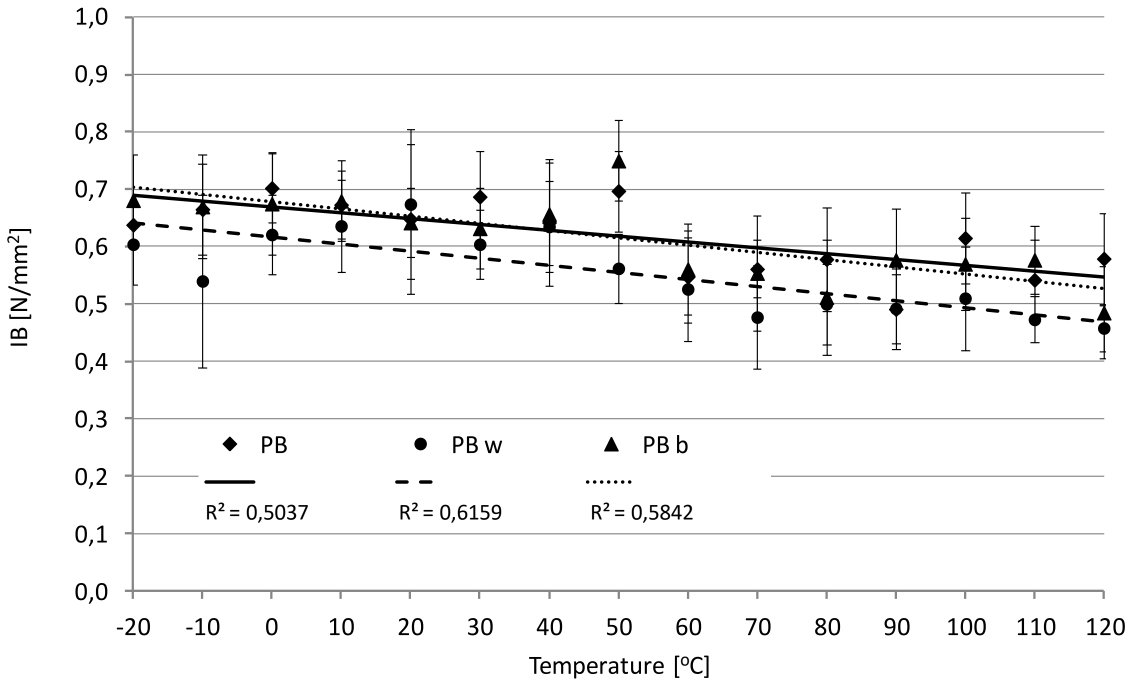

Figure 3. Dependence of particleboards IB on the exposure temperature

As in the case of MOR and MOE, also IB values of boards decrease with increasing temperature (Fig. 3). In tested temperature range from -20°C to +120°C, the decrease in IB value for boards finished with melamine film was PB_w - 22% and PB_b - 30%, respectively (Table 1). For raw particleboard (PB), a decrease of IB in the full range of research was 9%. In case of IB (similar to MOR and MOE), a decrease in the value for temperatures above +50°C was noted, but it was not so clear (greater variation in homogeneous groups than for

MOR and MOE) (Table 1). It should be added that in the whole temperature range, boards meet the requirements of EN 312:2010 regarding IB (above 0.35 N/mm^2).

Table 1. The relative values of the studied strength properties (MOR, MOE, IB) in relation to the boards obtained at 20°C with regard to one-factor analysis of variance of examined strength characteristics in reference to temperature exposure (a, b, c, d, e, A, B, C, D, E, 1, 2, 3, 4, 5 – homogeneous groups).

Temperature [°C]	MOR [%]			MOE [%]			IB [%]		
	PB	PB_w	PB_b	PB	PB_w	PB_b	PB	PB_w	PB_b
-20	111^{e}	91^{BC}	110^{3}	121^{e}	114^{D}	114^{4}	98^{bcde}	90^{BCDE}	106^{45}
-10	108^{de}	101^{C}	110^{3}	114^{de}	113^{D}	120^{4}	103^{cde}	80^{ABCD}	104^{345}
0	107^{cde}	94^{BC}	115^{3}	105^{bcd}	110^{D}	113^{4}	108^{e}	92^{CDE}	105^{345}
10	108^{de}	93^{BC}	115^{3}	112^{cde}	111^{D}	116^{4}	104^{cde}	94^{DE}	106^{45}
20	100^{bcd}	100^{C}	100^{23}	100^{abcd}	100^{C}	100^{3}	100^{bcde}	100^{E}	100^{345}
30	101^{bcd}	85^{BC}	103^{23}	100^{abcd}	94^{C}	100^{3}	106^{de}	90^{BCDE}	98^{2345}
40	97^{bc}	79^{B}	99^{23}	89^{a}	96^{C}	100^{3}	99^{bcde}	94^{DE}	102^{345}
50	96^{b}	80^{B}	90^{2}	98^{abc}	93^{C}	99^{3}	108^{de}	83^{ABCDE}	117^{5}
60	82^{a}	53^{A}	68^{1}	95^{ab}	81^{B}	89^{2}	84^{abc}	78^{ABCD}	87^{1234}
70	83^{a}	53^{A}	65^{1}	90^{a}	75^{AB}	82^{12}	87^{abc}	71^{A}	86^{123}
80	80^{a}	48^{A}	69^{1}	85^{a}	69^{A}	83^{12}	89^{abcd}	74^{ABC}	80^{12}
90	77^{a}	47^{A}	63^{1}	88^{a}	69^{A}	82^{12}	76^{a}	73^{AB}	90^{1234}
100	81^{a}	45^{A}	67^{1}	92^{ab}	66^{A}	83^{12}	95^{bcde}	76^{ABC}	89^{1234}
110	80^{a}	49^{A}	62^{1}	95^{ab}	72^{AB}	84^{12}	84^{ab}	70^{A}	90^{1234}
120	80^{a}	47^{A}	60^{1}	94^{ab}	65^{A}	78^{1}	89^{abcd}	68^{A}	76^{1}

The decrease in strength of boards in the studied temperature range results from impact on both wood particles and glue joints. During heating of boards, elementary wood particles forming particleboard shrink, as a result of which microcracks in the material that may weaken its internal structure may arise. Green *et al.* (1999) report that permanent changes in the strength of wood caused the impact of higher temperature are a consequence of hydrolysis of acetyl and formyl groups of hemicelluloses, as a result of which acetic and formic acids are formed. An analogous process of degradation of wood material and glue lines also occurs as a result of the impact of hardener residues present in the joints. With regard to gelled glue, it should be noted that temperature itself up to 200°C does not affect degradation of UF and MF glue joints (Hirata *et al.* 1999).

CONCLUSION

As a result of research of both raw and finished with melamine film furniture particleboards exposed to temperature in the range from -20°C to +120°C, the following conclusions were formed:

1. The increase in temperature causes a decrease in the mechanical properties of P2 type furniture particleboard.
2. Particleboards covered with melamine film are characterized by a greater range of decrease in strength properties as a result of an increase in the temperature of use compared to unfinished boards.
3. The increase in the temperature of use of furniture particleboard finished with melamine film in the range from -20°C to +120°C causes a decrease in MOR and MOE by over 40% and IB by over 20%.

4. P2 type furniture particleboards meet the requirements of EN 312:2010 for MOR in the temperature range from -20°C to 50°C, and for MOE and IB in the full temperature range from -20°C to 120°C.

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Streszczenie: *Wpływ temperatury na wybrane właściwości wytrzymałościowe meblowych płyt wiórowych*. W ramach pracy zbadano wpływ temperatury na wybrane właściwości meblowych płyt wiórowych. Przemysłowe płyty wiórowe typu P2 w trzech wariantach wykończenia: płyty surowe (1), płyty pokryte filmem melaminowym w kolorze białym (2) i w kolorze czarnym (3) (po 10 próbek na wariant) zostały poddane działaniu temperatur od -20^{o}C do +120^{o}C, z od stopniowaniem, co 10 K. Czas oddziaływania poszczególnych temperatur wynosił 7 dni. Dla badanych płyt oznaczono MOR, MOE. IB, odporności laminatu na pękanie. Wykazano, że temperatura powyżej +50^{o}C wywiera negatywny wpływ na właściwości wytrzymałościowe płyt. Zaobserwowano duży spadek wszystkich badanych parametrów w przedziale temperatur od +60^{o}C do +120^{o}C. Stwierdzono również, że wykończenie płyt filmem melaminowym nie wpływa na poprawę ich wytrzymałości.

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