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Selected properties variability of wood on trunk height of Norway spruce (*Picea abies* (L.) H. Karst) of Istebna Bukowiec origin from the provenance surface in Głuchów – pilot research

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Abstract: Selected properties variability of wood on trunk height of Norway spruce (*Picea abies* (L.) H. Karst) of Istebna Bukowiec origin of the provenance surface in Głuchów - pilot research. Spruce is one of the most important forest-forming species, forming a large number of populations differing in quality of the being created wood. For research, a single, representative trunk of a 40-year-old tree of Istebna Bukowiec provenance, was obtained from the Głuchów research field. The test results oscillated around the averages for the species but were clearly higher than those obtained in earlier studies of the same origin, from the same experimental surface, but from a younger stand. The tested samples were characterized by high variability of flattening and eccentricity, medium variability of annual ring width and the share of late wood and high homogeneity of wood density.

Keywords: Norway spruce, wood density, ovality, eccentric growth, annual rings, late wood

INTRODUCTION

Spruce (*Picea abies* (L.) H. Karst) is the second species, right away after pine, in terms of occurrence in Poland. As a ruling species and co-occupying, it occupies 6.3% of forests in Poland [Domaszewicz et al. 2017]. Its area of occurrence includes two distinguishable ranges: north and south-west [Jaworski 2011]. In the natural range of spruce, 13 genetic regions have been identified throughout the region, of which 3 of them: the Eastern and Southern Carpathians, Western Carpathians and north-eastern Carpathians, are found in Poland and contain 12 mother regions [Puchniarski 2008].

The origin and growth habitat are factors affecting the size of the annual increments created. In conifers, narrow-leaved wood is considered a higher density material. The highest density is characterized by wood originating from the apical part of the trunk, especially from the root collar, and moving towards the apex, the density decreases. In cross-section the density of coniferous trees increases from the core to the perimeter, omitting juvenile wood [Krzysik 1978]. However, not all studies are unambiguous in this respect. For example, according to Michalec, Wąskik and Barszcz [2016], the density and share of late spruce wood from tree stands of the lower and upper shelves did not show any significant differences. However, in the studies of Barzdajn [1996] and Matras [2002] spruce wood from mountain areas, despite narrow annual growth, was characterized by a lower density than the population from the north-eastern range. The maternal spruce origin is in Istebna Bukowiec at an altitude of 630 m above sea level [Bieniasz et al. 2017]. In the oldest experiment of the International Union of Forest Research Organizations (IUFRO 1938) it was shown that that regardless of the location of the research area, said spruce reaches highest height [Masternak, Polak-Berecka 2014]. In Bieniasz and other studies [2017] on origin of spruce descended from Istebna Bukowiec, the average width of the annual ring in the experimental area in Głuchów was 3.24 mm, the share of late wood was 9.97% and the average density of air-dry wood was 397 kg/m³.
The aim of the research is to determine the variability of selected properties of spruce wood (density, graininess, flattening, eccentricity, share of late wood) at the trunk height on the example of a single Istebna Bukowiec tree from the area originated in Gołuchów. This will allow the assessment of the technical quality of the wood, its potential suitability for woodworking.

MATERIAL AND METHODS

The research was carried out on the material obtained in 2017 on the area of Forest Experimental Station WULS in Rogów, located in the Forestry Gluchów (branch 231d, formerly - 179c). From a representative tree from the provenance of Istebna Bukowiec, a breast hight slice and sequentially more slices from a height of 2 m up to the top of the tree were obtained. The examined tree with the designation 31-11-61 had a height of 19 m. After natural drying and seasoning in laboratory conditions (climate close to normal), the samples were planed and ground.

Wood moisture content has been determined according to EN 13183-3: 2005. The flattening and eccentricity of the samples was calculated using the following formulas and relationships:

\[ S = \frac{D_{\text{max}} - D_{\text{min}}}{D_{\text{max}}} \times 100 \text{ [%]} \]

\( S - \text{ovality [%]}, \)
\( D_{\text{max}} - \text{the largest diameter [mm]}, \)
\( D_{\text{min}} - \text{the smallest diameter [mm]}, \)

\[ S_{\text{NS}} = R_N - \frac{D_{\text{NS}}}{2} \text{ [mm]} \]
\[ S_{\text{WE}} = R_W - \frac{D_{\text{WE}}}{2} \text{ [mm]} \]

\( S_{\text{NS}} - \text{theoretical center on the north-south axis [mm]}, \)
\( S_{\text{WE}} - \text{theoretical center on the west-east axis [mm]}, \)
\( R_N - \text{radius on the north axis [mm]}, \)
\( R_W - \text{radius on the west axis [mm]}, \)
\( D_{\text{NS}} - \text{diameter of north-south axis [mm]}, \)
\( D_{\text{WE}} - \text{diameter of the west-east axis [mm]}, \)

\[ M = \sqrt{S_{\text{NS}}^2 + S_{\text{WE}}^2} \text{ [mm]} \]

\( M - \text{eccentric growth (eccentric location of pith) [mm]}. \)

The wood density was determined using X-ray computed tomography (CT NeuViz 16 tomograph with integrated DAS detector (16-line tomograph - activation of 16 layers with one gantry rotation in 0.5s - minimum 0.75 mm resolution) and the Dicom Viewer program. Transverse section samples on the NS axis were placed in the maximum number of measuring fields with dimensions of approximately 20x20mm. The graininess and share of late wood was measured in the WinDENDROTM 2016a program in the north, south, east and west directions.
RESULTS AND DISCUSSION

The average values of flattening of the spruce trunk and the eccentricity of the core position in the stem are respectively - 3.3% and 5.4 mm (table 1). These features were characterized by a high coefficient of variation, at 70 and 76%. Spruce wood is extremely susceptible to the simultaneous occurrence of flattening, eccentricity and reaction wood. These are the disadvantages that increase the amount of waste during processing [Krzysik 1978]. In the analyzed trunk the size of the flattening was not large. Macroscopically, no sclerosis was found.

![Graph of eccentricity and ovality](image1.png)

**Fig.1.** Variability of eccentricity and ovality at the height of the trunk in tree number 31-11-61

![Graph of density and width of annual increments](image2.png)

**Fig.2.** Dependence of density and width of annual increments on height.
Analyzing the variability of these traits at the trunk height, it can be seen that overall eccentricity decreases with height (fig. 1), while the flattening shows no more pronounced tendency (it is accidental).

### Table 1. Test results of slices from tree number 31-11-61.

<table>
<thead>
<tr>
<th>tree</th>
<th>the height of the sample collection [m]</th>
<th>the number of rings [-]</th>
<th>ovality [%]</th>
<th>eccentric growth [mm]</th>
<th>width of the ring [mm]</th>
<th>share of late wood [%]</th>
<th>share of late wood [mm]</th>
<th>density [kg/m³]</th>
<th>humidity [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>31-11-61</td>
<td>1.3</td>
<td>32</td>
<td>4</td>
<td>11.4</td>
<td>3.91</td>
<td>15</td>
<td>0.59</td>
<td>400</td>
<td>10.7</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>4</td>
<td>7.2</td>
<td>3.70</td>
<td>18</td>
<td>0.65</td>
<td>411</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>26</td>
<td>0</td>
<td>12.2</td>
<td>4.28</td>
<td>15</td>
<td>0.61</td>
<td>404</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>24</td>
<td>3</td>
<td>3.6</td>
<td>4.16</td>
<td>17</td>
<td>0.72</td>
<td>417</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>21</td>
<td>0</td>
<td>7.6</td>
<td>4.40</td>
<td>17</td>
<td>0.73</td>
<td>421</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>2</td>
<td>3.8</td>
<td>4.01</td>
<td>22</td>
<td>0.86</td>
<td>442</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>16</td>
<td>6</td>
<td>0.9</td>
<td>4.16</td>
<td>19</td>
<td>0.78</td>
<td>480</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>12</td>
<td>6</td>
<td>5.6</td>
<td>4.22</td>
<td>21</td>
<td>0.88</td>
<td>493</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>8</td>
<td>6</td>
<td>0.4</td>
<td>4.08</td>
<td>19</td>
<td>0.76</td>
<td>450</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>8</td>
<td>2</td>
<td>1.8</td>
<td>4.15</td>
<td>13</td>
<td>0.55</td>
<td>447</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td></td>
<td>3.3</td>
<td>5.4</td>
<td>4.11</td>
<td>17.6</td>
<td>0.71</td>
<td>437</td>
<td></td>
</tr>
<tr>
<td>standard deviation</td>
<td></td>
<td></td>
<td>2.3</td>
<td>4.1</td>
<td>0.20</td>
<td>2.8</td>
<td>0.11</td>
<td>31.9</td>
<td></td>
</tr>
<tr>
<td>coefficient of variation [%]</td>
<td></td>
<td></td>
<td>70</td>
<td>76</td>
<td>4.8</td>
<td>15.9</td>
<td>15.8</td>
<td>7.3</td>
<td></td>
</tr>
</tbody>
</table>

The annual ring width of the examined wood varied within a small range, therefore the dependence of the width of the grain, density and share of late wood is not very clear (table 1, fig. 2).

Based on the comparison of the results obtained with the studies of Bieniasz et al. [2017], it can be initially stated that the raw material collected from older stands from the same experimental plots has higher parameters. It is noticeable in particular in the width of annual growth (they are 0.87 mm wider) and density, where in the examined stem it was on average 40 kg / m³ more.

Generally, the wood of the studied spruce was characterized by low density variation on the cross-section of the stem, which is a favorable raw material feature. This wood may be a potential substitute for thicker but more variable pine wood, e.g. in the application of layered Barlinek boards.

**CONCLUSIONS**

On the basis of the conducted research and analysis of wood from the spruce trunk (*Picea abies* (L.) H. Karst) origin of Istebna Bukowiec from the provenance surface in Gołuchów, the following conclusions were made:

1. In the examined trunk the eccentricity decreases with its height and is characterized by high variability.
2. The average flattening is small (well over 3%), but at the same time has high variability in the length (height) of the trunk.
3. From the base to the top of the trunk, the graininess, the share of late wood and density grow slightly.
4. Due to the small variability of graininess, the share of late wood and density, the tested wood has a potentially high usefulness in wood processing.

REFERENCES


The presented research was created in project NR BIOSTRATEG2/298950/1/NCBR/2016 “EFRAWOOD” co-financed by The National Centre for Research and Development (NCBR) under Strategic research and development programme “Environment, agriculture and forestry” – BIOSTRATEG.

Streszczenie: Zmienność wybranych cech drewna na wysokości pnia świerka pospolitego (Picea abies (L.) H.Karst) pochodzenia Istebna Bukowiec z powierzchni prowieniencyjnej w Gołuchowie – badania pilotażowe. Świerk pospolity jest drugim gatunkiem, zaraz po sośnie, pod względem liczności występowania w Polsce. Ze względu na szeroki zasięg tworzy charakterystyczne i jednocześnie odmienne dla danych obszarów populacje cząstkowe, różniące się między sobą cechami jakościowymi i wytrzymałościami pozyskiwanego z nich drewna. Pochodzenie Istebna Bukowiec w dotychczasowych badaniach prowieniencyjnych wyróżniało się bardzo wysokimi zdolnościami przystosowawczymi. Badanie pojedynczego (i jednocześnie typowego dla drzew wytypowanego pochodzenia) 40 letniego pnia świerkowego wykazało, że wraz z wysokością maleje mimośrodowość położenia rdzenia, a słoistość i udział drewna późnego oraz gęstość nieznacznie rosną. Ogólnie drewno badanej świerka cechowało się niską zmiennością gęstości na przekroju poprzecznym pnia, co jest korzystną cechą surowcową.
Variability of annual rings and density of Scots pine (Pinus sylvestris L.) wood of Bolewice origin from the provenance surface in Rogów

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Abstract: Variability of the Scots pine (Pinus sylvestris L.) wood of Bolewice origin from the provenance surface in Rogów. Scots Pine (Pinus sylvestris L.) is the main forest-forming species of Poland and the basic raw material of the domestic wood industry. The provenance of the Bolewice pine is considered one of the most valuable in Poland, characterized by high quality breeding. In the pilot studies of wood from two trees of this provenance from the LZD surface in Rogów large changes in the share of late wood and the width of annual growth from the core to the perimeter were noticed. The material tested was also characterized by high density variation on the north-south axis.

Keywords: Scots pine, annual rings, wood density, late wood, origin and provenance of trees

INTRODUCTION

Scots pine (Pinus sylvestris L.) is the most common tree in Polish forests. This species, due to the wide range of occurrence, is characterized by high variability of morphological and fitness features, physiological-growth and adaptive-immune traits [Andrzejak, Żybara 2012].

It is generally accepted that Europe has 3 subspecies of Scots Pine, but the uniform description is hindered by its geographical variability. On the basis of long-term provenance studies in Poland, 25 regions of pine origin were identified in which seeds for renewals and afforestation are obtained. Some are extremely valuable for foresters and industry [Nowakowska 2007; Przybylski et al. 2015]. One of such origins is the so-called Bolewice pine. This ecotype comes from the Bolewice Forest District (Wielkopolskie Province) and is considered one of the most valuable in Poland, characterized by high breeding quality [Giertych 1997; Barzdajn 2008; Szeligowski et al. 2015].

The first provenance stands of Scots pine were founded by Ludwik Vilmorin in 1820-1830 in France [Sabor 2006] and to this day it is the most important method of assessing the variability between and within the population of trees [Kulej 2001; Szeligowski et al. 2015]. On the surface of the Forest Experimental Station in Rogów in the study from 1976, the Bolewicki pine was characterized by above-average survival and thus good adaptive properties. Pine from Bolewice found itself in the group of the highest and thickest trees. It was characterized by the highest efficiency of 345.4 / ha. Despite the largest number of trees with the worst straightness of the arrow and branch thickness, it obtained a high breeding value [Szeligowski et al. 2015].

The density of dry pine wood is 300-490-860 kg/m³ [Krzysik 1978]. This characteristic depends mainly on the width of annual growth and the share of late wood. Krzysik (1978) states that the optimal width is 0.5 - 2.0 mm. As in other conifers, the density is interchangeable due to the position in the trunk. Wood has the highest density in the aperture,
decreasing with the height of the trunk. Density also changes on the cross-section, increasing along with distance from the core [Krzysik 1978; Dzbeński et al. 2000].

The goal of this research is to link the width of yearly increments with the density of Bolewice pine wood from the Rogów provenance area. This will allow technical evaluation of this wood and determine whether high quality of breeding also goes along with high quality of wood.

MATERIAL AND METHODS

The Rogów comparison surface of Scots pine was established in 1966 on the initiative of the Forest Research Institute in order to study the offspring of 16 domestic mother populations in central Poland (Skierniewice Forest District). The breeding was established in the Lipce forestry, branch 44j, on post-agricultural lands. Habitat was defined as fresh mixed coniferous forest. The one-year-old pine seedlings were planted in a 1x1 m trough, in a random block arrangement with five repetitions [Szeligowski et al. 2015]. The material for testing was acquired in 2016 as part of a partial thinning using the Kraft method. From the two harvested trunks, the rollers were cut at 1.3 m height and the middle beams on the N-S axis. Wood after natural drying was seasoned under normal climate conditions.

Moisture content of wood was made using the capacitive method according to EN 13183-3:2005. The measurement of annual rings in the N-S directions was made using a ruler and an unaided eye. In order to determine the proportion of late wood, the scanner and the WinDENDRO™ program were used. Density on samples obtained from central beams was determined using the stereometric method in accordance with the recommendations of standard ISO 13061-2: 2014

RESULTS AND DISCUSSION

On the N-S axis of the cross-section (Fig. 1, 2) the average width of the rings varies from the core to the perimeter. The widest annual growths occur in juvenile wood (even more than 5 mm in the first increment), and at once with the distance from the core decrease (only 1.10 mm for the last increment). This is a typical arrangement of annual growth widths in conifers from artificial plantings [Krzysik 1978; Tomczak 2009]. During the first years of growth, young pine trees planted in 1x1 m trusses [Szeligowski and others 2015] had a large access to light and generated large increments. After melting the stand, competition increased to light, which translated into smaller width of annual increments.

![Fig. 1. Variability of the annual growth and the share of late wood from the core to the periphery in the north and south directions in the ribs of tree 3-2-194](image-url)
Fig. 2. Variability of the annual growth and the share of late wood from the core to the periphery in the north and south directions in the bbs of tree 1-2-66

The share of late wood was inversely proportional to the width of annual growth due to the slightly changing width of late wood in individual rings (average 0.76 mm). This is one of the main factors causing a change in the density of coniferous wood from the core to the perimeter [Krzysik 1978].

This is confirmed by studies carried out on beams from trees 3-2-194, 1-2-66 obtained on the NS axis (Fig.3). The lowest density of wood was noted near the pith (samples N1, S1), where the average value was 435 kg/m³. The density increased as the samples moved away from the pith, with the circumference obtaining an average value of 589 kg/m³ (Fig.3). Such a high difference in density on the cross-section of the trunk is unfavorable when using such material in the wood industry. For example, using such pine wood for the production of flooring materials would indicate the separation of the pith zone from the peripheral. In the production of laminated floorboards (eg Barlinek floorboards), individual layers can be obtained by peripheral cutting (low density wood will be separated in the form of a core log).

Fig. 3. Change in wood density from core to perimeter in trees 3-2-194 and 1-2-66
CONCLUSIONS
On the basis of conducted pilot studies and wood analyzes of two trunks of Scots pine (*Pinus sylvestris* L.) of the Bolewice origin from the breeding area of the provenance in Rogów, the following conclusions were made:

1. The pine of the Bolewice ecotype in the early years of life produces wood with wide annual increments and a small share of late wood. As the trees age, the rings become narrower and the share of late wood grows.
2. The density of wood is significantly related to the width of annual growth and the share of late wood.
3. The density of wood shows a high variation in the cross-section of tree trunks. The value of density is the lowest at the core and the highest at the circumference of the stem (increase by more than 200 kg/m³).

REFERENCES
Streszczenie: Zmienność słoistości i gęstości drewna sosny zwyczajnej (*Pinus sylvestris* L.) pochodzenia Bolewice z powierzchni proweniencyjnej w Rogowie. Sosna zwyczajna jest gatunkiem o wysokiej zmienności ze względu na szeroki naturalny zasięg występowania. Populacje różnią się między sobą zdolnością przystosowawczą, cechami morfologicznymi i jakością pozyskiwanego z nich surowca. Sosna pochodzenia Bolewice jest uważana za jeden z cenniejszych polskich ekotypów. W badaniach pilotażowych dwóch pni tej proweniencji z powierzchni doświadczalnej w Rogowie, stwierdzono, że gęstość drewna wyraźnie rośnie od rdzenia do obwodu (wzrost o ponad 200 kg/m³ w drewnie powietrznosuchym). Wspomniana właściwość związana jest z malejącą od rdzenia do obwodu pnia szerokością przyrostów rocznych i wzrastającym w nich udziałem drewna późnego. Wysoka zmienność analizowanych cech nie jest korzystna przy wykorzystaniu surowca w przemyśle drzewnym.

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Shrinkage and density of archeological pine wood from 17th century pavement

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Abstract: Shrinkage and density of archeological wood from 17th century pavement. In Central Europe, in the 17th century, the custom of reinforcing and laying roads with wood was preserved. The remains of these structures are still found in many places and its' material is often in surprisingly good condition. As part of the work, selected physical properties of pine wood found at the depth of 1.5 m, constituting a part of the road laid around 1680, were examined. The condition of the wood was varied. This wood was characterized by high initial humidity, high longitudinal contractions and low density after drying. The process of drying the wood was accompanied by the formation of numerous transverse cracks and deformations.

Keywords: Scots pine, archeological wood, density, shrinkage, moisture content

INTRODUCTION

Wood as an organic material generally exhibits low resistance to the destructive effects of biotic factors, in particular fungal organisms (Blanchette and Hoffmann 1994, Krajewski and Witomski 2005). For this reason, archaeological wood is usually more or less degraded (damaged). The state of preservation of archeological wood is mostly influenced by environmental conditions and woods' natural resistance, while time plays a secondary role (Dzbeński 1969, Kozakiewicz and Matejak 2013). Wood has a chance to survive for a long time in a dry or wet environment (e.g. in deeper layers of moist soil). Such finds include, among others, found wooden surfaces or road foundations.

The beginnings of wooden roads date back to the Neolithic culture, when passages through swamps and swamps were built on wooden trunks. Wood-lined roads, typical in forest areas from the Baltic Sea to the Black Sea, inhabited by Slavic tribes, were called the "most" (bridge) (in from their "moszczenia" (expected to line) with wood and fagin). An example of such a road was the "smolny (tar) bridge", which was built in the 13th century to transport tar and potash from the Goleniowska Forest to the port of Szczecin. It is estimated that in the urban areas of Central Europe, the custom of strengthening streets with wooden bales survived until the 17th century. The width of such transitions was usually 2.5 m, but it could reach as much as 5-6 m. Narrow roads were usually made of transverse poles with a length of approx. 2 m, also fastened to beams running along the road (Kozakiewicz and Matejak 2003). Nowadays, the wooden foundation of forest roads is still being used, in particular in the areas of natural and valuable wetlands (Trzciński et al. 2017).

The degradation of wet archaeological wood is usually assessed, among others, by pressing a metal probe, moisture determinations, calculation of contract density, loss of wood mass or size of contractions (Dzbeński 1969, Zborowska 2010). Partially degraded archaeological wood extracted from the wet environment usually undergoes strong shrinkage, cracking and deformation when drying out (Mańkowski et al. 2016, Andres et al 2017). The purpose of this work was to determine the state of preservation of pine wood and extracted from moist soil layers and originating from the 17th century road surface.
MATERIAL AND METHODS

Scots pine wood (*Pinus sylvestris* L.) was used for the study - the name is to EN 13556: 2003. The samples were cut from the elements of pine trunks or their fragments lying at a depth of approx. 1.5 m. They formed a reinforcement of the road arranged around 1680. The top layer was stone crushed. Trunks with diameters from a dozen to several dozen centimeters long and up to 5.5 m in length constituted the foundation of the road. Diversified diameters and varying size of visible knots indicate that wood was used for construction almost from the whole length of trunks of cut trees, ie from their attenuated to apical areas. Visible annual increments on cross-sections allow to state that they were trunks obtained from trees aged up to approx. 90 years.

Samples for testing were obtained from complete cross-sections of 5 elements (stems) with a typical degradation grade typical for the entire material, evaluated using a metal probe. Determinations of physical properties of archaeological wood were carried out according to standard methods. The wood was used to obtain cuboidal samples for shrinkage, density and humidity (ISO 13061-1:2014, ISO 13061-2:2014, ISO/DIS 13061-13:2016). The results obtained were also subjected to standard statistical analysis. For particular properties, the position metrics (arithmetic mean) and dissemination measures (standard deviation and coefficient of variation) were determined, among others.

RESULTS AND DISCUSSION

The pine archaeological wood was in a wet state with humidity well above the saturation point of the fibers (in some elements the humidity exceeded even 300%). The average moisture content of archaeological wood was slightly over 200% (Fig.1). Indirectly this indicated partial degradation of wood - biotically damaged wood is characterized by a higher moisture content (Dzbeński 1969, Andres et al 2017). For comparison, saturated with water, healthy wood in living pine trees has a humidity in the range of approx. 40% (heartwood) to 150% (sapwood) - Kozakiewicz (2013).

Probably, considering the old conditions of road use, initially the partial distribution of wood occurred as a result of the activity of fungal organisms, and the subsequent retention of elements in ever deeper, moist layers of soil was more conducive to the activity of anaerobic bacteria (Krajewski and Witomski 2005).

Pine archaeological wood in the wet state (initial) was characterized by a higher density compared to fresh (wet) contemporary wood (Fig.1). This only seemingly advantageous feature is due to the higher humidity of the excavation wood. In fact (after removing the moisture) it has an average of half the density compared to healthy wood, demonstrating quite strong weakening (destruction) of cell walls. Also very high coefficients of variation and standard deviations were noted for density. In an absolutely dry state, some areas of archaeological wood had a density typical of healthy modern wood or slightly higher (mainly heartwood), while others were extremely light with a density of even less than 100 kg/m$^3$ (mainly sapwood). This is typical kind of damages. Pine hardwood has a naturally higher durability compared to bentwood. According to EN-350-2: 2016, the heartwood of pine wood is affected by fungi causing decay, medium to low resistance (class 3-4), and pine wood the lowest (class 5).

The results of the contraction tests are presented in Figure 2, which fully confirmed the initial material evaluation based on the measured moisture content and the penetration of the metal probe. The average values of contractions in the tangent and radial directions were close to the values recorded for modern (native) pine wood. A huge difference was noted in the value of contractions along the fibers. In archaeological wood, it obtained an average value of 5.5%, whereas in modern wood this shrinkage is only about 0.2% (it is over 25 times smaller).
This clearly indicates damage to the wood excavated from the road (partial degradation of its structure).

**Fig. 1.** Moisture content and density of archeological pine wood form five randomly chosen logs (over one hundred samples) with comparison to contemporary wood

**Fig. 2.** Shrinkage of archeological pine wood form five randomly chosen logs (over one hundred samples) with comparison to contemporary wood

It was a process with varying intensity. Some zones of archaeological wood were completely healthy and others strongly or very heavily damaged (mainly areas at the outer contour of the elements coinciding with the sapwood zone). This translates into exceptionally high standard deviations and variability coefficients of the examined features. The coefficient of variability of the examined features of archaeological wood is at the level of about 30-40%, whereas in the modern one it usually does not exceed 10%.
Partially degraded wood usually has more than normative shrinkage values when drying (Dzbeński 1969, Zborowska 2010), which usually leads to numerous and deep cracks and significant changes in shape, and in extreme cases, to loss of cohesion - disintegration into smaller, heavily deformed pieces (Andres et al 2017).

The observed changes seem to be typical. The examined archaeological wood constituting a fragment of the road from around 1680, before being found (and was found today at a depth of 1.5 m), was originally laid almost on the surface of the tract - in a zone particularly vulnerable to attack by fungi (use class 4 - direct contact with ground and water, according to EN 335:2013). Under these conditions of use, deep wood impregnation is currently recommended (EN 460:1994). Probably the survival of the wood was determined by its form (logs with large diameters) and a relatively fast covering with new layers contributing to the maintenance of a moist protective state.

CONCLUSIONS

Based on the research and analysis of pine wood from the 17th century road surface, the following conclusions were made:

1. The condition of individual elements of pine excavation wood is varied from good to bad (moderately strong or strong degradation covers about 50% of its thickness, mainly sapwood).
2. Pine archaeological wood was characterized by high initial humidity, and low density after drying and high longitudinal shrinkage (many times higher than in healthy wood) while maintaining similar to modern wood shrinkage in the radial and tangent direction.
3. The process of drying archaeological wood was accompanied by the formation of numerous transverse cracks and deformations, resulting from high longitudinal shrinkage.

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Streszczenie: Skurcz i gęstość drewna sosnowego z XVII- wiecznej nawierzchni drogowej. Użycie drewna do podbudowy i nawierzchni dróg było aż do XVII wieku dość powszechne w Środkowej Europie. Pozostałości takich konstrukcji są odnajdywane w wielu miejscach, a drewno często zaskakuje dobrym stanem zachowania. W ramach pracy zbadano wybrane właściwości fizyczne wykopalskiego drewna sosnowego. Próbki pobrano z pni zalęgających na głębokości 1,5 m, które stanowiły fragment drogi ulożonej ok. 1680 roku. Stan zachowania drewna był zróżnicowany (na ogół dobry stan naturalnie strefy twardzielowej oraz na zły bieli). Drewno charakteryzowało się wysoką wilgotnością w strefie naturalnie strefy twardzielowej oraz wysokim skurczem wzdłużnym oraz niską gęstością po wysuszeniu. Procesowi wygęszczań towarzyszyło powstawanie licznych pęknięć poprzecznych i deformacji, szczególnie w strefie bielastej. Badania tego typu stanowią swoisty, kilkusetletni poligon doświadczalny do oceny naturalnej trwałości drewna i mogą zostać wykorzystane przy współczesnych konstrukcjach dróg z wykorzystaniem drewna w rejonach przyrodniczo cennych.

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An attempt to estimate the impact of investment expenditures of wood-industry companies on the sold production of the sector

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Abstract: An attempt to estimate the impact of investment expenditures of wood-industry companies on the sold production of the sector. The increasing consumers requirements regarding the features and quality of the product they use is forcing continuous technical progress in all branches of industry. The main goal of the improvements introduced by companies is to achieve customer satisfaction and, consequently, gain new markets and achieve satisfactory financial results. Favourable economic effects can be expected when the value of sold production of industry increases. The development of enterprises allows to gain new markets, produce more, increase employment and compete effectively with other entities. In this article, we will analyze the value of capital expenditures of Polish wood-sector divisions as the main factor affecting the development of the sector.

Key words: wood-industry companies, sold production, investment outlays, innovativeness.

INTRODUCTION

The main factor of the country's economic growth is the continuous development of enterprises operating in this country. The measure of the size of the economy is called Gross Domestic Product - GDP. It reflects the value of all goods and services produced by entities operating in a given country. Growing year by year value of produced goods and services mean the country's economic development - constant technical and technological progress is a prerequisite for this.

Polish wood industry is an important sector of the economy in the country and constantly evolving. In 2014 wood-industry companies generated approximately 8.5% of the added value of the entire domestic industry. It is worth noting, that the share of this industry sector in the added value earned by industry has been growing. In the monetary value, the sector's share in the value added of the Polish economy was gradually increasing, almost doubling its value: from almost 17 billion PLN in 2005, to 32 billion PLN in 2014 [Czemko et al., 2017]. Also, Poland with its 4.5% share of world furniture exports, is one of the biggest furniture exporters in the world, alongside China, Germany and Italy [Grzegorzewska, Stasiak-Betlejewska, 2014]. In the area of innovations Polish wood-industry companies, especially furniture manufactures, are most active and modern [Szostak, Ratajczak, 2009]. From this point of view, it seemed to be interesting to check if and in what extent the investment expenditures on research and development affect the values of sold production of wood-sector enterprises.

METHODOLOGY

The growing importance of wood-sector enterprises in the national economy was a reason to analyze the share and dynamics of sold production of this industry. Values of wood-industry sold production were analysed in relation to whole industry. The wood-sector share
of sold production data were collected for the years 2014-2016; the dynamics of these values was calculated for the 2007-2016 years. The next step was to examine what investment expenditures in years 2014-2016 has been incurred by wood-industry enterprises and whether these values affect the sector’s sold production. The relevant data was taken from the Central Statistical Office Yearbooks (GUS).

RESULTS

The share of sold production of wood-industry’s divisions in 2014-16 years is presented in Table 1.

Table 1. Share of sold production of wood-industry products in 2014-2016 years

<table>
<thead>
<tr>
<th>Share of sold production of wood-industry products (previous year=100)</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Manufacture of products of wood, cork, straw and wicker</td>
<td>2.3</td>
<td>2.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Manufacture of paper and paper products</td>
<td>3.3</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Manufacture of furniture</td>
<td>3.4</td>
<td>3.6</td>
<td>3.8</td>
</tr>
</tbody>
</table>

Source: Authors own calculations based on Central Statistical Office data (GUS)

The analysis of the data presented in Table 1 shows that the share of sold production values are characterized by an upward trend. The upward trend is maintained in all branches of the wood-industry: manufacture of products of wood, cork, straw and wicker, manufacture of paper and paper products and manufacture of furniture. The lowest share of the sold production reached the manufacture of wooden products, in 2014 this share amounted to 2.3% of the total industry. It may indicate improvement of this situation are increasing values of the share of sold production in subsequent years, (in 2015 – 2.5%). Although they are not large, but noticeable. The highest values of share of the industry’s sold production were recorded in the furniture manufacturing. This wood-industry sector share of total industry’s sold production reached 3.4% in 2014, and even 3.8% in 2016. Also, the analysis of data summarized in Table 1 allows to observe, that the highest increases of sold production could be observed precisely for this division of industry.

Analyzing the share of sold production of wood-industry in total industry, it is worth checking the dynamics of these values. Table 2 presents the dynamics of sold production of the wood-industry Polish companies from 2007 to 2016.

Table 2 analysis leads to the conclusion, that the biggest fluctuations in the sold production volume from year to year are noted by the manufacture of furniture. The highest increase in the value of sold production of this industry division was recorded in 2011 (a value over 15.4% higher than in the previous year). This positive result of furniture manufacture’s sold production was lost in the next year and reached 93.6%.
Table 2. Dynamics of sold production of wood-industry products in 2007-2016 years

| Dynamics of sold production of industry by divisions (previous year =100) |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  | 2007            | 2008            | 2009            | 2010            | 2011            | 2012            | 2013            | 2014            |
| Total            | 110.7           | 103.6           | 95.5            | 109             | 107.5           | 100.5           | 101.8           | 104.1           | 106             | 103.6           |
| Manufacture of products of wood, cork, straw and wicker | 112.9           | 101.8           | 94.5            | 107.6           | 103             | 102.5           | 103.4           | 109.7           | 105.4           | 102.2           |
| Manufacture of paper and paper products                    | 109.2           | 96.0            | 105.7           | 118.3           | 106.3           | 103.3           | 108.1           | 104.7           | 106.3           | 103.8           |
| Manufacture of furniture                                   | 109.5           | 104.1           | 99.8            | 94.2            | 115.4           | 93.6            | 110.4           | 112.9           | 110.8           | 109.6           |

Source: Authors own calculations based on Central Statistical Office data (GUS)

The best year in terms of the results of the sold production for the manufacture of wood, cork, straw and wicker was the year 2007 - increases in the examined values in comparison to the previous year reached about 13%. For the division of manufacture of paper and paper products the year 2010 turned out to be the best when it comes to increases in the dynamics of sold production.

The highest declines in the dynamics of sold production for the two above-mentioned divisions of industry in comparison to the previous year were observed in 2009 (for manufacture of wood, cork, straw and wicker products), and 2008 (for manufacture of paper and paper products).

Analyzing the data presented in Table 2, a constant increase in the sold production of all the discussed sections of wood-industry, especially in 4 last years, can be noticed. This may be a positive premise of the sold production values achieved in the future.

A necessary condition for the growth of the economy as a whole, and also for individual industry sectors is investment outlays. In a stable situation of the economy, it can be expected, that enterprises are eager to allocate funds for activities that can increase the competitiveness of the company, namely innovations and technological improvements in production process. Table 3 shows investment outlays in wood-industry divisions in 2014-2016 years.

The highest share of investment outlays among all analyzed wood-industry divisions are noted in division manufacture of paper and paper products. The share rates of enterprises investment outlays from this division in 2016 reach 3,2%. Manufacture of wood, cork, straw and wicker products takes the second place in classification of investment expenditures - in 2016, the share of expenditures reaches 2,2%. The lowest values of investment outlays in the sector of wood-industry enterprises in 2016 is shown by furniture production.

Comparing the wood-industry discussed divisions values of investment outlays, it can be observed, that in 2014 the investment expenditures of manufacture of wood, cork, straw and wicker and manufacture of furniture was at a similar level. Also, the number of entities qualified for the above mentioned divisions of wood-industry sector was comparable. In the following year, the manufacture’s of wood and wood products investment expenses increased to 146% in relation to the value from 2014. A comparable increase in investment outlays could also be expected in the furniture manufacturing. Unfortunately, the investment outlays this industry division incurred in 2015 amounted to 102,8% of the value from the previous year. This happened despite the increase in the number of entities included in this industry division.
Table 3. Investment outlays in wood-industry divisions in 2014-2016 years

<table>
<thead>
<tr>
<th></th>
<th>Investment outlays in industry by divisions</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>in PLN</td>
<td>in percent</td>
<td>Dynamics (previous year=100)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>91064,4</td>
<td>100</td>
<td>115,5</td>
</tr>
<tr>
<td>Manufacture of products of wood, cork, straw and wicker</td>
<td></td>
<td>1689,8</td>
<td>1,9</td>
<td>132,0</td>
</tr>
<tr>
<td>Manufacture of paper and paper products</td>
<td></td>
<td>2529,9</td>
<td>2,8</td>
<td>98,2</td>
</tr>
<tr>
<td>Manufacture of furniture</td>
<td></td>
<td>1666,8</td>
<td>1,8</td>
<td>149,1</td>
</tr>
</tbody>
</table>

Source: Authors own calculations based on Central Statistical Office data (GUS)

In the following year, investment expenditures were further reduced. This happened in all of discussed industry divisions. The reduction in investment outlays took place in all the concerned divisions of wood-industry, despite the increase in the number of companies included in the mentioned divisions.

The data provided in Table 3 are supplemented with the information about enterprises that introduced innovations or improvements in the production process during 2014-2016 – this data is shown in Table 4.

Table 4. Product and process innovative enterprises by number of persons employed during 2014-2016

<table>
<thead>
<tr>
<th></th>
<th>Product and process innovative enterprises in industry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enterprises which introduced new or significantly improved products or processes during 2014-2016 (in % of total enterprises)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>Total</td>
<td>37,8</td>
</tr>
<tr>
<td>Manufacture of products of wood, cork, straw and wicker</td>
<td>27,5</td>
</tr>
<tr>
<td>Manufacture of paper and paper products</td>
<td>36,7</td>
</tr>
<tr>
<td>Manufacture of furniture</td>
<td>30,2</td>
</tr>
</tbody>
</table>

Source: Authors own calculations based on Central Statistical Office data (GUS)
The data presented in Table 4 are a supplement to information about the innovativeness of Polish wood-industry enterprises, from the employment point of view. As we can observe, the share of enterprises which introduced new or improved products or processes in total amount of enterprises reached only about 38%. Only manufacture of paper and paper products division reached a similar level of innovative enterprises’ share in the total number of entities, exactly 36.7%. The share of innovative enterprises in their total number in other discussed wood-industry divisions is significantly lower than value mentioned above and for the years 2014-2016 it is less than 30%. The analysis of values presented in Table 4 shows, that the share of enterprises introducing innovative solutions in the field of products and processes is higher in the case of large enterprises employing over 250 people. This share reaches 50% for manufacture of wood, cork, straw and wicker products, about 48% for manufacture of furniture and even 68.4% for manufacture of paper and paper products.

CONCLUSIONS

Polish wood-industry is an important sector of the economy in Poland, and it is constantly evolving. It is believed that the ability to innovate is an indispensable factor in the competitiveness of enterprises. Polish wood-industry enterprises try to keep up with the constantly developing market and introduce the necessary innovations in the construction of products and manufacturing processes to effectively compete with other entities. Growing in recent years value of sold production of all branches of the wood industry may be evidence of the enterprises development.

To gain the opportunity to research and develop new products and improvements in existing ones, funds are necessary. As the data presented in the paper indicate, investment expenditures are characterized by significant fluctuations. Due to a more stable financial situation, large enterprises employing 250 or more people make greater use of funds for innovative activities and become more competitive.

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The effectiveness of new media in the promotion of the furniture industry

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Abstract: The effectiveness of new media in the promotion of the furniture industry. Nowadays, new media are a response to the needs of consumers in the area of social communication, while being an effective and efficient platform for marketing communication focused on shaping a positive image and strong brands. This article analyses the websites of selected companies, as well as a questionnaire designed to verify the effectiveness of new media in terms of costs for promotion, employment of specialists or further plans related to the development of promotions in this area. The research has clearly proved that at present traditional media have become insufficient in the process of brand promotion, and its profits and recognition are determined by professionally conducted activities on the Internet.

Keywords: new media, promotion, social media, furniture industry

INTRODUCTION

Marketing is one of the forms of communication, the tools of which have already been used in antiquity, and now is one of the basic departments in each company. Enterprises for a long time have used – as the main marketing tool – the so-called old media: press, radio, television, leaflets, bulletin boards, etc. While the development of ICT technology has started a new form of promotion, now called the new media. The Internet is the main tool considered to be modern methods, without which the company could not function on the market [Kotler, Keller 2012].

The Internet has become an environment, which consists of many complexes, i.e.: portals, vortals or communicators. At present, social media is very important from the point of view of every company. They allow you to create a free enterprise profile (fanpage) giving you the opportunity to reach a large group of future clients. Unlike the website, a fanpage, if it is run according to the appropriate rules, may in a short time gain interested parties and increase the company’s recognition. Companies specialized in the area of new media also offer support on the market.

With the increasing use of the Internet for marketing purposes, more and more enterprises, also from the furniture industry, decide to use this form of promotion. Therefore, the article attempts to examine the effectiveness of new media in the promotion of the furniture industry. For this purpose, a questionnaire survey was conducted, which was directed to companies with diverse structure and size. The analysis of the results showed how the promotional strategies are implemented by entrepreneurs and whether their benefits were noticed, i.e.: higher profits and brand recognition, and what company costs are allocated to this form of promotion.

It is worth mentioning that the subject matter related to new media is very current, while the number of Internet users in Poland is growing every year. The very Google search engine is used by about 20 million Internet users a month, which is 93% of their total number. This is the best proof that companies from the furniture industry should take care of the appropriate promotion in new media.
NEW MEDIA AS A FORM OF MARKETING COMMUNICATION

Currently, marketing is not only focused on sales, but is a set of actions that are designed to recognize the needs of consumers and create a corresponding product. Such actions resulted in economic development and, consequently, increased competitiveness. One of the basic marketing tools is promotion, which is more and more often called marketing communication. Its main goal is to promote the product and make the company aware of its existence. It is to encourage and convince you to be interested in the company’s offer. For the promotion to be more effective, companies conduct market research aimed at establishing a dialogue with the consumer. This allows you to tailor the product to current customer needs and increase sales.

Companies aiming at building their position and competitiveness should use new media for this. In addition to running your own website, social media is an important form of promotion. They allow you to quickly reach a large number of recipients by creating an appropriate profile. In some companies, specialists are employed for this purpose, who answer questions on a regular basis, update the offer, insert photos of products. In the customer’s sense, this allows you to build the expert image of the given company in a certain area.

The development of the Internet, computers and mobile devices also improves communication, advertising and information spreading. It develops in three different directions. The first one is individual communication, where the letter or telegram has been replaced by e-mail and communication on social networks. The next direction is group communication. Bulletin boards have been moved to advertising websites. The last direction of changes is mass communication, i.e. books that appear on the web as e-books or newspapers as Websites [Mangold, Faulds 2009].

The Internet also conceals a number of different types of websites. These are, among others, portals that have the largest amount of content. They allow you to place ads in a wide range, as they are usually multi-thematic, unlike vortals that specialize in one direction. Such a website includes slogans broadly related to the theme. In addition to the desire to obtain information, the Internet user has the ability to communicate through social media. In addition to their basic function, they contribute to the development of advertising. This form of promotion is becoming more and more popular. According to numerous sources, the presence in the network has an impact on the functioning, sales and even survival of the company [Kietzmann et al. 2011].

Using the Internet brings a number of advantages, for companies this results in, among others: easier data flow, increased number of investors or easier access to foreign markets. However, entrepreneurs also mentions threats, such as: the company’s network virus attack or burglary into the system [Bajdaka et al. 2003].

Social media is the most popular and probably the strongest type of online marketing [Bonek and Smaga 2012]. They have been gaining global popularity since 2005. Messengers were their predecessors, which are still very popular. For example, they include Skype, which is the most-used voice communicator in the world [Kaznowski 2008].

Social media is not just a new way of communication. They are mainly associated with portals in which we add photos, posts, and create a group of friends. However, all websites that are created by adding content by users are defined as social media. It is not dependent on the direction in which they operate (entertainment or education). The first social networking site on a global scale was Wikipedia, the content of which was and still is created by Internet users. In addition to adding information, they oversee and work on its quality [Isaacs 2014].

In addition to interpersonal contacts, social media is also used for marketing purposes. Due to the huge number of people registered in social media, they have become the place to promote companies. According to Bonek and Smaga [2013], being on Facebook is dictated by fashion
– you have to exist in this space. Some companies have a well-developed profile and conduct it in a thoughtful way, while others do not have knowledge about it and their actions are ineffective.

From the marketing side, Facebook is a place where you can achieve many benefits. Due to its popularity, it has a huge range, allows you to keep interesting profiles, thanks to the possibility of creating competitions, actions or games. However, if the entrepreneur would like to promote his niche product, other services would be a better solution. Although it is possible to create targeted groups on Facebook, users log in the profile mainly for entertainment, not to make a purchase. In order to reach the product to professionals or hobbyists, information should be placed on specialized websites and forums devoted to a given topic. If the manufacturer represents exclusive brands targeted at people with a high material status, social networking portals are better, for example, Goldenline.

If the entrepreneur represents exclusive brands targeted at people with a high material status, social networking portals are better, for example, Goldenline. However, this does not mean that the most popular social networking site is an inappropriate place for entrepreneurs. Facebook is an appropriate space for the promotion of, for example, online stores. It gives the possibility of easily informing the customer about the offer, about promotions or presentation of their products using the gallery. Currently, companies specializing in the area of promotion in social media and implementing it in the company structure are created [Bonek and Smaga 2012].

Companies create profiles on websites by building interactive contact with many target groups. The ARC Market and Opinions research shows that 61% of users of the most popular website use the profile created by the selected company. They want to express their sympathy for the brand by clicking “I like it”. However, further IIBR studies show that although users show interest in companies, only 18% of them remember what profile they liked [Bonek and Smaga 2012]. Not all companies are able to take full advantage of the marketing opportunities offered by social media. This is related to the lack of knowledge about customer behaviour, as well as ignorance of new marketing solutions [Świerczyńska-Kaczor 2012].

Currently, social media are part of popular word-of-mouth marketing. Many consumers ask for the opinion of others before buying a product. The present customer has a wide range of alternative products, so he goes around the forums, asks friends and strangers. Nielsen’s research from 2009 showed that the search for information and assessment of alternatives with the participation of the Internet is not diminishing, but increases the pool of considered solutions [Królewski and Sala 2016]. There are countless available websites, links, forum entries, opinions on blogs, which is often too overwhelming with offers. On websites, such as Facebook or Twitter, a database of recommended products or articles is created, due to the fact that users can share offers of companies. It is a powerful branch of marketing, researched by scientists and experts.

A promotional campaign on social media should always start with defining goals and the target group. This allows you to choose the most appropriate promotional tool, thanks to which the company’s visibility may increase.

The feature that affects the effectiveness of this type of company’s activities is their continuous activity. They should display current information about promotions and new products – so that the customer will remember our position on the market.

EFFICIENCY OF NEW MEDIA IN THE FURNITURE SECTOR – ANALYSIS OF OWN RESEARCH

The study, in order to determine the effectiveness of new media in the furniture industry, was carried out using the Internet survey method, with a questionnaire. The study was of qualitative character. Enterprises received a link to the survey via e-mail and via Facebook. Companies from half of Polish voivodeships replied to the survey. The largest
number of enterprises came from the Masovia voivodeship (6 companies), 2 companies from the Podlasie, Greater Poland, Lower Silesian, Kuyavia-Pomeranian and Lesser Poland provinces. Only one company came from the Pomeranian Voivodeship. The survey questionnaire was addressed to enterprises with a diversified number of employees. The largest companies offered the most answers, and the medium ones the least. 9 large and 5 micro-companies, as well as 4 small and 2 medium-sized companies took part on the survey. All companies participating in the survey confirmed that their company uses the promotion via the Internet. This confirms the popularity and large impact of new media on modern company marketing.

The study was aimed at determining how long a given form of promotion has been used. Most companies – 14, have used new media over six years. Only in two companies it is a period of less than one year. It can be concluded that enterprises started using the Internet in the 90s of the XX century, already noticing the great opportunities for online promotion (see chart 1).

The next question was to get more detailed data. Namely, whether companies use promotional opportunities in social media. As many as 16 out of 20 companies use social networking sites, and only three companies replied that they do not promote their products using social media. This is another proof that companies should use the Internet space. Due to the large number of users who have accounts on social networks, companies have a chance to reach a large group of recipients.

Due to the high score of responses stating the use of social media, the next question was to identify the most popular websites used by enterprises in the furniture industry. Most companies used the following sites: Facebook (16), Instagram (9) and Twitter (4), none of the companies used the Nasza Klasa website. Promotion in social media could be related to the popularity of given websites. They allow the free creation of company profiles and thus the creation of a certain relation between it and the user (see chart 2).
The next question addressed to the respondents allowed to determine whether the promotion in the new media gives actual results, namely whether the company’s recognition on the market is increasing. None of the companies responded negatively to this question. The remaining part of them could not unequivocally determine the impact of new media on the visibility of their company, which could be due to the lack of analysis in this area. More than half of the respondents noticed an increase in the recognition of their company since the use of new media, which confirms their effectiveness. Most of the positive answers were given by large companies, which also in further questions answered that they employ people with detailed knowledge in this field.

The answers to the question about profit growth from the start of the promotion on the Internet is different. In this area, most companies were unable to clearly state the relationship between promotion in new media and increased turnover. Only seven respondents confirmed
higher profits of the company (see chart 3). Also in this question, none of the respondents stated that it clearly did not affect the company’s finances. The insufficient knowledge of a given field of promotion may have an impact on the low growth of profits and incorrect methods of using new media.

The next question was open, allowing respondents to provide their own answer. The question concerned other benefits that are noticed by entrepreneurs using the promotion in new media. Some people did not notice other advantages, but the vast majority mentioned one extra advantage. The following were mainly listed: the possibility of direct interaction with potential users, building positive connotations with the brand, the possibility of flexible response to possible changes/events in the environment in real time, direct contact with customers. The following were also mentioned: the possibility of faster presentation of new products and interesting implementations, better and more effective communication in the case of promotional campaigns, better reaching the target group thanks to the possibility of profiling recipients, as well as reaching the youngest group of potential clients and future business partners (architecture students – future employees or owners of design offices). Information was also obtained on the employment of separate qualified persons in online promotion by companies. There are agencies on the market specializing in this field, offering their activities to companies that do not have knowledge in this area. Due to the global use of the Internet, and consequently social media, a random person should not deal with this. If an employee from the company is appointed for this, s/he should know the basic principles, e.g.: of building customer relations with interesting and original initiatives that would distinguish the company from the competition. Currently, companies create contests on their profiles, provide scientific articles and offer free advice. Over half of the companies do not employ people involved in the promotion (see chart 4). This does not mean that nobody uses such services, as eight respondents confirmed the recruitment of specialists. It can be concluded that this solution is used by medium and large companies, as in these cases the outlays for promotion are higher than in smaller enterprises. These companies often employ agencies that provide a comprehensive advertising service (a survey response, one of the large companies).

![Chart 4](chart4.png)  
**Chart 4.** Answers to the question regarding the employment of a separate person dealing with promotion in new media  
Source: Prepared on the basis of own research.

The next question asked concerned the determination of costs related to the promotion in new media. Some of the respondents did not answer this question due to company secrets,
others did not have data on this subject. However, there were responses from micro and small enterprises with specific amounts. The financial scope range from PLN 1,000 to 2,000 per month for expenses related to promotion in new media. It can be assumed that in larger companies the financial outlays are proportionately higher. Entrepreneurs also emphasized that costs are variable – they depend on whether a promotional campaign is being run at a given time, while fixed costs are related to domain and server maintenance.

The next question was also open and allowed the respondent to speak freely. It concerned problems related to promotion in new media. Half of the respondents had no objections to the effects of the promotion, but the next part of people exchanged some critical opinions, i.e.: requiring marketing tool – based on, and often referred to as, content marketing. This involves posting, for example, articles on social networking sites on a specific topic addressed to the recipients interested in this area. Content marketing was mentioned as a drawback by several companies. Other difficulties noticed by entrepreneurs were: a small reaction of Internet users, low effectiveness of promotion, because the offer is usually the responsibility of private individuals who do not make a purchase at the end. Some respondents also notice a problem in the possibility of the customer giving a negative opinion on the forum.

Based on the next question, it was possible to determine the effectiveness of online advertising used by the company. The effectiveness of the online advertising can be studied in many ways, mainly using special indicators. An exemplary method may be, e.g.: the CTR indicator (clickthrough ratio), i.e. the ratio of views to clicks. The higher the ration, the more advertisement was viewed and the more people clicked on it to read it. Other indicators are: the rejection indicator, which determined how many visits on the site ended with only one visit or the opening indicator, indicating how many messages were opened in relation to the correspondence sent. In the study, the result was evenly distributed, half of the companies do not use the analysis of the effectiveness of advertising on the Internet (see chart 5). This can lead to financial losses, an advertising that does not attract customers is ineffective and leads to financial losses. To avoid expenses that exceed the costs, the companies should check that their activities are effective.

Chart 5. Answers to the question regarding the performance of tests determining the effectiveness of on-line advertising
Source: Prepared on the basis of own research.
The last question that was answered by respondents was to determine if the companies are planning to continue investing in this form of promotion. The vast majority of enterprises will continue their activities, but individual companies do not see benefits in this and do not plan further development in this area (see chart 6). This may be due to the lack of expected profits resulting from not fully used online promotion opportunities and bad marketing activities (lack of knowledge) or too low financial outlays.

![Chart 6](image)

**Chart 6. Answers to the question defining plans for companies to develop / start promotion in new media**
Source: Prepared on the basis of own research.

On the basis of the performer tests and after their analysis, the following conclusions can be drawn:

- each company participating in the research uses the promotion in new media,
- greater involvement of large companies was noted while providing answers,
- the vast majority of companies, apart from the website, also run their profile in social media, because they want to reach the largest group of potential customers,
- the influence of new media on the increase of profits and recognition of the company was confirmed,
- in most enterprises, no separate person is employed, who is responsible for the effectiveness of new media in the promotion,
- almost half of enterprises conduct analyses to determine the effectiveness of new media,
- most companies plan to develop promotion with the help of new media.

**SUMMARY**

The article analyses the effectiveness of new media in the promotion of the furniture industry. The results of the conducted research indicate that new media affect effective promotion in the furniture industry – however, it depends on several factors. First of all, it was noticed that it is important to hire specialists who professionally deal with running a website, fanpage or social media. Moreover, it is very important to constantly monitor marketing activities on the web – and this depends on the size of the company. Most companies confirming the increase in recognition an profits – these are large enterprises that used the above-mentioned factors. The research also confirmed that small and medium-sized
Enterprises – participating in the study – see a chance for their rapid development thanks to professional promotional activities in new media. In summary, companies use new media for promotion, including social media, but not all consider them to be an effective form of marketing. It depends on the size of the company. Large enterprises recognize the new media as a tool thanks to which their profits and recognition increased. They also employ persons responsible for promotion in new media and carry out analyses determining the effectiveness of these operations. Thanks to this, it is possible to respond to individual errors or inappropriate ads, and thus the expenses for promotion are controlled. The research shows that the vast majority of companies will continue to develop promotions in new media, but to make it effective, it should use the knowledge of specialists and control the effectiveness of its activities. Today, in order for the company to grow, increase sales and be competitive, it should invest in promotion, use new solutions, i.e.: social media and hire or train employees involved in this area of promotion. It can be said that even the best product without proper advertising will not provide the company with revenues.

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Streszczenie: Efektywność nowych mediów w promocji branży meblarskiej. Współcześnie nowe media stanowią odpowiedź na potrzeby konsumentów w obszarze komunikacji społecznej, będąc jednocześnie skuteczną i efektywną płaszczyzną prowadzenia komunikacji marketingowej zorientowanej na kształtowanie pozytywnego wizerunku i silnych marek. W niniejszym artykule dokonano analizy witryn internetowych wybranych firm, a także przeprowadzono badanie kwestionariuszowe, mające na celu zweryfikowanie efektywności nowych mediów pod względem kosztów przeznaczanych na promocję, zatrudnianie specjalistów czy dalszych planów związanych z rozwojem promocji w tym obszarze. ankiety została skierowana do firm z branży drzewnej o zróżnicowanej strukturze i wielkości. Badania jednoznacznie dowiodły, że obecnie media tradycyjne stały się niewystarczające w procesie promocji marki, a o jej zyskach i rozpoznawalności decyduje profesjonalnie prowadzona działalność w Internecie.

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Wooden verandas in Gdańsk-Oliwa construction

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Abstract: Wooden verandas in Gdańsk-Oliwa construction. After the first partition of Poland in 1772, Oliwa was annexed to Prussia, and in 1874 it received city rights. The spa rank of the city, which competed with the neighboring resort in Sopot, rose significantly at that time. With the development of the city of Oliwa, the nature of its development changed. They were erected in the nineteenth century, functionally and stylistically differentiated, buildings with verandas, which became a characteristic feature of the architecture of spas and European bathing resorts.

The verandas, placed in the facades of the buildings, were independent, mostly wooden annexes. They took various forms, they could be open or glazed, single - or multi-storey, placed in the façade in front of the entrance to the building or other elevation, covered with separate single-or gable roofs, supported by pillars. The functional layout of the buildings was an unheated rest room. In addition to the recreational function, they enriched architecture and raised the prestige of the building, expanding the living space that is particularly needed in the curative and recreational season. Wooden verandas were an important element in the composition of building facades in Oliwa.

Key words: Oliwa, Wooden verandas, construction, forms and shapes of the decor

INTRODUCTION

The history of Oliwa for a long time was mainly related to the history of the Cistercian abbey, founded at the end of the 12th century. In the 17th century, the charms of these areas began to be noticed. In Polanki district near Oliwa, a complex of mansions was created, picturesquely situated at the foot of high, forest-covered hills¹.

After the partitions of Poland, Oliwa, then a village, was annexed to the Kingdom of Prussia. In 1874, Oliwa received city rights and became an urban commune. New buildings were erected in the city, streets and sidewalks were being built. The construction of a line of electric trams to Wrzeszcz (1901) and to Jelitkowo (1908) contributed to the further development of Oliwa.

Apart from a series of manors existing there before, new buildings appeared in the form of villas, guest houses and hotels. Functionally and stylistically diverse buildings were erected, mainly residential villas, workers' houses and small tenement houses.

Also began in the seventies of the nineteenth century to pay attention to the advantages of the coastal location of Oliwa. Dissemination of the healing and recreational character of a trip to spas has resulted in a need for accommodation. This spa and recreational character of the city significantly raised its rank, which allowed it to compete with the neighboring resort in Sopot. In the documents from the early twentieth century, the city appeared as "Oliva Ostseebad und Luftkurort". It was also connected with the specific development of this type of town corresponding to the demand for hotel services. There are large villas with Art

Nouveau forms sunk in the gardens, guesthouses and hotels with a spa style with large, wooden verandas in the facades. Olive, however, did not equal the rank of the nearby health resort and remained largely a green residential settlement for the inhabitants of Gdańsk. It probably influenced the diversification of buildings visible to this day. In the documents from the early twentieth century, the city appeared as "Oliva Ostseebad und Luftkurort".

In the architecture of the late nineteenth and early twentieth centuries, especially in recreational and spa towns, there was a fashion for scenic beauty. This involved, among other things, the use of natural materials in construction. The use of skeletal structures, wooden architectural elements and decorations became popular, which resulted in "idyllic" character of the buildings. In most houses, both picturesque villas and buildings with simple cubic solids, there are at least small wooden elements. Numerous brackets' remains, framework constructions, brackets of significantly extended hoods and filling of peaks, balustrades of balconies and loggias, all with woodcarving decoration appear numerously. However, the most interesting and decisive for the specificity of the city architecture are wide, wooden verandas, placed in the facades of buildings. The character of the building is shown by postcard - fig.1 from epoch.

![Figure1](ul. Polanki 127, 128, 129, view from the beginning of the 20th century, (source: http://www.dawnaoliwa.pl/opisy/ulice/nr/polanki127.html)

OLIVE WORMS

Verandas have gained popularity in residential architecture since the late nineteenth century. They were independent, mostly wooden or brick annexes to the building. They took various forms, they could be open or glazed, single- or multi-storey, placed in the façade in front of the entrance to the building or other elevation, covered with separate single- or gable roofs, supported by pillars. The functional layout of the buildings was an unheated rest room, a form of a winter garden. They were most often set up in residential buildings in rural and suburban areas. In addition to the recreational function, they also enriched architecture and raised the prestige of the building. In the 19th century, the verandas became an element characteristic of the architecture of spas and European bathing resorts. The inspiration was traditional alpine architecture, called the "Swiss style".

This trend was usually associated with local traditions, which brought different forms depending on the region. In 1867, a wooden summer villa was shown at a world exhibition in Paris, which greatly popularized this type of building. Wooden houses with columns, verandas, balconies, with "lace" decorations have become fashionable. Wood gave a sense of "rusticity." It probably also had an impact on the dissemination of wooden architectural...

elements, like verandas. In Poland, verandas were used more often in the north, in the south and also in suburban places round Warsaw, such as in Otwock.

In the Tri-City /Gdańsk +Sopot + Gdynia/, many richly decorated verandas can be found in Sopot villas, they were also popular in Wrzeszcz, where they were given slightly different forms. Verandas and porches have been present since the end of the 19th century, also in the area of Żuławy Wiślane, although it was a secondary element, it was added to existing facilities, performing a recreational and prestigious function 6.

![Weranda, Oliwa, ul. Obrońców Westerplatte 10](image)

In Oliwa, verandas were placed in new buildings, but probably also were added to the existing ones, for example on the occasion of increasing the building or building porches, creating vestibules or enlarging the living space especially needed in the curative and recreational season.

Verandas were an important element in the composition of facades. They were often the main accent of the façade, located in the middle of the building or emphasized the extreme axes. In most cases they were arranged symmetrically and placed on a rectangular plan. In buildings with fragmented plans, they appeared in various places, for example embedded in corners. Generally, two solutions can be distinguished: representative verandas, placed in the front elevations, and economic, located in the rear elevations.

In the facades of the Oliwa tenement houses, there are several variants of the layout of the representative verandas. In the case of one veranda in the composition of the façade, it was placed on the axis of the building ceasing the face or inscribed between two lateral projections, the last solution being relatively rare (e.g. in the building at Obrońców Westerplatte 16). In the case of using two verandas, they were arranged symmetrically at the edge of the façade, usually leaving the last axis of the building's windows. In the tenement
houses with a wide central projection, the verandas were arranged on its sides (e.g. Obrońców Westerplatte 8).

In the corner buildings, they were placed in both facades from the street side (e.g. Obrońców Westerplatte 35). The location of the verandas was not dependent on the location of the rooms inside the building, which sometimes complicated the functional arrangement. In villas the verandas were slightly smaller and differently located. In one façade one porch was placed. Their location was often asymmetrical, for example in the corner of the building (e.g. Podhalańska 6), sometimes on the extreme axis. The picturesque villas consisted of many architectural elements, deliberately arranged asymmetrically to create open, surprising compositions. Verandas in villas were usually founded on a rectangular plan, much less often on a polygon set (e.g. Obroncow Westerplatte 8). Fig.3.

![Figure 3. Basic schemes for the arrangement of verandas in facades of buildings in Oliwa](image)

All verandas in Oliwa had a wooden frame construction, self-supporting, located on the foundation underlying the foundations of the building. They were also connected to the ceiling for greater stability. The wooden skeleton consisted of vertical poles and horizontal beams. The latter divided the verandas into three parts; bottom and top segments were more or less the same height, sometimes the window was slightly lower, sometimes reduced to a narrow frieze. The window part occupied the most space, which was important due to the lighting of the veranda itself and the rooms behind it.

The divisions between floors have been highlighted with prominent cornices that cover the foreheads of the floor beams. In some verandas, narrow hoods were used in these places. The space between the posts and horizontal beams strengthening the nada and podokienne parts was filled with wooden boards or boards at the contact point, which in most cases was applied in the form of a laubzekin openwork decoration.

Below and above the wide windows, additional vertical divisions were introduced by inserting wooden beams with a cross-section of structural pillars, with the vertical divisions of the sub-window area often differing from the window zone divisions. Window occupied the largest part. The divisions of the wall, the number of windows and their patterns were very diverse. Depending on the width of the front of the veranda, three to five windows were placed there, with different divisions. In wide verandas, the division into three parts (sometimes four) separated by columns was usually used. On the sides there were narrower windows (single or double, two-level), three- or four-sectioned in the middle, with often the side parts of large central windows additionally separated by columns placed outside. Fig. 4.

Sometimes in the middle part there were two windows with similar shapes to the side ones. There were also rows of even windows divided by bars into many small quarters. The
Window blanks were rectangular, with rectangular overhangs, sometimes the middle windows were closed with the top of the arc or diagonal sections. Sometimes, in the part of the lateral sides of the windows, the openwork woodcarving decoration was placed. In the side walls of the verandas, depending on their depth, one or two windows were placed.

In very shallow, rarely occurring verandas, it was limited to one narrow, single, usually two-level window. Two medium-sized windows were placed in the deeper ones. The verandas were communicated with the adjacent rooms in their apartments. In the ground floor, in some cases an additional entrance was placed in the side wall, communicating the veranda directly with the front garden. In the verandas situated on the axis of the building, the middle part of the ground floor was left open and hence entered the main entrance. Then, usually also the middle parts of the subsequent storeys were left uncovered (e.g. Obrońców Westerplatte 8), although this was not the rule (Polanki 128).

Unfortunately, renovations of buildings and adjacent verandas were not always conducted in accordance with conservation art.

The problem mainly concerns windows, which in part have been replaced with modern, plastic instead of wooden ones. What is worse when replacing, sometimes even old divisions were not preserved and elements of decoration were destroyed. Where original windows have been preserved, they were usually open inwards, single, sometimes double. In some parts of the verandas narrow, unopened windows were installed, but they constituted a small part of the whole.

Decorative blinds and closing strips or posts in older windows were used. Forms of decoration probably originally were standardized throughout the building (preserved in the upper store in Obronców Westerplatte nr 7, 28, 36), sometimes the verandas were used somewhat simplified elements, without decorations.

Simpler window forms or other decorations may indicate the subsequent addition of a veranda. Unfortunately, in the majority of cases where the original windows have been preserved, the windows in the buildings have been replaced, and vice versa. Few removable windows were located in older buildings (e.g. Polanki 129). Very rarely, in the middle belt, part of the structure was filled with boards instead of windows (e.g. Polanka 11).

Figure 4. Design of the building at Polanki 128 in Oliwa, view of the facade and section, 1898, from the collection State Archives in Gdańsk, reference number 15/670
Figure 5. Villa's veranda set on a polygon, Oliwa, ul. Obronców Westerplatte 7

Figure 6. Veranda of the tenement house founded on a rectangular plan, Oliwa, ul. Obronców Westerplatte 8

Figure 7. Veranda willi, Oliwa, ul. Leśna 3

Figure 8. Veranda kamienicy, Oliwa, ul. Obronców Westerplatte 36
Verandas in tenement houses and most of the verandas in the villas were covered with separate monopole or gable roofs. The extended ends of the roof rafters were decoratively profiled and supported by side hoods. In a few villas, different forms of roofs were used like a tent roof, turrets and other forms (e.g. Podhalańska 20, Obrońców Westerplatte 17). The verandas were usually two-storey, less frequently - three-storey (e.g. Obrońców Westerplatte 18, 34), in tenement houses wide, slightly narrower in the villas. Sometimes, a balcony was placed above the porch. A specific form of construction and glazing, slightly different from others, has been obtained by the veranda of the villa at Leśna 3. High windows, reaching the cornice dividing the storeys, at the same time giving up the window decoration.

The rectangular windows of the central zone were divided into lofts with smaller sidings on the sides, leaving two large central quarters. A similar division was applied in square windows above. Ornaments are preserved to this day colorful stained glass, milk or etched fast. In the window and window panels, whose clear frames were the construction elements, decorative decorations were placed, with very different motives.

In this way, rich chiaroscuro effects were obtained, leaves on the sides, leaves, variously winding, stylized plant flagstones, for example interlacing wheels, stars, oblique grids, forms referring to arabesques. These motives were repeated in the decoration of other elements, such as the tops of verandas or buildings or brackets.

The under-window panels were filled with variously cut, vertical elements resembling balustrades, supplemented with small details like circles, diamonds, small leaves. And here different forms were used, but less varied than in window decorations.

CONCLUSIONS

Oliwa verandas are a valuable testimony to material culture. Tenements and villas whose elevations have been varied with verandas are numerous. Most of the verandas located next to small tenements can be found in the Obrońców Westerpaltte, Wita Stwosza and Polanki streets. At the beginning of the 20th century, large representative villas were also erected with porches. Numerous verandas occurred in Liczmański, Leśna and Podhalańska streets, where villas from the beginning of the 20th century were dominant.

They made architecture attractive and raised the prestige of buildings. A significant number of buildings with verandas gave the city a spa and recreational character, creating a rural atmosphere. Such a large use of verandas is a testimony to the city's pursuit of fashionable trends in architecture, attempts to compete with nearby Sopot, high aspirations of residents and city authorities.

Some of them, beautifully restored, have kept their charm. Unfortunately, despite the careful preservation of wooden construction and decoration, during renovations windows or doors have often been exchanged contrary to the art of conservator. Plastic windows are inserted, which material does not allow for faithful reconstruction of the nature of the original profiles and decorations. They often constitute dissonance with the original windows still in the building. Part of the verandas still need renovation.

The veranda is an architectural element taking various forms depending on the inventiveness of the architect and woodcarver, in the case of wooden constructions and decorations. Large verandas are the dominant façade of the facade, a small decorative addition. Material from which they were made is very important. Different types of verandas of wood, brick or metal give a different character to the buildings. They can also differ in the arrangement of structural elements, roof forms and decorations. With such varied possibilities, verandas could become a certain feature of the architecture of the district, housing estate or town.
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Streszczenie: Drewniane werandy w budownictwie gdyńskiej Oliwy. Po rozbiorach Polski, Oliwa została przyłączona do Prus, a w 1874 r. otrzymała prawa miejskie. Wtedy znacznie podniosła się uzdrowiskowa ranga miasta, które konkurowało z sąsiednim kurortem w Sopocie. Wraz z rozwojem miasta Oliwy zmieniał się charakter jego zabudowy. Wznoszono w XIX wieku zróżnicowane funkcjonalnie i stylistycznie budynki z werandami, które stały się elementem charakterystycznym dla architektury uzdrowisk i kąpielisk europejskich. Wiązało się to między innymi z zastosowaniem w budownictwie drewna, do konstrukcji szkieletowych, elementów architektonicznych i dekoracji; decydującym o specyfice miasta elementem architektonicznym stały się szerokie, drewniane werandy, umieszczone w fasadach budynków. Stanowiły samodzielne, najczęściej drewniane przybudówki do budynku. Przybierały różne formy, mogły być otwarte lub oszklone, jedno- lub wielokondygnacyjne, umieszczone w fasadzie przed wejściem do budynku albo przy innej elewacji, przykryte osobnymi dachami jedno- lub dwuspadowymi, podpartymi słupami. Wszystkie werandy w Oliwie miały drewnianą konstrukcję szkieletową, samonośną, usytuowaną na podmurówce powiązanej z fundamentami budynku. Były również powiązane ze stropem dla zachowania większej stabilności. Drewniany szkielet składał się z pionowych słupów i poziomych belek. Te ostatnie dzielily werandy na trzy części – pas podokienny, pas okien i pas nadokienny. W funkcjonalnym układzie budynków stanowiły nieogrzewane
pomieszczenie wypoczynkowe - formę ogrodu zimowego. Poza funkcją rekreacyjną, wzbogacały architekturę i podnosiły prestiż budynku, powiększając przestrzeń mieszkalną szczególnie potrzebną w sezonie kuracyjno-wypoczynkowym. Werandy stanowiły ważny element kompozycji fasad budynków, co szczególnie widać w architekturze Oliwy.

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Kalkulationsbasis für Investitionen in der Holzbearbeitungsbranche
Systematische Analyse der Kostenstruktur

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Schlüsselwörter: Sägewerk, Kostenstruktur, Holzverarbeitung

EINFÜHRUNG

1. KOSTENARTEN
Priorität beim Aufschlüsseln der Investitionsgrundlagen haben neben den Verkaufserlösen die Kosten. Diese Kosten sind zum einen nach ihrer Quantität zu analysieren, zum anderen in Fix- und variable Kosten aufzuschlüsseln. Die Analyse der Kosten beschränkt sich hier einfachheitshalber auf die Aufsplitzung in die zwei Kategorien „Fixkosten“ und „variable Kosten“. Unter Fixkosten versteht man die (periodisch) anfallenden Kosten in einem Produktionsbetrieb, welche ungeachtet einer etwaigen Produktion entstehen. Die relevantesten Positionen wären:
- die Anlageninvestition
- die Finanzierungskosten
- die personellen Fixkosten
- Versicherungen und Pflichtbeiträge (werden hier nicht berücksichtigt)
Grundsätzlich wird von einer idealisierten Produktionssituation ausgegangen, d. h.:
- Die komplette produzierte Ware kann abgesetzt werden, so dass keine zusätzlichen Lagerflächen respektive Lagerkosten entstehen.

4 REFA: Methodenlehre Teil 3, S. 43.
5 „Periodisch“ heißt: es wird das (Bank-)Jahr zugrunde gelegt.
– Die kontinuierliche Versorgung mit dem Rohmaterial ist sowohl in qualitativer wie quantitativer Hinsicht sichergestellt.
– Darüber hinaus wird durch ausgereifte Arbeitsvorbereitung immer das richtige Produkt zeitnah und rechtzeitig für die Verladung zur Verfügung gestellt.

Bild 1 bringt die „Splitzung“ der relevanten Kosten im Sägewerk zur Darstellung.

Bild 1. Kostenstruktur im Sägewerk

2. WIRTSCHAFTLICH RELEVANTE EINGANGSPARAMETER (KOSTEN)
2.1. Investitionskosten

Die Investitionskosten umfassen im Wesentlichen folgende Positionen:
– Grundstück- und Erschließungskosten
– Fundament- und Baukosten
– Maschinenanlageninvestition inklusive Montage und Inbetriebnahme
– Fahrzeuge für internen und externen Werktransport

Durch die Aufsummierung der Kosten der einzelnen Positionen erhält man das gesamte Investitionsbudget respektive die Investitionsgesamtkosten, welche es zu finanzieren gibt.

2.2. Finanzierungskosten

Bei einer einfachen Ermittlung der jährlich anfallenden Finanzierungskosten⁶ wird ein streng lineares Finanzierungsmodell zugrunde gelegt. Des Weiteren wird davon ausgegangen, dass die Investition zu 100% von Banken finanziert wird. Es wird also von einer etwaigen Verzinsung von anfallenden Opportunitätskosten⁷ abgesehen. Neben den Investitionsgesamtkosten müssen noch die Tilgungsdauer des Kredites und der dementsprechende Zinssatz berücksichtigt werden. Es wird angenommen, dass der Zinssatz über den Tilgungszeitraum konstant bleibt. Anhand des Gesamtinvestitionsbudgets und der Tilgungsdauer kann das durchschnittliche gebundene Kapital ermittelt werden:

\[
\frac{\text{Gesamtinvestitionsbudget}}{2} = \text{durchschnittlich gebundenes Kapital}
\]

Dieses durchschnittlich gebundene Kapital wird mit dem (Jahres-) Zinssatz beaufschlägt. Bild 2 veranschaulicht die obenstehende Formel zur Ermittlung des durchschnittlich gebundenen Kapitals.

Unter Tilgung versteht man die (kredit-)vertraglich fixierte Ab- bzw. Rückzahlung einer Schuld innerhalb eines bestimmten Zeitraumes.⁸ Diese Durchführung einer Tilgung wird als Tilgungsdienst bezeichnet. Der aus dem Kreditvertrag vereinbarte Tilgungsdienst ist hier immer linear gestaltet. Nach dem vertraglich fixierten Tilgungszeitraum wird also die

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⁷ Vgl. ebd., S. 303.
Abzahlung des Investitionskredites getätigt, wobei die Tilgungsraten immer in gleicher Höhe jährlich zu entrichten sind.

Bild 2. Darstellung des durchschnittlich gebundenen Kapitals

Tilgungsdienst:

\[
\frac{\text{Gesamtinvestitionensbudget}}{\text{Tilgungszeitraum}} = \text{jährliche Kredittilgungsrate}
\]

Jährliche fixe Finanzierungskosten:

\[
\sum \text{jährliche fixe Finanzierungskosten}
\]

2.3 Personalkosten

Um die Personalkosten berechnen zu können, muss zuerst der Personalaufwand abgeschätzt werden. Für die Abschätzung des Personalaufwandes kann beispielsweise ein Personalentwicklungsplan erstellt werden. Ein Personalentwicklungsplan \(^9\) schlüsselt das zum regelgerechten Betrieb nötige Personal in Anzahl und Position auf. Dabei kann der etwaige Standardstundenlohn bzw. Monatsgehalter hinterlegt werden. Ein Personalentwicklungsplan ist insbesondere für die Außendarstellung bei einem Planfeststellungsverfahren von neu zu schaffenden Arbeitsplätzen hilfreich. Auch wo um Subventionen nachgefragt wird, kann dieser nützlich sein.


Die vorab geschätzten variablen Personalkosten werden auf die Produktionseinheit „1 Festmeter (1 fm)” normiert. Dies geschieht dadurch, dass die variablen Personalkosten für ein Jahr hochgerechnet werden und man durch die geplante Jahresseinschichtskapazität dividiert. Die hier vorgenommene Splitting in variable und fixe Personalkosten ist aber nur hinreichend korrekt unter der Voraussetzung, dass ein regelgemäßer Produktionsablauf gewährleistet ist und die Produktionseckdaten zu 100% erfüllt werden.

\(^9\) Vgl. REFA Arbeitspädagogik, Kapitel 4.5.1.
Aus dem Personalentwicklungsplan ist das Verhältnis von Angestellten, deren Gehälter und Nebenkosten als Fixkosten einfließen, und gewerblichen Mitarbeitern, dessen Löhne als variable Kosten gelten, ersichtlich.

2.4 Rundholzkosten

Einer der größten und wichtigsten Kostenblöcke in der Sägeindustrie ist der Einkaufspreis des zu verarbeitenden Rohmaterials, die sogenannten Rundholzkosten. Diese sind zumindest in Mittel- und Nordeuropa (abgesehen von umstrittenen Verträgen zwischen Staatsforsten und bestimmten Großabnehmern) relativ transparent gestaltet: Sie sind je nach Holzart, Region, Qualität und Durchmessersklasse in der Fachpresse und im Internet aktuell abrufbar.11

Normalerweise werden sogenannte Rahmenverträge zwischen Verkäufer und Käufer geschlossen. Diese Rahmenverträge fixieren die monatlichen Übernahmemengen sowie den Preis pro Festmeter für die entsprechende Qualität und die Durchmessersklasse.

Anschauungsbeispiel:

<table>
<thead>
<tr>
<th>Lieferbedingungen:</th>
<th>„frei Sägewerk“</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holzlänge:</td>
<td>4-6 m</td>
</tr>
<tr>
<td>Holzart:</td>
<td>Fichte / (picea abis)</td>
</tr>
<tr>
<td>Holzqualität:</td>
<td>B/C</td>
</tr>
<tr>
<td>Liefermenge pro Jahr:</td>
<td>500.000 fm (Mengensumme)</td>
</tr>
<tr>
<td>Liefermenge pro Monat:</td>
<td>40.000 fm (min) - 60.000 fm (max)</td>
</tr>
<tr>
<td>Vertragslaufzeit:</td>
<td>5 Jahre</td>
</tr>
</tbody>
</table>

| Preis bei Durchmessersklasse 1a (10 – 14 cm): 36,00 EUR pro fm |
| Preis bei Durchmessersklasse 1b (15 – 19 cm): 46,00 EUR pro fm |
| Preis bei Durchmessersklasse 2a (20 – 24 cm): 75,00 EUR pro fm |
| Preis bei Durchmessersklasse 2b (25 – 29 cm): 70,00 EUR pro fm |
| Preis bei Durchmessersklasse 3a (30 – 34 cm): 75,00 EUR pro fm |
| Preis bei Durchmessersklasse 3b (35 – 39 cm): 80,00 EUR pro fm |


Im Vorfeld gilt also zu klären, mit welcher Rundholzverteilung zu kalkulieren ist. Über die geplante Jahreskapazität und die vorab geschätzte Durchmesserverteilung kann ein

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Durchschnittspreis und über eine geometrische Durchschnittsbildung der gemittelte Rundholzpreis errechnet werden.

2.5 Variable Produktionskosten

Weitere produktionsrelevante variable Kosten fallen für folgende Posten an:
- elektrischer Strom
- Wasserverbrauch
- Diesel- und Schmierstoffe
- Ersatzteile
- Ersatzwerkzeuge und Schärfkosten 12

Aus Platzgründen kann in diesem Beitrag auf diese Posten nicht näher eingegangen werden. Bild 3 veranschaulicht die variablen Kosten im Sägewerk in einem Säulendiagramm.

Bild 3. Variable Kosten im Sägewerk

3. WIRTSCHAFTLICH RELEVANTE AUSGANGSPARAMETER (AUSBEUTE)

3.1 Ausbeute


Bild 4 veranschaulicht die Ausbeute mit prozentualer Aufteilung der einzelnen Produkte im Sanky-Diagramm.

13 Vgl. Lohmann (1993), Holzhandbuch, Kapitel 3.5

**Anschauungsbeispiel:**

<table>
<thead>
<tr>
<th>Produkt</th>
<th>Marktpreis pro m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hauptware</td>
<td>220 EUR / m³</td>
</tr>
<tr>
<td>Seitenware</td>
<td>110 EUR / m³</td>
</tr>
<tr>
<td>Hackschnitzel</td>
<td>9 EUR / Rm (Schüttmeter)</td>
</tr>
<tr>
<td>Sägemehl</td>
<td>6 EUR / Rm (Schüttmeter)</td>
</tr>
</tbody>
</table>

Auflockerungsfaktor für Sägemehl und Hackschnitzel:

<table>
<thead>
<tr>
<th>Ausbeute</th>
<th>Vorab geschätzt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hauptware</td>
<td>42 %</td>
</tr>
<tr>
<td>Seitenware</td>
<td>15 %</td>
</tr>
<tr>
<td>Hackschnitzel</td>
<td>28 %</td>
</tr>
<tr>
<td>Sägemehl</td>
<td>15 %</td>
</tr>
</tbody>
</table>

Berechnungsmatrix zur Kalkulation des Produktionserlöses pro fm wurde in Tabelle 1 dargestellt (Werte vorabgeschätzt).
Dieser Wert (hier 119,16 €/fm) kann nun als Verkaufserlös pro fm eingesetzt werden. Für alle Sägewerke ist die Bedeutung der Ausbeute immens hoch. Es ist ersichtlich, dass für Schnittware eine wesentlich höhere monetäre Wertschöpfung besteht als für die mehr oder weniger beliebten Nebenprodukte aus der Koppelproduktion. Diese Ausbeutezahl ist in bestimmten Grenzen über technologische wie auch organisatorische Parameter (Indikatoren) beeinflussbar wie z.B.:

- gut vorsortiertes Rundholz in engen Einteilklassen
- entsprechend passende Schnittbilder
- dünne Schnittfuge der eingesetzten Werkzeuge (Kreissägeblätter)
- „neue“ Einschnittstechnologien\(^{14}\) wie etwa „der Krümmung nachschneiden“

### 3.2 Anlagenverfügbarkeit

Unter „Anlagenverfügbarkeit“\(^{15}\) versteht man den technologisch-organisatorischen Wirkungsgrad einer Produktionsanlage, wobei die Bruttoproduktionszeit zur Nettoproduktionszeit (d. h. echten Produktionszeit) in Relation gesetzt wird. „Bruttoproduktionszeit“ bedeutet in diesem Fall die geplante Arbeitsstunden pro Schicht. Diese Arbeitszeit wird auch den Mitarbeitern vergütet. Leider ist im Sägewerksbetrieb nicht gewährleistet, dass während der Bruttoarbeitszeit regelrecht „durchproduziert“ wird. Dies liegt an der Verkettung des Produktionsablaufes. Die Bruttoproduktionszeit wird vermindert durch diverse Produktionsstörungen, Anlagenstörungen und kleinere Störungen des Produktionsablaufes. Fehlzeiten entstehen unter anderem durch folgende Faktoren:

- schlechte Arbeitsvorbereitung (zu viele Umstellungen des Produktionsprogramms während der Schichtzeit)
- nicht genügend Vorhaltung von Produktionsmaterialien und Betriebsmittel (wie z. B. Stapel- und Verlustlatten)
- inkorrekte Personalbestellung
- inadäquate Umschlag- und Verladekapazität
- Fehlen einer vorausschauenden Wartung

Diese Fehlzeiten müssen von der Bruttoarbeitszeit abgezogen werden. Bei einer Analyse der Fehlzeiten wird ersichtlich, dass einige Positionen durch organisatorische

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\(^{15}\) Vgl. Greigeritsch (2009), Kapitel 3.
Maßnahmen ausgemerzt werden könnten, um die Fehlzeiten zu minimieren. Meines Wissens kann eine normale Anlagenverfügbarkeit beim modernen Industriesägewerk mit etwa 70-75% veranschlagt werden. Die Betrachtung der Anlagenverfügbarkeit ist für die Produktivität insofern von großer Bedeutung, als dank ihr die Produktivität gesteigert bzw. vermindert werden kann, ohne auf die jährlichen Fixkosten Einfluss zu nehmen.

4. BREAK – EVEN - ANALYSE

Am Ende können nun alle verschiedenen Faktoren oder Einflussgrößen miteinander in Beziehung gesetzt und graphisch dargestellt werden. Präsentiert werden fünf verschiedene Diagramme in folgender Reihenfolge: Ein Diagramm für fixe Kosten (Bild 5.1) und eines für variable Kosten (Bild 5.2), wozu eine Superposition entwickelt wird (Bild 5.3). Daraufhin kommt noch eine Umsatzkurve (Bild 5.4) und schließlich eine Umsatzkurve mit einer Gesamtkostendarstellung (Bild 5.5), die zu einem finalen Break-even-Diagramm führt.

Das „Break-even“-Diagramm ist eine graphische Darstellung der “Gewinnschwelle”, d. h. die graphische Gegenüberstellung der linearen Gewinn- und Kostenfunktion einer Investition. Sie dient der Ermittlung der Menge, ab deren Produktion die Investition in die Gewinnzone kommt, d. h. die Erlöse größer sind als die anfallenden Kosten. Es handelt sich genauer gesagt um ein Koordinatensystem, bei dem auf der Abszisse (x-Achse) die Produktion dargestellt wird, mit der Referenzeinheit „fm“ abgebildet. Im Schnittpunkt der eingetragenen Verkaufserlöskurve (Gerade) und der Kostenkurve ist die Gewinnschwelle abzulesen. Dieser Schnittpunkt von der Umsatzkurve und der Kostenkurve wird „Break-even-point“ genannt. Ab diesem „Zeitpunkt“ wird, da die Produktion sich linear über das Jahr verteilt, bis zum Jahresende, d. h. bis zur Jahresproduktionskapazitätsgrenze Gewinn erzielt.

Bild 5.1 Fixkosten (Investitionskosten und Personal) Bild 5.2 Variable Produktionskosten (siehe auch Seite 9)

Vereinfachte lineare Darstellung in Schritten der Gesamtkosten und des Jahresumsatzes in einem Produktionsbetrieb:

Bild 5.1 – 5.6 veranschaulichen die jeweiligen Kostenkurven, Umsatzkurve und Relationen zueinander

Es folgt nochmals die gleiche Darstellung, bei der aber der Break-even-Punkt explizit eingearbeitet worden ist und bestimmte Zonen wie z. B. der „Verlustbereich“ und der „Gewinnbereich“ hervorgehoben wurden.

Mathematisch betrachtet ist der Break-even-Punkt folgendermaßen zu kalkulieren:

**Umsatzkurve:**
\[ U = \text{Verkaufspreis pro Einheit} \times \text{Break-even-Menge} \]
\[ U = p \times x \]

**Kostenkurve:**
\[ \text{jährliche Fixkosten} + \text{variable Produktionskosten pro Einheit} \times \text{Break-even-Menge} \]
\[ K = K_f + k \times x \]

Da per Definition im Break-even-Punkt der Umsatz und die Kosten gleich groß sind, folgt:
\[ U = K \]
\[ p \times x = K_f + k \times x \]

umgestellt auf \( x \) ergibt sich (Break-even-Menge):
\[ x = \frac{K_f}{p} - k \]

Der (etwaige) Gewinn errechnet sich aus dem geplanten Jahresumsatz abzüglich der Gesamtkosten für die voraussichtliche Jahresproduktionsmenge \( P \):
\[ \text{Gewinn} = U - K \]
\[ U = P \cdot x \cdot p \]

LITERATUR

Streszczenie: Podstawy kalkulacji inwestycji w branży tartacznej. Systematyczna analiza struktury kosztów. W opracowaniu zaprezentowano podstawy kalkulacji służące do oszacowania opłacalności inwestycji w branży tartacznej. W tym celu sporządzono przegląd rodzajów kosztów występujących w tartaku oraz zestawienie najważniejszych parametrów ekonomicznych dotyczących kosztów finansowania inwestycji, robocizny, drewna okrągłego i wydajności tartaku. Następnie wskazano zależności pomiędzy poszczególnymi czynnikami i przedstawiono je w postaci wykresu opłacalności (Break-even-Diagramm).
Density profile of particleboard produced from post-industrial waste wood charged with synthetic resin load

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Abstract: Density profile of particleboard produced from post-industrial waste wood charged with synthetic resin load. Three-layer particleboards bearing 20-100% particles made from post-industrial UF- or PF-bonded plywood were studied. The particleboards were bonded with UF binder. The effect of the type and content of waste plywood mixture particles on the thickness, density and density profile of the particleboards was examined. It was found that the addition of UF-resin particles had no effect of the density profile of the boards. Particleboards with 80% and 100% content of PF-resin particles exhibited insufficient internal bond that resulted in loosen panel structure, increase in thickness and decrease in density. The observed increase in thickness was 7% and 14%, respectively, for the boards with 80% and 100% of PF-resin particles in the core layer. Density decreased by 6% and 23% when compared to the reference series.

Keywords: particleboard, phenol-formaldehyde resin, plywood, urea-formaldehyde resin, waste wood

INTRODUCTION

Particleboard production in Poland is a significant branch of wood-based panels industry. However, the main obstacle in its further development is deficient wood supply which has been observed for years (Hikiert and Oniśko 2006). The deficiency is induced by the increasing demand for wood in wood industry, restrictions applied by The State Forests and Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources (OJ L 140, 5.6.2009) as well. Thus, manufacturers are forced to import raw material or to reduce production volume, so that a search for new unexplored resources seems to be justified.

In the literature, there are numerous works on the use and recycling of waste and post-industrial wood. But they mainly regard wooden residues that contain zero or small amounts of chemical additives. The preferred ways to exploit that feedstock is burning (Risholm-Sundman and Vestin 2005, Tatáno et al. 2009) or composting (Borazjani et al. 2000, Wiltcher et al. 2000, Wróblewska and Czajka 2007). While wide analyses of the factors affecting applicability of the recycled material in particleboard manufacturing are still lacking – especially regarding materials charged with synthetic resins like UF and PF. Therefore, undertaking the research focused on recycling of materials containing UF and PF resin load is rational.

The aim of this study was to determine the density profile of particleboard produced from post-industrial plywood bearing synthetic resins load. In order to determine the effect of the binder on particleboard properties, UF and PF-bonded plywood was shredded separately.

MATERIAL AND METHODS

The particleboards were produced from the particles obtained from post-industrial plywood according to the procedure described elsewhere (Laskowska and Mamiński 2017). It was demonstrated that the particles obtained with a 14-mm mesh screen exhibited the
properties closest to those determined for the industrial particles. Two types of recovered particles were used: containing residual UF- or PF-resin thereafter referred as “UF-particles” and “PF-particles”.

Three-layer particleboards (16-mm thick, 650 kg/m³) were prepared. The face/core layer rate was set at 25%/50%. Paraffin emulsion was spread over the particles at 1% rate. UF-resin load was 12% and 10%, respectively, for face and core layer. The adhesive formulation for face layer: UF 50.0 ppw, 10% aq. (NH₄)₂SO₄ 1.0 ppw, water 15.0 ppw; for core layer UF 50.0 ppw, 10% aq. (NH₄)₂SO₄ 1.5 ppw, water 14.5 ppw. The parameters of the hot pressing mats were as follows: unit pressure 3 MPa, platen temperature 180°C, time 300 s. Mat thickness was monitored in real time with accuracy ± 0.01 mm. The face and core layer industrial particles were obtained from a particleboard plant in Poland. Their fractional compositions were typical as for industrial applications. The contents of the recovered particles in the core layers were 20, 40, 60, 80 or 100%. The boards made of industrial particles only were used as the reference.

The density profile on the cross section of the particleboard samples was determined using a laboratory X-ray density profiler (Laboratory Density Analyzer DA-X) manufactured by GreCon Inc. (Tigard, OR, USA). The tests were conducted on samples with a length and width of 50 mm × 50 mm, at scanning speed of 0.05 mm/s. Density was measured with intervals of 0.02 mm on the thickness of a sample. The following parameters of the density profile were determined: mean density (DMean) and the maximum density in face layers (DMaxL and DMaxR). The maximum density on the left-hand side (DMaxL) i.e. the maximum density of the particleboard determined in the area whose surface was heated by the upper press plate; the maximum density on the right-hand side (DMaxR) i.e. the maximum density of the particleboard determined in the area whose surface was heated by the lower press plate. Statistical analysis was performed by t-test at 0.050 confidence level using STATISTICA Version-12 software of StatSoft, Inc. (Tulsa, USA).

RESULTS AND DISCUSSION

Density profile of the boards containing UF- and PF-particles are shown in Figs. 1 and 2, respectively. The effect of particles mixture composition on the density parameters is presented in Fig. 3 and 4.

![Figure 1. Density profile of the particleboards containing UF-particles in the core layer](image-url)
The analysis of density profile for particleboards is a valuable tool to describe relations between panel density and its mechanical and physical properties (Suzuki and Miyamoto 1998, Wong et al. 1999, Cai et al. 2004, Gamage et al. 2009).

Density profiles of the boards containing UF-particles were very much alike that observed for the reference panels (Fig. 1), while 80- and 100% additions of PF-particles resulted in decrease in DMean by 6% and 23%, respectively, when compared to the references (644 kg/m$^3$) (Fig. 2). The reduction was statistically significant. The observation can be explained by the negative effect of alkaline PF-resin present in recovered particles on the curing of the UF binder (Czarnecki et al. 2003). In consequence, bonding between particles within a board was insufficient, which rendered loosen core layer structure, increased thickness (Fig. 3a) and reduced DMean (Fig. 3b). Thickness of the boards with 80% and 100% of PF-particles was, respectively, higher by 7% and 14% when compared to the reference panels. The differences were statistically significant (p < 0.050).

**Figure 2.** Density profile of the particleboards containing PF-particles in the core layer

**Figure 3.** Thickness (a) and DMean (b) of examined particleboards
The DMaxL and DMaxR values were insignificant at p < 0.050 both for the reference and investigated particleboards. However, differences in peak density were found to be related with the content and the type of the recovered particles in panels. DMaxL and DMaxR for reference panels reached, respectively, 906 (±6) kg/m$^3$ and 894 (±13) kg/m$^3$ (Fig. 4). The higher was content of PF-particles, the looser structure of a board and lower DMaxL and DMaxR were observed. The phenomenon was not noted for the particleboards made of UF-particles. Peak density of panels with 80% and 100% of PF-particles was, respectively, 9% and 15% lower than that for the reference. Thus, the above confirms that densification of mats depends on dimensions, shape, moisture content, bulk density of particles as well as on the target density of a board and pressing temperature.

As indicated by Keylwerth (1958), three-layer particleboards with peak density close to the surface exhibit higher modulus of rupture and modulus of elasticity than those with more uniform density profile. At the same time, UF curing and bond formation can be affected by the presence of residual “old” UF or PF resin that – according to Pocius (2002) – is a weak boundary layer between wood and adhesive being applied. Czarnecki et al. (2003) report that reduced mechanical performance of the panels containing PF-particles can result from inhibition of acid-induced curing of UF adhesive by the residual alkaline PF resin.

CONCLUSIONS
1. The type and content of recovered particles (UF- or PF-resin loaded) significantly affected the density profile of three-layer particleboards.
2. Profile of the particleboards containing UF-particles was similar to that for the reference boards made of 100% industrial particles, while 80% and 100% addition of PF-particles resulted in significant increase in thickness and decrease in mean density when compared to the reference series.
3. Thickness of the boards with 80% and 100% of PF-particles was, respectively, higher by 7% and 14% when compared to the reference particleboards.
4. Mean density of the particleboards with 80% and 100% of PF-particles was, respectively, lower by 6% and 23%, respectively, when compared to the references.
5. The higher was content of PF-particles, the looser structure of a board and lower DMaxL and DMaxR were observed.
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**Streszczenie:** Profil gęstości płyty wiórowych wytworzonych z dodatkiem przemysłowych odpadów drzewnych zanieczyszczonych żywicami syntetycznymi. Wytworzono trzywarstwowe płyty wiórowe, w których udział mieszanin wiórów z odpadów sklejki w warstwie wewnętrznej wynosił 20 - 100%. Wióry zaklejano żywicą UF. Zbadano wpływ rodzaju i udziału wiórów z odpadów sklejki na grubość, gęstość i profil gęstości płyty wiórowych. Stwierdzono, że płyty wytworzone z dodatkiem wiórów zawierających żywicę UF miały taki sam profil gęstości jak płyty wytworzone z wiórów przemysłowych. Natomiast płyty zawierające w warstwie wewnętrznej 80% i 100% wiórów zanieczyszczonych żywicą PF charakteryzowały się niedostatecznym połączeniem wiórów z odpadów sklejki. W wyniku tego dochodziło do rozluźnienia struktury warstwy wewnętrznej płyty, skutkującego wzrostem ich grubości, a w konsekwencji spadkiem ich średniej gęstości. Grubość płyt zawierających w warstwie wewnętrznej 80% i 100% wiórów z żywicą PF była odpowiednio o 7% i 14% większa, a gęstość średnia odpowiednio o 6% i 23% mniejsza, w porównaniu z płytami z wiórów przemysłowych.

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Methods of limiting occupational risk related to noise exposure in enterprises of the furniture industry in Poland

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Abstract: Noise pollution is one of the most common harmful factors occurring in the work environment of furniture industry enterprises. The largest sources of noise are activities related to the operation of machinery, equipment, means of transport and technological processes. If the permissible noise limit is exceeded, the employer is obliged to adapt to specific safety rules. Otherwise, the noise can trigger a series of harmful changes in the body. The article analyzes the methods of eliminating and limiting the occupational risk associated with exposure to noise used in the furniture sector in Poland. The research conducted in the enterprises of various sizes allowed to show the implemented activities and the awareness of employers and employees of the essence of this problem.

Keywords: noise, noise reduction methods, occupational risk, furniture industry

INTRODUCTION

The material work environment of the furniture industry is burdened with many risk factors, exposure to which causes health consequences for people. According to data published by the Central Statistical Office (GUS) in 2017, exposure to noise, dust and chemicals is the main reason for the emergence of occupational diseases. In this context, ergonomics plays a particularly important role, as it covers issues that allow depicting the work environment to the needs and capabilities of a human being, while contributing to the comfort of performing tasks as well as minimizing threats to health and life [Nowacka, p.14-17].

The article attempts to show the methods related to the reduction of occupational risk related to the noise hazard, which – despite numerous and continuous changes in technology and organization, is still the most common harmful factor in the work environment of the furniture industry.

The biggest sources of noise in the furniture industry are activities related to the operation of machines, devices, means of transport and technological processes. If the permissible noise limit is exceeded, the employer is obliged to adapt to specific safety rules. In order to examine the awareness of employers and employees on the essence of the problem, as well as to depict the methods used to reduce the occupational risk related to exposure to noise, as well as the correctness of implemented activities, a questionnaire survey was conducted among representatives of Polish enterprises in the furniture industry. Both micro, small and medium, as well as large enterprises from this sector were analysed. Describing its results is one of the goals of the following article.

NOISE IN THE WORK ENVIRONMENT

Noise was assumed to determine all undesirable, annoying sounds that are harmful to health or increase the risk of an accident at work [Act 2005]. In order to assess the occupational risk related to this factor – to determine the level of its intensity – the
entrepreneur is obliged to perform measurements. Their results are used to compare the acoustic conditions existing at the workplace with the applicable standards.

The permissible noise values in the work environment have been specified in the regulation of the Minister of Labour and social Policy of June 6, 2014 on the highest permissible concentrations and intensities of agents harmful to health in the work environment [Act 2014] and amount to 85 dB in relation to the 8-hour daily work dimension, and the corresponding daily exposure should not exceed $3,64\times10^3\ \text{Pa}^2\times\text{s}$. The value of 80 dB is also significant, determined by the action threshold, which is a signal to start planning activities that reduce occupational risk. The goal of the proceedings implemented in the company should be to obtain the lowest possible noise level.

If the permissible values are exceeded, according to the Regulation of the Minister of Economy and Labour of August 5, 2005 on occupational health and safety at work related to exposure to noise or mechanical vibrations [Act 2005], the employer should prepare and apply a program of organizational and technical solutions, aimed at lowering its emissions. If, despite the use of organizational and technical methods, noise is not reduced to an appropriate level, the employer is obliged to issue and supervise the use of personal protective equipment in the form of hearing protectors, as well as to provide training in their use. In addition, it should mark safety areas of work in which noise exceeds the admissible values, as well as ensure preventive medical examination of the employee.

The furniture industry is largely based on the processing of wood and wood-based materials [GUS(1)(2)], therefore, regardless of the trauma risks, employees employed in the operation of machinery and equipment for wood processing are exposed to factors harmful to health, in particular harmful effects of wood dust, noise and vibration. Excessive noise in workplaces is related in particular to the use of machinery and equipment for woodworking in this sector (e.g. machining tools, saws or planning machines). Professor Hanna Pachelska, in her publication “Ergonomics in the wood industry” gives the noise characteristics of individual machine tools, where the emission level varies from 95 dB in the case of a format circular saw, up to 108 dB when working with a thicknesser [Pachelska, p.157-171]. It should be noted that the noise levels emitted by such machines far exceed the limit values in the regulations, however – as it has already been mentioned, these are necessary tools in furniture factories, and this means that noise is an unavoidable element of the work environment in this industry.

METHODS OF ELIMINATION AND RESTRICTION OF OCCUPATIONAL RISK ASSOCIATED WITH NOISE EXPOSURE

In order to prevent the effects of noise and eliminate and reduce occupational risk in enterprises, employers are required to prepare and implement technical and administrative-organizational solutions. They should be preceded by thorough tests and analysis of acoustic conditions at work stations. The most important technical methods for reducing noise include [Koradecka, p. 212-245]:

- changing the loudest technological processes into less noisy ones,
- implementation of mechanization and automation in the enterprise, enriched with sound insulating control cabins for service,
- using machines and tools generating low noise levels,
- proper layout of the company, including the isolation of rooms in which mental work is carried out, from production halls and grouping of machines emitting noise of similar levels,
- using acoustic silencers,
– silencing the source of noise through sound absorbing and insulating enclosures and screens,
– installing sound absorbing materials and systems on ceilings and walls of rooms,
– active noise reduction.

It is worth noting that the use of the above-mentioned protection against noise is the most effective when taken into account at the design stage of the company.

Technical measures to limit noise emissions are worth supporting with administrative and organizational solutions, such as [Nowacka, p.159-165].
– rotations of employees at workplaces,
– using breaks at work,
– separation of special soundproof rooms for employees working in noise exposure,
– operating machinery on the secondo r third shift in order to limit the number of people exposed to noise,
– medical prevention.

In the event that the organizational and technical solutions fail to achieve the desired results, i.e. they fail to achieve noise levels below 85 dB, employers are obliged to use hearing protectors that are properly selected for the acoustic conditions at the workplace in the form of earmuffs or anti-noise insoles. The ear muffs are independent or are attached to protective helmets. They are also equipped with electronic systems, e.g. allowing for active noise reduction or damping regulation. Anti-noise inserts are divided into disposable and reusable. They can be modelled at default, by the user or at the factory, at the client’s request. It is important that the hearing protection is applied by the user during the entire period of exposure to noise. Otherwise, their effectiveness drops dramatically [Kotarbińska, p. 2-5].

One of the world’s largest manufacturers of protective equipment in its product category recommends earmuffs with attenuation level (SNR 37 dB for XS) as protection against noise in the wood industry [3M].

The above-mentioned measures must meet the requirements contained in the Regulation of the Minister of Economy of December 21, 2005 on essential requirements for personal protective equipment [Act 2005a].

**ANALYSIS OF APPLIED METHODS OF ELIMINATION AND LIMITATION OF NOISE IN FURNITURE INDUSTRIES ON THE BASIS OF A QUESTIONNAIRE STUDY**

The questionnaire survey aimed at analysing the methods of eliminating and reducing noise in furniture industry enterprises was carried out between September 19 and 29, 2017 in the form of an anonymous questionnaire, in which representatives of 20 enterprises from the micro, small, medium and large companies from the furniture industry participated (25% of the surveys fell on each individual group), and respondents answered the same questions about the methods of eliminating and limiting the occupational risk associated with exposure to noise. The questionnaire in the form of an electronic form has been made available to persons declaring as responsible for OHS in the company or having knowledge in this field.

The survey consisted of two parts. In the first one, the company was verified in terms of its scale, while the second part covered 20 questions regarding methods of limiting the occupational risk related to exposure to noise. Respondents taking part in the study, left some of the questions unanswered, or their statements were not clear. Considering the comparative nature of the study, in the above cases, some of the survey questions have not been analysed.

All participants of the study unanimously stated that noise in the work environment is “a significant threat to the health of the employee” for them.
In order to conduct occupational risk assessment, entrepreneurs carry out tests to assess noise levels at various time intervals. The largest frequency of research (once a year) is declared by large companies – 80% of them declared so. All respondents from the group of micro-enterprises declare the lack of the need to conduct research, as well as 80% of small and 60% of medium enterprises.

Fig. 1. Frequency of tests concerning the noise emission level in individual groups of enterprises
Source: Prepared on the basis of own research.

As confirmed by research, only large and medium-sized companies allocate funds for noise reduction in a wider scope than providing earmuffs and disposable earbuds to employees – on both cases, they constitute 80% of representatives of their groups.

All surveyed large enterprises and 80% of medium enterprises, employing the largest number of people at the same time, adopted a strategy of successive updating of noise protection, as the machine park and the production hall plan changed.

In order to reduce noise emissions, entrepreneurs use different methods. In every large company participating in the research, noise is fought through the automation of the technological process, the use of earmuffs and disposable earbuds. Earmuffs are also readily used in medium-sized enterprises, as well as in 80% of micro and 60% of small ones. Not too noisy machines is a dominant method in small companies (80% of them declare its use), although it is also chosen by 60% of large and micro enterprises and 40% of medium ones.

Among respondents, there are companies in which some employees allocate their funds to their own hearing protection tools. This phenomenon concerns 20% of large and micro companies and 40% of medium-sized ones.
In the surveyed enterprises, where noise levels are not exceeded or workplaces are not burdened with excessive noise, 45% of employees use hearing protectors.

In the surveyed enterprises, office workers who have short-time contact with noise declare the use of hearing protectors. In the case of large enterprises, they constitute 80%, and 40% in medium and 20% in micro enterprises.
The surveyed entrepreneurs were also asked to determine the level of awareness of machine operators about the volume level of sound emitted by the machines. Three out of five micro and small enterprises have ensured that machine operators have such knowledge, while medium and large enterprises have declared that they have informed all their employees about the acoustic conditions in which the work takes place.
Entrepreneurs in their activities support themselves with certified occupational health and safety management systems. The largest percentage of them are medium-sized enterprises in the number of 60%, small and large companies in 40% and every fifth micro-enterprise.

CONCLUSION
As confirmed by the research, Polish entrepreneurs in the furniture industry are aware of the threat to the health of their employees staying in the noise environment, as well as have a wide range of measures to level it. Although their administrative and technical methods are numerous, they prove to be not fully effective, as evidenced by the use of largely individual noise abatement measures.

The effectiveness of the measures used may be much lower than expected, as in most cases they were not implemented at the design stage of the enterprise. A dependency emerges from the answers given in the surveys described – the larger the scale of the company, the greater the percentage of machine operators aware of the acoustic conditions in which they work. However, office workers who downplay individual hearing protection in the case of short-term contact with noise are burdened with a big threat, which may cause them to hear impulse noise, particularly dangerous to health.

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Streszczenie: Metody ograniczania ryzyka zawodowego związanego z narażeniem na hałas stosowane w przedsiębiorstwach branży meblarskiej w Polsce. Zagrożenie hałasem jest jednym z najpowszechniejszych czynników szkodliwych występujących w środowisku pracy w przedsiębiorstwach branży meblarskiej. Największymi źródłami hałasu są czynności związane z pracą maszyn, urządzeń, środkami transportu oraz procesami technologicznymi. W przypadku przekroczenia dopuszczalnej normy hałasu, pracodawca ma obowiązek dostosować się do konkretnych zasad bezpieczeństwa. W przeciwnym razie, hałas może wywołać szereg szkodliwych zmian w organizmie. W artykule przeanalizowano metody eliminowania i ograniczania ryzyka zawodowego związanego z narażeniem na hałas stosowane w sektorze meblarskim w Polsce. Przeprowadzone badanie w przedsiębiorstwach o różnej wielkości pozwoliło na ukazanie wdrażanych działań oraz świadomości pracodawców i pracowników istoty tego problemu.

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Determination of bending strength and modulus of elasticity in the tangential and radial directions of yellow pine (Pinus ponderosa Douglas ex C. Lawson)

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Abstract: Determination of bending strength and modulus of elasticity in the tangential and radial directions of yellow pine (Pinus ponderosa Douglas ex C. Lawson). The study was done for both yellow pine sapwood and heartwood. Bending strength of sapwood of yellow pine tested in tangential and radial direction, respectively, was 101 ± 10 MPa and 88 ± 10 MPa. Bending strength of the heartwood of yellow pine tested in tangential and radial direction respectively, was 121 ± 13 MPa and 122 ± 16 MPa. The modulus of elasticity of yellow pine wood was not as diverse as bending strength according to the wood area and measurement direction. Modulus of elasticity of pine wood reached 8200 MPa. Significant differences of load-deflection curves of yellow pine sapwood and heartwood under flexural load were found.

Keywords: bending strength, deflection, load, modulus of elasticity, radial, tangential, yellow pine

INTRODUCTION

Yellow pine (Pinus ponderosa Douglas ex C. Lawson) is a species of coniferous wood of the Pinaceae family. Trees reach a height of 72 m, trunk can be up to 2.5 m diameter. Pinus ponderosa is commonly known as the ponderosa pine, bull pine, blackjack pine, or western yellow pine. The inner layers of the bark and young shoots are yellowish, hence the name. Part of botanists distinguished five subspecies of ponderosa pine, depending on the morphological characters and adaptations to different climatic conditions (Callaham 2013a, b). Yellow pine is most common of Americans pines and is often confused with Jeffrey’s pine (Thieret 1993). In the home country, the yellow pine is one of the most important trees due to its precious wood and small soil requirements. It grows well on sandy and poor soils. The wood of yellow pine in the countries of harvest (USA, Canada) has similar uses as pine wood (Pinus sylvestris L.). Yellow pine is the most commercially valuable and productive timber tree. High-quality logs are used for production boards, cabinets, molding. Lower-quality yellow pine wood is used for the production of lumber and construction products. For this type of material it is important to have sufficient flexural strength.

Resistance to static bending is one of the essential characteristics of wood limiting its applicability (Wagenführ 2007, ISO 13061-3:2014). The analysis of these issues is important since the strength of the wood bending plays an essential role in the work of building elements such as floors, beams, elements of roof truss. The static bending strength is the next commonly used test after strength in compression parallel to grain. The bending strength of wood exhibits intermediate values between strength in compression and ultimate tensile stress. The static bending strength and modulus of elasticity show a significant variation, dependent on species, density, moisture content, anatomical structure, annual ring width, share of latewood, wood defect (Green et al. 1999, Wagenführ 2007). The age of the trees from which the samples for the studies are derived is also important (Mackes et al. 2005). Obtained results of the test also depend on the dimensions of the samples, bending forces action, span (distance between the centres of reaction supports). It has been shown that the
modulus of elasticity of wood differs depending on where sampling is taken from the tree trunk (Jelonek 2013a, b).

The aim of the study was to identify bending strength and modulus of elasticity of yellow pine (*Pinus ponderosa* Douglas ex C. Lawson). An important aspect of ongoing research was to verify variation of bending strength and modulus of elasticity of yellow pine depending on the wood area (sapwood, heartwood) and direction of bending forces (load in tangential and radial direction to the grain).

**MATERIAL AND METHOD**

The study uses samples of yellow pine wood (*Pinus ponderosa* Douglas ex C. Lawson), originating from the USA. After conditioning of the samples to the air-dry state, density of wood was marked by stereometric method as required by ISO 13061-2 (2014). Wood moisture content is determined according to ISO 13061-1 (2014). Testing of modulus of rupture (MOR) and modulus of elasticity (MOE) of wood was made in accordance to ISO 13061-3 (2014) and ISO 13061-4 (2014) standards, respectively. Studies were conducted for sapwood and heartwood of yellow pine. The wood properties were determined in the tangential and radial directions. MOR and MOE tests were carried out using a computer program coupled with a strength machine Instron® model 3369 (Norwood, USA). Statistical analysis was performed using STATISTICA version-12 software of StatSoft, Inc. (Tulsa, USA). The statistical analysis of the results was carried out at a significance level of 0.05.

**RESULTS AND DISCUSSION**

Studies show that the moisture content of the wood of yellow pine (*Pinus ponderosa* Douglas ex C. Lawson) used in the study was 9.2 (±0.4)%%. Densities of sapwood (S) and heartwood (H) were 486 ± 40 kg/m³ and 654 ± 80 kg/m³ respectively, and these differences were statistically significant (t = -7.34007, p = 0.000000). Green et al. (1999) indicate that the density of ponderosa pine with a moisture content of 12% is approx. 400 kg/m³. The yellow pine wood in the countries of harvest (USA, Canada) has similar uses as pine wood (*Pinus sylvestris* L.). The density of yellow pine wood is like the density of pine wood (*Pinus sylvestris* L.). According to Wagenführ (2007), pine wood (*Pinus sylvestris* L.) density in an air-dry condition ranges from 330 kg/m³ to 890 kg/m³, with the mean value 510 kg/m³.

<table>
<thead>
<tr>
<th>Wood area</th>
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<td>t</td>
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<td></td>
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Significant differences have been demonstrated between MOR of sapwood of yellow pine in tangential (T) and radial (R) directions. MOR of sapwood pine in a tangential direction vary in a significant way from the MOR of heartwood in the tangent direction (Table 1). Analogous dependencies were found in the case of MOR tested in the radial direction for sapwood and heartwood of pine. These dependencies stem mainly from the differences in the density of sapwood and heartwood of the yellow pine. It is generally assumed that the higher the density of wood the higher the value of MOR (Krzysik 1974, Wagenführ 2007).
were no significant differences between the values of the MOE of yellow pine according to wood area and measurement direction (p > 0.050).

![Figure 1. Bending strength (a) and modulus of elasticity (b) in the tangential (T) and radial (R) directions of yellow pine](image)

MOR of sapwood of yellow pine tested in tangential and radial direction was 101 ± 10 MPa and 88 ± 10 MPa, respectively. While MOR of yellow pine heartwood tested in tangential and radial direction were 121 ± 13 MPa and 122 ± 16 MPa, respectively (Figure 1a). According to Green et al. (1999) MOR of pine ponderosa reaches 65 - 73 MPa. The lower values of MOR pine ponderosa are given by the authors for lower density pine ponderosa (400 kg/m³), hence significant differences in research results. From the literature data it shows that pine wood (*Pinus sylvestris* L.) is characterized by MOR at level 87 - 88 MPa (Wanin 1953, Göhre 1954).

![Figure 2. Load-deflection curves of yellow pine sapwood under flexural load](image)

MOE of yellow pine was not as diverse as MOR according to the wood area and measurement direction. Generally, it can be stated that the MOE of yellow pine is about 8200 MPa (Figure
These values are similar to the literature data. According to Green et al. (1999), MOE of pine ponderosa is included in the range 8900 - 9500 MPa. For Scots pine (*Pinus sylvestris* L.) MOE is approx. 12000 MPa (Krzysik 1974).

Figure 2 and 3 show the relationship between load and deflection of yellow pine sapwood and heartwood under flexural load. Notable differences in changes in the deflection under the influence of load depending on the wood area (sapwood, heartwood). Wood of yellow pine from the sapwood area under the load showed “gradual” distortion until complete destruction. It should be assumed that in sapwood in terms of density, the vary of earlywood and latewood is significant (Richter and Dallwitz 2000, Wagenführ 2007). In the wood of the yellow pine originating from the heartwood, there was no such explicit dependence.

CONCLUSIONS
1. The bending strength of the yellow pine wood differs significantly depending on the wood area (sapwood, heartwood) and measurement direction (tangential, radial). MOR of yellow pine wood was within the range 88 - 122 MPa.
2. No significant differences were found between the values of the modulus of elasticity of yellow pine wood depending on the wood area and measurement direction. MOE of pine wood was approx. 8200 MPa.
3. Significant differences in load-deflection curves have been demonstrated according to the test factors: wood area (sapwood, heartwood), measurement direction (tangential, radial).

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Streszczenie: Oznaczenie wytrzymałości na zginanie statyczne i modułu sprężystości w kierunku stycznym i promieniowym sosny żółtej (Pinus ponderosa Douglas ex C. Lawson). Badania przeprowadzono dla drewna bielu i twardzieli sosny. Wytrzymałość na zginanie statyczne drewna bielu sosny żółtej badana w kierunku stycznym i promieniowym wynosiła odpowiednio 101 ± 10 MPa i 88 ± 10 MPa. Natomiast wytrzymałość na zginanie statyczne drewna twardzieli sosny żółtej badana w kierunku stycznym i promieniowym wynosiła odpowiednio 121 ± 13 MPa i 122 ± 16 MPa. Wartość modułu sprężystości przy zginaniu statycznym drewna sosny żółtej nie była tak zróżnicowana jak wytrzymałość na zginanie statyczne w zależności od badanej strefy drewna (biał, twardziel) i kierunku działania obciążenia (styczny, promieniowy). Moduł sprężystości drewna sosny wynosił ok. 8200 MPa. Wykazano istotne różnice w przebiegu krzywych opisujących związek między odkształceniem a przyłożonym obciążeniem dla drewna bielu i twardzieli sosny żółtej.

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Density – induced surface roughness of dry formed fiberboards

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Abstract: Density – induced surface roughness of dry formed fiberboards. The aim of the research was to determine the effect of density of dry formed fiberboards, produced in laboratory conditions, in the density range from 200 to 900 kg/m³, on their roughness parameters, such as Ra, Ry and Rq. In the range of research, the preliminary characterization of mechanical properties of the tested panels was also carried out. The tests have shown that with increasing density of the tested panels in the mentioned range, there is a significant improvement in surface roughness, although these changes are most intense in the density range from 200 to 400 kg/m³.

Keywords: density; fibreboard; surface properties; surface roughness

INTRODUCTION

As it is indicated in PN-EN 316:2009 standard, the dry formed fiberboards are made of lignocellulosic fibers pressed together with high temperature and / or pressure. They have the thickness of at least 1,5 mm. What is more important, the fibers, during panel production, are carried and formed on the shape of a panel by the air. The names of the HDF, MDF and LDF derive from different density of panels. The density of low density fibreboard (LDF) is between 450 and 650 kg/m³.

In the state of the art, some authors have investigated the effect of influence of physical properties on MDF panels. Here, Rolleri and Roffael (2007) have included influence of EMC (equilibrium moisture content) on the average roughness of the MDF boards. The same authors (Rolleri and Roffael 2008) have investigated the influence of different climatic conditions on the wettability of MDF panels with different degrees of roughness. In their studies, they have proven that the roughness of the surface has a strong effect on the wettability of MDF panels. The other authors (Bekhta and Niemz 2009) have argued, that depending on the kind of fibreboard, and thus, on the surface type and roughness parameters, the water is absorbed in various quantities. A similar contribution to these study is included in the work of other researchers (Akbulut et al. 2000). They investigated the relationship between the roughness of the surface and surface absorption of MDF panels manufactured from different wood species. As it is known, the boards may have different surface types, more or less rough. In order to reduce the roughness of the panels they can (or, either should) be sanded. According to the study of Sulaiman et al. (2009), in case of solid wood, the rough surface of wood can cause a weaker surface contact and, as a result, weak glue or poor finishing quality. Therefore, smooth and not highly absorbent surfaces are required for MDF fibreboard to be used for finishing and painting. In the research of Ayrilmis et al. (2010), the authors proved that smoother surface of MDF panels was less wettable and absorbent compared to rougher surface.
Due to the fact that the above mentioned studies have been generally concerned on medium density fibreboards, the purpose of this paper was to focus on wide type of dry formed fiberboards – LDF, MDF and HDF, in the light of surface roughness. The study was designed to show the relationship between the density of the panels and the selected mechanical and physical factors.

**MATERIALS AND METHODS**

**Dry formed fiberboards of different densities**

A 16 mm – thick dry formed fiberboards, with the density of 100, 200, 300, 400, 500, 600, 700, 800 and 900 kg/m$^3$ (hereinafter called “panel type”), from industrial coniferous fibers and melamine – urea – formaldehyde (MUF) resin, with 4% w/w melamine share, were produced in laboratory conditions. The resination of fibers’ mass was 12%. As a hardener an aqueous solution of (NH$_4$)$_2$SO$_4$ was used, and the curing time of glue mass in 100ºC was about 82 s. No hydrophobic agent was added during panels’ production. The moisture content of all used fibers was about 5%. The pressing parameters were as follows: temperature 200ºC, time factor 20 s/mm, maximum unit pressure 2.5 MPa.

**Modulus of rupture and modulus of elasticity**

The following mechanical parameters of produced panels were investigated: bending strength and modulus of elasticity during bending, according to appropriate European standard procedure EN 310:1994. A number of 12 samples of every panel type was used to mentioned test. Prior to the test, the density of every single sample was measured. According to the results, the maximum measured difference between assumed and achieved density of produced panels was less than 5%.

**Surface roughness**

The surface roughness parameters have been measured with use Mitutoyo portable roughness tester SJ – 201. The following roughness parameters were measured: Ra, Ry and Rq. For every panel type, as many as 12 samples of dimensions 50 x 50 mm$^2$ have been used, where one measurement has been done on every face side of the sample. This gave 24 measurements for every panel type. The surface of the samples has not been sanded, but the panels were produced with use the same press plates, to avoid the differences caused by various elements used during mat pressing. On the basis of this measurements, the average values of mentioned parameters, as well as standard deviation of these, have been calculated.

All the tested samples were conditioned prior to the tests in 20ºC/65% RH to constant weight.

**RESULTS**

The pictures of the surfaces of tested panels with the densities from 200 to 900 kg/m$^3$ are presented on figure 1. As it is shown, the panels of lower densities have much more higher number of visible single fibers on the surface, which have not been incorporated onto panel surface by pressing. This is due to relatively small assumed panel density, and, when the mat was pressed, there was no sufficient support of the surface layer by core zone, to densify the face layers as much as it was done in case of the panels of densities 500 kg/m$^3$ and higher.

The results of measurement of modulus of rupture of the dry formed fiberboards produced with different density, are shown on figure 2. The measured values of modulus of rupture significantly increases with panel density increase. The mentioned raise is significantly recognized in case of panel 500 and higher densities. Since in case of bended materials, the most responsible zones for carrying the load are located in the outer layers, it
can be concluded that the densification of these panels is higher. Due to this, the roughness parameters, namely Ra and Rq, are lower, what means that the surface is more smooth. This phenomena can be found on figure 4 and figure 6.

![Figure 1](image1.jpg)

It should be added, that according to EN 622-5: 2009 standard requirements for MDF panel of general purpose to use in dry conditions, also for furniture production, the minimum value of modulus of rupture for panels of the thickness range from 12 to 19 mm should be not less than 20 N/mm². This mean that the mentioned standard requirement is fulfilled by panels of densities 600 kg/m³ and higher.

The values of modulus of elasticity of the panels of different density are presented on figure 3. It this case the modulus of elasticity significantly raises with the density increase.
According to EN 622-5: 2009 standard requirements for MDF panel of general purpose to use in dry conditions, also for furniture production, it should be pointed, that the minimum value of modulus of elasticity for panels of the thickness range from 12 to 19 mm should be not less than 2200 N/mm². In the light of this requirement, the panels of density 600 kg/m³ and higher fulfil the mentioned requirement.

The results of measurement of arithmetical mean deviation Ra of the assessed panels are displayed on figure 4. According to presented data, the surface roughness, described by Ra parameter, significantly decreases with the density increase in the range of 200 – 900 kg/m³. However, it can be stated, that over 500 kg/m³ density, the intensity of improvement of Ra parameter is much more smaller compare to the densities under 500 kg/m³.

According to EN ISO 1302:2004, the results of Ra parameter about 20 μm is for 3 roughness class of 14 classes, and is connected to precise cutting surface processing. The Ra decreasing values from 10 to 5 μm are for 4 and 5 class, and represents precise cutting surface processing and surface finishing. The registered values of Ra, which are in the range of 7.8 – 29.1 μm, represents the values of the roughness of the sanded particleboards tested by Beer et al. (2010). For these particleboards the Ra parameter was within the range of 12 – 21 μm.
The values of maximum height of the profile $R_y$ of the tested panels are presented on figure 5. Similarly to $Ra$ values, the $R_y$ decreases with the panel density increase.

The highest registered values are 183 $\mu$m for panel 200, and the lowest – 58 $\mu$m for panel 900.

Since the $R_y$ parameter is responsible for maximum height of the profile, it can be also the useful tool to assess the feature of the panel surface before finishing. According to assumed way of further finishing of fibrous panel, the height of profile can influence the
lacquer or paint demand, or, in case of laminating, can determine the glue covering, and, thus, the final quality of finishing.

On the figure 6 the values of root mean squared Rq of the assessed panels are presented. As it is shown, the values of Rq parameter also decreases with density increase. As it was mentioned in case of Ra analyzing (figure 4), the reduction of Rq parameter is more intensive for panels 200 – 400, and, when exceeding the density of 400 kg/m$^3$, is smaller.

It is worth to underline, that also the uniformity of the surface, measured by standard deviation calculated from single measurements, is improved when the panel density increases. As it can be seen on the figure 4, figure 5 and figure 6, the standard deviation values, marked as the error bars, are reduced almost double, when compare the extreme panels.

CONCLUSIONS

According to the conducted research and the analysis of the achieved results, the following conclusions can be drawn:

1. The modulus of rupture and modulus of elasticity of the dry formed fiberboards increases when the panels density increase from 200 to 900 kg/m$^3$.
2. The arithmetical mean deviation Ra, the maximum height of the profile Ry and root mean squared Rq of the assessed panels decreases with the increase of the panels density.
3. The intensiveness of the surface roughness parameters (Ra, Ry, Rq) improvement is reduced for panels of density 500 kg/m$^3$ and higher.
4. The uniformity of the surface, represented by standard deviation of the measured roughness parameters, significantly improves with the density increase.

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Streszczenie: Wpływ gęstości na chropowatość suchoformowanych płyt pilśniowych. Celem badań było określenie wpływu gęstości płyt pilśniowych suchoformowanych, wytworzonych w warunkach laboratoryjnych, w zakresie od 200 do 900 kg/m$^3$, na ich parametry chropowatości, takie jak Ra, Ry i Rq. W zakresie badań przeprowadzono również wstępna charakterystykę właściwości mechanicznych badanych płyt. Badania wykazały, że wraz z wzrostem gęstości badanych płyt we wspomnianym zakresie, następuje znaczna poprawa chropowatości powierzchni, aczkolwiek zmiany te są najbardziej intensywne w zakresie zmiany gęstości od 200 do 400 kg/m$^3$.

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Influence of dry formed fiberboards density on their thickness swelling and water absorption

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Abstract: Influence of dry formed fiberboards density on their thickness swelling and water absorption. The aim of the research was to determine the thickness swelling and water absorption of dry formed fiberboards produced in laboratory conditions as a result of interaction with moisture, depending on the density of the panels. In the range of work, in addition to the aforementioned tests, the bending strength and modulus of elasticity in bending of the tested panels were also determined. The studies have shown that with the increase in panel density, the value of their swelling in thickness and water absorbability increases significantly. It has also been shown that with increasing density of the panels, the intensity of their thickness and mass increase in relation to the time of soaking the panels in water for 24 hours decreases.

Keywords: dry formed fiberboard, MDF, LDF, HDF, moisture, thickness swelling, water absorption

INTRODUCTION

According to EN 316:2009 standard, the medium density fiberboards, as a group of panels, are made of lignocellulosic fibers bonded together with high temperature and / or pressure. They are of the thickness of at least 1.5 mm. What is more important, the fibers are transported and formed on the shape of a panel by the air. The HDF, MDF and LDF names derive from different density of panels. For example, the density of low density (LDF) fibreboard should be between 450 and 650 kg/m³.

Moisture and its influence on the properties of fiberboards

Ducoulombier and Lafhaj (2017) proved, that wood fiberboards applied for thermal insulation of buildings, had a significantly higher moisture permeability comparing to the remaining tested materials: glass wool, rock wool, expanded polystyrene and polyester fiberfill. The same positive opinion about lignocellulosic fiber panels used in building insulations, was given by Holcroft and Shea (2014). They tested the moisture buffering capacity of hemp-lime, hemp fibre, sheep’s wool materials, alongside two more conventional materials (glass wool and gypsum plasterboard). In the light of further application as the thermal insulation material, Troppová et al. (2015) investigated the influence of temperature and moisture content on the thermal conductivity of wood – based fibreboards. They found, that the thermal behaviour of fibreboards when installed as building facade insulation can be remarkably affected by changes in temperature and moisture content.

Selected factors influencing properties of wood – based composites

The ambient aging of wooden fibers cause the less wettability of the fibers, also for water soluble resins (Bai and Gao 2011). It was noted, that MDF made with ambient-aged wood fibers, had lower mechanical properties than MDF made with fresh fibers. Such difference resulted from the alterations of surface properties of wood fibers after ambient aging. It has been shown that also the heat treatment of wood fibers used for dry formed fiberboards production, can lower the wettability and reaction to water (Garcia et al. 2008). These fibers were heated in temperatures 150 and 180°C within 15, 30 and 60 min. Halligan (1970) showed that in case of particleboards, the panels’ reaction to water and occurred thickness swelling can be reduced by steam post – treatment of the panels. This process,
together with resin content influence, are indicated as a most promising way to extend the durability of particleboards, by lowering their thickness swelling. The influence of resin type on the durability and mechanical properties of wood-based composites was tested by Korai et al. (2015). In this research, phenol–formaldehyde resin-bonded particleboard, methylene diphenyl diisocyanate resin – bonded particleboard (MDI board), aspen oriented strand board (aspen board), Scots pine oriented strand board (pine board), methylene diphenyl diisocyanate resin – bonded medium – density fiberboard (F-MDI board), and melamine – urea – formaldehyde resin – bonded medium – density fiberboard (F-MUF board) – overall six board types, were subjected to high relative humidity (90% and 20°C) or cyclic humidity of high/low relative humidity (90/45%, 20°C) for 5 years. The MDI board, pine board, F-MDI board, and F-MUF board showed almost no reduction of modulus of elasticity after such testing.

In case of medium density fiberboards, the results of testing kenaf fibre panels showed that resin type and moisture content have more important influence on the mechanical properties, where resin content is the least significant. On the other hand, for selected physical properties, such factors as resin content and moisture content have much lesser influence than compared to resin type (Ali et al. 2014). According to Bekhta and Niemz (2009), the lower the density of boards in the range of 517 – 931 kg/m³ – the higher equilibrium moisture content of the panels. For dry formed fiberboards of low density, starting from 50 kg/m³, it has been found that the decrease of fibers size allows to achieve better mechanical properties of the panels (Kawasaki et al. 1998). It was also established, that the panels of low density had a lower thickness swelling. The water vapour resistance factor of both, wet and dry processed industrial soft fibreboard increases, and the diffusion coefficient decreases with raising density (Sonderegger and Niemz 2012). In case of particleboards, the increasing of equilibrium moisture content (EMC) of the panels in the range of 2.5 – 18%, leads to significant reduction of mechanical properties of the panels (modulus of rupture and elasticity, as well as internal bond strength), even more that 50% lower than the highest results (Halligan and Schniewind 1974). For panels produced from wooden fibers bonded with soybean protein adhesive, the higher fibers’ initial moisture content caused reduction of thickness swelling, linear expansion and water absorption (Li et al. 2009). Also density profile of the fiberboards can have the influence on the several properties of the panels, including thickness swelling. According to Wong et al. (2000), the homo – profile fiberboards, with even density on entire thickness range, showed higher thickness swelling and water absorption than conventional fiberboards with “U” shape of density profile, throughout the dry / wet conditioning cycle. However, there is no literature data concerning the variability of thickness swelling and water absorption of dry formed fiberboards of different density.

RESEARCH OBJECTIVE

The aim of this research was to characterize the influence of the density of dry formed fiberboards produced in laboratory conditions, on their thickness swelling and water absorption when soaked in water.

MATERIALS AND METHODS

As thick as 16 mm dry formed fiberboards, with the density of 100, 300, 500, 700 and 900 kg/m³ (hereinafter called “panel type”), from industrial coniferous fibers and melamine – urea – formaldehyde (MUF) resin, with 4% w/w melamine share, were produced. The resination of fibers’ mass was 12%. As a hardener an aqueous solution of (NH₄)₂SO₄ was used, and the curing time of glue mass in 100°C was about 82 s. No hydrophobic agent was added during panels’ production. The moisture content of all used fibers was about 5%. The pressing parameters were as follows: temperature 200°C, time factor 20 s/mm, maximum unit pressure 2.5 MPa. The following parameters of produced panels were investigated: bending
strength and modulus of elasticity during bending, as well as swelling in thickness and water absorption. The appropriate European standard procedures were applied (EN 310:1994, EN 317:1999). The water absorption (WA) was calculated as follows:

\[ W_A = \frac{m_2 - m_1}{m_1} \cdot 100 [\%] \]  

(1)

where: \( m_1 \) – sample mass before soaking [g], \( m_2 \) – sample mass after soaking [g]

The measurement of samples’ mass and thickness was conducted in following periods of time: 0 min, 5 min, 30 min, 2 h, 6 h and 24 h of total soaking time. As many as 12 samples of every panel type was used for completing the above mentioned tests. The standard universal testing machine, computer controlled, was used to measure the mentioned mechanical properties of tested panels.

The maximum measured difference between assumed and achieved density of produced panels was less than 5%.

All the tested samples have been conditioned prior to the testing in 20°C/65% RH to achieve the constant weight.

RESULTS

The pictures of the face surfaces of the produced panels of different density are presented on figure 7. As it can be seen, the panels of lower density, like 100 and 300, have significant number of free fibers on the surface.

![Figure 7](image)

This is caused by low density of entire panel, and thus, low densification of surface layers. The surface of the panels gets more homogeneous with density increase, however,
there is no significant difference between the panels 700 and 900. The size of the presents samples is 50 x 50 mm$^2$.

The results of measurement of modulus of rupture of investigated panels of variable density is presented on figure 8. As it can be seen, the bending strength increases with density increase. Excluding the strength of panel 100, where the measured modulus of rupture is in the range of measurement error, the significant raise of the bending strength is found when the density raises from 300 to 500 kg/m$^3$, and modulus of rupture raises from 2.09 to 17.2 N/mm$^2$, what means over 723% improvement of bending strength. It should be added, that according to EN 622-5: 2009 standard requirements for MDF panel of general purpose to use in dry conditions, also for furniture production, the minimum value of modulus of rupture for panels of the thickness range from 12 to 19 mm should be not less than 20 N/mm$^2$.

In the light of this requirement, the only 700 and 900 panels fulfil the mentioned requirement. If analyzing the average values with standard deviations, it should be mentioned, that all the measured average values of modulus of rupture of tested panel types are statistically significantly different.

![Figure 8. Modulus of rupture of tested panels](image)

On figure 9 the average values of modulus of elasticity of tested panels with different density are presented. The value of modulus of elasticity for panel 100 is 0, since it was impossible to achieve the pure elasticity region when bending the samples of such low bending strength, as it was mentioned on figure 8. The modulus of elasticity raises when the panels’ density raise. According to EN 622-5: 2009 standard requirements for MDF panel of general purpose to use in dry conditions, also for furniture production, it should be pointed, that the minimum value of modulus of elasticity for panels of the thickness range from 12 to 19 mm should be not less than 2200 N/mm$^2$. In the light of this requirement, the only 700 and 900 panels fulfil the mentioned requirement. If analyzing the average values with standard deviations, it should be mentioned, that all the measured average values of modulus of elasticity of tested panel types are statistically significantly different.
The results of measurement of thickness swelling of the produced panels of variable density are presented on figure 10. As it has been shown, the thickness swelling of panels 300, 500, 700 and 900 raises, and, the increase of the thickness is connected to density of the panels. This gives the conclusion that the thickness swelling increases with the density increase. When analyzing the dynamics of swelling in thickness, it can be concluded that the lower density panels (e.g. 300 and 500) raise in thickness more intensive at the beginning of the soaking, and the thickness stabilize after first 6 h of soaking.

The thickness of panels 700 and 900 raises during entire 24 h of soaking. The reason of this can be more tight structure of the panels of higher density, where the activity of water is reduced and more time – dependent. According to EN 622-5: 2009 standard requirements for MDF panel of general purpose to use in dry conditions, also for furniture production, it should be pointed, that the maximum value of thickness swelling of panels of the thickness range from 12 to 19 mm should not exceed 12% after 24 h of soaking the panels in water. In the light of this requirement, none of the tested panels of the density in the range of 300 – 900 kg/m³ fulfil the mentioned requirement.
In case of panel 100, the initial soaking time of 5 min gave the raise of the thickness about 4.8%, but the continuation of soaking provided the reduction of thickness to about 11%, regarding the initial thickness. It is also worth to note, that even after 24 h of soaking, the thickness reduction, however less intensive than at the beginning, was still in progress. The reduction of the thickness of panels of such low density can be caused by capillarity forces between the fibers in the structure of the panels. Such porous structure of the panels is easy to penetrate by water, as well as, the water can reduce the bonding lines strength between fibers, which are smaller and of lower amount, comparing to panels of higher density. The reduction of strength of bonding lines cause the progressive destruction of panel structure, what appears thickness reduction.

![Figure 11. Water absorption of tested panels of variable density](image)

The average values of water absorption of the tested panels of different density, when soaked in water, are presented on figure 11. As it can be seen, the water absorption is strongly connected to density of the panels, and decreases with the panel density increase. The highest average value of the water absorption, reached 854% after 24 h of soaking, was noted for panels of lowest investigated density – 100 kg/m³. The lowest mass of water uptaken after 24 h of soaking was noted for panel 900, and it was 69%.

The dynamisc of water uptake by investigated panels, measured as a mass change of the samples, was inversely proportional to panel density: the higher density – the lower intensiveness of water uptake. However, it can be concluded, that even for panel 900, the real water uptake was completed after 6 h of soaking. There is no significant changes of the samples mass during remaining soaking time.

CONCLUSIONS

According to the conducted research and the analysis of the achieved results, the following conclusions have been drawn:

1. There are significant changes of the surface structure of dry formed fiberboards visible with the density increase in the range of 100 – 700 kg/m³. Over this range no significant changes have been noted.
2. The modulus of rupture of the dry formed fiberboards raises with the density raise in the range of 100 – 900 kg/m³, however, the most significant raise of this parameter was found for density change from 300 to 500 kg/m³.
3. The values of modulus of elasticity of dry formed fiberboards significantly raise with the panels density increase.
4. The thickness swelling of the panels of density 100 kg/m$^3$ decreases during soaking in water. For the remaining investigated panels in the density range of 300 – 900 kg/m$^3$, the thickness swelling increases with the density increase.
5. There is no significant difference between the thickness swelling of panels of density 700 and 900 kg/m$^3$ after 24 h of soaking in water.
6. The water absorption of the dry formed fiberboards raise with the panel density decrease.
7. The intensiveness of thickness swelling and water uptake of dry formed fiberboards decrease with panel density increase.

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Streszczenie: Wpływ gęstości suchoformowanych płyt pilśniowych na ich spęcznienie na grubość i nasiąkliwość. Celem badań było określenie względnego przyrostu grubości i masy płyt pilśniowych suchoformowanych, wytworzonych w warunkach laboratoryjnych, na skutek interakcji z wilgocią, w zależności od gęstości płyt. W zakresie pracy, oprócz wspomnianych badań, określono również wytrzymałość na zginanie i moduł sprężystości przy zginaniu badanych płyt. Badania wykazały, że wraz ze wzrostem gęstości płyt znacząco rośnie wartość ich spęcznienia na grubość oraz nasiąkliwość. Stwierdzono również, że wraz ze wzrostem gęstości płyt maleje intensywność przyrostu ich grubości i masy w odniesieniu do czasu moczenia płyt w wodzie przez okres 24 h.

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Cellulose diversity in trees and its impact on properties of wood - state of the art

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Abstract: Cellulose diversity in trees and its impact on properties of wood - state of the art. The article presents general information about cellulose and its sources. Furthermore, it outlines the influence of genetic, habitat and climatic features on the variability of cellulose properties in woody plants. In addition, the article points out the relationship between cellulose diversity and methods of tree cultivation. The article also presents examples of the innovative applications of cellulose in medical and electronic devices, which show a growing interest in this material in contemporary world.

Keywords: cellulose, cellulose diversity, genetic diversity, growth conditions, applications of cellulose

INTRODUCTION

Diversity is the main tool for decreasing risks in the nature. Forest diversity contains traits which can be useful for the adaptation of species to the changing environment [Vendramin, Morgante, 2005]. Forests are an integral part of the world’s ecosystems, and approximately 80,000–100,000 different tree species are estimated to cover 31% of land area globally [Porth, El-Kasaaby, 2014]. Earlier evolution did not account the most dangerous environmental factor [human- its explosive and polluting demographic and industrial development]. Trees have reacted well to the change, and it is commonly thought that genetic variation is still enough to supply materials for the adaptation of the populations and to sustain their dynamics growth and protection [Porth, El-Kasaaby, 2014]. In technical terms, the most important attribute of wood is its excellent mechanical performance at low weight, as well as the use of wood as structural material [Konnerth et al., 2009]. Wood is also most common material that is used to paper production, others plant feedstocks as straw or reed has secondary role in industrial production of paper. Cellulose can be used to produce many other materials such as artificial fibers such as rayon, viscose or staple fiber which are a substitute for cotton. It can also be used in the production of explosives, celluloid, cellophane, fibrous or artificial leather. It is worth to highlight that chemical processes that create cellulose increase value of wood, by increasing efficiency usage of raw material. In the chemical processing, the use of wood raw material is between 50-90% while in the mechanical processing efficiency decrease to only 25% [Surewicz, 1996].

A wood cell wall is built-up of layers which differ in their chemical composition, e.g. cellulose content, but also in their structure. The most important structural feature being variability in the angle of cellulose fibrils with regard to the longitudinal cell axis. Since the secondary cell wall [S2] is by far the thickest cell wall layer [>80% of the total thickness of a wall] in wood cell walls, research efforts concentrate on this cell wall region and research is ongoing [Konnerth et al., 2009].

GENERAL INFORMATION ON CELLULOSE IN WOOD

Cellulose is based on β-D-glucopyranose residues connected with each other by 1,4-glycosidic bonds connections, it means that cellulose is an polysaccharide made of simple
sugar [cellobiose, not glucose units]. Figure 1 shows the chemical structure of cellulose biopolymer.

Together with lignin is a basic component of plant cell wall. Cellulose is the most common organic material component in the world, about 33% of plant matter is a cellulose. All vascular plant has it in their cell wall structure, in different percentage, for example in cotton is around 90% and in wood is average 50%. The amount of cellulose depends on species and environment conditions. Cellulose from wood pulp has chain lengths from 300 to 1700 units. Plant fibers like cotton have chain lengths ranging between 800 and 10,000 units [Klemm et al., 2005]. The mature and lignified cell wall contains of cellulose, lignin and non-cellulosic polysaccharides. In wood cellulose is usually about 40-50%, lignin about 30%, hemiceloloses- 20% and less than 1% of mineral matter. Proportions are different based on species [Koch, 1964]. In wood, the content of individual chemical components is also affected by the environment habitat [climate and soil] and the location of the sample on the cross-section and longitudinal section. In studies made by Krutul [Krutul, 1996] on Pinus silvestris L. samples, the amount of cellulose increase from the core to the trunk perimeter.

In living organism cellulose, as a component of cell wall is protecting and maintaining the structure, shape, and functioning of each cell. The cell wall also prevents expansion when water enters the cell [Brooker et al., 2008]. Each cell has a thin anisotropic primary and secondary wall. Amount of cellulose in interior surface is significantly lower than in much thicker secondary wall which consist of 3 layers [S1,S2 and S3] and it is primarily made from cellulose and is not heavily lignified [Koch, 1964]. Cellulose has important role, because of the properties, but it can be digested by the enzyme called cellulase. Most animals do not produce cellulase, but fungi and bacteria has a capability to produce this enzyme. Based on that, cellulose can be classify as a biodegradable material [Brooker et al., 2008]. The main product of cellulose hydrolysis is cellulose. Cellulytic enzymes produce by fungi has the ability to distinguish cellobiose molecules in cellulose. Crystalline cellulose forms are characterized by high resistance to microbial enzymatic degradation. Amorphous cellulose has a significantly lower resistance and it can be easier hydrolysed. [Krzysik, 1957]. Cellulose can be also decompose chemically into its glucose units by treating it with concentrated mineral acids at high temperature. Cellulose from corn, rapeseed, rice straw or wood can be used as a biofuel feedstocks. In current focus on finding need source of renewable energy, natural, cellulose feedstocks has big come back to energy sector. [Nomiyama et al., 2014]. Cellulose as a white, fibrous substance was and still is used for paper and wood-based material production. The paper based product typically consider 90–99% cellulose fibers which are the primary structural element and the most important component which influenced final properties of the products [Sahin, Arslan, 2008]. Cellulose contains 49.4 % oxygen, 44.4 % of carbon and 6.2% hydrogen and it is insoluble in water and organic solvent with a very high tensile strength [Koch, 1964].

VARIABILITY OF CELLULOSE PROPERTIES FROM WOODY PLANTS

A milestone in the global carbon cycle is the hydrolysis of the cellulose in plant cell walls, which is the most abundant source of carbon on land [Wilson, 2011].
Cellulose is a polysaccharide and biopolymer that builds plant cell walls. It is consisting of 3000 or more glucose units. About 90% of cotton and 50% of wood are cellulose which makes cellulose the most abundant of all naturally occurring organic compounds [https://www.britannica.com].

Crystals of cellulose form microfibrils, which are settled in matrix polymers and represent the major of the cell wall [Gierlinger et al., 2010]. Plant cell wall of wood consists of different sublayers [S1, S2, and S3] formed at different periods during cell differentiation [Plomion et al., 2001]. The S2 layer is the thickest [75–85% of the total thickness of the cell wall] and most important for mechanical stability.

The more cellulose chains are organized, that is, parallel to each other, better the strength parameters of wood. Also, a good indicator of cellulose order is the standard deviation from the average microfibre angle. The orientation of microfibrils in mature cells, mainly in the S2 wall, the most abundant in cellulose, determines the properties of wood [Krauss, 2010]. Cellulose from the peripheral zone of the wood trunk has a fibrous structure, which means that the axes of the micelles are parallel to the axis of the cellulosic fiber. Cellulose from the core zone exhibits a spiral micelle system [Fabisiak, 2005]. The cellulose orientation and the genetic influence of the species on the arrangement of cellulose chains and the wood strength still have to be understood [Gierlinger et al., 2010].

INFLUENCE OF GENETIC TRAITS ON CELLULOSE DIVERSITY

The genetic diversity of long-life woody trees species is significantly the lowest compared to the herbaceous and annual life forms. Angiosperm species showed higher genetic diversity among-population [Porth, El-Kasaaby, 2014]. For example, species from smaller founder populations, small populations or those with past population bottlenecks show generally less genetic diversity. In the study of Hamrick et al., [Hamrick et al., 1992], the species: Alseis blackiana, Picea glauca, Robinia pseudoacacia and Pinus sylvestris showed high genetic diversity. On the other side of the spectrum were Acacia mangium, Pinus resinosa, P. torreyana, Populus balsamea, Ficus carica and Thuja plicata with very low diversity. Also cellulose content, length of coils and density of Pinus taeda wood, high values of genotypic correlation have been obtained, which creates a chance for improvement of the quality of these traits by means of selection [Sykes et al., 2003 per Klisz, 2011]. As reported Klisz 2011, a lot of authors i.e., Cown 1974, Frimpong-Mensah 1987, Gartner et al., 1997, Zhang et al., 1994, stated that for most features of the wood structure, stronger variation was observed between the trees than inside the trunk of the tree.

INFLUENCE OF HABITAT AND CLIMATE ON CELLULOSE DIVERSITY

Sunlight is an essential factor in the growth of plants, therefore the position of the woody plants in the stand indirectly affects the properties of the wood they produce. In turn, the dynamics of tree growth, their biosocial position affect the dynamics of coil growth. Dominant trees are characterized by the longest coils [Fabisiak, 2005 per Klisz, 2011]. The variability of wood considered at the level of the habitat is determined mainly by environmental and antrpogenic factors. Under the influence of air pollutants, changes occur in the wood in the dimensions of the anatomical elements of wood, which are proportional to the degree of environment pollution [Fabisiak, 2005]. The level of habitat variability depends on the change in the rate of plant growth which is influenced by the system of two environmental factors: air temperature and water availability in the soil [Gindl et al., 2000 per Klisz, 2011]. The profile of wood properties variability in trees, including the proportions of early and late wood, are directly influenced by the effect of the availability of water, the length of the growing season and the temperature of this period. Individual variation is the result of the impact of genetic and environmental factors. The interaction of these two factors affects the
variability of wood properties in trees growing under the same habitat conditions [Klisz, 2011].

DIVERSITY OF CELLULOSE DEPENDING ON BREEDING METHODS OF TREES

Diversity is essential for the adaptation of tree populations and monitoring the genetic dynamics of trees is fundamental for developing long-term strategies. [Vendramin, Morgante, 2005]. Environmental factors [habitat conditions, breeding treatments and climatic conditions] have a greater impact on the characteristics of annual rings than the genetic factor [Klisz, 2011]. For every woody plant, the care treatments look differently. For example, in the case of conifers it is extremely important to select a stand to take into account phenotypic features such as: straightness and fullness of the arrow, thin bark, and a small-crowned crown, thanks to which you can grow a larger number of trees with greater abundance [Fonder et al., 2008, per Puchniarski, 2008].

INNOVATIVE APPLICATIONS OF CELLULOSE

Currently, biomaterials from renewable sources are at the forefront of scientific development owing to their unique properties, such as the non-toxicity, biocompatibility, biodegradability, environmental friendliness, and inexpensive production. Over the past decades, scientists have tried to find the best biomaterials which could serve as the alternative materials to the commonly used industrial products [e.g. plastics, glass, silicon]. Research has shown that, among other biomaterials, the common cellulose is one of the most fascinating and innovative materials [especially in nanometric dimensions] that can be used in biomedical applications, electronic devices, thermal insulation of buildings, and in paper industry. Examples of innovative cellulose applications in medical and electronic devices, are described below.

In biomedicine, cellulose extracted from plants and bacteria, offers a great potential for usage in such areas as: diagnostic tools, drug delivery systems, tissue engineering, hydrogels, and wound healing [bandages].

Microfluidic paper-based analytical devices [μPADs] have recently been in the focus of attention as the novel tools for disease diagnostics and biomedical investigations. In these devices, cellulose paper is used as a membrane for immobilization of antibodies or antigens. They are especially useful in detection of cancer markers, proteins, pathogens and microorganisms. Recently, μPADs have become a promising alternative to traditional devices by offering excellent new prospects for diagnostic applications in points-of-care and biochemical analysis [Lisowski, Zarzycki, 2013; Hu et al., 2014].

In the pharmaceutical industry, it is very important to find non-toxic, biodegradable and biocompatible drug carriers that can be easily loaded with drugs and delivered orally, topically or parenterally. Currently, cellulose and its derivatives are exploited as a hydrophilic polymeric matrix in applications for drug delivery. Hence, in pharmacy, cellulose is a highly promising biomaterial for controlled-release drug dosing that is safe for human body [Dai, Si, 2017; Chin et al., 2018].

Tissue engineering is another example of an innovative cellulose application. This new field of technical sciences combines medical knowledge with material engineering methodology to produce replacements of damaged tissues. The studies have shown that biodegradable polymeric materials offer significant advantage of being able to support the tissue regeneration and repair, and then be removed from them after they have served their function [Sheikh et al., 2015]. The studies have shown several possibilities of using cellulose-based scaffolds for engineering of cartilage tissue [Müller et al., 2006] and bone tissue [Zaborowska et al., 2010; Demitri et al., 2016]. These results show that cellulose and its derivatives are attractive materials as the future scaffolds for tissue regeneration.
Cellulose-based hydrogels are commonly used in cases where biodegradability and biocompatibility are required which is particularly important in biomedical applications. Over the past decades, many applications of cellulose-based hydrogels have been tested and demonstrated, such as: superabsorbents, devices for controlled drug delivery, blood purification, sensors, cosmetics and wound dressing [Sannino et al., 2009; Chang, Zhang, 2011].

In industry, cellulose is increasingly used in electronic devices as a biodegradable material. It is becoming a promising alternative to glass and plastics and can also be used as a substrate in flexible electronics. Below, the common applications in such devices are described.

Throughout the years, scientists have been conducting research studies to find a low-cost alternative to the traditional energy-storage devices. The studies have shown that cellulose used as a substrate in these devices can offer the proper medium. For instance, a nanoporous cellulose paper, carbon nanotubes [acting as the electrodes], and an electrolyte, can be all integrated and create a basic unit in these devices. Subsequently, this basic unit can serve as the building block in fully flexible supercapacitors and batteries with a paper-sheet thickness. Research has shown that these flexible energy storage devices based on cellulose can work in a very wide range of temperatures and environmental conditions [Pushparaj et al., 2007].

Organic light-emitting diodes [OLEDs] are commonly used in many technologically advanced products, such as smartphones, displays and cameras. The rapid development of technology caused that the next generation of OLED displays can be flexible, foldable and even rollable, when traditional substrate materials [e.g. plastics] are replaced with cellulose nanofibers. The studies have demonstrated the deposition of an electroluminescent layer on a transparent base substrate made of wood-cellulose nanocomposites. This cellulose substrate exhibits flexible and ductile properties which can be utilized in production of flexible OLED displays [Okahisa et al., 2009].

CONCLUSION

The examples presented potential use of cellulose show a growing interest in this material in contemporary world. The cellulose, especially nanocellulose, due to its desired properties can soon replace such materials as carbon fibers or stainless steel in many applications. Currently, cellulose advantage in flexibility and tensile strength over these materials is being seriously discussed. Moreover, cellulose is fully ecological and friendly to people and the environment.

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Streszczenie: Zróżnicowanie celulozy w drzewach i jej wpływ na właściwości drewna - stan wiedzy. W artykule przedstawiono ogólne informacje dotyczące celulozy oraz źródło jej pochodzenia. Wykazano wpływ cech genetycznych, siedliskowych oraz klimatycznych na zmienność właściwości celulozy w roślinach drzewiastych. Ponadto przeanalizowano zależności między różnorodnością celulozy a metodami kultywacji drzew, z których jest ona pozyskana. W artykule przedstawiono również przykłady innowacyjnego zastosowania celulozy w urządzeniach medycznych oraz elektronicznych, co jest dowodem na rosnące zainteresowanie tym biomateriałem w współczesnym świecie.

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The application of TQM in the wood sector company

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Abstract: Total Quality Management (TQM) is an idea focused on quality, long term success based on customer satisfaction consisting of whole company personnel involvement in its implementation. Current TQM methods are vital management components used in the most developed countries and adapted as know-how in the greatest global corporations. This paper concentrates on implementation of this idea in Polish wood processing enterprises, including new quality management systems enabling competitiveness increase in constantly growing wood market. For this purpose, the research on TQM implementation have been carried out in one of the Polish wood processing plants, with consideration of the manufacturer's German clients' requirements.

Keywords: TQM, quality management, wood sector, wood processing branch

INTRODUCTION

High competitiveness in majority of business sectors forces the enterprises to increase their efforts to make their products meet growing expectations of the clients. More and more enterprises worldwide – including Poland – starts to think about comprehensive Total Quality Management (TQM). This attitude represents business management, where each organization activity aspect is quality oriented [Kaynak 2003].

TQM is a philosophy, an idea, vision using a specific approach, strategy, education, motivation, dedication, tools and resources to make changes in an enterprise. The TQM rules have not been codified. They consist in using methods and tools considering one's enterprise unique character [Brilman 2002].

TQM is a quality management programme, proposing a holistic and innovative development direction for the whole company structure [Wiengarten, Fynesb, Chengc, Chavezd 2013]. The TQM wider view on quality management, which concentrates on constant improvement and maintaining high quality of products and management services – by involving employees, providers and clients in order to meet, or exceed the expectations of the latter [Cua, McKone, Schroeder 2001]. Peković and Galia point out the meaning of TQM – as a tool improving the solutions innovativeness in terms of work efficiency and culture [Pekovic, Galia 2009]. This is commonly known, that there is a strong relation between TQM and products quality obtained by an enterprise, which determines the market success of its brand [O'Cass, Ngo 2007]. TQM is a philosophy, an idea, vision using a specific approach, strategy, education, motivation, dedication, tools and resources to make changes in an enterprise. The TQM rules have not been codified. They consist in using methods and tools considering one's enterprise unique character [Brilman 2002].

Considering the above, one should assume, that TQM provides a vision of management aimed at promotion of stable and constant growth of an organisation, by involving all of its members in economic creation of quality level desired by the clients. TQM frequently point at the holistic and innovative directions for the company [Wiengarten, Fynesb, Chengc, Chavezd 2013].

In Polish literature several difficulties with TQM direct translation were met, that's why Polish respective term is expressed as „management through quality”, which means
organisation management where the main efficiency criterion is quality of the products and actions effectiveness [Kaynak 2003].

TQM IN WOOD PROCESSING INDUSTRY
TQM is suitable for wood processing businesses, regardless their sizes. Polish wood business is strongly diversified, both, in sizes of companies (see Table 1) and variety of branches. According to Polish Entrepreneurs Classification (PKD), wood sector includes:

- production of wood, cork, straw and wicker;
- production of paper and paper products;
- production of furniture.

Table 1. Diversified Polish wood business

<table>
<thead>
<tr>
<th>Type of company</th>
<th>Number of employees</th>
<th>Number of enterprises in Poland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro</td>
<td>&lt; 10 employees</td>
<td>30839</td>
</tr>
<tr>
<td>Small</td>
<td>&lt; 50 employees</td>
<td>2074</td>
</tr>
<tr>
<td>Medium</td>
<td>&lt; 250 employees</td>
<td>360</td>
</tr>
<tr>
<td>Large</td>
<td>250 and more employees</td>
<td>55</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>33328</strong></td>
</tr>
</tbody>
</table>

Source: Own records based on GUS 2014 report

Individual branches affect each other, remaining dependent one on another very often, facing strong competition in the sector in the same time. The problem consists in large diversification of production technology and modernisation level in individual companies.

Currently, the important tendency on wood processing market, which is related to the search for new technological solutions, is the material substitution phenomenon, based on its double character. On one hand traditional materials are replaced with modernised, improved wood products, on the other hand wood is replaced with non-wood products, like plastics. In such case, the most frequent tendency is production of wood materials and products which could meet the widest range of functional criteria [Knowledge Transfer Report 2014]. In this context, the most important remains products and services quality management in the sector.

In the wood sector, introducing products on market is related to the final product quality compliance. The client expects its product to meet its requirements and delivery terms. Smaller orders allow more individual client approach, where each individual piece can be completely checked, which creates no major quality issues. Continuous serial production provides different situation, when final products quality is maintained with quality system, or management.

Quality systems in wood industry concern mainly furniture business, large sawmills and wood products manufacturers. Large companies, particularly exporters, need constantly to improve their products and apply quality systems in order to be competitive in comparison to many Polish, or foreign companies.

The tools supporting quality management systems implementation and maintaining in an enterprise is certification of products. Nowadays, the most reliable forest resources certification system in the world is Forest Stewardship Council (FSC), which certifies products obtained from forests, in terms of forestry good practices. FSC system includes Forest Management (FM) and Chain of Custody (CoC). The main aim of FM certification is to assess forest economy according to FSC standards. Considering the variety of conditions present in the forestry business worldwide, 10 rules and 56 criteria of good forestry practice have been established. They line out general subject range, which needs to be considered in the certification process. The indicators define specific forest economy and protection
parameters, such as maximum logging areas or dead trees necessary to preserve the biological diversity.

RESEARCH METHODOLOGY
In order to verify the new quality management systems process implementation in Polish wood processing enterprises, in a Polish young wood imitating panels manufacturer has been subject to TQM adaptation analysis. TQM analysis in the above enterprise had been performed in the form of case study.

The existing quality control system, regardless its ISO and German BAM standards compliance, required changes and altered approach. In this case quality system needed to be improved and new quality management instruments needed to be introduced. According to the TQM requirements, this could be achieved solely by work and involvement of the whole team. One of the most vital challenges was to educate production employees, about importance of their ideas and solutions for the company development. In order to make that happen, respective information procedure has been carried out (figure 1).

![Diagram showing quality management stages](Source: Own records)

**Figure 1. From the quality control to the total quality management - stages of quality management**

The procedure was aimed at facilitation of information flow and decision making important for quality systems development in the enterprise. For instance: junior employee directly related to production has an idea to improve quality and decrease production cost, or waste generation, informs his/her immediate superior (foreman). Then, the foreman transfers this suggestion to the management. Next, the approving group – dependent on the idea – consisting of various members (such as production manager, quality control manager, main technologist, operation manager, or health and safety specialist) approves or rejects the solution – or proposes its own remarks. The approved idea is then implemented under supervision of competent persons.

Extremely important TQM implementation stage was the analysis of production issues (frequent mechanical and electrical malfunctions), as well as technological problems. These problems caused frequent downtimes and decreased productivity, which affected the quality as well (tab. no. 2).
Table 2. Chosen production line – problems study

<table>
<thead>
<tr>
<th>Problem</th>
<th>Type of problem</th>
<th>Effect</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading elevator control malfunction</td>
<td>Electrical</td>
<td>Unable to load the panels to the press – 40 minutes downtime</td>
<td>Elevator control unit replacement</td>
</tr>
<tr>
<td>Concentration adjustment on dehydrating machine</td>
<td>Technological</td>
<td>Panels density incompliant with specification</td>
<td>Installing the automatic water adjustment valve</td>
</tr>
<tr>
<td>Broken chain of the loading conveyor</td>
<td>Mechanical</td>
<td>Unable to transport the panels – 25 minutes downtime</td>
<td>Chain replacement</td>
</tr>
</tbody>
</table>

Source: Own records

The analysis of frequent malfunctions and incompliances proved many problems to exist, but also indicated their solutions. According to TQM essence the priority for the management was to educate all employees, that searching solutions is the task of the whole staff. This makes the production issues resolvable in terms of causes and effects identification. On this stage cooperation with operation manager is vital, as it is his/her job to fix the malfunctions and assist in resolving the issues.

Table 3. Waste classification report for a chosen production line

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Quantity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEMI-MANUFACTURED PRODUCT</td>
<td>Damaged parts (broken, torn)</td>
<td>1004</td>
<td>15.36%</td>
</tr>
<tr>
<td></td>
<td>Cracked parts</td>
<td>288</td>
<td>4.41%</td>
</tr>
<tr>
<td></td>
<td>Cancer spots</td>
<td>2226</td>
<td>34.05%</td>
</tr>
<tr>
<td></td>
<td>Holes</td>
<td>505</td>
<td>7.73%</td>
</tr>
<tr>
<td>MACHINE GENERATED WASTE</td>
<td>Damaged parts (when unloaded, in the press)</td>
<td>19</td>
<td>0.29%</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>4</td>
<td>0.06%</td>
</tr>
<tr>
<td></td>
<td>Thin</td>
<td>6</td>
<td>0.09%</td>
</tr>
<tr>
<td>LOGISTIC SYSTEM RELATED WASTE</td>
<td>Wrong binding</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>Wet parts</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>INCOMPLETE PRESSING</td>
<td>Incomplete drying</td>
<td>106</td>
<td>1.62%</td>
</tr>
<tr>
<td></td>
<td>Soft edges</td>
<td>462</td>
<td>7.07%</td>
</tr>
<tr>
<td></td>
<td>Stratification</td>
<td>24</td>
<td>0.37%</td>
</tr>
<tr>
<td></td>
<td>Cavities</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>Broken parts</td>
<td>64</td>
<td>0.98%</td>
</tr>
<tr>
<td></td>
<td>Spots</td>
<td>369</td>
<td>5.64%</td>
</tr>
<tr>
<td></td>
<td>Blisters</td>
<td>779</td>
<td>11.92%</td>
</tr>
<tr>
<td></td>
<td>Undercolouration</td>
<td>77</td>
<td>1.18%</td>
</tr>
</tbody>
</table>

Source: Own record.

Another TQM implementation part was the analysis including exclusively quality preserving difficulties, which supposed to influence resolving the production problems. To make that happen the waste has been analysed (see: table 3). The report prepared after the precise waste analysis contained its classification and frequency data. This operation helped to determine the key obstacles affecting the waste generation share in the production.
For instance, according to „The waste classification report for a chosen production line” the biggest issue was created by cancer spots and parts mechanically damaged (broken, torn). These data helped to make steps to improve the situation and solve the problem. The first production line analysed for the above problems was T2 hard panels line. The panels made there are used in construction industry, so they must meet extremely strict internal and external (BAM) standards. The quality and technological issues from this line helped to determine and make actions, which not only reduced the volume of waste, but also the number of complaints. The main problems in this line were: panels thickness incompliant with the specification, excessive bulging of panels after being soaked with water, periodical problems with resistance to static bending. Following changes have been introduced:

- Triple laser thickness measuring device;
- Gaseous emulsion dosage modification;
- Implementation of production procedures including the panels thickness measuring before being put into the press;
- Change of the rectifier roll speed on the dehydrating machine outlet;
- Implementation of production procedure in terms of feed control.

The introduction of changes on T2 line in first half of 2014 reduced the waste range from 10% to less than 6%. The vital aspect improving the organisation functioning was the change in the staff members’ personal philosophies and focusing on high quality of the products. The training cycles and communication process inside the enterprise increased the personnel awareness and improved its attitude to changes.

CONCLUSION

TQM approach is an example of a comprehensive approach to management as such, which is often a starting point for an enterprise development focusing. The significant conviction that the whole team is responsible for the quality of the products and fact, that this quality is generated by every production process factor constitutes the basis of the process organisation assumptions. Collective responsibility and focusing on constant improvement have common foundations and are compatible with many current intelligent organisation concepts, in which knowledge is a key resource and a combination of conceptual work of the executive is a basic prerequisite of process organization.

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Factors influencing the cutting power in longitudinal milling of solid wood

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Abstract: Factors influencing the cutting power in longitudinal milling of solid wood. Some factors which affect the cutting power during longitudinal milling process of solid wood are studied in this paper. These factors are: the cutting speed, the feed speed and milling area. The input power of the cutting mechanism in idle and power motion is measured for the purposes of the study. Modern equipment with corresponding for this study software is used. The present studies have been conducted in the processing wood details from beech (Fagus sylvatica L.). A comparative analysis of these results and the results obtained in the treatment of details from pine (Pinus sylvestris L.) is made. The obtained results are analyzed and some recommendations that support the practice of longitudinal milling of wood are proposed.

Key words: wood milling, solid wood, cutting modes, wood milling tools, cutting power

INTRODUCTION

The cutting power is an indicator whose determination is needed in the design of new machines or when changing the working conditions of existing ones. Its determination allows choosing an electric motor for the cutting mechanism of the machine which will ensure the operation depending on its intended purpose.

In terms of practice, it is found that the cutting power depends on a number of technological factors. They can be divided into several main groups [Grigorov 1992]:
- factors relating to the processed material – physico-mechanical properties, temperature, moisture content, wood defects, etc.
- factors relating to the cutting tool – level of teeth wear, linear and angular parameters, etc.
- factors relating to the cutting process – the area of milling, the direction of the wood fibers, etc.
- factors relating to the kinematics of the process – cutting and feed speed.
- others.

Based on many experimental studies, a number of computational methods have been developed. They are widely used in the theory of cutting power and cutting forces. One of them is that of Prof. Bershadsky, created in the 60s of the last century. This method is difficult and modernized over the years. However, it is suitable for solving any type of tasks [Bershadsky and Tsvetkova 1975].

After some mathematical transformations, with an accuracy sufficient to the practice, the following dependence can be accepted

\[ N_c = K b h u = P v, \]  
(1)

where \( K \) is the specific cutting work, J.m\(^{-3}\);
\( b \) – the milling width, m;
\( h \) – the milling height, m;
\( u \) – the feed speed, m;
\( P \) – the cutting force, N.
The milling is a process of open cutting (with some exceptions) and according to the general law of cutting, the specific cutting work can be determined by the equation [Gochev 2005]

\[ K = k + \frac{a_p \cdot p}{e_{av}}; \text{ when } e > 0.1 \text{ mm,} \]

where \( k \) is the pressure on the front side of teeth, Pa;
- \( a_p \) – the coefficient of the cutting tool’s teeth wear \( (a_p = 1 + \frac{0.2 \Delta \rho}{\rho_0}) \);
- \( \Delta \rho = \rho - \rho_0 \) – the change in the radius of wear of the milling tool cutters, \( \mu m \);
- \( \rho_0 \) – the radius of the sharp teeth, \( \mu m \);
- \( p \) – the fictitious specific force on the back side of the teeth, Pa;
- \( e_{av} \) – the average thickness of the chip, mm.

Taking into account the wood species and its moisture content, the formula acquires the following appearance

\[ K = a_{ws} a_w (k + \frac{a_p \cdot p}{e_{av}}), \]

where \( a_{ws} \) is the wood species coefficient;
- \( a_w \) – the wood’s moisture content coefficient.

Very often, the milling is carried out in the field of micro-chips, in which:

\[ K_\mu = a_{ws} a_w (k_\mu + \frac{(a_p - 0.8) \cdot p}{e_{av} \mu}); \text{ when } e_\mu < 0.1 \text{ mm.} \]

Since there is not much research in this area in modern literature, the purpose of this article is to determine the cutting power at different cutting speed, feed speed and milling areas during longitudinally milling of widely distributed wood species in the furniture industry under different operating modes.

METHODOLOGY

To conduct the experimental research, a milling machine with lower spindle position \( FD–3 \) (ZDM – Plovdiv) was used. Some of the more important technical parameters of the machine are:
- diameter of the mandrel \( d_m = 30 \text{ mm} \);
- power of the motor which drives the cutting mechanism \( N_m = 3 \text{ kW} \);
- revolutions of the motor's shaft \( n_m = 49 \text{ s}^{-1} \);
- vertical stroke of the spindle \( h_v = 90 \text{ mm} \);
- working table width \( B = 720 \text{ mm} \);
- working table length \( L = 840 \text{ mm} \).
As a cutting tool, a groove cutter with a steel body and hard alloy teeth was used. Some of its more important technical parameters are:

- thickness of the cutting teeth \( s = 12 \text{ mm}; \)
- number of the cutting teeth \( z = 6 \text{ pcs.}; \)
- diameter \( D_m = 140 \text{ mm}; \)
- diameter of the connection opening \( d = 30 \text{ mm}; \)
- weight \( m = 0,88 \text{ kg}. \)

The selected input factors, which are changed to determine the cutting power during the experimental research, are: cutting speed \( v \); feed speed \( u \); cutting area \( A \). For implementing the different feed speed values, a universal roller feeder was used. It is mounted on the machine and can be seen in Figure 1. The speeds that can be achieved are 2, 3, 4, 6, 10, 16, 21, 32 m.min\(^{-1}\). The number of feed rollers is 3 pcs. The cutting speed is varied by changing the pulley which is mounted on the shaft of the motor.

Accordingly, belt pulleys with diameters of 125, 190 and 250 mm were used. The current values are obtained taking into account the gear ratio and the slip coefficient

\[
v = \pi D_m \frac{n_m}{i} m, (1-\varepsilon),
\]

where \( i \) is the gear ratio of the belt drive – defined by the diameters of the drive and drive belt pulleys \( i = D_2/D_1 \) (Figure 2). The machine spindle is driven by a belt drive – \( D_1 \) is the diameter of the pulley mounted on the motor, \( D_2 \) is the diameter of the spindle pulley; \( \varepsilon \) – sliding coefficient of the belt.
Some beech timber with a cross section of 50x50 mm and a length of 1520 mm was used as experimental samples (Figure 3). Their density is determined by the weighting method with an electronic scales and their moisture content with an electronic moisture meter.

For determining the cutting power in the experiment, the following dependence was used [Gochev 2008]

$$N_c = \frac{N_{\text{load}} - N_{\text{idle}}}{100}\eta,$$  \hspace{1cm} (6)

where $N_{\text{load}}$ is power of the cutting mechanism in load condition, kW;

$N_{\text{idle}}$ – input power of the cutting mechanism in idle condition, kW;

$\eta$ – the cutting mechanism coefficient of efficiency.

The efficiency coefficient was calculated by the equation

$$\eta = \left(1 - \frac{N_{\text{idle}}}{N_{\text{load}}} \right) \cdot 100.$$  \hspace{1cm} (7)

Figure 4. Measuring device US301EM – Unisyst Engineering” Ltd. (Bulgaria)

Figure 5. Connection scheme of the device to the mains

For reporting of the input power of the cutting mechanism in idle and load condition a device US301EM (Figure 4) was used. It is designed to measure current, voltage, active, reactive and full power in single or three-phase electric circuit. The voltage range of the device is 0-100 V, and the current 0-5 A. To connect it to the mains, three current (CNC® CURRENT TRANSFORMER 50/5 A) and three voltage (UNITRAF AD Ltd 220/100V) transformers were used. The connection scheme can be seen in Figure 5. For more accurate reporting of the results, the company software and the notebook were used. The results are automatically converted to Microsoft Excel which eliminates the mistakes of the human factor. Some preliminary tests had been carried out before the experimental studies began. Their purpose was the determination of the levels of variation of some factors.

For the purposes of this study, a three-factor- regression analysis was performed. The obtained results were processed using the software products QstatLab5 and Microsoft Excel. They are compared with some previously performed ones for the same level of variation of the input factors when milling pine. The experimental matrix is presented in Table 1.
Table 1. The experimental matrix

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<tr>
<th>№</th>
<th>( v, \text{m.s}^{-1} )</th>
<th>( X_1 )</th>
<th>( u, \text{m.min}^{-1} )</th>
<th>( X_2 )</th>
<th>( A, \text{mm}^2 )</th>
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</table>

RESULTS

The measured average values for the density and moisture content of the beechwood test samples are: \( \rho = 650 \text{ kg.m}^{-3} \) and \( W = 13 \% \). Those for the pine wood are \( \rho = 450 \text{ kg.m}^{-3} \) and \( W = 12 \% \).

The obtained equation after processing the results for beech by the method of regression analysis with the software product QstatLab 5 is

\[
N_{\text{bee}} = 0,550 + 0,131 \cdot x_1 + 0,291 \cdot x_2 + 0,193 \cdot x_3 - 0,023 \cdot x_1^2 - 0,081 \cdot x_2^2 + 0,071 \cdot x_3^2 + +0,099 \cdot x_1 \cdot x_2 + 0,123 \cdot x_2 \cdot x_3
\]  

(8)

When comparing the calculated value of \( F_{\text{cal}} \) – Fisher's criterion with the critical one \( F_{\text{crit}} \), used for verification, it is found that the model is adequate and the equation can be used for description of the corresponding process.

As a benchmark, previous results obtained in milling of pine at the same levels of variance of input quantities are used (Gochev et al.)

\[
N_{\text{pine}} = 0,354 + 0,055 \cdot x_1 + 0,169 \cdot x_2 + 0,202 \cdot x_3 - 0,018 \cdot x_1^2 - 0,016 \cdot x_2^2 + 0,000 \cdot x_3^2 + +0,008 \cdot x_1 \cdot x_2 + 0,072 \cdot x_2 \cdot x_3 + 0,018 \cdot x_1 \cdot x_3
\]  

(9)

From the analysis of the obtained regression equations it becomes clear that the factors feed speed \( x_2 \) and milling area \( x_3 \) have a significantly greater impact on cutting power.
The difference between the wood species is that in beech the milling area is dominated by the feed speed. The results of the influence of feed speed on the cutting power of both wood species – for the average levels of the other two factors \((v=44 \text{ m.s}^{-1}, A=96 \text{ mm}^2)\) are shown graphically in Figure 6. In this case, it is clearly noticed that as the feed speed increases, the wood species becomes more and more influential. Initially, at the lowest values of \(u\), the power difference is minimal – 0.17 kW for the pine and 0.18 kW for the beech. The fact that the machine does not work in its practical operation modes can be pointed out as a reason for this. As a result, the engine works much below its rated power and the wood species practically does not affect. Subsequently, the difference in the cutting power is up to 0.25 kW.

Figure 7 shows the effect of the feed speed of beech in different areas of milling. It can be seen that the maximum value is at a feed rate of 10 m.min\(^{-1}\) and a milling area of 144 mm\(^2\) – 1,16 kW. Taking into account the idle power consumption of the electric motor and the efficiency coefficient, it is clear that it exceeds its nominal. In this case, it is overloaded, which is not advisable. Figure 8 shows the power consumption of the electric motor driving the cutting mechanism at high feed rates. By comparison, the maximum cutting power values obtained for the pine when solving the corresponding regression equation (equation 9), are 0.23; 0.51 and 0.78 kW, respectively for milling areas 48, 96 and 144 mm\(^2\) and feed speed 10 m.min\(^{-1}\). In this case, the engine runs around its nominal values, even under the toughest operating modes.

![Figure 6. Influence of feed speed \((u)\) on cutting power \((Nc)\) in milling of beech and white pine](image-url)
The factor that has the least impact on the target function under consideration is the cutting speed. When cutting the workpieces, it is noticeable that with its increase, the cutting power also increases marginally. As a reason for this, the different electricity consumption required to drive the larger and heavier pulleys can be indicated. Moreover, the results show that with the increase of the other two factors, the magnitude of the impact of the cutting speed on the target function under consideration decreases.

Figure 7. Effect of the feed speed \( (u) \) in the milling of beech on the cutting power \( (N_c) \) at different areas of milling \( (A) \)

![Figure 7](image)

Figure 8. Power consumption of the engine when milling beech at high feed rates

![Figure 8](image)

Figure 9 graphically presents the results for both wood species at fixed average variation levels of the other two factors. It is noted that the differences in cutting power between the smallest and the highest variation levels are 0.11 kW for pine wood and 0.26 kW for beech wood, i.e. in both cases are insignificant.
Figure 9. Influence of cutting speed ($v$) on cutting power ($N_c$) in milling of beech and white pine

Figure 10 shows the relationship between the factors cutting speed and the milling area for the beech. It is clearly visible that during the largest areas of milling the cutting speed has virtually no effect on the above-mentioned target function.

![Graph showing the relationship between cutting speed and cutting area for beech milling.]

Figure 10. Effect of the area of cutting ($A$) in the milling of beech on the cutting power ($N_c$) at different cutting speeds ($v$)

Only at the smallest levels of this factor, it can be assumed that the particular input quantity exerts an influence on the cutting power. When solving the regression equation for the pine it can be seen that the relationship between the factor and the output quantity is weaker.

CONCLUSIONS AND RECOMMENDATIONS

Based on the conducted experimental studies and their comparison with previous results obtained about the influence of some factors on the milling power of beech and pine, following major conclusions and recommendations can be made:
1. The results obtained for the cutting power show that the area and the feed speed have approximately equal influence while cutting speed is virtually irrelevant;
2. The feed speed is not recommended to exceed 10 m.min\(^{-1}\) at larger areas of milling during beech processing. The reason for this is that the engine is loaded above its rated power (3 kW);
3. Displayed dependencies allow rational selection of cutting modes and optimizing processes according to a specific criterion. In addition, they can be used as guides when selecting an electric motor which drives the cutting mechanism when designing new milling machines;
4. In the following studies of the authors the influence of other factors on the cutting power is checked – as cutting tools, its linear and angular parameters, the influence of other wood species used in the production of solid wood furniture, etc.

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Optimization of technological parameters for continuous edge banding of furniture panels

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Department of Furniture Production, Faculty of Forest Industry, University of Forestry - Sofia

Abstract: Optimization of technological parameters for continuous edge banding of furniture panels. A number of experimental studies were conducted with the usage of hot melt adhesives, in order to determine the adhesion strength and the aesthetic performance in a continuous edge banding of chipboard. Various indicators have been established for different edge banding strips made of beech wood, melamine and PVC. Using the created computer program allow it to predict the strength of adhesion and visual quality of the edged furniture components, prior to their actual production.

- Proposed set of operating modes for edge banding process, optimized by various criteria:
  - According to the type of the edge banding material to be used
  - Power Saver mode
  - Excellent outlook (appearance)
  - Maximum performance (output)
  - Maximum adhesion strength
  - Edit mode, when working with chipboard with variable density.

The results from the undertaken studies and the proposed optimized operating modes will help the furniture manufacturers for the proper management of the edge banding process and will improve the quality of the manufactured furniture.

Keywords: furniture, hot melt glue, edge banding, adhesion, operating data.

INTRODUCTION

Edging is a mandatory technological step for protecting and refining the narrow surfaces of the lined particle boards. Nowadays the machines used for that process are modern, with high level of performance, and require a precise set-up adjustment of the individual units. Great variety of recommended parameters for the machine, wide ranges of different types of glue and edge strips are available to choose from, and those are responsibility of the machine operator. Making the right decision though is extremely difficult, sometimes even impossible, due to the frequent change of the used materials. The result could show aesthetic defects and hidden and reduced bond strength. Adjusting the process parameters to the optimal limits for certain cases will guarantee the desired bond strength and visual properties of the edged plates and the furniture in general.

EXPERIMENTAL SECTION

Materials
Three-ply chipboards - thickness 16 mm, manufactured by "Kronoshpan Bulgaria" and veneered with a suited veneer or synthetic foil, were examined for the study. For the edging were used beech veneer edge strips, paper based foil, soaked with synthetic resin /melamine edge foil/, and PVC edge foils. The adhesive used for the prolonged edge banding is Kleiberit, type HM788.7.

1. Machines
For the prolonged edge banding is used edge bander Olimpic, with a compression unit shown in figure 1.
2. Test method

The current study has used such method by which the adhesive compound is applied with a tensile load perpendicularly to the veneering surface, presented in Figure 2. The tensile forces are spread via T-shape steel body (stamp), attached to the edge material by a cyanoacrylate adhesive. On both sides of the stamp (5) the edge material is interrupted by a cutting in depth equal to the depth of the coating material and the adhesive.

As additional criteria, the following evaluation points have also been adopted: visual assessment of the quality of the edged test pieces, which is actually the absence of a visible trace of glue, pressed along the edges; tight adhesion of the facing strips to the edges of the boards; minor unevenness on the visible front side of the edge; undistorted construction of the edging material and the thickness of the applied adhesive layer.

3. Tested parameters:
   - Specific amount of the applied adhesive on the edge of the particle board /Q, g/m²/;
   - Temperature of the adhesive /t, °C/;
   - Compression force on first compression roller /F₁, N/;
   - Compression force at the second press group /F₂₋₄, N/;
   - Feed rate at edging /U, m/min/;
   - Density and structure of the particleboard /ρ, kg/m³/. 
RESULTS

The resulted mathematical models, describing the adherence process of edgebanding with the different types of materials and the rest of the examined parameters of the operation, allow for an optimization study. An algorithm and a computerized program, for stepwise cyclic scanning and optimization based on certain criteria, have been developed. A set of operating parameters have been obtained, ensuring that the requested conditions are met. Technological Regime type 1. "According to the type of the edging material".

In this case, it is necessary to consider the differences between the individual edging materials, by observation of the additionally set restrictive conditions. The limits, which are set for the test parameters, are as follows:

- bonding strength – Y=2,7-2,8 N/mm², exceeding the standard values;
- appearance – "good";
- amount of glue – Q=150-250 g/m²;
- compression force - F1=50-190 N, F2 =246-866 N;
- adhesive temperature - t=150-180°C;
- density of the plates ρ=755 kg/m³ - average value, in order to increase the degree of applicability;
- feed rate – U=10 m/min, which is valid for the commonly used edgebanding technique.

The obtained and recommended data are listed in Table 1.

Table 1. The obtained and recommended data

| Edge banding with beech veneer strips |  
| Y [N/mm²] | Q [g/m²] | t [°C] | F1 [N] | F2 [N] | ρ [kg/m³] |
| 2,79 | 150 | 174 | 190 | 862 | 755 |

| Edge banding with paper edge foil |  
| Y [N/mm²] | Q [g/m²] | t [°C] | F1 [N] | F2 [N] | ρ [kg/m³] |
| 2,73 | 150 | 150 | 190 | 246 | 755 |

| Edge banding with PVC edge foil |  
| Y [N/mm²] | Q [g/m²] | t [°C] | F1 [N] | F2 [N] | ρ [kg/m³] |
| 2,60 | 250 | 162 | 190 | 246 | 755 |

With PVC edge foil, it is necessary to increase the amount of the adhesive, so that the required bonding strength to be met. When edging with the different edging materials, it is necessary to adjust the values of the other mode parameters, according to the table.

Technological Regime type 2. "Power-saving modes".

In this case, it is necessary to define such parameters of the operational regimes, which will ensure the maximum possible savings of materials and energy. This should be done by limiting the minimum bond strength and setting an acceptable visual appearance for this option. The limits, which are set for the test parameters are as follows:

- bonding strength – Y=2,0-2,1 N/mm², close to the standard values;
- appearance – "good or very good";
- amount of glue – Q=150-180 g/m²;
- adhesive temperature - t=150-160°C;
- compression force across the range - F1=50-190 N, F2 =246-866 N;
low plate density is assumed \(\rho=720 \text{ kg/m}^3\) - to study the most unfavorable case. When using thicker plates, the adhesive strength improves;

feed rate – \(U=10\) m/min, which contributes to energy-saving edging.

After several tests with the set parameters, the following sample mode combinations, presented in Table 2 below, were compiled. The suggestions made for the parameter values, in these cases, provide a ‘very good’ bond strength and ‘no flaws/defects’ in appearance. When working with PVC film, it is necessary to adjust the pressing force \(F2\) by increasing to the maximum.

If higher density plates are used, the modes are correct, and the resulting bond strength will increase.

Technological Regime type 3. "Optimum appearance".

In order to reach an optimal level of visual appearance, it is necessary to consider the differences between the edgebanding with the individual edging materials, whilst complying with the additional conditions.

The limits, which are set for the test parameters are as follows:

- bonding strength – standard – \(Y=2.0-2.2\) N/mm\(^2\);
- appearance – “from very good to excellent”;
- amount of glue – \(Q=150-250\) g/m\(^2\);
- adhesive temperature - \(t=150-180\)°C;
- compression force across the range - \(F1=50-100\) N, \(F2 =246-400\) N;
- average plate density is assumed \(\rho=755\) kg/m\(^3\) - to study the most common case;

### Table 2.

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<td>(t) [°C]</td>
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<td>150</td>
<td>190</td>
<td>554</td>
<td>720</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Edge banding with PVC edge foil</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Y) [N/mm(^2)]</td>
<td>(Q) [g/m(^2)]</td>
<td>(t) [°C]</td>
<td>(F1) [N]</td>
<td>(F2) [N]</td>
<td>(\rho) [kg/m(^3)]</td>
</tr>
<tr>
<td>2.09</td>
<td>150</td>
<td>150</td>
<td>190</td>
<td>862</td>
<td>720</td>
</tr>
</tbody>
</table>

### Table 3.

<table>
<thead>
<tr>
<th>Edge banding with beech veneer strips</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Y) [N/mm(^2)]</td>
<td>(Q) [g/m(^2)]</td>
<td>(t) [°C]</td>
<td>(F1) [N]</td>
<td>(F2) [N]</td>
<td>(\rho) [kg/m(^3)]</td>
</tr>
<tr>
<td>2.29</td>
<td>210</td>
<td>174</td>
<td>50</td>
<td>308</td>
<td>755</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Edge banding with paper foil edge</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Y) [N/mm(^2)]</td>
<td>(Q) [g/m(^2)]</td>
<td>(t) [°C]</td>
<td>(F1) [N]</td>
<td>(F2) [N]</td>
<td>(\rho) [kg/m(^3)]</td>
</tr>
<tr>
<td>2.29</td>
<td>150</td>
<td>180</td>
<td>64</td>
<td>246</td>
<td>755</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Edge banding with PVC edge foil</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Y) [N/mm(^2)]</td>
<td>(Q) [g/m(^2)]</td>
<td>(t) [°C]</td>
<td>(F1) [N]</td>
<td>(F2) [N]</td>
<td>(\rho) [kg/m(^3)]</td>
</tr>
<tr>
<td>2.3</td>
<td>170</td>
<td>180</td>
<td>64</td>
<td>308</td>
<td>755</td>
</tr>
</tbody>
</table>
feed rate – $U=10 \text{ m/min}$, which is common for the most of the edging machines. Sample mode combinations are presented in Table 3.

To obtain an appearance without flaws, it is necessary to change the settings when changing the edge material.

Technological Regime type 4. "Maximum performance".

Edging furniture is a long process, especially when single-sided machines are used and all 4 edges have to be lined. In these cases, high feed rate should be used /if possible/ and the time for individual precise adjustments of the process parameters must be extremely short. It is particularly important to obtain sufficient strength, regardless of the used edging materials and in the same time acceptable appearance. The limits set for the test parameters, are as follows:

- bonding strength – exceeding the standard – $Y=2.4\text{-}2.5 \text{ N/mm}^2$;
- feed rate is accepted as – $U=20 \text{ m.min}^{-1}$, which is common for the modern machines.
- appearance – "from good to very good";
- amount of glue – $Q=200\text{-}250 \text{ g/m}^2$;
- adhesive temperature - $t=180\text{-}210^\circ\text{C}$;
- compression force across the range - $F1=110\text{-}130 \text{ N, } F2 =246\text{-}866 \text{ N}$;
- average plate density is assumed $\rho=755 \text{ kg/m}^3$ - to study the most common case;

After the conducted experiment with the set parameters, result analysis and selection of the data, was compiled the following technological regime, presented in Table 4:

Table 4.

<table>
<thead>
<tr>
<th>$Y$ [N/mm$^2$]</th>
<th>$Q$[g/m$^2$]</th>
<th>$t$ [$^\circ\text{C}$]</th>
<th>$F1$ [N]</th>
<th>$F2$ [N]</th>
<th>$\rho$[kg/m$^3$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.49</td>
<td>210</td>
<td>192</td>
<td>120</td>
<td>862</td>
<td>755</td>
</tr>
</tbody>
</table>

The presented regime is with selected values for the individual factors, that provide the set bonding strength for the three types of edging materials and the obtaining of a good appearance.

Technological Regime type 5. "Maximum bond strength"

Obtaining the highest possible bonding strength can not be an end itself or at any cost, but it is required in certain cases on heavily loaded furniture elements. To satisfy these high strength requirements, a very accurate and correct selection of values for the individual factors is required. In this case, it is necessary to take into consideration the differences in adhesion with the individual edging materials, complying to the additional conditions. The selected values for the mode parameters must be within the reasonable limits of the process. The limits set for the test parameters are as follows:

- bonding strength – exceeding the maximum value – $Y=3.0 \text{ N/mm}^2$;
- feed rate is selective – $U=10 \text{ or } 20 \text{ m/min}$;
- appearance – "good";
- amount of glue – $Q=200\text{-}350 \text{ g/m}^2$;
- adhesive temperature - $t=150\text{-}210^\circ\text{C}$;
compression force across the range - \( F_1 = 50-180 \) N, \( F_2 = 246-866 \) N;
- average plate density is assumed \( \rho = 755 \) kg/m\(^3\) - to study the most common case;
With the beech veneer edge, maximum strength is obtained at both speeds.

Table 5.

<table>
<thead>
<tr>
<th>( Y ) [N/mm(^2)]</th>
<th>( Q ) [g/m(^2)]</th>
<th>( t ) [°C]</th>
<th>( F_1 ) [N]</th>
<th>( F_2 ) [N]</th>
<th>( \rho ) [kg/m(^3)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,19</td>
<td>350</td>
<td>150</td>
<td>110</td>
<td>246</td>
<td>755</td>
</tr>
</tbody>
</table>

Edging with beech veneer at 10m/min

<table>
<thead>
<tr>
<th>( Y ) [N/mm(^2)]</th>
<th>( Q ) [g/m(^2)]</th>
<th>( t ) [°C]</th>
<th>( F_1 ) [N]</th>
<th>( F_2 ) [N]</th>
<th>( \rho ) [kg/m(^3)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,48</td>
<td>350</td>
<td>185</td>
<td>130</td>
<td>246</td>
<td>755</td>
</tr>
</tbody>
</table>

Edging with beech veneer at 20m/min

The paper foil edge and the PVC foil reach a bonding strength above 3,0 N/mm\(^2\), only at feed rate 20 m/min.

Table 6.

<table>
<thead>
<tr>
<th>( Y ) [N/mm(^2)]</th>
<th>( Q ) [g/m(^2)]</th>
<th>( t ) [°C]</th>
<th>( F_1 ) [N]</th>
<th>( F_2 ) [N]</th>
<th>( \rho ) [kg/m(^3)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,39</td>
<td>350</td>
<td>165</td>
<td>120</td>
<td>246</td>
<td>755</td>
</tr>
</tbody>
</table>

Edging with paper foil edge at 20m/min

<table>
<thead>
<tr>
<th>( Y ) [N/mm(^2)]</th>
<th>( Q ) [g/m(^2)]</th>
<th>( t ) [°C]</th>
<th>( F_1 ) [N]</th>
<th>( F_2 ) [N]</th>
<th>( \rho ) [kg/m(^3)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,11</td>
<td>350</td>
<td>205</td>
<td>180</td>
<td>246</td>
<td>755</td>
</tr>
</tbody>
</table>

Edging with PVC edge foil at 20m/min

The higher bond strength also requires an increased amount of glue, which partly lead to smudging of the edge and visible glue joints.

Technological Regime type 6. "Correction mode for plates with different density"

The use of plates with different density is a common practice due to the different producers, the batch or the quality of the raw material and the final product.

Table 7.

<table>
<thead>
<tr>
<th>Different type chipboard</th>
<th>Edging with beech veneer edge.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Y ) [N/mm(^2)]</td>
<td>( Q ) [g/m(^2)]</td>
</tr>
<tr>
<td>2,41</td>
<td>150</td>
</tr>
</tbody>
</table>

Solving the problem with lower strength

<table>
<thead>
<tr>
<th>Different type chipboard</th>
<th>Edging with paper edge foil.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Y ) [N/mm(^2)]</td>
<td>( Q ) [g/m(^2)]</td>
</tr>
<tr>
<td>1,83</td>
<td>150</td>
</tr>
</tbody>
</table>

Solving the problem with lower strength

<table>
<thead>
<tr>
<th>Different type chipboard</th>
<th>Edging with PVC edge foil.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Y ) [N/mm(^2)]</td>
<td>( Q ) [g/m(^2)]</td>
</tr>
<tr>
<td>2,67</td>
<td>150</td>
</tr>
</tbody>
</table>

Solving the problem with lower strength

<table>
<thead>
<tr>
<th>( Y ) [N/mm(^2)]</th>
<th>( Q ) [g/m(^2)]</th>
<th>( t ) [°C]</th>
<th>( F_1 ) [N]</th>
<th>( F_2 ) [N]</th>
<th>( \rho ) [kg/m(^3)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,64</td>
<td>250</td>
<td>180</td>
<td>50</td>
<td>862</td>
<td>720</td>
</tr>
</tbody>
</table>
In these cases, a change in bond strength is observed, without any apparent change in the edging material or mode parameters. As it was determined, from the conducted tests, the board density substantially affects the micro cavities in the edge and hence on the bond strength. It is necessary in these cases to correct the parameters of the regimen in order to preserve the strength of the joint and not to alter the appearance negatively. The set parameters limits for examining and solving these problems are as follows:

- bonding strength – to keep the value constant, when the density is changing;
- desired bonding strength – above minimum $Y=1,2-1,3 \text{ N/mm}^2$;
- feed rate – $U=10 \text{ m/min}$;
- appearance – "good";
- amount of glue – $Q=150-350 \text{ g/m}^2$;
- adhesive temperature - $t=150-210^\circ\text{C}$;
- compression force across the range - $F_1=50-190 \text{ N}, F_2 =246-866 \text{ N}$;
- maximum initial density of the plates is assumed $\rho=790 \text{ kg/m}^3$ – and with a decrease in density, it is expected the bond strength to be reduced, which will have to be corrected.

To solve a problem with the bonding strength at reduced plate density, the regimes, shown in a combined Table, should be used.

As it can be seen from the so made selection, for the beech furniture strips, this is achieved only by changing the compression force value in the second compression group from $554 \text{ N}$ to $862 \text{ N}$, which is executed in a very short time. All other parameters are unchanged, preserving the other features of the mode.

As for the melamine foils – it is required adjustment of both compression forces.

Edging with a PVC edge foil, as a rule, is sensitive to the change in the plate density. Choosing a new appropriate mode minimizes this negative effect for the bonding strength. In this case, it is necessary to make a correction in all of the parameters of the regime in order to preserve the relative high bonding strength.

CONCLUSION

Based on the conducted research, the following conclusions could be made:

1. The use of a single and fixed edging parameters for all materials, speeds and requirements is an extremely wrong method of practice. The proper solution is to use pre-set kits of technological parameters for edging with different edging materials.
2. With increased bonding strength requirements, the set of recommended regimes, as shown above, should be used. Generally, when a high forces of strength or perfect visual appearance are not required, it should be used the universal mode.
3. Changing the feed rate, necessarily requires additional correction of the other parameters so to keep the resulting bonding strength and appearance within the same range.
4. When using particle boards with different density or edge structure, correction modes must be used, so to maintain the achieved bond strength within the desired range.
5. By using the so made program and the mathematical models, the needed mode parameters can be determined, according to the production requirements and thus to form optimal edging modes according to several preferred parameters.
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Streszczenie: Optymalizacja parametrów technologicznych dla ciągłego oklejania krawędzi paneli meblowych. Przeprowadzono szereg badań eksperymentalnych z zastosowaniem klejów topliwych, w celu określenia wytrzymałości na zerwanie i jakości wykonania podczas ciągłego oklejaniu krawędzi płyt wiórowych. Ustalono różne wskaźniki dla różnych taśm obrzeżowych wykonanych z drewna bukowego, melaminy i PCV. Za pomocą stworzonego programu komputerowego przewidywano wytrzymałość na przyczepność i wizualną jakość wąskich płaszczyn mebli oklejonych taśmami.

Do analizowanych kryteriów procesu oklejania krawędzi należały:
- Zgodnie z rodzajem zastosowanego materiału do oklejania krawędzi
- Oszczędność energii
- Wysoka jakość wykonania
- Maksymalna wydajność (wydajność)
- Maksymalna siła przyczepności
- Tryb wykonania podczas obróbki płyty wiórowej o zmiennej gęstości

Wyniki badań i proponowane zoptymalizowane tryby pracy pomogą producentom mebli w prawidłowym zarządzaniu procesem oklejania krawędzi i poprawią jakość produkowanych mebli.

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1756, Sofia, Bułgaria
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Furniture as functional pieces of art and the need to aestheticise life

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¹) Faculty Social Sciences, Warsaw University of Life Sciences – SGGW
²) Department of Wood Sciences and Wood Preservation, Faculty of Wood Technology, Warsaw University of Life Sciences – SGGW

Abstract: Furniture as functional pieces of art and the need to aestheticise life. Aestheticizing is currently an extremely important activity focused on making man’s environment more beautiful; an environment which furniture are a part of. It goes without saying that creating and realising of aesthetical needs of man is a stimulus which greatly increases consumption. This is why everyday use objects such as furniture must be not only functional and utilitarian but also beautiful, designed with taste. Constant changes in trends and aesthetic needs, the creativity in applied art and creativity of the designers affect not only the aestheticising of our everyday life but also contribute to the constant demand for new and original items, which show new aesthetical versions of everyday reality.

Keywords: aestheticising of life, furniture design

PREFACE

Contemporary civilization is changing fast. There are new approaches to the role of aesthetics which goes exclusively beyond the sphere of art, and its scope is being extended to popular and applied art. Today, aesthetic experience is not strictly autonomous in character any more. What is ‘aesthetic’ seeps into the multidimensional aspects of everyday life and culture, and thus influences the forms of the furniture which are pieces of applied art. Aestheticizing is currently an extremely important activity focused on making man’s environment more beautiful; an environment which furniture are a part of. It goes without saying that creating and realising of aesthetical needs of man is a stimulus which greatly increases consumption. This is why everyday use objects such as furniture must be not only functional and utilitarian but also beautiful, designed with taste. Constant changes in trends and aesthetic needs, the creativity in applied art and creativity of the designers affect not only the aestheticising of our everyday life but they also contribute to the constant demand for new and original items which represent new aesthetical versions of everyday reality.

The beauty of every item, including furniture, is decided mostly by its construction and form, which is the natural and inescapable marriage of the materials used and the practical purpose of the item [Machniewicz 2012]. An expert of the subject, S. Machniewicz stresses that: the core of man’s entire creativity whose result is the material subject matter which is a part of the culture of aesthetics. The form is the primary element of this activity. It is in the form that expresses moods, preferences, technical possibilities and the life needs of man in a given place and time [Machniewicz 2012]. Such understanding of form is identified with the concept of style. In Machniewicz’s aesthetic system, both these terms are conditioned by construction and decoration factors, the former being the primary one. Daily life needs and the atmosphere of a given period of time will find their expression in an art form of a particular style (determined by the atmosphere) which the history of art frames into specific terminological constructions.

According to Machniewicz’s concept of aestheticising daily life, the style of contemporary utility objects has its own characteristics and metaphorical expression; it is very original if
with certain conditions in the tradition of aesthetic thought as it was formed on the ruins of the aesthetic culture of the 19th century which was referred to as stylish ugliness, the ear or art’s woe and the ugliness of everyday life [Przedpełski 1979]. The new contemporary style expresses itself in dovetailing the form to the application of a given object. Its metaphorical representation, and a form of allegory, is the mass-producing machine, and its personification is the factory. Such a definition of art in the first half of the 20th century can only be interpreted as functionalism. Thus, form and function and two notions with reach tradition of correlations. Functionalism regarded beauty of the form of an object in relation to its purpose. Thus, the aesthetic value of an object is decided not by the ornaments but by the qualities which are connected strictly to the purpose of that object [Tatarkiewicz 2005].

These and other difficulties was also something American philosopher Richard Shustermann was trying to sort out; to him philosophy is first and foremost ‘a tool for good life and self-fulfilment’. He shows that he is perfectly aware of the paradox of aestheticisation and strongly criticises this pattern which is realised in a chaotic pursuit of new experiences (he calls it a superfluous aestheticisation). A deeper model, which is supported by Shustermann, consists of an attempt by an individual (in an ideological vacuum) to determine their own concept of a good life based on moral self-development [Wieczorek 2018]. Therefore, we can say that in the twilight of moral universalism this is life that grows to the rank of ethical ideal. In other words: aesthetic care about order, harmony and integrity of your own life model are becoming the sole criterion of moral evaluation. The aestheticising of various spheres of human life was a subject of Mike Reatherstone’s work, who states its three basic meanings [Baudrillard 1983]

1. The first meaning is manifested through artistic subcultures gathered around Dadaism, historical avant-garde and surrealism, whose purpose was to blur the divide between art and everyday life. Everyday use objects were elevated to the rank of art, and were called ‘ready-mades’ (e.g. fountain-urinal by M. Duchamp), which resulted in questioning of how art was viewed so far. On the one hand, it was ‘brushed-up’ by pulling it out of museums and academic centres. On the other hand, everyday use objects (as well as post-consumption wastes which were used by Andy Warhol in his work) are now viewed as items possessing artistic value.

2. In the second meaning, the entire human life is turned into a work of art. This modification applies to the body, behaviour and the entire lifestyle of an individual. It strives to find new aesthetics and new experiences, and to explore its own personality. These tendencies are represented in Dandyism which appeared in the 19th century in England. Through extravagance in clothing and lifestyle, the Dandies manifested their superiority and their disdain for the masses.

3. The third meaning refers to a myriad of signs and symbols which seep into the everyday life, which is the result of the development of culture dominated by consumptionism. Its creations in the form of visual stimuli occur in mass media, in commercials and exhibitions. They appeal to our desires; they aestheticise but also make the world less real. This leads to blurring, typical of post-modernism, of the boundaries between the reality and an image. Described by Baudrillard [1983] a simulated world is a world where the commodity has gained a marker value, and we live ‘an aesthetic illusion of the reality’
So understood aestheticising is strongly rooted in culture and seems to be its undeniable element. It is not always that we are consciously under its influence. Even the most mundane of our consumer choices are often dictated by the aesthetics which agrees with the current fashion or with a common view that a product is deemed aesthetically pleasing. Functionality is no longer a sufficient value when the offer is so rich and varied. Initiated by the Dadaists, thinking of everyday use objects as works of art affected the development of industrial designing as applied art. The term ‘designer’ appeared and become one of the means of elevating an object to the rank of a work of art, stressing its value and uniqueness. This is usually connected with small-scale production of a product, the recognition of the product by artistic institutions and with very high price, totally disproportionate to the labour and materials used in its production. The value of such goods is a trademark value. Such designers as Floris Wuben use and offer the best of what the nature provides in furniture designing. They create furniture which, visually, are not a direct marriage of functionality and ergonomics. On the other hand, technological progress has opened new means for creating furniture. Furniture which was utilitarian objects were now also things of beauty [Krawczyk 2006]. Wood has accompanied man from the beginnings of civilization. The development of furniture making is a process which has accompanied people from the time man learnt about certain properties of wood and learnt how to process wood. In Egypt, much attention was paid to the visual aspect of furniture. Less decorative wood species were veneered using more precious woods. Roman furniture were richly decorated with woodcarving and they became an example for Romanesque and Gothic furniture. In Poland, woodcarving was developing in 16th–18th centuries. Gdańsk furniture are a very good example of that progress [Swaczyna 1995]. The process of making of a piece of furniture was based solely on the manual ability of woodworkers. The aesthetics in furniture making did not always go hand in hand with their usability. The development of upholstery in the 17th century changed that. Upholstery materials increased the aesthetical value of furniture. It was only the development of technology and the industrial revolution of the 19th century that put an end to the making of furniture only by hand; now they were beginning to be mass-produced [Kaesz 1990]. Furniture which were utilitarian objects became also objects of great beauty.

At first, furniture were treated as ordinary utilitarian objects. With time, much more attention was paid to their design and make. The material for the making of furniture was important not only for its mechanical properties but it also stressed the social status of the furniture’s owner. Observing the current array of available furniture, we can say that the situation has changed and that furniture, in particular those made of wood, still have an important function in our homes. Furniture are becoming more and more stylistically refined, which is why the contemporary customer-user takes is for a fact that furniture must be functional and aesthetically pleasing. This phenomenon is the result of a great change which took place in furniture production. Manufacturers don’t build their competitive advantage on the utilitarian values of their furniture. More and more often, an important part in building a relation between the customer and the furniture producer is the identity and emotional vibe built into the product. That identity of the product brand is nowadays built mostly thanks to the design and beautiful aesthetics.

CONCLUSIONS

From their very beginning, furniture were considered as utilitarian objects, and along with the development of the craft more attention was paid to the aesthetics. The shape, attractiveness, and even the wood species were the signs of not only the style of the epoch but also of the social status of the person who ordered a given piece of furniture.

In order to understand the contemporary applied art, we must take a look at the development of furniture making from its very beginnings – from a piece of ‘furniture’
hollowed out in a tree log to royal thrones. It is very likely that the appearance of furniture was a result of evolutionary adaptation of man to live on the Earth. Walking upright forced man to begin to look for comfortable solutions allowing for a change of the position [Grzeluk 2000].

The history of furniture making is the evolution of homo sapiens. Technological progress opened new possibilities to create furniture. Furniture which were utilitarian objects were now also things of beauty [Krawczyk 2006].

M. Rosińska stresses that: ‘inflation of art which we are experiencing currently is based on the ability of designing to satisfy the needs of the consumers which have become aesthetic [Rosińska 2012]. In his work titled ‘Aesthetics beyond Aesthetics’ W. Welsch stresses that this peculiar apologia of aesthetics leads to a situation where the reality of everyday life is viewed as a negotiable 'piece of art’, unfinished and easily styled and morphed [Welsch, 2005]. The tendency to stylize also in furniture industry is one of the embodiments of the expansion of design and ‘taste culture’.

Thus, as S. Magala says: ‘[...] design is most of all an important ingredient of enchanting the world, supposedly disenchanted by economists, atheists, positivists, Marxists and Darwinists. That’s why it is reaching more and more space around foreseeable events and moods’ [Magala 2008]. According to Magala, to re-enchant the world is the basic function of design now. The enchanting is about making a commercial use of the visual rhetorics of design. This statement makes designing a tool of ‘spontaneous reaction’ towards the market and consumers. Design, most often taking the form of luxurious aesthetically beautiful objects, allows the consumer to be noticed and is a proof of their social status. Design, in particular art design, is the initiator and catalyst of progressive aestheticising of social life, turning the world into stylised space and an experience of pleasure and entertainment.

Streszczenie: Meble, jako użytkowe dzieła sztuki i potrzeba estetyzacji życia. Estetyzacja jest współcześnie niezwykle istotną aktywnością zorientowaną na upiększanie środowiska ludzkiego oraz wytwarzanych produktów użytkowych, do których należą meble. Jest sprawą oczywistą, że rozbudzanie i realizowanie potrzeb estetycznych człowieka zalicza się do bodźców, który w istotny sposób zwiększa konsumpcję. Dlatego przedmioty codziennego użytku, takie jak meble, muszą być obecnie nie tylko funkcjonalne, praktyczne i użytkowe, ale również piękne. Zaprojektowane z gustem, wyczuciem i smakiem. Ustawiczne zmiany trendów i potrzeb estetycznych, twórczość w dziedzinie sztuki użytkowej, kreatywność projektantów wpływają nie tylko na estetyzację codziennego ogropytexstego ludzkiej, ale przyczyniają się do wzrostu ciągłego zapotrzebowania na „rzeczy oryginalne, niepowtarzalne”, pokazujące nowe odsłony estetyzacji codziennych rzeczywistości.

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Schlüsselwörter: Holz, Schutzbehandlung, Methoden Holzkonservierung

Im Jahre 1950 Dr. Peters im Kapitel „Schutzbehandlung des Holzes“ im Handbuch der Holzkonservierung, das von herausgegeben von Prof. Dr. Johannes Liese im Springer-Verlag im Jahr 1950. schreibt folgendes, dass die verwendeten Verfahren zur Schutzbehandlung des Holzes sollen der Übersichtlichkeit halber in vier Gruppen eingeteilt werden:

1. Auslaugung des Holzes durch Wasser oder Wasserdampf.
   - Auslaugung durch Wasser
   - Auslaugung durch Wasserdampf (Dämpfen des Holzes)

   - Das Ankohlen des Holzes
   - Ummüllung des Holzes durch luft- und wasserdichte Schutzschichten

   - Anstriche mit giftig wirkenden Stoffen (Oberflächengeschutz)
   - Einlagerung von Giftstoffen n Bohrlöchern oder Impfschutzen des Holzes
   - Eintauch- und Einlagerungsverfahren
   - Das Saftverdrängungsverfahren
   - Die Tränkung unter Anwendung von Vakuum und Druck

4. Sonstige Tränkverfahren [Handbuch der Holzkonservierung 1950]

Im Jahre 1809 schreibt Adolph Siemsen folgendes: Alle mir bekannt gewordenen Mittel zur Vertilgung des bereits gegenwärtigen Hauschwammes und Mauersalzes lassen sich füglich nach unter folgenden vier Klassen bringen:

I. Austrocknungsmittel des Fußbodens
   II. Austrocknungsmittel der Wände im Erdgeschoß
   III. Beizmittel des Tannenholzes
   IV. Isoliermittel des Tannenholzes.

I. Austrocknungsmittel des Fußbodens
Um dem vom Hauschwamm bereits angesteckten Fußboden auf immer gegen die große Übel zu sichern, empfiehlt man folgende Mittel:
1. Man reinige die alte Grundlage des Fußbodens der Wohnzimmer von dem vorhandenen Schutt, und wähle dafür oder anstatt der feuchten Grunderde, vielmehr trocknen Sand und Eisen-Hammerschlag [Cuny …1801; Wagener, Samuel Christoph 1801].
3. Man nehme Eichenholz zur Unterlage, fülle die Felder mit trocknen Mauersteinen aus, und nagelt die Dielenbretter darüber [Oekonomisches Portefeuille zur Ausbreitung… 1786].


Lagerhölzer Pfeiler von Ziegelsteinen, worauf sie ruhen sollten, und schrob die Bretter fest, um im Nothfall eins Revision halten zu können. Man ließ auch m dem Mauerwerke nach außen Luftlöcher, um der atmosphärischen Luft freien Durchgang zu verschaffen, und glaubte auf diese Art den Schwamm vertilgt, und seinen ferneren Anwuchs vorgebeugt zu haben. Allein diese hoffnung. Womit man sich schmeichelte, dauerte nicht lange. Denn kaum war ein Jahr verflossen, so zeigte sich der Schwamm nicht alein an Stellen, wo man ihn sonst nicht bemerkt hatte, sondern auch die Fußböden, wo man es sich am wenigsten vermuten war, hoben sich jetzt mehr als sonst, ja sie waren an einigen Stellen so mürbe, daß man besorgen mußte, durchzufallen. Beim Aufnehmen einiger Bretter, zeigte sich der Schwamm so fürchterlich, als man ihn vorher nicht bemerkte. Er hatte nämlich seinen Sitz nicht allein im Holze sondern überaus auch alles Mauerwerk und alle Steine, die ihm vorgekommen waren. Der hervorbrechende Gestank war unbeschreiblich”.

II. Austrocknungsmittel der Wände im Erdgeschoß

1. Man reinige die innern Wände von Kalk und Lehm, und bestreiche sie mit Theer oder mit Oelfarbe.

Die Alten überstrichen schon die Wände, um sie vor Nässe zu sichern, mit Erdpech, und um die salzige Feuchtigkeit abzuhalten, trugen sie, nach Plinius, einen Scherbenmörtel darauf. Der Firniß- Ueberzug ist allerdings für die saltzhaltigen Wände zu empfehlen, wenn sie nur noch so trocken sind ihn anzunehmen; jedoch muß man dann die Panehle von Tannenholz ganz weglassen oder sie mit eichen verwechseln, weil die tannenen von der anbringenden salinisichen Feuchtigkeit, ihrer Harzlösenden Eigenschaft wegen, auch ohne den Hausschwamm, sehr bald zu stocken pflegen. Der Löflerische Firniß, den man um die Maurerziegel von Nässe zu bewahren, empfohlen hat, besteht aus Leinöl mit etwas Bleigliätte (Silberglatte) Mennig, Pech und Ziegelmehl.


Leider lehrt die tägliche Erfahrung, daß die bloße Hinwegschaffung des Kalbewurfs, wenn das Mauersalz die Steine schon durchdrungen hat, ganz und gar Nichts nutzt. Der erneuerte Anwurf ist gewiß bey feuchtem Baugrunde nach Jahr Frist, wozu man in Rostock die Pfingsten-Zeit bestimmt hat, wieder ebenso schadhaft, als der vorige nur seyn konnte. Einige rathen Holzkohlen in dwen Gyps zu drucken, welche aber, in diesem Fall, dem Mörtel beständig Feuchtigkeit aus der Atmosphere zuführen, wodurch seine Bindekraft sehr leiden muß. Mit dem Ausbrechen der Steine muß man durchaus so weit gehen, als es die schadhafte Mauer nur irgend zulassen will.


4. Man bringe den Untergrund aus den angesteckten Zimmern heraus, und suche dem Fundamente durch nahe gebrachtes Flammenfeuer, oder durch einen freien Luftzug auf mehrere Wochen, den höchsten Grad von Trockniß zu verschaffen [Wagener, Samuel Christoph 1801]
Auf diese angepriesene Art, hat man freilich schon manches Gebäude verbessern gesucht; wenn man aber dabei auf die Eigentümlichkeit des Baugrundes und auf die Beschaffenheit der Fundamentsteine nicht besondere Rücksicht nehmen will, so kann auch der Erfolg davon jederzeit nur relativ und sehr unsicher sein. Es kommen auch Felsenstücken vor, die stets feucht, und fast beständig mit einem Salzbeschlag bedeckt sind. Es gibt z.B. nach Lampadius, zu Freiberg in den aus Gneis erbauten Häusern einzelne sehr leicht feucht werdende Stellen. Die Wand mag bakallt seyn, wie sie will, der Stein zieht Wasser bis zum Niederlaufen an der Wand an. Sehr wahrscheinlich ist eine Sorte leicht verwitternden Genieß, aus dessen verwittertem Feldspath das Kali frey geworden ist.

III. Beizmittel des Tannenholzes


Der Gebrauch der vitriolischen Holzbeize ist zwar beim feuchten Baugrunde nicht anzurathen, bey einer trocknen Baustelle ist er ebenso angelegenheit, als das Einsalzen des Fleisches für unsere Haushaltungen zu empfehlen. Durch das Einböckeln sucht man nämlich die zur Fäulnß geneigten Thele aufzulösen, und die festen Fleischfasern näher zu bringen, weshalb das Böckelfleisch auch leichter ist, als vorher. Durch die mit Metalloxyd gemischte schwefelsaure Beize vertiget man nicht weniger die zur Fäulnß geneigten Holzfasern, erstickt die etwa gegenwärtigen Schwammpilz-Keime, und füllt zugleich die kleinen Höhlungen im gebeitzten Holze mit oxydirtten Eisen- oder Kupfertheilchen aus, so daß der Harzlösende, fressende Saft des sich etwa nährenden Hausschwammes, als eine schwächere Beize, dem Tannenholze nicht mehr schädlich werden kann.

III. Isoliermittel des Tannenholzes


Erprobte Vorschriften zur Entfernung des Hauschwammes und des Mauersalzes bey neuen Bauten. Da man, der Natur der Sache nach, durch alle vorgeschlagenen Mittel das große Schwammübel und den verderblichen Mauerfraß nur etwas mindern, aber sehr selten
gründlich heilen kann: so hat man bey Uebernahme neuer Bauten vor Allen für eine trockne
und freie Baustelle zu sorgen, und zur sicheren Entfernung obiger Hausübel auf folgende
Punkte notwendig zu achten.

Das Eichenholz, das vom Hauschwamm und vom Salpeterfraß nicht leidet, wäre allerdings
für das in der Regel feuchte Erdgeschoß unserer Wohnungen dringend zu empfehlen, wenn
uns nicht die Kostbarkeit desselben davon zurückbrächte. Da stattdessen aber doch das im
feuchten Baugrunde unpassende Tannenholz seyn muß, so sorge man für festes und trocknes
Bauholz, dass wenigstens einiger YEARS lang auf schattigen und trocknen Plätzen aufgelagert
worden ist. Vom gefällten Tannenholz lehrt die Erfahrung, daß es seine Feuchtigkeit erst im
zweiten Jahr verliert, und zwar in dem Verhältniß, daß alsdann der Rheinländische Cubikfuß
nur 36 Pfund schwer ist, der vorher noch über 60 Pfund am Gewichte hielt.

Diätetische Darstellung des schädlichen Einflusses, welchen bumpfige und mit unreinen
Dünsten angefüllte Wohnungen auf den menschlichen Körper haben.

Die Luft, worin wir leben und unsere Geschäfte treiben, hat in ihrem reinen Zustande
solche vortreffliche Eigenschaften, daß ihr beständiges Einatmen für den Menschen
durchaus keine nachteilige Folgen haben kann. Der Genuß einer reinen, freien Luft, wovon
wir ständig an 28 Kubikfuß consumieren, ist, nach Hufeland, eine ebenso notwendige, ja
noch unentbehrlichere Nahrung zur Erhaltung des Lebens, als Essen und Trinken. Zur
Beförderung unserer kostbaren Gesundheit ist es also durchaus Pflicht, Alles von unserem
Körper zu entfernen, was den Luftantheil, worin wir uns befinden, verunreinigen kann.
 Unsere atmosphärische Luft besteht, nach den neuesten Untersuchungen in hundert
Theilen dem Gewichte nach, aus 74 Stickgas und 26 Sauerstoffgas. Wird dieses Verhältniß
durch den Betritt fremdartigen Stoffe, wobey insonderheit Verlust an Sauerstoff verbunden
ist, verändert: so können wir dieß neue Luftgemisch für unsern Körper allemahl ungesund
nennen. Unser beständiges Respiriren hebt freilich in den Wohnzimmern das nothwendige
Verhältniß in den Bestandtheilen der reinen atmosphärischen Luft schon auf, weil wir
anmäßig statt dieser eingesogenen, unauflhörlich kohlensaures Gas und Stickgas nebst
Wasserdampf wieder aushauchen Beim Oeffnen der Thüren und Fenster wird, mit der
eindringenden Luft, der Verlust von Sauerstoff bald wieder hergestellt, wovon die Luft in
unsern Wohnzimmern unbedingt 16 Procent enthalten muß. Steigt im Gegenteil der Gehalt
des kohlensauren Gases darin bis auf ein Sechstheil: so athmen wir schon schwer, und
befinden uns nicht wohl, denn diese Luftart ist für sich zum Athemholen ganz untauglich.
Nollet empfand beim Einatmen dieses Gases etwas Erstickendes, und zugleich eine gelinde
Schärfe, die ihn zu Husten und Niesen reizte. Eben diese ungesunde Luftart ist es, welche der
Hauschwamm in unseren Wohnungen in großer Menge hervorzubringen im Stande ist. Seine
bekannte Ausdümstung von mulstrigem brenzlichem Geruche, besteht nämlich aus
Kohlenstoff und Wasserstoff, die in die Zimmerluft übergehn, und selbiger den Antheil
Sauerstoff rauben, durch dessen Verlust die Gesundheit des Bewohners so sehr gefährdet
werden kann, insonderheit da jene beden Elementar-Stoffe in der atmosphärischen Luft die
Bildung eines höchst mephistischen Luftgemisches des kohlenstoffhaltigen Wasserstoffgases
bedünstigen. Ueber die Schädlichkeit dieser Luftart wird man am besten aus den Versuchen
des berühmten English Physikers Davy in seinen Researches chemical and philosophical.
London 1800. belehrt werden. Herr Davy war nämlich begierig, die dem Gefühl
bemerkbaren Wirkungen des kohlenstoffhaltigen Wessersoffgases kennen zu lernen, um sie
mit denen des oxydierten Stickgases, das nach vorhergegender Erregung tödtet, zu vergleichen.
Bey dem ersten Versuche athmete Herr Davy beynahe eine Minute lang eine Mischung aus
drei Quart Kohlenstoffhaltigen Wasserstoffgase, und beynahe zweiw Quarz atmosphärischen
Luft. Es bewirkte einen leichten Schwindel und Schmerz im Kopfe, mit einem momentanen
Verlust der Willenskraft; der Puls ward dabei schneller und schwächer. Diese Wirkung ging

Die Ausrottung des Hausschwammes wird aber in allen den Ländern und Gemeinden nicht ausführbar seyn, wo es noch solche Cammern und Bau-Kollegia gibt, als der Herr von Justi in seiner Staatswirtschaft Thl. II, S. 60 schildert:
"Die Cammern, Versichert er, suchen manchmal in solchen Dingen eine Erspahrung, wo sie am wenigsten stattfinden kann. Sie hüten sich auf alle Art vor dem Baue und lassen öfters die Gebäude flicken, so lange es nur einigermaßen gehen will, ob gleich die Wirtschaft und die Sachen darunter leiden. Wenn sie ja einen neuen Bau führen müssen: so geschieht es so leicht als möglich. Und nur gleichsan auf den Raub, dadurch aber ein schlechter Vortheil gestuftet wrd, weil in der Folge öfters viel größere Unkosten daraus entstehen, und die aufgewendeten sind gleichsan verspült worden“.


Wie wohltätig ist also das jüdische Polizeygesetz, daß die gänzliche Entfernung der mit Mauersalz verunreinigten Baumateriale enthält, und auf solche Art deb Haueigner zur sorgfältigem Verbeserung und zur vorsichtigen Anlegung seines Wohnhauses verpflichtet, haupsächlich um die Erhaltung seiner Gesundheit dadurch zu befördern. Dieß göttliche Gesetz verdient also auch heutiges Tages von allen Nationen beachtet und genau befolgt zu werden, weil es sich nicht bloß auf Aegypten und Palästine, oder auf jüdische Gegenden beschränkt, sondern weil es auch für nördliche Staaten sehr wohltätig werden kann.

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Streszczenie: Ochrona drewna. W artykule przedstawiono różne metody ochrony drewna przed szkodliwymi czynnikami biologicznymi. Opisy metod pochodzą z literatury niemieckiej z XVIII i XIX wieku. Porównano stosowane w przeszłości sposoby zabezpieczania drewna z technikami konserwacji drewna przedstawionymi w rozdziale „Schutzbehandlung des Holzes” znajdującym się w podręczniku „Holzkonservierung” wydanym pod redakcją prof. dr Johannes Liese.

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Determination of the colour parameters of iroko wood subjected to artificial UV light irradiation

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Abstract: Determination of the colour parameters of iroko wood subjected to artificial UV light irradiation. Iroko wood (Milicia excelsa (Welw.) C.C. Berg) had been subjected to artificial ultraviolet irradiation. Four fluorescent lamps were used for ultraviolet radiation, each with a capacity of 100 W. Wood samples were subjected to ultraviolet radiation within a spectrum range of 340-360 nm. Applied radiation source imitated solar radiation, UVA solar radiation in particular. Tests show that the greatest changes in L*, a*, b* parameters of wood occurred after 20 h of UV radiation exposure. Significant changes in the iroko wood colour ΔE occurred within the first 80 hours of exposure. The longer the wood was exposed, the observed changes were becoming smaller. Iroko wood shows a greatest changes in the first hours of exposure, and later shows higher colour stability.

Keywords: colour, exotic wood, irradiation, iroko, lightness

INTRODUCTION
Iroko is one of the most popular wood species for flooring, due to the sufficient strength properties and physical properties: hardness, dimensional stability, interesting wood figure and coloration (Kozakiewicz and Szkarłat 2004, Kozakiewicz et al. 2012).

Iroko grows in Western, Central and Eastern Africa, for example in the forests of Ghana, Cameroon, Equatorial Guinea, Gabon, Congo and the Democratic Republic of the Congo. The boundaries of the growth rings are indistinguishable or do not exist, despite that figure is enriched with irregular fibres arrangement and paratracheal axial parenchyma being vasicentric, aliform and confluent (Richter and Dallwitz 2000, Wagenführ 2007). Earlywood is quite narrow, with a width of up to 7.5 cm, of yellow and white colour. In the freshly sawn wood heartwood is bright lemon colored, changing under the influence of light (which accelerates change of colour) and oxygen from air into darker shade of yellow-brown, or even dark brown. Intensity of the colour change is also affected by the chemical composition of wood, partially dependent on habitat, on which tree has grown (Kozakiewicz et al. 2012). The colour of the wood also depends on micro-topography of surfaces created by the mechanical processing of wood. Wood as organic material is prone to staining over time both in terms of external and internal parts. In these conditions, process of staining is affected by many different factors like, in particular, solar radiation, temperature, relative air humidity and dependent on these equilibrium moisture content (Liu et al. 1994, Tolvaj and Mitsui 2010). Particular importance (as a factor) in changing coloration of the wood is assigned to ultraviolet radiation (Miller et al. 1998, Deka et al. 2008, Jankowska et al. 2010, Laskowska et al. 2016).

MATERIAL AND METHODS
Testing utilized iroko wood, (Milicia excelsa (Welw.) C.C. Berg), according to the EN 13556 (2003) standard coded as MIXX. The iroko heartwood was conditioned for three
months in a normal conditions (temperature 20°C ± 2°C, relative humidity 65% ± 5%). For testing, 10 mm × 50 mm × 50 mm samples were used (last dimension along the grain). Faces of the samples were of tangent-radial section, and were finished by planing. Samples without visible defects but with natural striped grain were selected. Randomly selected 20 samples were subjected to UV irradiation.

Four fluorescent lamps were used for ultraviolet radiation, each with a capacity of 100W. Wood samples were subjected to ultraviolet radiation within a spectrum range of 340 - 360 nm. Radiation source applied imitated solar radiation, and UVA solar radiation in particular. This band causes of the greatest changes in the appearance and structure of organic materials, exposed in the external environment. This is due to the fact that UVA is a 90 - 95% of the solar radiation reaching the Earth's surface (Miller et al. 1998). Measurement of colour was held at two points on a sample, allowing to gather results from 40 measuring points. Samples of wood were processed by 300 h, the colour parameters was measured after every subsequent 20 h of exposure.

Measurement of wood colour was based on a mathematical model of colour space - CIEL*a*b* and L*C*h. The lightness (L*), chromatic coordinate on the red-green axis (a*) and chromatic coordinate on the yellow-blue axis (b*), the parameters C* (saturation, colour intensity) and h (hue angle) were determined. Determination of the total colour ΔE was carried out in accordance with ISO 7724-3:1984. To study the colour parameters a colorimeter NH300 company 3nh® (Shenzhen, China) was used. The sensor head was 8 mm in diameter. Measurements were made using a D65 illuminant. STATISTICA Version-12 software of StatSoft, Inc. (Tulsa, USA) was used for statistical analysis. The statistical analysis of the results was performed at a significance level of 0.05. The control group was iroko wood not subjected to UV irradiation.

RESULTS AND DISCUSSION

Moisture content of wood, tested in accordance with the requirements of ISO 13061-1:2014, was 8.9 ± 0.2%. Density of the tested wood determined in accordance to ISO 13061-2:2014 was 564 ± 29 kg/m³ and iroko wood was relatively low. Wagenführ (2007) and Kozakiewicz et al. (2012) state, that iroko wood density, in dry state may be variable, from 550 up to 850 kg/m³.

![Figure 1. Lightness (L*) of iroko wood under the influence of ultraviolet radiation](image)

Basing on the observation of visual characteristics, noticeable colour change the surface of the wood iroko subjected to UV irradiation has been found. Darkening of wood was most clearly visible. The results of visual tests are confirmed by the numeric values.
Thanks to the determination by colorimetry, change of individual parameters are presented numerically $L^*$, $a^*$, $b^*$.

Lightness ($L^*$) of iroko wood has changed in a significant way during 80 h exposure to ultraviolet (Fig. 1). It was shown that the greatest changes in the lightness of wood occurred after 20 h of UV radiation exposure. Similar dependencies have been reported during the exposure of cedar, gaboon, meranti and pine wood (Laskowska et al. 2016). Toivaj and Mitsui (2010) showed that the greatest changes in the lightness of black locust, beech, Japanese cedar and spruce occurred within the first 20 h of sunlight irradiation time. Lightness $L^*$ of iroko wood directly after planning equalled 64.21 (±1.65). After 20 h of UV exposure, lightness $L^*$ decreased by 12%. After 80 h of UV radiation exposure, the $L^*$ value change was linear, no noticeable differences between subsequent radiation intervals were noticed. Noted changes of iroko wood colour caused by artificial UV exposure proved to be stronger than the colour change after the annual exposure to natural sunlight (Jankowska et al. 2010) where the lightness ($L^*$) changed from 58.68 down to 52.76.

Changes the values of the other components were also observed. Research shows that the greatest changes of component colour of iroko wood occurred after 20 h of exposure (an increase of 46%). After that, increase of $a^*$ became linear (Fig. 2). After UV exposure iroko wood showed tendency to become redder. Chromatic coordinate value changes were analyzed on the axis of the colour yellow-blue ($b^*$), which is shown in the fig. 2. Changing parameter ($b^*$) depending on the time of exposure showed similar as in the case of component colour $a^*$, not that significant however. The greatest colour changes of the $b^*$ component in iroko wood occurred after 20 h of exposure (an increase of 8%). It is worth noting that on further exposure of iroko wood, tendency to the colour change to the yellow band was getting less visible. After 200 h of exposure iroko wood reported identical $b^*$ values as directly after planing. These changes are likely to result from changes in saturation ($C^*$) wood under the influence of ultraviolet radiation. In fact, linear relationship exists between the $b^*$ and $C^*$ ($b^* = 0.914C^* + 0.528, R^2 = 0.936$).
The most important parameter describing the colour stability of wood is total colour difference $\Delta E$, the result of changes to the individual parameters (components) (Deka et al. 2008). On the basis of the value of $\Delta E$ it can be concluded, that the largest total colour change of iroko wood occurs at the beginning of its exposure to UV radiation (Fig. 3). These changes were particularly noticeable in the first 80 hours of exposure. The longer the wood was exposed, the observed changes were becoming less noticeable. Wood shows great discoloration in the first hours of exposure, and later shows higher colour stability. $\Delta E$ after 20 h and 80 h of exposed iroko wood reached 8.06 (±1.11) and 9.87 (±1.28), respectively. According to the 5-degree scale proposed by Malicki (1997), iroko wood, which is the 1-2 class range, belongs to the species of low colour stability. Equally low colour stability of iroko wood is shown one-year exposure to natural sunlight (Jankowska et al. 2010).

Change of hue angle in iroko wood under the influence of ultraviolet radiation showed to be logarithmic (Fig. 4). The value of the $h$ parameter significantly changed within the first 80 hours of exposure. Hue angle of freshly planed iroko wood reached 74.59 (±0.94). After 20 h and 80 h exposure parameter value ($h$) lowered by 5% and 8%, respectively, and these differences were statistically significant ($p < 0.050$). It was shown that the greatest changes in the $C^*$ parameter of wood occurred after 20 h of UV radiation exposure (10% gain). After that, $C^*$ characteristic became linear. As a result of further exposure iroko wood, trend for changing of colour was getting smaller. This is an important tip for manufacturers.
CONCLUSIONS

Basing on above studies, it was found that ultraviolet radiation significantly affects iroko wood colour. It was shown that the greatest changes in L*, a*, b* parameters of wood occurred after 20 h of UV radiation exposure. Changes of colour ΔE were particularly noticeable in the first 80 hours of exposure. The longer the wood was exposed, the observed changes were becoming smaller. Iroko shows greatest colour changes in the first hours of exposure, and later is characterized by high colour stability.

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Streszczenie: Badania składowych barwy drewna iroko poddanego sztucznemu naświetlaniu UV. Drewno iroko (Milicia excelsa (Welw.) C.C. Berg) poddano sztucznemu naświetlaniu w zakresie długości fal od 340 do 360 nm. Pomiar parametrów barwy drewna referencyjnego oraz naświetlanego dokonano na podstawie matematycznego modelu przestrzeni barw CIEL*a*b* i L*C*h. Do badania parametrów barwy użyto kolorymetru NH300 firmy 3nh® z głowicą o średnicy 8 mm. Zmiany barwy ΔE były szczególnie zauważalne w ciągu 80 pierwszych godzin naświetlania drewna. Im dłużej drewno było wystawione na ekspozycję promieniowania, tym obserwowane zmiany stawały się coraz mniejsze. Jasność (L*) drewna iroko uległa zmniejszeniu, natomiast składowe a* i b* po początkowym wzroście dążyły do poziomu wyjściowego. Zmiana kąta barwy (h) drewna iroko pod wpływem promieniowania ultrafioletowego miała charakter logarytmiczny – wartość tego parametru uległa zmniejszeniu. Przeprowadzone badania potwierdziły podatność drewna iroko na zmiany barwy pod wpływem promieniowania ultrafioletowego, przy czym drewno ściemniało wykazuje już znaczną stabilność barwy.

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Influence of addition of microfibrillated cellulose (MFC) on selected properties of low-density particleboard

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Abstract: Influence of addition of microfibrillated cellulose (MFC) on selected properties of low-density particleboard. The study investigates the properties of particleboards with low-density (520 kg/m^3) made using urea-formaldehyde (UF) resin modified by addition of microfibrillated cellulose (MFC). 5%, 10% and 15% of MFC (solid content 3.6%) were added relative to adhesive resin (concentration 65%), in two different types of fibres size - "long" and "short". Mechanical and physical properties of prepared particleboards were examined. Based on obtained results, it was found that the addition of MFC doesn’t have a significant impact on mechanical properties of produced boards. The addition of MFC to adhesive resin, improves moisture resistance of particleboards. MFC-modified boards had up to 18 p.p. lower average thickness swelling value after 24 hours soaking in water than control boards. Moreover, it was found that both fibre size and the amount of MFC additive, have significant effect on thickness swelling of particleboards.

Keywords: particleboard, microfibrillated cellulose, urea-formaldehyde, density, lightweight, MFC

INTRODUCTION

Innovative materials using environmentally friendly, easily available and low-cost raw materials are crucial to meet growing needs of humanity, while protecting the natural environment. New solutions from wood-based panels industry, through use in furniture and construction, reach millions of houses around the World. With dynamic development of furniture and construction industry, demand for wood-based panels is growing [Grochownia and Krzemińska 2017]. Over the last 20 years, production of wood-based materials in the world, increased by 180%, and in 2016 amounted to 416 million m^3. The volume of particleboards production, the main and strategic raw material for furniture industry is also growing [Utkina 2017]. Global production of this material in 2016, compared to 2015, increased by 8% and amounted to approximately 93 million m^3. In Europe, the production of particleboards remains stable - 44 million m^3 of boards in 2016 were produced. However, while in Western Europe production of particleboards in 2006 - 2016 decreased by 32%, at the same time, in Eastern Europe production increased by 46% [http://www.fao.org].

In Europe, basic raw materials for production of particleboards are: industrial by-products (chips and sawdust) - 39%, recycled wood - 32% and fresh round wood - 29% [Wijnendaele 2015]. The availability of these raw materials in many European countries (among others in Poland, Italy and Austria) is critically low [Wijnendaele 2015; Mantau et al. 2010; Balducci et al. 2008]. The average distance of transport of raw material for needs of particleboards producers in 2014 was 129 km, and the maximum 250 km [Wijnendaele 2015]. Due to the low efficiency of wood transport over further distances and concentration of production in Eastern Europe, purchase of raw material in this part of Europe will be difficult. The cost of lignocellulosic material for particleboards production, due to increased demand for energy purposes, is also growing - in a decade, from 2004 to 2014 increased about 60% [Wijnendaele 2015; Teischmiger 2010; Oniško 2011].

The use of alternative sources of raw material, such as annual plants, fast-growing trees [Boruszewski 2015; Balducci et al. 2008; Frąckowiak et al. 2008], but also production of boards with reduced density [Shalbafan and Tackmann 2016; Dziurka and Mirski 2013; Czechowska 2012], can improve difficult situation on raw materials market. Previous studies confirm suitability of materials such as: hemp [Grigoriou et al. 2000], flax, sunflower,
Jerusalem artichoke, miscanthus [Balducci et al. 2008], mustard [Dukarska et al. 2015], rape straw [Dziurka and Mirski 2013], cereal straw [Piotrowski 1999] as a raw material for particleboards production.

The density of particleboards is one of the main factor determining their properties [Drouet 1992]. Lightweight panels have been known and manufactured for many years, but due to their poor strength properties, they are rarely used in furniture industry [Dziurka 2010]. Reducing average density of particleboards will improve efficiency of raw materials, and thus reduce the amount of wood needed to produce 1m³ of finished product [Shalbafan 2013]. Other reasons are also design trends (thick elements with low weight), lower transport cost, ease of assembly and limited weight of furniture package [Shalbafan 2013; Czechowska 2012]. There are many strategies to reduce density of wood-based panels [Dziurka et al. 2015; Czechowska 2012; Dziurka 2010]. Shalbafan [2013] divided them due to:

a) production technology, e.g. hollow-tube profile [www.sauerland-spanplatte.de],

b) raw materials used for boards production, e.g. light wood species, annual plants [Dziurka and Mirski 2013], polymer beads [Borysiuk et al. 2010], foamable adhesives [Monteiro et al. 2016],

c) sandwich concept, e.g. honeycomb board [www.egger.com] and foam core particleboard [Shalbafan 2013].

The standard binders used for particleboards are amine resins, mainly urea-formaldehyde (UF) resins. Despite many advantages, such as low price and easy to use, UF resins in case of particleboards with reduced density, offer limited opportunities to achieve high strength parameters [Dunky and Niemz 2002; Zenkteler 1996]. One of the modification methods and improving parameters of UF resins is addition of fillers. The fillers are usually insoluble substances dispersed in adhesive, such as powders (silica, aluminum oxide) and fibres (glass fibre, cellulose fibre) [Clauß et al. 2011].

One of new types of fillers for resins are micro and nano particles of various substances [Nicewicz 2017]. Zahedsheijani et al. [2012] confirmed suitability of nanoclay to improve thermal stability of UF resin. In other studies, nano - SiO₂ was used as a filler for melamine-urea-formaldehyde resin in water-resistand plywood production [Dukarska and Czernicki 2016]. In recent years, various micro and nano fibres of cellulose were interesting addition to wood adhesives resin [Mahrdt et al. 2016; Veigel et al. 2012]. Cellulose products, due to their size and method of production, can be divide into three groups, often called the same term - nanocellulose. These are microfibrillated cellulose (MFC), nanofibrillated cellulose (NFC) and cellulose nanocrystals (NCC). MFC is usually obtained by mechanical treatment (grinding) with or without chemical pre-treatment. This material consists of fibers which form a three dimensional network, and these fibres have both crystalline and amorphous regions. They have diameter of a few nanometers to several micrometers, and length of about 50 - 200 micrometers. NFC is similar material, however, fibres have a diameter of 5 - 40 nm and length > 1 μm . Before the mechanical treatment, cellulose can be subjected to special chemical processing, e.g. with using TEMPO (2,2,6,6-tetramethyl piperidine-1-oxyl radical) - this causes that NFC consists mainly of crystalline regions. The last type, NCC, is obtained by acid hydrolysis. These are exclusively crystalline regions of cellulose, whose diameter is 5-20 nm and length 100-600 nm [Tuukkanen 2017; Islam et al. 2014].

Cellulose is the most abundant natural polymer in the World. Its resources are estimated at 1.5 x 10¹² tons of biomass per year [Klemm et al. 2005]. While the NCC and NFC is mainly produced on pilot scale, MFC is currently manufactured in industrial plants [www.weidmannfibertechnology.com]. The possibility of using this product as an additive in industrial production of wood adhesives seems promising. Veigel et al. [2011] research showed that a 2% MFC additive for UF resin, improved specific fracture energy of adhesive
bonds about 45%, compared to unmodified resin. In the case of standard OSB boards and single-layer particleboards with standard density (650 kg/m\(^3\)), the 1% NFC additive improved selected strength properties by 16% [Veigel et al. 2012]. In the same studies, the positive effect of NFC addition to UF resin on swelling of particleboards after 24h was also confirmed.

![Figure 1. Scanning Electron Microscope image of Weidmann MFC](source: weidmannfibertechnology.com)

![Figure 2. Weidmann microfibrillated cellulose](source: weidmannfibertechnology.com)

In this study suitability of MFC additive, as reinforcing filler, for UF resin used as a binder for 3-layers lightweight particleboards was investigated. The effect of various fibre sizes and different amounts of MFC additive on selected strength properties and water resistance were also investigated.

**MATERIALS AND METHODS**

In present study microfibrillated cellulose with the trade name WMFC Q_ADVANCED in two different variants of size of fibers - "long" and "short" was used. Product in form of white paste, with solid content about 3.6%, was provided by Weidmann Fiber Technology AG (Switzerland). The "long" fibres variant have a narrow particle size (length) distribution focused around 100 μm, and high aspect ratio. The "short" variant had a low aspect ratio and particle length focused around 90 μm. The fibers were obtained as a result of mechanical treatment of bleached softwood pulp. As an adhesive, a commercially available urea-formaldehyde resin (UF) form Achema (Lithuania), with solid content 65% was used. Aqueous ammonium sulfate (30 wt%), in an amount 3 wt% relative to solid resin, was added as a hardener. The glue content was 8% and 10%, for core and surface layer respectively. Paraffin emulsion (50 wt%), as a hydrophobic agent, in an amount of 1% relative to absolutely dry weight of particles was used. The defined amount of MFC was added to adhesive resin for both core and surface layers, in different amounts depending on the variant (Table.1) and mixed with high speeds homogeniser for 4 minutes to achieve properly distribution of fibres in adhesive solution. The lignocellulose raw material for production of 3-layers particleboards were industrial pine particles, typically used for core and surface layers, obtained in particleboards factory in north-eastern Poland. The assumed density of boards was 520 kg/m\(^3\) with dimensions 320 x 320 x 15 mm\(^3\). During mixing of particles in laboratory glue blender, adhesive resin was pneumatically sprayed. Mat was manually formed and press by 270 s with maximum unit pressure 2,5 MPa and temperature...
The boards were conditioned for 7 days in a normal climate. In total, 21 boards (3 pieces for each variant) were produced, and samples (dimension in accordance with EN 326-1:1994) were prepared. Subsequently, selected physical and mechanical properties were determined, as below:

- Density according to EN 323:1993
- Density profile with using density analyzer GreCon DAX,
- Modulus of rupture (MOR) according to EN 310:1993,
- Modulus of elasticity (MOE) according to EN 310:1993,
- Internal bond (IB) according to EN 319:1993,
- Thickness swelling and water absorption after 2h and 24h according to EN 317:1993.

For each property group, mean values were calculated and compared by on-way analysis of variance (ANOVA).

**Table 13. Composition of produced particleboards**

<table>
<thead>
<tr>
<th>Variant</th>
<th>Amount of MFC added to adhesive resin (in % of weight of wet resin)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WMFC Q_ADVANCED &quot;SHORT&quot;</td>
</tr>
<tr>
<td>K - control</td>
<td>0</td>
</tr>
<tr>
<td>5S</td>
<td>5</td>
</tr>
<tr>
<td>10S</td>
<td>10</td>
</tr>
<tr>
<td>15S</td>
<td>15</td>
</tr>
<tr>
<td>5L</td>
<td>0</td>
</tr>
<tr>
<td>10L</td>
<td>0</td>
</tr>
<tr>
<td>15L</td>
<td>0</td>
</tr>
</tbody>
</table>

**RESULTS**

Average density of each variant of manufactured boards (table 2) do not differ more than ± 5% from assumed density (520 kg/m³). Due to the strong effect of density on many board properties, it is necessary to note that differences between boards produced in accordance with the assumptions of the variants K; 5S; 10S; 15S; 5L; 10L; 15L were not statistically significant (ANOVA p > 0,05).

**Table 2. Average density and standard deviation of tested particleboards**

<table>
<thead>
<tr>
<th>Variant</th>
<th>K</th>
<th>5S</th>
<th>10S</th>
<th>15S</th>
<th>5L</th>
<th>10L</th>
<th>15L</th>
</tr>
</thead>
<tbody>
<tr>
<td>average density [kg/m³]</td>
<td>534</td>
<td>537</td>
<td>520</td>
<td>527</td>
<td>544</td>
<td>542</td>
<td>528</td>
</tr>
<tr>
<td>standard deviation</td>
<td>26</td>
<td>33</td>
<td>20</td>
<td>23</td>
<td>26</td>
<td>17</td>
<td>26</td>
</tr>
</tbody>
</table>

Density profile (figure 3) of all board’s variants, showed that there are no differences in structure of boards, therefore this factor did not affect differences in examined properties. All board’s variants had characteristic of 3-layer particleboards U-shape profile.
Figure 3. Density profile of tested particleboards

Modulus of rupture test (figure 4) showed, that generally (except variant 10L) MFC-modified boards variants had higher strength than control variant. However, differences between MFC-modified variants and control boards were not statistically significant (ANOVA, p > 0.05). Differences in average MOR values, between "long" (5L;10L;15L) and "short" (5S;10S;15S) types of MFC-modified boards were also not significant. Highest strength (9,15 MPa), 11% higher than control variant, had variant 5S, with 5% addition of "short" MFC fibres. This results are comparable with previous results of Veigel et al. [2012], which also showed a small, 6% increase of MOR in the case of 1% NFC addition. Lowest strength (4% lower than control variant) had variant 10L, with 10% addition of "long" fibers.

Figure 4. Modulus of rupture and standard deviation of tested particleboards

Modulus of elasticity, as a strongly correlated with MOR, had similar value distribution. Differences between MFC-modified and un-modified groups were not statistically significant (ANNOVA, p > 0.05). The highest stiffness was shown by boards from variant 5S, and was 12% higher than revealed by the boards from control variant. The lowest, 1% lower than
boards from control variant MOE value, had boards with 10% addition of "long" type of MFC.

![Figure 5. Modulus of elasticity and standard deviation of tested particleboards](image)

Based on ANOVA, differences in thickness swelling after 2 and 24 hours between boards from control group and MFC-modified boards were statistically significant. Due to high standard deviation values for thickness swelling after 2 hours, this study focused on thickness swelling after 24 h. Figure 6 showed that lowest thickness swelling value (12.7%), 18 p.p. lower than boards from control variant, had variant 5S. Highest thickness swelling after 24 hours (16.2%), 5% higher than control boards, had variant 5L. Differences between MFC-modified variants, between "long" and "short" MFC types, were also significant (ANOVA, p < 0.05).

![Figure 6. Thickness swelling after 2 and 24 hours and standard deviation of tested particleboards](image)
Effect of addition of "long" and "short" MFC - fibers on thickness swelling after 24 hours was different. For the "short" type of MFC, a small, 5% MFC addition significantly reduces thickness swelling. With increase of additive (variant 10S and 15S), thickness swelling after 24h increases and reaches values similar to control group. In contrast to the "long" MFC-type, thickness swelling decreases with increase of "long" MFC share in adhesive resin, therefore the lowest thickness swelling (among "long" MFC group) had variant 15L. Similarly to previous studies for nanofibrillated cellulose [Veigel et al. 2012], the addition of microfibrillated cellulose to urea-formaldehyde resin, may improve lightweight particleboard’s resistance to moisture, however, it depends on type and size of the MFC particles used.

![Figure 7. Internal bond and standard deviation of tested particleboards](image)

All particleboards variants had internal bond in range of 0.93 - 1.11 MPa (figure 7). Differences between MFC-modified and un-modified groups were not statistically significant (ANNOVA, p > 0.05). The highest IB value, 10% higher than boards from control variant, had variant 5S. The lowest IB (0.93) had variant 15L. There is no clear correlation between both content and size of MFC particles in adhesive resin and values of internal bond.

CONCLUSION

Based on the obtained results, addition of MFC to urea-formaldehyde resin has a positive effect on moisture resistance of 3-layer lightweight particleboards. MFC additive has no significant influence on tested mechanical properties, i.e. modulus of rupture, modulus of elasticity and internal bond. The density profile of boards modified by MFC had typical U-shape. The addition of microfibrillated cellulose to the urea-formaldehyde resin improved (up to 18 p.p.) thickness swelling after 24 hours. Both particles size and amount of MFC additive had an effect on thickness swelling of produced particleboards.

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Streszczenie: Wpływ dodatku mikrowłókien celulozy (MFC) na wybrane właściwości płyt wiórowych o obniżonej gęstości. W ramach badań określono właściwości płyt wiórowych o obniżonej gęstości (520 kg/m³), do których wyprodukowania użyto żywicy mocznikowo-formaldehydowej z dodatkiem mikrowłókien celulozy (MFC). Zastosowano odpowiednio 5%, 10% i 15% dodatek MFC względem roztworu żywicy klejowej o stężeniu 65%, w dwóch różnych wariantach wielkości włókien - "długich" i "krótkich". Następnym krokiem było zbadanie właściwości mechanicznych i fizycznych wyprodukowanych płyt. Na podstawie uzyskanych wyników badań stwierdzono, że dodatek MFC nie ma istotnego wpływu na wybrane właściwości mechaniczne płyt. Wartości wytrzymałości na zginanie statyczne, modułu sprężystości przy zginaniu statycznym oraz wytrzymałości na rozciąganie prostopadle do płaszczyzny płyty, nie wykazywały istotnych statystycznie różnic między wariantami płyt modyfikowanymi MFC a wariantem płyt kontrolnych. Dodatek mikrowłókien celulozy poprawia odporność płyt na wilgoć - płyty modyfikowane MFC charakteryzowały się do 18 punktów procentowych mniejszą wartością spęcznienia na grubość po 24 godzinach moczienia w wodzie, względem wariantu kontrolnego. Wartość spęcznienia na grubość zależała zarówno od wielkości cząstek jak też od ilości dodatku MFC do żywicy klejowej.

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Analysis of selected properties of particleboard modified with *Miscanthus giganteus* JM Greef & Deuter ex Hodk. & Renvoize

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Abstract: Analysis of selected properties of particleboard modified with *Miscanthus giganteus* JM Greef & Deuter ex Hodk. & Renvoize. The purpose of this study was to determine possibility of pine particles substitution in core layer of particleboard with particles obtained from *Miscanthus giganteus* JM Greef & Deuter ex Hodk. & Renvoize. Urea-formaldehyde resin was use as a binder. *Miscanthus* share in core layer was 25%, 50%, 75% and 100%, parts by weight. Physical and mechanical properties of prepared particleboards were examined. Based on obtained results, it was found that 3-layer particleboards with 25% addition of *Miscanthus* in core layer, meet requirements of EN 312:2010 for P1 board.

Keywords: particleboard, *Miscanthus giganteus* JM Greef & Deuter ex Hodk. & Renvoize, core layer

INTRODUCTION

Particleboard is the most commonly used material to produce furniture in Europe. For several years, in Poland, production quantity of this type wood-based panels has remained stable, and in 2016 was 4.45 mln m$^3$ [Faostat 2017]. The demand for particleboard is constantly growing. Furniture sector is one of the most dynamically developing branches of Polish industry [Borowski et al. 2016]. Response to increased market demand, is growing import particleboards to Poland, which in 2012-2016 increased by 115%, and in 2016 was 1.56 mln m$^3$.

In Central Europe, medium and small-sized softwood, forests and sawmill waste are basic raw materials for particleboards production [Fierek et al. 2013]. Raw materials market for particleboards production is difficult – growing demand for wood raw material, use of wood for energy purposes and garden furnishings, make it necessary to search alternative resources for pine wood [Oniśko 2011]. Moreover, the number of companies competing for raw material to particleboards production is growing. An example are new investments of Tanne Sp. z o.o. and Egger Sp. z o.o. in north-eastern Poland, which in 2018-2019 will have total production capacity about 1.2 mln m$^3$ per year – currently it is 27% of total particleboards’ production in the country [Hikiert 2016; Anonim 2018].


Species of genus *Miscanthus* belong to *Poaceae* family and mainly grown for energy purposes. Their origin is Southeast Asia, however, they are plants with good adaptive properties, and Central Europe’s climatic conditions are sufficient to obtain high biomass
yields. Depending on conditions, crop of this plant is 10-30 tons of dry mass from 1 ha per year [Kościk 2003, Kotowski 1997].

Urea-formaldehyde (UF) resin is the most commonly used resin in particleboard’s production. UF resin offers many advantages such as low cost, high reactivity, easy to use in industry, low adhesion to metal surfaces [Dunky and Niemz 2002]. However, disadvantage of this types resins is formaldehyde emission [Balducci 2008; Borysiuk and Wilkowski 2015]. Generally, strength properties are significant better for particleboards made from alternative, annual plants if polymeric isocyanate (PMDI) resins will be use as a binder [Balducci 2008; Dukarska 2013]. However, due to few times higher price and high adhesion to metal platens, their practical application in industry can be difficult.

In this study possibility of substitution of industrial pine particles by particles obtained from Miscanthus was investigated. Due to majority share of core layer in total weight of boards, and also not to change surface of boards, Miscanthus particles were added only for particleboard's core layer. Share of Miscanthus particles in core layer was variable, depending on variant. Particleboards samples were tested, to check compatibility of boards with requirements of the EN 312:2011 standard.

MATERIALS AND METHODS

The raw materials for the manufacture of 3-layers particleboards were 2 types of industrial pine particles, typically utilized in surface and core layers. Particles from Miscanthus were grinded using a laboratory mill. As an adhesive, urea-formaldehyde resin “Silekol S123” with solid content 64% was used. Aqueous ammonium chloride (10 wt%) was added as a hardener. The glue content was 10% and 12%, for core and surface layer respectively. A hydrophobic agent was also used - a paraffin emulsion (50 wt%) in an amount of 1% relative to dry weight of particles. In this study, 5 different variants of particleboards were made, depending on Miscanthus content in core layer (table 1).

Table 1. Composition of particleboards

<table>
<thead>
<tr>
<th>Variant</th>
<th>Type of raw material: P - Pinus sylvestris L.; M – Miscanthus giganteus JM Greef &amp; Deuter ex Hodk. &amp; Renvoize [wt%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>core layer</td>
</tr>
<tr>
<td>K – control</td>
<td>P 100</td>
</tr>
<tr>
<td>1</td>
<td>P75/M25</td>
</tr>
<tr>
<td>2</td>
<td>P50/M50</td>
</tr>
<tr>
<td>3</td>
<td>P25/M75</td>
</tr>
<tr>
<td>4</td>
<td>M100</td>
</tr>
</tbody>
</table>

In total, 15 boards with assumed density 650 kg/m³ and dimensions 320 x 320 x 16 mm³ were produced. Surface layers share in the board was 35 wt%. The formed mat was press by 288 s with maximum unit pressure 2,5 MPa and temperature 200°C. The boards were conditioned for 5 days in a normal climate. In the next step samples were prepared (dimensions in accordance with EN 326-1:1994) to determine selected physical and mechanical properties, as below:

- Density profile with using density analyzer GreCon DAX,
- Density according to EN 323:1993,
- Modulus of rupture according to EN 310:1993,
- Modulus of elasticity according to EN 310:1993,
– Internal bond according to EN 319:1993,
– Thickness swelling and water absorption after 2h according to EN 317:1993,
– Determination of resistance to axial withdrawal of screws according to EN 320:2011.

RESULTS
Average density of each variant of boards are presented in table 2. The highest density 676 kg/m³ was noticed in control variant, the lowest - variant 5, which core layer consisted only of Miscanthus. Differences between boards produced in accordance with the assumptions of the variants K; 1; 2; 3 were not statistically significant (ANOVA p > 0.05). However, boards produced in accordance with the assumptions of the variant 4 had significantly lower density, due to higher thickness of boards. It is necessary to remark, that some of variant 4 boards, have been deformed after pressing. This was probably caused by low cohesion of core layer.

Table 2. Average density, thickness and standard deviation of tested particleboards

<table>
<thead>
<tr>
<th>variant</th>
<th>K</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>average density [kg/m³]</td>
<td>676</td>
<td>652</td>
<td>653</td>
<td>643</td>
<td>592</td>
</tr>
<tr>
<td>average thickness [mm]</td>
<td>15.6</td>
<td>15.7</td>
<td>15.8</td>
<td>16.2</td>
<td>17.1</td>
</tr>
<tr>
<td>standard deviation</td>
<td>33</td>
<td>19</td>
<td>24</td>
<td>32</td>
<td>27</td>
</tr>
</tbody>
</table>

Figure 1. Density profile of tested particleboards

Density profile (figure 1) of all boards’ variants, showed characteristic of typical 3-layer particleboard U-shape profile. For boards produced in accordance with the assumptions of the variant 3, 4 and 5, thickness was higher than in K variant. As in the case of average density determination (table 2), the reason could be low cohesion of core layer and deformation after pressing. The modulus of rupture test (figure 2) showed, that all boards variants with Miscanthus particles had lower strength than control boards. Based on ANOVA, differences between boards from variants K; 2 and 3 were not statistically significant. Modulus of rupture was significantly lower for boards from variant 1 and 4. All boards variants meet the minimum requirement for bending strength for P1 type board (solid line presents the value in accordance with the requirements of the standard EN 312: 2011, i.e. 10 N/mm²). Except of boards from variant 4, all other boards also meet requirements for P2 type (dotted line presents the value in accordance with the requirements of the standard EN 312: 2011, i.e. 11 N/mm²).
All boards from variants with *Miscanthus* particles share had lower modulus of elasticity then boards from control variant, but differences for boards from variants K; 1; 2; 3 were not significant (figure 3).
The lowest stiffness was shown by boards from variant 4. EN 312 does not specify the minimum requirements of modulus of elasticity for P1 boards, but all tested boards met requirements for P2 boards (solid line presents the value in accordance with the requirements of the standard EN 312: 2011, i.e. 1600 N/mm²).

Figure 4 shows, that internal bond (IB) of tested boards decreases proportionally, with increasing share of Miscanthus particles in core layer. There is a significant correlation (cor. coefficient -0.98) between IB and share of Miscanthus particles in core layer. Boards from variant 1, have 36% lower IB value than boards from control variant.

The lowest, 90% lower than boards from control variant IB value, had boards from variant 4. The reason for low IB of core layer is probably low bond strength between UF resin and Miscanthus particles, which, like most grasses, are covered with wax [Park et al. 2012]. Next reason for the decrease in IB value, may be content of soft parenchyma in core of Miscanthus stalks [Klimek et al. 2018].

The thickness swelling after 2 hours soaking in water (figure 5), was generally higher for boards modified by Miscanthus particles, but there was no clear correlation between swelling and Miscanthus share in core layer. Boards with 100% Miscanthus in core layer (variant 4), swelled 219% more than the boards from control variant. Similar to thickness swelling, water absorption was significantly higher for modified boards, and there was no clear correlation between water absorption and Miscanthus share. European standard EN 312:2010 does not specify thickness swelling and water absorption requirements for P1 and P2 type boards.
Figure 7. Resistance to axial withdrawal of screws and standard deviation of tested particleboards

Boards produced with particles obtained from Miscanthus had significantly lower resistance to axial withdrawal of screws than boards from control variant. Board from variant 2 had 14% lower resistance than boards from control boards. Similar to other tests, the lowest resistance was shown by boards produced in accordance with the assumptions of the variant 4 (51.5 N/mm).

CONCLUSION

Based on the obtained results, addition of Miscanthus particles to the core layer in particleboard technology had negative effect on strength parameters and hydrophobic properties. The density profile of boards modified by Miscanthus had typical U-shape. Internal bond decreases significantly with increasing share of Miscanthus particles in core layer. Modulus of rupture, modulus of elasticity, resistance to axial withdrawal of screws also are lower for modified boards. Thickness swelling and water absorption are significantly higher for boards with Miscanthus. However, boards with 25% share of Miscanthus in the core layer meet all requirements for P1 type boards, according to EN 312:2010. Furthermore, except internal bond, boards from variant 2 also meet requirements for P2 type.

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Streszczenie: Możliwości modyfikacji wewnętrznej warstwy płyty wiórowej cząstkami roślin z rodzaju Miscanthus. Celem badań było określenie przydatności cząstek pozyskanych z miskanta olbrzymiego do substytucji wiórów sosnowych w wewnętrznej warstwie płyty wiórowej. Żywica mocznikowo-formaldehydowa została użyta, jako środek zaklejający. Udział cząstek miskanta w warstwie wewnętrznej wyniósł 25%, 50%, 75% i 100% części wagowych. W następnym etapie określono wybrane właściwości fizyczne i mechaniczne wytworzonych płyta. Na podstawie otrzymanych wyników badań stwierdzono, że 3-warstwowa płyta wiórowa z 25% udziałem cząstek miskanta w warstwie wewnętrznej, spełnia wymagania normy EN 312:2010 (dla płyty typu P1).

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